

Pedagogical Agents

With the advance of interface technology, animated on-screen characters have been increasingly used both in commercial and educational applications. The characters are used to simulate natural human *social* affordance and are called by different names, including interface agents, animated agents, embodied agents, virtual tutors, and pedagogical agents. Researchers from various disciplines have investigated the efficacy of character use in applications from the unique perspective of their disciplines, such as artificial intelligence, human/computer interaction, educational technology, and social psychology.

In educational technology, the animated characters that are often called pedagogical agents play a range of instructional roles to effect motivation and learning in computer-based tutoring systems. It is acknowledged that pedagogical agents could overcome some constraints and expand functionalities of conventional computer-based learning. Traditionally, computer-based learning environments (e.g., intelligent tutoring systems) have been tailored to meet a student's individual needs, focusing mainly on the cognitive processes of learning. However, in social cognitive theory, learning is not only a solo activity occurring inside one's mind, but is also influenced significantly by interactions with tools and others. Conventional computer-based learning environments often fail to provide situated social interaction that is regarded as a significant influence on both learning and motivation. Pedagogical agents can overcome this limitation through simulated social interactions. Anthropomorphized pedagogical agents can promote a sense of social presence in educational applications that is otherwise missing. It is claimed, therefore, that pedagogical agents make instructional communication more social and natural. While interacting with a pedagogical agent acting as a tutor or co-learner, a learner may

build a social and intellectual partnership with the agent. Pedagogical agents define computers as social-cognitive tools for learning, serving to build social relations, share empathy, and model new beliefs and attitudes.

Enrichment of Computer-Based Learning

An easy-to-use interface

Computers are often regarded merely as tools to perform tasks, but computer users tend to expect computers to behave like social entities. It is well known that people unconsciously apply similar social rules and expectations to computers as they do to humans. It is further argued that students *consciously* expect their pedagogical agent to be as competent and friendly as human instructors in the real world. Learners perceive and interact socially with pedagogical agents even when their functionality and adaptability are limited. From ample research over the last two decades, there is a consensus in general that the presence of a pedagogical agent can make learners' interaction with computers more social, natural, and easy. After working with an agent, learners across age groups have evaluated their learning experience as more enjoyable and more engaging and perceived the learning environment as less difficult and the technology as easier to use. Also, the learners have expressed stronger desire to continue to use the program and demonstrated higher interest in the material, compared to those learners working without an agent.

Agents as socio-cognitive tools

Teaching and learning are highly social activities. Interactions with teachers, peers, and instructional materials influence the cognitive and affective development of learners.

Traditionally, it is presumed that cognition exists inside an individual's mind and that the cognitive process occurs internally. When individuals perform intellectual activities, however, they dynamically interact with other participants, tools, and contexts, and this could facilitate

enhanced performance and/or frame individuals' cognition and intellect. Therefore, interventions failing to address the social-cognitive dimension of learning might not accomplish their instructional goals. It is warranted, then, that computer-based learning environments should be designed to afford this social-cognitive dimension. Pedagogical agents might share learners' cognition, functioning as cognitive tools. Pedagogical agents can be equipped with knowledge and skills that learners would not have or might perform simple and mechanical tasks to preserve the cognitive capabilities of the learner for higher mental activities. Agents can be designed to learn with the learner and/or they can take turns generating ideas. In this way, learners could build an intellectual partnership with the agents and enhance performance in computer-based learning.

Agents as interaction partners

Intellectual development is achieved when learners interact with others. The Vygotskian concept of the zone of proximal development (ZPD) is at the center of learning and developmental processes. ZPD, the distance between a learner's actual development and his or her potential development when assisted by others, defines developmental functions that have not yet matured but are in the process of maturation. In collaboration with more capable others, learners can grow intellectually beyond the current limit of their capabilities. Also, from a Piagetian perspective, cooperation and free discussion enable us to acquire and construct knowledge. Cognitive conflicts that learners experience while interacting others are an essential part of the intellectual development process. Interactions with others establish the favorable conditions for counteracting an individual's egocentrism. Clearly, agent/learner interaction would not be equivalent with human-peer interaction. Even so, a pedagogical agent that may or may not command advanced knowledge can still bring forth different perspectives to instigate learners'

cognitive conflict in computer-based environments. When designed carefully, pedagogical agents simulate social and interactive contexts, providing support and sharing empathy.

Agents as social models

An individual's cognitive development is inevitably rooted in the social context where the individual is placed. Social modeling refers to psychological and behavioral changes that result from observing others in social contexts. Through vicarious experience, one acquires resources and expertise mediated through social models. Social modeling research illustrates how the presence of others and the roles they play can influence one's self-efficacy beliefs and social and intellectual functioning. The use of a pedagogical agent is of great value as a social model. A learner's positive affect enables the learner to face challenges and persist in learning. Simulated social relations and social interactions might mediate a learner's positive affect toward a learning task. For example, a pedagogical agent serving as a mastery model may demonstrate positive attitudes towards the task and/or the desired levels of performance so that a learner can learn vicariously. Or an agent may work along with a learner as a companion and even figuratively learn from the learner, serving as a coping model. Research finds that a less smart agent helps a low-performing learner to build confidence and encourages the learner to persist in the task. Similarly, pedagogical agents have been used as role models for females and ethnic-minority students who lack interest and/or confidence in succeeding in mathematics and science learning. These agents inspire the students to sustain efforts to accomplish each learning task and to continue with intellectual pursuit in the domain.

