

A Review of Educational Agents: Definitions, Features, Roles and Development Trends

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Abstract: *The educational agent is a typical product of the integration of technology and education. As a result of the rapid advancement of artificial intelligence technology, its functionality and applicability have significantly improved, garnering extensive attention in the educational world. As a computer-generated virtual agent, it can perceive the educational environment and autonomously respond to the learners' needs. This article reviews the definitions, features, roles, and development trends of educational agents to find that being educational, autonomous, proactive, and socially interactive is their inherent features; that they can play multiple roles, such as the instructor, learning companion, and evaluator, to serve diverse educational needs; and that future development focuses in this area include enhancing emotional interaction capabilities of agents, strengthening their integration with virtual reality and augmented reality, and transitioning from single-agent to multi-agent systems.*

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Introduction

AN AI agent is a computer program capable of perceiving the external environment, responding to it or autonomously accomplishing prescribed objectives (Xu et al., 2021; Franklin & Graesser, 1997). Typically, an agent functions by detecting real-time changes in its environment, actively or passively reacting to influence the environment, and reasoning to comprehend perceived information, solve problems, draw conclusions, and make decisions (Hayes-Roth, 1995). The educational agent is seen as a digital solution effective in enhancing the quality of teaching and learning. It is designed to integrate into teaching or learning environments, playing a virtual role akin to the teacher or learning companion, to meet various educational needs. Amid the constant upgrading of technology, the functions of the educational agent have continued to evolve. In the earlier years, it primarily acted as a tutor, assisting the teacher in answering the students' questions and giving timely feedback (He, 2017). Yet, as result of the advances in AI and virtual reality (VR) technology, its capabilities have significantly expanded. For example, they can now recommend personalized learning materials and enable human-machine affective interaction, capable of creating more immersive, life-like interactive scenarios (Wang et al., 2022).

The focus of recent research on the educational agent has been on its specific applications in education. Topics like design of educational agents and their effects have been heavily discussed. Septiana et al. (2024) reviewed relevant literature published between 2013 and 2023 on agents' provision of guidance, feedback, and intervention, as well as emotional support, for learners in digital environments. The study finds that interventions on learning from agents were mainly applied to asynchronous learning systems, such as online learning, with inadequacies in adapting to personalized needs of the learners based on their emotional states. Martha and Santoso (2019) conducted a systematic review of studies between 2007 and 2017 on design of educational agents and their effects on learning environments. They discovered that educational agents could be in diverse forms, including text, voice, 2D characters, 3D characters, and human-like figures, and that the choice of forms in design may significantly affect the pedagogical effectiveness of agents. 3D characters and multimodal designs (combining text, voice, and visual elements) were found to be more effective.

Amid the conceptual development of education-related agents, a variety of terminologies have emerged. For instance, a portion of researchers adopted the "educational agent" as the descriptor, while the "pedagogical agent" seems to have more frequently appeared in the literature (To ensure the consistency of representation in this paper and emphasize that its focus is on agents for educational purposes, the term "educational agent" or simply

“agent” is used as the descriptor hereinafter). At the same time, the definition of the educational agent also varies in current research. Some researchers contended that the educational agent should be anthropomorphic and different from an intelligent tutoring system as a tool, whereas others asserted that it was a form of intelligent tutoring system, either with or without a human-like image. These variations may cause confusion, dampening the deepening of research in this area. Furthermore, with the introduction of new technologies, such as generative AI, the functionality of educational agents has become increasingly sophisticated, and their role in education has undergone continual iteration. To assist the advancement of educational agent research, this study will survey the existing definitions of the educational agent and descriptions of its features, highlight its roles in education, and analyze the development trends of the technology.

