Pedagogical Agents

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Abstract

In this chapter we synthesize the pedagogical agent literature published during 2005–2011. During these years, researchers have claimed that pedagogical agents serve a variety of educational purposes such as being adaptable and versatile; engendering realistic simulations; addressing learners' sociocultural needs; fostering engagement, motivation, and responsibility; and improving learning and performance. Empirical results supporting these claims are mixed, and results are often contradictory. Our investigation of prior literature also reveals that current research focuses on the examination of cognitive issues through the use of experimental and quasi-experimental methods. Nevertheless, sociocultural investigations are becoming increasingly popular, while mixed methods approaches, and to a lesser extent interpretive research, are garnering some attention in the literature. Suggestions for future research include the deployment of agents in naturalistic contexts and open-ended environments, and investigation of agent outcomes and implications in long-term interventions.

Keywords

Pedagogical agent • Conversational agent • Teachable agent • Intelligent tutoring system

Introduction

Pedagogical agents are anthropomorphous virtual characters employed in online learning environments to serve various instructional goals. For instance, they frequently act as instructors or motivators and can interact with learners via gestures, natural language, or facial expressions. Pedagogical agents are frequently integrated in online learning environments because they may be capable of providing cognitive support to the learner (Baylor, 1999) and social enrichment to the learning experience (Gulz, 2005). For instance, agents can provide human-like assistance (e.g., by answering questions), and reduce learner anxiety and frustration (e.g., by appearing welcoming and friendly). Two subcategories of agents often examined in the literature are conversational agents and teachable agents: Conversational agents are able to hold conversations with learners, and teachable agents are characters that the students teach to complete various activities (e.g., solve puzzles).

In this ~~chapter~~ we describe and synthesize the pedagogical agent research that was published between 2005 and 2011. We begin by presenting a short description of pedagogical agents with regard to the topic's historical roots. Next, we discuss the theoretical foundations upon which the deployment of agents is grounded in the literature. Then, we identify claims made by pedagogical agent researchers and evaluate the empirical evidence that exists to support those claims. We conclude by synthesizing the current foci of the field and presenting fruitful lines of future inquiry.

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Historical Roots

The development of pedagogical agents can be traced back to the 1970s Intelligent Tutoring Systems (ITS). An ITS exhibits characteristics similar to a human tutor such that it may be able to answer student questions, detect misconceptions, and provide feedback. Such a rich system requires contributions from a number of fields including education, computer science, instructional design, and psychology, all of which have contributed to a deeper understanding of how virtual characters can be effectively utilized in educational settings. While the original ITS were abstract entities that focused on tutoring, the next three decades saw advances in agent representation (i.e., visual embodiment) and interactive capabilities. Over the years, ITS evolved into modern virtual characters that encompass complex visual forms, are able to interact with learners using multiple channels of communication (e.g., text, speech, and deictic gestures), and are able to exhibit social skills and intelligence by communicating with users on a broad range of issues that include not just the tutoring topic, but also topics of broader interest.

The vision and role of agents in the learning ecology has also shifted during these three decades. While ITS were initially seen as abstract intelligent systems able to assist learners cognitively (e.g., by posing or answering questions relevant to student tasks), more recently, agents are seen as inherently social (and relational) artifacts. In addition, the field has expanded its scope in terms of roles that pedagogical agents might play in learning environments. Such roles include tutors, coaches, and actors (Payr, 2003); experts, motivators and mentors (Baylor & Kim, 2005); learning companions (Kim, Baylor, & Shen, 2007); change agents (Kim & Baylor, 2008); and lifelong learning partners (Chou, Chan, & Lin, 2003).

Theoretical Foundations

The field's multidisciplinary roots contribute to the diversity of perspectives that its researchers employ to investigate the use of pedagogical agents in education. Chief among those perspectives are the Computers as Social Actors paradigm, social-cognitive theories, and, more recently, cognitive load theory.