Pedagogical Agents Design

To promote building social relations between an agent and learner, the learner should perceive the agent as natural and believable. To this end, agent design often adopts human metaphors, rendering persona to pedagogical agents. Two design issues frequently arise in agent research: 1)

specifying an agent's instructional role, and 2) defining the agent's personal attributes. First, pedagogical agents are designed to represent different human instructional roles, such as expert, tutor, mentor, or co-learner. For example, the agents *Steve* and *Adele* developed by the Center for Advanced Research in Technology for Education at University of Southern California, represent experts in naval engineering and medical diagnosis. These agents demonstrate expert knowledge in the domain and observe learners' performance to provide adaptive feedback. The agent *AutoTutor* developed by the Institute for Intelligent Systems at University of Memphis, engages learners in a dialogue and highlights their misconceptions in order to promote deeper reasoning. A mentor agent might simulate the qualities of an ideal human mentor, including both professional expertise and a personal and caring demeanor. Nonetheless, the most popular use is to design an agent to be peer-like. An agent that functions as a simulated peer learns *with* the learner and/or serves as a coping model for challenging tasks. The simulated peer has been permuted flexibly to a peer tutor, a collaborator, a competitor, or even a troublemaker. *MathGirls*, developed by the CREATE lab at Utah State University, embeds a female-peer agent that tutors middle-grade girls in mathematical concepts and encourages the girls to have positive attitudes toward mathematics learning and their self-efficacy in the learning.

The second issue inquires into what type of personal attributes (e.g., agent gender, ethnicity, personality, etc.) a designer should equip an agent with in order to stimulate relationship building between a learner and agent and, thereby, maximize the effectiveness of the program. On one hand, this inquiry about personal attributes would make a worthwhile contribution to the increasing diversity in the learner population today. In classrooms, similar personal attributes of a learner and others often serve as an influential factor for the efficacy of an instructional intervention. Given that learners interact with pedagogical agents socially and

naturally as they do with human instructors and peers, it seems natural to expect that a learner would be motivated to work with an agent sharing a similar attribute. Indeed, research shows that when an agent's personal attributes match the learner's, the learner tends to build a more developed social relationship with the agent, compared to when they do not match. That is, the learner perceives the agent more positively and prefers to continue with the agent. The learner also listens to the agent more carefully and takes the agent's instructional messages more seriously. Nevertheless, there are incidences when this developed relationship functions as a distractor from learning.

In addition, the author has suggested seven constituents for the effective design of pedagogical agents to produce successful modeling effects. Grounded in human/computer interaction and social psychology research, the constituents include 1) agent competency, 2) interaction type, 3) affect, 4) gender, 5) ethnicity, 6) multiplicity, and 7) feedback. The author has examined the effect of various permutations of the constituents on learners' perceptions, social judgments, self-efficacy, and learning. To conclude, it seems improbable that there is a single, optimal agent that would work well with learners diverse in cognitive and personal characteristics.

Reflections and Recommendations

With the increasing accessibility of advanced technologies in school and at home, the educational technology community has explored a variety of ways that utilize advanced technologies to help address educational challenges. When embodied pedagogical agents are introduced in the field, many researchers have viewed this technology merely as one variation of multimedia-based learning or a combination of multimedia (i.e., text, image, sound, video, etc.). However, over the last decade, studies have found consistently that agent presence is much more

than a collective medium; rather, an agent plays a distinct social and affective role for a broad range of learners. It promises to augment the bandwidth of a learner's interactions with computers and to add social richness to the interactions. In particular, youth today grows with everyday technologies, often called *digital natives*. In their use of technologies, the boundary between real and virtual is often blurred; interacting with animated digital characters (e.g., avatars and agents) is becoming commonplace. Pedagogical agents could supply simulated teachers or peers for the youth who grapples with learning challenges and, also, serve as supplemental tools for the teachers who are overloaded with daily demands.

Continued research efforts are needed to establish the effectiveness of pedagogical agents on both learner affect and cognition. A volume of research already attests to the effectiveness of pedagogical agents on promoting motivation and affective engagement in the learning process. However, the effectiveness of an agent on cognitive skill acquisition is still unclear. Some studies demonstrate that agents have produced significant cognitive gains including knowledge transfer, yet others fail to demonstrate this effect, even when they have established evidence for increased motivation. This conflicting trend sometimes promotes skepticism over pedagogical agent use, and, consequently, some researchers focus their research on affective development without expectation of cognitive skill changes. This implies that designers judge the option carefully. Certainly, when an application is geared toward facilitating learners' positive affect, agent presence can be a robust choice, taking advantage of social affordance through the illusion of life.

Lastly, in the face of inequity in STEM education, pedagogical agents might play a role to help achieve equity. STEM stands for science, technology, engineering and mathematics. The gender and ethnic inequity in this area is often attributed to the unsupportive learning context in

schools and undesirable social influences such as stereotyping. This leads to growing awareness on the social and cultural aspect of females' and ethnic minorities' learning processes. It is clear that more research is called for in designing effective learning technology for these students. The effective technology should support the students' identification with STEM and include specific features that stimulate their motivation. Pedagogical agents can be one such technology. A pedagogical agent acting as a role model might motivate female and minority students to STEM learning that is not typically popular but worth pursuing. Research has shown that agent presence has a strong appeal for many females and ethnic-minority students and successfully elicits the students' social responses. These students' online learning experience seems to relate closely to their everyday classroom experience. Their positive experiences with their pedagogical agent are influenced largely by their marginalized experiences in the everyday STEM classrooms. Thus, it seems natural that minority students better identify themselves with the learning domain when working with an agent than when not. One important implication of this is that the careful observation of student characteristics and accurate understanding of challenges that students face in the classroom should be a primary step to guide the effective design and use of pedagogical agents.

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See also Animated Agents in Learning Systems, Virtual Tutors, Human Computer Interaction, Cultural Considerations in Technology-Enhanced Learning and Instruction, Affective Factors in Learning, Instruction and Technology, Avatars and Agents in Virtual Systems.

Further Readings

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