Definitions and Features

Current Definitions of the Educational Agent

Present in the literature are a wide variety of definitions of the educational agent. For instance, Baylor and Kim (2005) argue that educational agents are computer-generated characters used to fulfil instructional objectives, playing roles like the expert, partner, and evaluator. Kuk et al. (2012) define educational agents as computer-generated virtual teachers in forms of human figures or animals and plants, who can communicate with the learners through text, speech, and actions. Johnson et al. (2000) emphasize that educational agents, regardless of their appearance, are virtual characters generated with computer graphics technology, aimed at facilitating learning. Liu et al. (2019) view educational agents as virtual entities performing in teaching scenarios, meant to enhance student learning outcomes. Several commonalities can be drawn from these definitions. First, educational agents are computer-generated virtual characters capable of interacting with learners through various media (e.g., text, voice, and actions). Second, their pivotal objective is to facilitate learning, whether by providing cognitive support or emotional incentives and social interaction. Third, educational agents can play various roles, including but not limited to the expert, peer, evaluator, and mentor, to cater to diverse learning contexts. Finally, the visual presentation and interactive capabilities of educational agents are their crucial vehicles for establishing fruitful relationships with the learners. These common perceptions underpin the design and development of various educational agents.

It should be noted that earlier studies tended to underscore the animated representation of the educational agent in defining it. For instance, Johnson and his co-workers advanced the definition in 2000 that educational

agents were virtual characters with animated images, capable of colorful, face-to-face interactions with the learners in learning environments (Johnson & Lester, 2016; Johnson & Lester, 2018). This definition mirrors the importance attached at the time to the interactive capability of educational agents, which was expected to facilitate the establishment of emotional connections between the learner and agent and the enhancement of learning experience. Given Johnson and his colleagues' impactful work, their 2000 study has been of far-reaching influence. Based on their findings, many other researchers also proposed that the visually interactive capability was the central element of the educational agent. Yet, as studies on agents advanced, the research community realized that such an emphasis significantly constrained the pedagogical potential of educational agents, impeding its broader application in educational settings (Al-Kaisi et al., 2020). Consequently, education researchers began to explore more possibilities for the design of agents, no longer fixated on their representations in animated forms. Johnson himself later accepted this conceptual shift, suggesting in his subsequent studies that the presentation and application of the educational agent should be contingent on the specific instructional context and the role it plays within it (Johnson & Lester, 2016).

Recent years have seen increased discussions on the concept of the educational agent from the technological perspectives, as the use of AI-driven educational technology expands. According to Gu and Hao (2025), the conceptual origins of the educational agent could be traced back to teaching machines and programmed instruction theory, and its initial design was focused on simulating real-world teaching and learning processes; when computer-assisted instruction emerged, the development of educational technology entered the multimedia stage, laying the groundwork for the diverse human-computer interaction capabilities of the educational agent; as AI technology began permeating the education sector, leading to the emergence of intelligent tutoring systems (ITS), educational agents advanced into the intelligent era, serving as teaching assistants by emulating the expertise of instructional specialists; with the advent of the learning companion system, a new-generation intelligent tutoring system, the educational agent can now act as both the tutor and learning companion for students. Currently, generative AI technology empowers educational agents with broader knowledge capabilities, advanced natural language interaction skills, and heightened adaptability, which enables them to provide adaptive responses for the learners' complex queries (Shen & Zhu, 2023). As a result, the educational agent has the potential to play a pivotal role in the teaching process, collaborating with the teacher and students to transform learning methods, cognitive approaches, and educational relationships, as well as the educational ecosystem across the board (Gu et al., 2024).

Features of the Educational Agent

The designers and developers of educational technology must consider both the intrinsic and extrinsic features of the educational agent in their work. Its intrinsic features are also referred to as “functional attributes,” outlined in the following three dimensions:

Educational Capabilities: Being able to provide the teachers and learners with effective support for enhancing the quality of teaching and learning is the crucial capability of the educational agent, which distinguishes it from other types of agents. To this end, educational agents typically perform the following basic instructional functions (Schroeder & Gotch, 2015; Sakellariou et al., 2024): “providing information,” such as educational content and learning materials; “demonstrating” to show students how to successfully complete tasks through concrete examples; “scaffolding” to assist students in accomplishing tasks by offering individualized feedback and suggestions beyond text-books; and “testing” to assess students’ mastery of subject knowledge by posing relevant questions.