Computers as Social Actors

A large body of literature is grounded in the Computers as Social Actors (CASA) paradigm (Nass & Brave, 2005; Reeves & Nass, 1996). This paradigm suggests that humans interact with media in inherently social and human ways. To illustrate this idea, Reeves and Nass (1996) gathered social psychology experiments investigating the ways humans interact with, respond to, and treat each other based on various personality traits. For instance, studies have shown that individuals exhibit a preference for people who flatter them over people who criticize them. Whereas in the original experiments humans interacted with humans, in the experiments conducted by CASA researchers, humans interacted with media (e.g., a computer program). Results from the CASA set of studies paralleled the results of the original studies. In other words, humans responded to media in largely the same ways they would have responded to other humans. For example, humans rated flattering computers more favorably than computers that responded to them in less flattering ways (Reeves & Nass, 1996). Applying this paradigm to pedagogical agent research implies that learners will treat pedagogical agents in social ways. For instance, prior research has shown that learners may stereotype agents according to appearance (Veletsianos, 2010) and that visual appearance may enable agents to function as social role models for learners (Kim & Baylor, 2006; Rosenberg-Kima, Baylor, Plant, & Doerr, 2008).

Social-Cognitive Theories

Kim and Baylor (2006) have argued that agents' pedagogical potential can be positioned in numerous social-cognitive theories, which they summarize in their paper. The nuances and specific suggestions for pedagogical agent design derived from these theories are outside of the scope of this chapter, but if the reader is interested in these, she/he can examine Kim and Baylor (2006, 2008), and Veletsianos, Miller, and Doering (2009). For the purposes of this paper, we briefly mention common elements of socio-cognitive theories that apply to the design of pedagogical agents:

- Distributed cognition: Rather than residing in individual's minds, in this perspective human cognition is distributed among individuals, tools, and artifacts in the world. Viewed in this perspective, pedagogical agents (i.e., objects external to individuals) mediate, support, and extend cognitive processes. For example, agents can scaffold learners by asking questions, providing hints, or offering alternative perspectives.
- Social interaction: From this perspective, learning is viewed as a social process of interaction and negotiation with others. Pedagogical agents can create a social fabric within the learning environment, departing from traditional notions of computer-based instruction and technology-enhanced skill acquisition, and interact with learners as instructors, peers, collaborators, etc. For instance, agents can support learners' emotional states by exhibiting empathy and building and sustaining relationships with learners.

- Social-cognitive theory: Bandura (1986) noted that humans learn by observing others. For example, an individual might learn how to replace a kitchen faucet by watching a video of someone modeling this process. Similar to humans, pedagogical agents may serve as models in instructional scenarios. Designers can capitalize on appearance-related characteristics (e.g., gender) to influence attitudes and task engagement (Rosenberg-Kima et al., 2008). For example, women and underrepresented minorities comprise a small proportion of students enrolled in K-12 computer science courses (Wilson, Sudol, Stephenson, & Stehlik, 2010), and one way to encourage these populations to consider a computer science course may be through the development of a persuasive agent that serves as a social model (e.g., young, female).

Cognitive Load Theory

Cognitive Load Theory (CLT) (Sweller, 1994, 2004) is a psychological theory that attempts to explain how different tasks and technologies place varying demands on a working memory that has limited capacity. Human cognitive architecture theorists conjecture that humans process information using a three-component system comprising a sensory buffer, short-term storage, and long-term storage (Baddeley, 1992). CLT is concerned with the short-term (also called working memory) and the long-term components of the human cognitive architecture.

The main concern of CLT is the ease with which information is processed in working memory. Baddeley (1992) pioneered the idea that working memory is divided in multiple channels. Working memory load may be influenced by the nature of the learning task (intrinsic cognitive load) and the design of the instructional material. Specifically, instructional material design may influence cognitive processes unrelated to learning and schema formation (extraneous cognitive load) or cognitive structures related to schema formation such as processing, construction, and automation (germane cognitive load). The focal principle of CLT is to increase germane and decrease extraneous cognitive load (Kester, Lehnen, Van Gerven, & Kirschner, 2006; van Merriënboer & Ayres, 2005).

Concerning pedagogical agents, cognitive load theory posits that agent-specific information that is peripheral to the content/task (e.g., superfluous facial expressions that have little instructional purpose) would increase extraneous cognitive load by requiring learners to unnecessarily process information and invest cognitive effort where there is no reason to do so. Investing cognitive resources to information/media that are peripheral to the task will therefore hamper learning. Woo (2008) and Clark and Choi (2005) argued that agents may increase cognitive load because learners may have to split their attention between the agent's numerous visual elements (e.g., gestures and facial expressions), or between the agent and other information on the screen (e.g., text). For example, a split-attention effect may be created when an agent uses both visual and auditory information in their instruction.