Generic Attributes of Agents: The educational agent shares three basic attributes with other agents: autonomy, proactiveness, and responsiveness (Li, 2018). “Autonomy” refers to its ability to take autonomous actions without being interfered by the learners or other agents. “Proactiveness” means that it can not only respond to external stimuli but also take initiative to perform actions based on preset objectives. “Responsiveness” is about its ability to perceive stimuli from the external environment and respond with appropriate actions in a timely manner.

Social Interactivity: Educational agents should be capable of interacting and collaborating with the learners or other agents (Xu et al., 2021), particularly in terms of emotional interaction with the learners. The social nature of educational agents represents their capacity for deep simulation of teaching and learning behaviors, and emotional interactivity enables them to understand and respond to the learners’ emotional states, thereby establishing deeper connections.

The extrinsic features of the educational agent have also been major considerations in the design and development processes. Multiple studies suggest that its presentation style, visual appearance, vocal traits, and interaction manners can significantly affect student learning outcomes (Baylor, 2009; Johnson et al., 2013). There are detailed discussions on extrinsic features of educational agents, primarily focusing on the following aspects:

Characters: Agents can be designed as human-like or non-human-like (e.g., animals). Factors like physical features, ethnicity, gender, and age must be considered in the design of human-like agents, (Martha & Santoso, 2019).

Presentation Styles: 2D and 3D are the most commonly adopted presentation styles. Additionally, based on their expected visibility, the presentation of agents can be categorized into four types: head-only, head-and-shoulders, upper body, and full body. As a result of the advancement of augmented reality (AR) and VR technology, learners can now interact with agents within the same virtual space.

Interaction Modes: The primary interaction modes of the educational agent include text-, voice-, facial expression-, body language-based communication, and combinations of these modes. In voice-based interaction, either synthetic or real human voice is adopted.

Emotional Expression: Educational agents need to exhibit emotions to enhance engagement with the learners. According to Septiana et al. (2024), emotions that educational agents may possibly express include happiness, sadness, enthusiasm, sympathy, anger and more, which can be conveyed through the following vehicles: (i) Facial expressions and body movements. Animated agents can simulate human facial expressions and gestures to express emotions. For example, a smile conveys happiness, a frown indicates sadness, and open arms signal enthusiasm. (ii) Voice and tone: Vocal and tonal modulation is a significant means of emotional expression. Agents can mimic human tones to convey different emotions. For example, raising pitch may express excitement or enthusiasm; lowering it can suggest sadness or calmness. (iii) Emotion-indicating expressions in text-based interaction: In text-based interaction, the agent may use certain words or phrases (e.g., “I’m delighted,” “I’m sorry,” “I’m surprised,” etc.) to help the learners understand its emotions and attitudes. Currently, it remains unclear which features are more important. The relationship between user preferences for agents with distinct features and their learning outcomes is not explicit (Dai et al., 2022; Zhang et al., 2024), which deserves further investigation.

Possible Roles of Agents in Education

Instructors

Educational agents first emerged as instructors in the initial stage, who guide the learners in carrying out academic tasks, using their knowledge repertoire and following established knowledge logic and reasoning rules. One of such instructional roles is the “expert.” This type of educational agents typically has a high level of mastery of advanced expertise in certain domains. In the form of learning material providers or knowledge testing systems, they offer the learners specialist and authoritative information and corresponding assessments. Such systems facilitate and reinforce learning primarily through instruction, training, and evaluation (Martha & Santoso, 2019). For example, Marni, a 3D animated agent for science education (Ward et al., 2013), is a

typical application of the “expert” agent. It uses the multimedia method to quiz users on learning materials, helping them go over curriculum content and develop correct comprehension. According to Ward et al.’s research findings, Marni users, after receiving 16 sessions of instruction (each lasting 20 minutes) showed no disparities in learning outcomes, compared to the students who were taught by human teachers. Researchers recommend creating “expert” agents as sober-minded and objective characters using formal and professional language, as well as concise and clear communication styles, and maintaining a certain emotional distance from the learners (Kim & Baylor, 2016).