Claims and Outcomes Associated with Pedagogical Agents

In this section we synthesize the literature in the field from 2005 to 2011 and provide continuity to the analysis that already exists in the literature. For this reason, we extend the analysis presented by Gulz (2004) in which she examined the claims and evidence presented in pedagogical agent research. In her analysis, Gulz found that researchers claimed that pedagogical agents could afford "increased motivation, increased sense of ease and comfort in a learning environment, stimulation of essential learning behaviours, increased smoothness of information and communication processes, fulfillment of need for personal relationships in learning, and gains in terms of memory, understanding, and problem solving" (p. 315), but that the evidence supporting these claims was often mixed and contradictory. The claims we identified in the current literature are described next.

Claim #1: Pedagogical Agents Are Adaptable and Versatile

One of the most prevalent claims (and rationales) for pedagogical agent integration is their perceived adaptability and versatility. Researchers claim that pedagogical agents are capable of aiding learning, delivering content, and supporting both cognitive processing and metacognitive skills (Clarebout & Elen, 2007) through flexibility, support, and scaffolded guidance (Biswas, Leelawong, Schwartz, Vye, & The Teachable Agents Group at Vanderbilt, 2005; Hawryskiewycz, 2006; Lin, Chen, Wu, & Yeh, 2008). In addition, researchers posit that pedagogical agents are able to monitor and adapt to students' learning styles, backgrounds, and behaviors in order to individualize instruction (Sklar & Richards, 2010; Woo, 2008). By using adaptive systems that are programmed to respond to users in an intelligent fashion, agents may provide learners with intelligent scaffolding via appropriate challenges or information. In essence, agents monitor learner behavior to ascertain when learners may need assistance, and then provide just-in-time support or guidance (Woo, 2008). The basis for this claim rests on the effectiveness of one-to-one *human* tutoring as an instructional strategy. Designing pedagogical agents as virtual tutors and positioning them in situations where they can offer one-to-one tutoring is expected to enhance learning (Graesser, Jeon, & Dufty, 2008). A widely cited example in the literature that effectively exemplifies these ideas is AutoTutor, whose pedagogical strategies include the use of dialogue, feedback, corrective statements, hints, fill-in-the-blank questions, and requests for more information from the user (Graesser et al., 2008).

The majority of research in the field focuses on pedagogical agents programmed with predetermined actions and activities. While this may be the case for a number of reasons, two likely explanations are (a) technological constraints and (b) the need for controlled environments to conduct experimental research. Technological constraints have limited the field in attaining the vision of widely deployed adaptive pedagogical agents, while the focus on experimental research in the field directs research towards the use of technologies with predetermined behaviors. Thus, our understanding of adaptive pedagogical agents and their use and impact is limited. The Tutoring Research Group at the University of Memphis, however, has been able to provide empirical evidence on this topic through their work with AutoTutor and the development of technologies capable of inferring learners' affective states (D'Mello, Craig, Witherspoon, McDaniel, & Graesser, 2008; D'Mello & Graesser, 2010). AutoTutor is capable of interacting with learners in a mixed-initiative format and has been shown to produce learning gains (Graesser, Chipman, Haynes, & Olney, 2005; Graesser, Jackson, & McDaniel, 2007). Other researchers have repurposed the Program Z artificial intelligence engine and the A.L.I.C.E Artificial Intelligence Markup Language to study pedagogical agents capable of holding content-related conversations with learners (e.g., Doering, Veletsianos, & Yerasimou, 2008; Veletsianos, Scharber, & Doering, 2008). Even though these studies have noted agents' versatility in conversing with learners on a number of topics, they also report instances in which agents were not capable of responding correctly or appropriately to learner inquiries. This finding highlights the limitations of mixed-initiative dialogue: whereas in agent-tutoring contexts the human and computer tutors tend to drive dialogue with limited input from students, in mixed-initiative settings agents encounter difficulties in managing learner-initiated input.

Claim #2: Pedagogical Agents Engender Realistic Simulations

Researchers have claimed that pedagogical agents provide realistic simulations by replicating human behavior (Sklar & Richards, 2010). For example, virtual agents may demonstrate procedural tasks, use gesture and gaze as instructional strategies, enact thinkalouds to simulate reasoning and metacognition, and model appropriate social behavior to demonstrate how humans act. In these ways, agents are actors, models, simulators, and manipulatives within digital learning environments. In addition, researchers hypothesize that pedagogical agents can add to the believability of simulations with a virtual body and by communicating in a natural manner with learners (Woo, 2008). Whether natural embodiment contributes to believability is unclear, however. For instance, Adcock, Duggan, Nelson, and Nickel (2006) conducted a study focused on teaching helping skills to 130 human service students by assigning them to one of two experimental conditions: an interactive learning environment with a pedagogical agent or static environment where they had to read a helper-client script. Although students perceived both systems positively, results showed that perceptions of believability did not differ significantly between the two environments, indicating that the two interventions were equally believable.

The literature also suggests strategies intended to enhance natural communication between agents and learners. These strategies include the use of relation-oriented dialogue such as small talk and remembering past interactions (Gulz, 2005) or having a visual representation that matches agents' roles (Veletsianos et al., 2009). If learners sense that they are accompanied by a real person, they develop a sense of companionship that increases self-identification (Baylor & Kim, 2005) and the overall emotional connection to the agent (Gulz, 2005; Woo, 2008). Agents can also embody personalities by sharing stories about themselves, demonstrating various attitudes, expressing opinions, displaying emotion and empathy, and providing encouragement (Gulz, 2005; Woo, 2008). Overall, natural communication is expected to add a sense of familiarity to the simulation, facilitate engagement, and increase enjoyment in both the learning process and domain content acquisition (Gulz, 2005; Kim & Baylor, 2006; Woo, 2008).

Claim #3: Pedagogical Agents Address Learners' Sociocultural Needs

Researchers have also claimed that agents can address a variety of learners' sociocultural needs in virtual environments by providing opportunities for social interaction (Kim & Wei, 2011). For example, when agents have appropriate skills and domain knowledge, they can act as peer learners and work alongside humans in collaborative activities (Gulz, 2005; Kim & Baylor, 2006; Sklar & Richards, 2010; Woo, 2008). As activity partners, virtual agents may lower learner anxiety and promote student empathy by providing peer-support, acting as role models, and allowing students to observe mistakes that the agent makes during the learning process (Chase, Chin, Oppezzo, & Schwartz, 2009; Gulz, 2005; Woo, 2008). It is also postulated that agents as peer learners may seem less intrusive or threatening than they do as overt instructors (Sklar & Richards, 2010). Furthermore, strategic use of pedagogical agents of various races and genders may provide learners from all backgrounds with social models that are similar to them, which may "positively [influence] their interest, self-efficacy, and stereotypes" (Rosenberg-Kima, Plant, Doerr, & Baylor, 2010, p. 35) about various professions, such as science and engineering. Similarly, an agent's appearance may activate stereotypes or trigger expectations of agent intelligence (Haake & Gulz, 2008; Veletsianos, 2007, 2010), and if agents do not live up to these expectations human counterparts may become irritated (Norman, 1997). For this reason, researchers have sought to manage and lower user expectations by proposing that designers take a more refined approach to agents' visual and aesthetic representations (Gulz & Haake, 2006).

When learners are given opportunities for unconstrained interaction with agents, the empirical literature shows that learners treat agents as conversational partners (Hubal et al., 2008; Louwerse, Graesser, Namara, & Lu, 2009) and interact socially with them. In qualitative studies of participants' experiences, learners have reported that such interactions have resulted in enjoyment (Doering et al., 2008). While the opportunity to interact with agents on topics that are not immediately relevant to the task may be perceived as distracting, Veletsianos (2012) showed that mindful integration of non-task contexts (e.g., greetings, interactions that establish common ground between agent and learner, etc.), may enable the "development of a social and relaxed atmosphere in which learning can happen" (p. 277). In an earlier study examining this same idea, Bickmore, Shulman, and Yin (2009) conducted a longitudinal randomized experiment in which participants (n=26) interacted with virtual exercise counselors that shared stories about *themselves* or with virtual exercise counselors that shared stories about *others*, and found that users conversed more and reported higher enjoyment with the agent that shared stories about themselves than with the agent that shared stories about someone else. In other words, the use of first-person narratives fostered greater interaction and enjoyment, lending credence to the hypothesis that non-task contexts might be beneficial to learning with agents.