Another major instructional role of the agent is the “tutor or mentor.” Compared to the agent as an “expert”, the agent as a tutor is more “approachable.” The latter not only assists with content knowledge learning with its expertise but also provide support regarding motivation and learning strategies. For instance, AutoTutor can adapt to the learners’ actions, using conversation patterns simulating human tutoring to motivate them (Graesser, 2016). Relevant practices demonstrate that communication capabilities of “tutoring” agents can positively affect learners' motivation level, academic success, and cognitive load (Dincer & Doganay, 2015), and that their capacity to provide prompts and feedback facilitate self-regulated learning and promote the use of metacognitive skills (Duffy & Azevedo, 2015). Therefore, agents as tutors or mentors should not only possess extensive knowledge repertoire but also feature capabilities of adaptive diagnosis, recommendation, prompting, and feedback. Also, they should be designed to be more friendly in terms of images and interaction modes.

Learning Companions

Recent years have witnessed rising prevalence of agents as learning companions, as well as more significant effects of this category on learning outcomes (Kim & Wei, 2011). The relationship between an agent as a learning companion and the learner is more equal and intimate, which allows it to engage in the learning process in a more natural and friendly manner. According to Bandura’s social learning theory, inter-peer social behavior has significant impacts on the learner’s actions and motivation (Gu & Hao, 2025). Verbal encouragement from their peers, for instance, helps enhance the learner’s self-efficacy. Hence, an agent as a learning companion can interact and collaborate with the learner to fulfil learning objectives while also serving as a motivator and facilitator, helping the latter stay focused and overcome challenges in their study.

The positive effects of educational agents as learning companions have been evidenced by many studies and practices. According to Tegos and Demetriadis’s (2017) research findings, students with an agent as their

partner achieved higher academic results and showcased better cognitive performance compared to those without it. Daradoumis and Arguedas (2020) argue that the emotional response from agents as learning companions facilitates students' self-reflection, prompting a more thorough understanding of concepts and long-term retention. Such emotional support is not only beneficial to the learner's intellectual outcomes but also favorable for their mental states, making the learning process more humane and emotionally engaging. Furthermore, certain researchers contended that educational agents as learning companions should be allowed to express negative emotions commonly related to learning, such as frustration and confusion, along with positive ones (Kort et al., 2001). By occasionally demonstrating difficulties with learning content, agents can act as ideal role models for coping academic challenges strategically.

Other Roles

In addition to being an instructor and learning companion, the educational agent can serve other purposes in the educational environment. First, "learning by teaching" is a productive way of using the agent, where it takes on the role of a tutee, and the learner assumes the responsibility of teaching it. In this process, the learner can deepen their understanding of knowledge by teaching while also observing and adjusting their own learning progress. This type of agents is often referred to as "teachable agents" in the literature. Zhao et al. (2012) summarized three benefits of teachable agents: (1) increasing reflection on knowledge and self-explanation in the learning process; (2) facilitating the learner's knowledge construction and reorganization; and (3) prompting them to take the ownership of their learning. Second, the educational agent can act as an evaluator, assessing the students' (both individuals' and groups') learning outcomes and providing feedback. For instance, in Maryadi et al.'s (2017) study, agents are used to provide automated and personalized feedback on assignments; in Lee & Fu's (2019) study, agents can perform peer assessment. Third, agents can contribute to educational outcomes by acting as teaching assistants without directly engaging in teaching. For example, agents can assist in educational administration, such as student information management, lightening staff's workload and improving school efficiency. Gunadi et al. (2019) developed a virtual assistant to collect comments from freshmen after their enrollment and found that compared to traditional means of information collection, the agent could interact with the students in a more friendly and engaging manner, thereby succeeding in gathering more authentic and comprehensive comments. Other studies have utilized agents to help the students adjust to fresh learning environments. For example, in Abbas et al.'s (2022) and Carayannopoulos's (2018) studies, educational agents were employed to

communicate with freshmen, helping them alleviate anxiety in the early days of college life.

In summary, agents can play diverse roles in education. Certain researchers claimed that agents have the potential to become ideal artificial instructors with the advancement of educational technology (Kim & Baylor, 2016), changing the communication dynamics and reshaping pedagogical relationships in educational environments (Sikström et al., 2022). Regardless of their roles, facilitate learning remains the core purpose of all educational agents.

Development Trends of Educational Agents

Despite decades of research on educational agents, their application has been less extensive than expected. Given ever-advancing technology and digital infrastructure, the use of educational agents is bound to expand in the future. Research on pathways for optimizing educational agents is ongoing, suggesting the following trends in their technological development.

Enhanced Emotional Interaction

Currently, the emotional interaction capabilities of educational agents remain relatively rudimentary, being limited to sporadic emotional exchanges with the learners through simple facial expressions, gestures, or language, which lack depth and adaptability. In the future, the introduction of affective computing and deep learning technology will enable educational agents to perceive, recognize, and understand the learners' emotional states in a more accurate manner and respond in a more intelligent, prompt, and friendly way (Xu et al., 2021). For example, leveraging affective computing, the educational agent can monitor the learners' emotional fluctuations in real time and offer personalized comfort and encouragement when detecting anxiety or frustration in them, thereby enhancing their emotional experience and motivation (Yusuf et al., 2025). Advanced emotional interaction like this will make educational agents appear human-like entities, rather than cold machines, with the ability to serve the emotional needs of the learners.

Deeper Integration with VR and AR

With the assistance of increasingly mature VR and AR technology, educational agents can further enhance learning outcomes by providing more immersive learning experiences. VR and AR technology will assist educational agents in creating highly realistic learning scenarios, making the learners feel as though they are in real-world settings (Yusuf et al., 2025). In medical education, for instance, the educational agent can simulate surgical

procedures using VR, which allows medical students to practice in a virtual setting while receiving real-time guidance from the agent. Additionally, AR enables the educational agent to overlay virtual information on top of a real-world environment, providing the learners with richer learning resources and interactive experiences. For example, by scanning textbooks with a smartphone camera, the agent can instantly display relevant 3D models or animations, facilitating the learner's grasp of complex concepts.

Transitioning from Single-Agent to Multi-Agent Systems

The application of multi-agent systems in education is predicted to be a significant trend in educational technology. Compared to single-agent systems, multi-agent systems have the capacity to accomplish more complex tasks and provide more efficient educational support through collaboration and interaction between multiple agents (Huang et al., 2025). For example, in a learning scenario, multiple agents can respectively take on roles of the teacher, teaching assistant, and learning partner, collectively offering personalized support to the learner. This collaborative approach can enrich the learning experiences of the student while also enabling educational agents enhance their intelligent level and adaptability through information sharing and joint decision-making (Liu et al., 2025). In addition, the multi-agent system facilitates division of responsibilities in the cases of complex educational tasks. In project-based learning, for instance, the agents can each be assigned a distinct duty like task allocation, progress monitoring, instruction delivery, or feedback evaluation, and together, contribute to the efficiency and quality of learning (Wu et al., 2024).

Conclusion

The study surveys the definitions, features, roles, and development trends of educational agents to conclude that their central purpose as a product of the integration of AI and education is to enhance teaching and learning outcomes through intelligent and personalized support; that they are characterized by autonomy, proactiveness, and responsiveness and social interactivity, alongside educational value, and presented as various virtual characters in educational scenarios; that they can play multiple educational roles, including the instructor, learning companion, evaluator, teaching assistant and more, with the potential to offer the learner systematic support; and that with the continuous advancement of technology, they will become more accurate responders to the learners' emotions, leveraging affective computing and deep learning, provide more immersive experiences, using

VR and AR technology, and transition from single-agent to multi-agent systems for accomplishing more sophisticated tasks.

The increased application of educational agents necessitates in-depth research into their ethical risks. Future studies should pay more attention to data security and privacy issues in the use of educational agents to ensure their legitimacy and compliance. Also, future educational agent research should strengthen interdisciplinary collaboration, as their advancement involves the efforts of researchers from multiple domains, such as education, psychology, computer science, and AI. Educational agent research, a potentially major research area in educational technology, is of vital significance for accelerating the across-the-board digital transformation of education.

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