Nevertheless, social interaction between agents and learners might also lead to frustration and disappointment, as well as reveal that learners often use abusive language, aggressive demeanor, and sexist commentary when conversing with pedagogical agents. For example, De Angeli and Brahnam (2008) conducted a descriptive lexical analysis of a random sample of 103 agent–user conversations (each consisting of 82 conversational turns on average) and found that approximately 10 % of user input could be categorized as offensive or insulting. Additionally, when 90 adolescents were asked to choose between a strictly task-oriented agent and a task- *and* relation-oriented agent, approximately 41 % of participants expressed preference for the strictly task-oriented agent, and rationalized this choice by explaining how a social agent might be distracting and tiresome (Gulz, 2005).

The different circumstances and designs of the studies described above may explain the differing results: Bickmore et al. (2009) reported on a long-term intervention focusing on exercise counseling while Gulz (2005) reported on a short-term study where students were asked to take on the role of a journalist conducting research in a foreign country. Similar results have been observed when examining the impact of agent gender, race, and ethnicity. For example, though research has shown that students tend to be influenced and persuaded by agents that match their gender, race, and ethnicity (e.g., Kim et al., 2007; Moreno & Flowerday, 2006), these results vary depending on other variables such as student age and race (Baylor, 2009). As a result, pedagogical agent studies have become more fine-grained in their treatment of agent variables. For instance, Gulz and Haake (2010) suggested that studying masculinity and femininity in agent appearance, as opposed to gender, may allow researchers to draw more refined inferences.

To summarize, the literature does not uniformly show that agents address learners' sociocultural needs. Pedagogical agents may initially ~~be novel but become~~ irritating after a while. Alternatively, agents may be helpful as navigational guides while being distracting as "talking heads." For this purpose, it is important for researchers and designers alike to examine and be mindful of the purpose that specific agents serve.

Claim #4: Pedagogical Agents Foster Engagement, Motivation, and Responsibility

Researchers often posit that increased motivation is a key function of pedagogical agent use (Kim & Baylor, 2006; Kim & Wei, 2011; Kramer & Bente, 2010; Lusk & Atkinson, 2007). For example, the social presence of an agent is expected to increase a learners' interest and attention, and, therefore, their motivation (Kramer & Bente, 2010) because (a) the agents' appearance can be representative of an ideal social model for the learner (Baylor, 2011), and (b) the agents can "enrich and broaden the communicative relationship between learners and computers as well as provide computers with motivational and affective instructional features that actively engage students" (Lusk & Atkinson, 2007, p. 748). Interaction with competent agents is also expected to facilitate motivation (Kim & Baylor, 2006; Kim, Baylor, & PALS Group, 2006).

The *persona effect* is a focal point in the literature. The persona effect suggests that the presence of agents causes learners to perceive their learning experience positively as a result of interpreting computers as social actors (Choi & Clark, 2006; Moreno, Mayer, Spires, & Lester, 2001). Furthermore, agents increase engagement by simulating believable human-to-human connections through the coordination of verbal communication with nonverbal cues, such as body language, gestures for attention, and navigational guidance (Dunsworth & Atkinson, 2007; Gulz, 2005; Lin et al., 2008; Lusk & Atkinson, 2007; Sklar & Richards, 2010; Woo, 2008). However, empirical support for the persona effect is mixed, possibly due to differences in the quality of agents employed. For instance, Baylor and Ryu (2003) found support for the persona effect; Frechette and Moreno (2010), Domagk (2010), and Choi and Clark (2006) found that agent presence did not contribute to student interest; and Hubal et al. (2008) found that the technology and setting in which an agent is being used is not sufficient to engage participants. Other researchers have encountered more complicated results. For instance, Dirkin, Mishra, and Altermatt (2005) evaluated 116 participants' perceptions of social presence and the learning experience in four experimental conditions: text only, voice only, voice and image, and fully social agent condition. Their results showed that students perceived higher degrees of social presence for the text only and fully social agent conditions than for the other two conditions. This evidence supports the persona effect hypothesis, but the fact that students in the text-only condition also rated their experience highly poses a conundrum that future research should investigate.

Researchers have also suggested that users can build valuable relationships with agents, and these relationships may increase learners' sense of responsibility, motivation, and reduce their sense of loneliness in a virtual environment (Gulz, 2005). Learner motivation is an integral part of the teachable agent paradigm (Schwartz, Blair, Biswas, Leelawong, & Davis, 2007). For example, Chase et al. (2009) discovered that when students were teaching their agents, they spent more time with the learning activities and were quick to acknowledge mistakes. The researchers hypothesized that teachable agents may engender a sense of responsibility as learners are motivated to teach their agents. The topic of agent–learner relationships introduces interesting philosophical, ethical, and social questions, and Bickmore (2003) has examined the possibility of agents establishing and maintaining long-term relationships with users. However, the topic of agent–learner relationships is one that has not, to date, been explored extensively in our field's literature. Is it ethical for pedagogical agent designers and researchers to design virtual characters that can connect with learners on a deep emotional level? If so, are such agents appropriate for all age levels? Regardless of how strong or weak a relationship is, what does it mean, in a phenomenological sense, for a learner to have a relationship with a virtual character? What does the future look like given that technology is continuously advancing and researchers are developing more believable, competent, and adaptive agents? These are difficult questions to answer, but scholarship investigating these questions will help us make sense of the possibilities, boundaries, pitfalls, and limitations of agent–learner relationships, and hence the degree to which agents can foster engagement, motivation, and responsibility.

Claim #5: Pedagogical Agents Improve Learning and Performance

The last claim that we found in the literature relates to agents contributing to learning and performance. Agent versatility, agent ability to engender realistic simulation, agent ability to address sociocultural needs, and increased motivation/engagement created through interactions with agents is expected to eventually lead to improved learning and performance outcomes (Gulz, 2005; Kim & Baylor, 2006; Kim & Wei, 2011; Kramer & Bente, 2010). Additionally, a number of researchers suggest that, compared to conventional information delivery, virtual agents tend to improve comprehension, retention, recall, problem-solving, self-efficacy, and transfer (Dunsworth & Atkinson, 2007; Gilbert, Wilson, & Gupta, 2005; Gulz, 2005; Murray & Tenenbaum, 2010). The affordances provided by pedagogical agents lead to deeper understandings in a variety of ways. For example, learning procedural tasks is improved through agents' use of nonverbal gestures, whereas attitudinal instruction is more effective with agents' use of facial expressions (Baylor & Kim, 2009). By combining verbal and nonverbal cues, agents may better support information procession than text or narration alone (Dunsworth & Atkinson, 2007). Use of natural language and communication is also expected to increase the effectiveness of dialogues and deepen learners' comprehension of domain content (Graesser & McNamara, 2010).

Furthermore, researchers claim that pedagogical agents help learners retain information longer (Kim & Wei, 2011; Woo, 2008), improve their problem-solving skills (Dunsworth & Atkinson, 2007), and foster knowledge transfer (~~Chin et al., 2010;~~ Kim & Wei, 2011; Lusk & Atkinson, 2007). [AU2] Learning from animated agents also results in "conceptually accurate solutions" (Dunsworth & Atkinson, 2007, p. 679) and an improved ability to transfer that knowledge (Lusk & Atkinson, 2007). Nevertheless, transfer of knowledge and skills in agent-based environments also requires pedagogical strategies such as the use of instruction that uses worked examples (Kim & Wei, 2011) and the use of subgoals in problem solving (Lusk & Atkinson, 2007).

Empirical research however, has shown that simply adding pedagogical agents in a digital environment does not lead to better learning outcomes, with any benefits observed usually being attributed to the pedagogy used by the agent, rather than to the agent itself (Clark & Choi, 2005; Moreno, 2004). For instance, Choi and Clark (2006) found no significant differences in learning between an a condition in which an agent was used ($n = 32$) and a condition in which an arrow was used ($n = 42$) in an experimental study conducted in the context of second language instruction. Louwerse, Graesser, Lu, and Mitchell (2005) found no significant differences in comprehension scores between learners assigned to a voice-and-agent condition and a voice-and-no-agent condition. The researchers suggested that "if enough social cues are provided by the voice only, the agent does not contribute much more to comprehension" (Louwerse et al., 2005, p. 701). Nevertheless, emerging evidence from the literature suggests that this finding may need further qualification (Domagk, 2010; Sträfling, Fleischer, Polzer, Leutner, & Krämer, 2010; Veletsianos, 2007, 2010). For example, Sträfling et al. (2010) and Veletsianos (2010) found differential effects between agents of different appearances. Evidence from Domagk (2010) indicated that even though the inclusion of a pedagogical agent does not have an impact on learning, (a) appealing agents promoted transfer (when compared to unappealing agents), and (b) unappealing agents (dislikable in image and voice) even hindered learning. On the other hand, Jackson and Graesser (2007) found an inverse correlation between deep learning and liking the learning experience, noting that agent designers and researchers face the dilemma of creating effective learning environments that learners enjoy and want to revisit. These results suggest more refined pedagogical agent design, with renewed attention to enjoyment, appeal, and appearance of pedagogical agents.

Current and Future Directions

Our review of the empirical research suggests that the evidence for the claims presented in the literature is mixed. While recent technological advancements have enabled researchers to ask questions that arise out of our improved ability to design different types of virtual characters (e.g., teachable agents), our evaluation shows that no single claim is supported by unambiguous empirical results.

The current literature includes suggestions for future research. While the suggestions arise from individual studies, a number of future directions are recurrent. Such directions include the need for longitudinal and long-term research (Baylor, 2011; Choi & Clark, 2006; Dehn & van Mulken, 2000; Gulz, 2004), multidisciplinary investigations (Kim & Baylor, 2006; Veletsianos, Heller, Overmyer, & Procter, 2010; Yung & Dwyer, 2010), investigations of agent–learner interactions in situations where agent behavior adapts (e.g., agents are able to dialogue with learners) (Clarebout & Elen, 2006; Domagk, 2010; Dunsworth & Atkinson, 2007), exploration of agents' visual form, appearance, appeal, and aesthetics (Baylor, 2009; Domagk, 2010; Gulz & Haake, 2006; Veletsianos, 2007), and investigations of agents' nonverbal communication (Baylor & Kim, 2009; Frechette & Moreno, 2010). In addition to the research directions identified in existing literature, based on our synthesis, we suggest that the following three areas also need to be considered by pedagogical agent researchers: cognitive and sociocultural foci, methodological focus, and supporting student-centered inquiry within open-ended environments.

Cognitive and Sociocultural Foci

The majority of scholarly work on pedagogical agents has so far focused on cognitive concerns, such as the impact of agent image on retention (Moreno et al., 2001) and the extent to which the presence (vs. absence) of an agent facilitates learning/motivation (Domagk, 2010). More recently however, researchers have called for an increasing emphasis on sociocultural investigations (Gulz, 2005; Kramer & Bente, 2010). Examples of such investigations include research relating to the influence of agents' visual appearance (e.g., Baylor, 2009; Gulz & Haake, 2010) and pertaining to understanding how learners and agents interact (e.g., Veletsianos et al., 2008). Research into the sociocultural elements of agent–learner interactions will help us better understand agent–learner interactions and relationships, the learner experience, the design of future agent-based systems, and learning processes. Kim and Baylor (2006) argued that agent-based learning is a social process, and as such, taking a sociocultural lens to investigate agent deployments will inform future work.

Methodological Focus

The majority of the work on pedagogical agents has focused on experimental and quasi-experimental investigations (Adcock & Van Eck, 2005; Mahmood & Ferneley, 2006), in which researchers have evaluated the influence of agent-related variables on various outcomes. Qualitative and interpretive investigations in the field are noticeably fewer, even though researchers have argued that such investigations would allows us to gain a deeper understanding of pedagogical agent deployments (Veletsianos & Miller, 2008).

As pedagogical agents are increasingly integrated in complex digital learning environments (e.g., virtual worlds and video games), and especially in open-ended learning environments (see below), we need to understand not just the impact that pedagogical agents and their various features may have on learning outcomes, but also the meaning behind agent–learner interactions, the use of the agents within the context of the environments they inhabit, and the potential roles they serve in such environments (e.g., agent as tutors, agents as peers, etc.). Overall, to gain a deeper, richer, and more diverse understanding of agent technologies we need to employ diverse methodologies. Steps towards this goal are already evident in the literature. For instance, mixed methods investigations to understand learner experiences with pedagogical agents are already available. For example, Adcock et al. (2006) supplemented their experimental results with user comments on the usability of two learning environments used in their study, thus gaining a richer understanding of how to enhance the agent-based learning environment for future implementations. Similarly, Veletsianos (2009) combined a quasi-experimental design with a grounded theory lens to understand pedagogical agent expressiveness and the "existence of multiple, complementary, and contradictory truths that coexist within the use and deployment of pedagogical agents in education" (p. 350). That study revealed that while agents might enhance affective aspects of learning, they also introduce the notion of human–agent relationships in learning environments, with which designers now have to grapple.

Supporting Student-Centered Inquiry Within Open-Ended Environments

The pedagogical agent field's focus on cognitive concerns is in stark contrast to recent discussions in the educational technology discipline. Specifically, open-ended learning environments, such as social networking sites and video games, are gaining increasing popularity as locales of student-centered learning activity. In such environments, social interaction and user contributions are central aspects of the learning experience. Agents that are able to engage in social-oriented dialogue may therefore be of value in online learning contexts, but the current directions of the field generally view the agent as an expert figure quick to provide instruction as opposed to one that aims to support student-centered inquiry and activity. Future research focusing upon (a) agents within digital learning environments vis-a-vis stand-alone agents, and (b) agents in open-ended learning environments, will be beneficial to the field. Examples of both of these foci are already present in the literature (e.g., Clarebout & Elen, 2006, 2007; Zumbach, Schmitt, Reimann, & Starkloff, 2006).

Conclusion

This chapter synthesized the existing literature on pedagogical agents, summarized the claims that researchers have made with regards to the potential benefits of pedagogical agents, and evaluated the empirical evidence that exists to support those claims.

The pedagogical agent field is as complex as it has ever been. Numerous factors contribute to this complexity, including:

- The way that experiments have been designed may have contributed to mixed results (Clark & Choi, 2005).
- Varied agent modalities used in varied content areas make comparisons difficult (Baylor & Ryu, 2003).
- A multiplicity of variables, such as agent role, voice, and voice quality, interact in complex ways, making generalizations difficult (Louwerse et al., 2005).

Thus, pedagogical agent researchers advise that the use of agents in digital environments requires careful evaluation (e.g., Baylor, 2009; Dirkin et al., 2005; Moreno & Flowerday, 2006). To improve comparisons between research efforts, Clark and Choi (2005) proposed five design principles for pedagogical agent researchers conducting experimental studies on learning and motivation: separate pedagogical agents from pedagogical methods; evaluate a variety of learning and motivation outcomes; make sure that measures are reliable and have construct validity; calculate the cost and benefit of agent and non-agent comparisons; and avoid testing agents that are visually and aurally complex.

In 2004, Gulz noted

> …we are still at a very early stage in the development of character enhanced systems, and consequently it is too early to go into evaluations of potential benefits of these kinds of learning environments. We have to await systems that are built for long-term real use and leave short-time lab studies behind. Evaluations today are bound to give uncertain results (p. 326).

Between 2004 and 2011, a handful of long-term studies have been conducted (e.g., Lindström, Gulz, Haake, & Sjödén, 2011; Veletsianos & Miller, 2008; Wagster, Tan, Wu, Biswas, & Schwartz, 2007). These studies are informative, but introduce additional issues that pedagogical agent researchers need to consider. For instance, Veletsianos and Miller (2008) asked what our experiences interacting with pedagogical agents would be like if we interacted with them over several months or years. This question becomes more difficult to answer considering that pedagogical agent theory does not always match practice, and it can be difficult for the designer to foresee such mismatches (Lindström et al., 2011). How would an agent's knowledge base need to change to be able to interact with learners over time, and would we be able to form long-term emotional bonds with agents? We echo Gulz's concerns with regard to the need for longitudinal studies, and advise pedagogical agent researchers to focus more of their energy on long-term evaluations of pedagogical agent implementation in real-world settings. Such endeavors will help us understand the actual use of agent technologies in messy real-world contexts.

Equally important, Moreno and Flowerday (2006) asked whether they would have found "the same effects had we used different social cues, content materials, learning measures, agent representations, or student populations" (p. 204). The educational psychology literature recommends systematic investigation of outcomes to answer questions such as the one above. We believe that such studies should be examined in relation to the goals of agent use. Such goals vary. For instance, agents may be used to provide on-demand instructional support, social enrichment, or even social and cultural diversity. The goals we devise for agents impact their design and, in turn, their behaviors and functions. For this reason, we need to understand and describe the unique contexts of agent-based naturalistic interventions in order to highlight how the "real world" influences the use, effectiveness, and design of pedagogical agents. Descriptions of how agent designs changed over time as a result of implementations in naturalistic settings will provide much-needed design knowledge to inform future practice and scholarship.

[AU3]

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