

## Avatars and Instruction: How Pedagogical Agents Can Improve Digital Learning

**H**uman beings of all ages are deeply social creatures, and it is no surprise that creators of instructional content have begun to explore ways that we might leverage this characteristic to improve learning outcomes. A growing body of research considers this possibility by evaluating the effectiveness of on-screen pedagogical agents (or avatars) in digital learning contexts. Driving this new wave of research is the following question: if the presence of other people (a teacher, peers, collaborators) is advantageous for learners, might a similar boost occur when a character is incorporated into on-screen content in a meaningful manner?

When it comes to multimedia best practices, simplicity is the reigning mandate. We know that across the age spectrum, a learner's cognitive processing resources are mighty but finite, so any extra visual or auditory elements are nothing more than problematic distractions that should be avoided (Mayer, 2005; see also Clark & Choi, 2005).

However, newer and more targeted research suggests that for effectively designed, on-screen pedagogical agents, the benefits to learning outweigh the processing costs (Johnson & Lester, 2016; Kim & Baylor, 2016). In fact, they can positively impact learning outcomes along with a number of other cognitive and affective benefits (Meij, Meij, & Harmsen, 2015; Moreno & Flowerday, 2006; Schroeder & Adesope, 2014).

In this paper, we summarize some key findings from this recent research and what it tells us about how we can utilize avatars to optimize learning.

### About This Paper

The Applied Learning Sciences team within McGraw-Hill Education School often reviews existing scholarship and literature from multiple sources across a variety of domains that influence, inform, and strengthen content, pedagogy, and implementation. This research brief is a synthesis of existing research intended to enlighten and inform the field about applied learning sciences in general.

The various ways in which this research manifests itself within each of our programs specifically is managed by a research lifecycle, efficacy studies, and additional internal and external factors embedded in product development processes for each program (including ongoing iterative research with teachers and in the field).

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## Which agent attributes matter most for optimizing learning outcomes?

**E**ducation researchers have experimented with pedagogical agents that serve as a guide, coach, expert, a peer or learning companion, virtual teammate, and, in some cases, a combination of these roles. Furthermore, they have explored a range of avatar attributes, including gender, ethnicity, age, likeability, formality, politeness, responsiveness, and visual appeal, among others (Meij et al., 2015). The manner in which the agent interacts with the learner varies: in some cases, the agent provides enthusiastic comments intended to keep the learner motivated and interested, while in other cases, the agent actively instructs or guides the learner, providing content-related feedback.

Across a number of studies conducted with various age groups, subject areas, and instructional tasks, researchers have generally found that pedagogical agents are most effective when they:

- Actively signal the learner’s attention to relevant information through commentary, gestures, facial expressions, or other methods (e.g., Clark & Choi, 2005; Johnson & Lester, 2016; see also Schroeder, Adesope, & Gilbert, 2013).
- Behave in a genuinely social and interactive manner (Kim & Baylor, 2016; Schroeder & Gotch, 2015; Veletsianos, 2007).
- Have some level of perceived expertise or knowledge (Kim & Baylor, 2016), though numerous studies demonstrate that both peer-like and expert-like agents can be effective.

The goal is to get the learner to regard the agent as a “real” social interaction partner. This activating of the learner’s social interaction schema is known to be beneficial both cognitively and affectively, keeping the learner motivated and supporting mental processes (Johnson & Lester, 2016; Meij et al., 2015; Schroeder et al., 2013); some researchers call this “the persona effect.” Agents are designed to provide helpful signaling and commentary, either via narration or on-screen text, ideally delivered in learner-paced segments (Mayer, 2005; Schroeder et al., 2013; Schroeder & Gotch, 2015). In some studies, agents’ gestures alone led to improved learning on both transfer and generalization tasks among elementary school children learning to solve mathematical equivalence problems (Cook, Friedman, Duggan, Cui, & Popescu, 2016) and in other contexts as well (Baylor & Kim, 2009).

## Is it simply a morale boost – or something more?

**N**umerous studies support the notion that including an agent helps learners to feel engaged, positive, and motivated to persevere with challenging material (Kim & Baylor, 2016; Schroeder et al., 2013). In a science learning inquiry environment, researchers recently found that incorporating a pedagogical agent significantly improved self-efficacy beliefs and motivation in young adolescent learners. While the intent of the study’s design was to provide better motivational scaffolding to girls in particular—a young female agent was used in a science context—the positive effects on self-efficacy were significant for boys as well as girls (Meij et al., 2015; see also Plant, Baylor, Doerr, & Rosenberg-Kima, 2009; Arroyo, Woolf, Cooper, Burses, &

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Muldner, 2011). Given the tightly coupled relationships between motivation, self-efficacy, self-stereotyping, effort, and learning outcomes, it is likely that many of the affective benefits provided by pedagogical agents might be deeply interrelated with the cognitive benefits seen in many cases [i.e., improved retention, transfer, generalization, and explanation of concepts].

While early experimentation with avatars (Lester et al., 1997; Moreno, Mayer, Spires, & Lester, 2001) aimed at making the learning experience more enjoyable and effectively satisfying in its own right, a more complex—and even more pedagogically promising—picture is taking shape. Several researchers have noted that the presence of a pedagogical agent may support learning outcomes by decreasing anxiety and also helping to orient the learner’s attention to key elements and concepts embedded in the instructional content (Johnson & Lester, 2016; Meij et al., 2015; Wang et al., 2008). The emerging explanation is a sort of dual effect: agents can improve learning both by directly supporting cognitive processing and by creating a more positive, satisfying learning environment (Cook et al., 2016).

### **Are agents more effective in certain subject areas than others?**

**A**n unexpected finding that has recently surfaced through meta-analysis [i.e., when researchers examine many studies together and look for patterns] is that the benefit of pedagogical agents appears to be somewhat greater for STEM instructional contexts than humanities subjects (Schroeder et al., 2013). The reason is unclear. It may mask a slightly different fact: pedagogical agents’ ability to signal information may be most critical and impactful when learning abstract content or processes, which arguably occur more frequently in STEM contexts [or, at least, in those used in most of the experiments in this domain]. Researchers have also posited that if learners carry the perception that STEM content is more challenging than content within the humanities, then the boosted engagement effect of the agent may help them persist and work harder, thus leading to better learning outcomes (Baylor, 2011).

It is also important to note that STEM contexts have been more frequently studied in pedagogical agent research thus far, and as this field of research continues to expand, future studies may provide further support to the effectiveness of agents in contexts within the humanities or in certain subsets of humanities learning tasks.

### **Concluding Remarks**

Interestingly, as research has unfolded the past two decades, there has been a debate about the perplexing “mixed bag” of results across experiments using widely varying avatars and tasks. From the perspective of improving instructional materials, however, it is worth noting that this mixed bag is a reassuring one. While there have been a few studies that found no benefit when an agent was included, no studies reporting have found that including an agent was detrimental to learning outcomes (e.g., Heidig & Clarebout, 2011; Schroeder & Adesope, 2014). Refining our understanding of precisely which avatar design attributes, student characteristics, and learning environments enable success will help guide future efforts.

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A recent meta-analysis found that the benefit conferred by pedagogical agents is even stronger for child and adolescent learners than for adult learners (Johnson & Lester, 2016; Schroeder et al., 2013), though the younger age group warrants further experimental investigation to catch up with their adult counterparts to date. This suggests promising future avenues for both research and application as we find ways to utilize pedagogical agents and avatars to enhance instructional content for K-12 learners. As studies in this domain continue to evolve, it will undoubtedly shed further light on the causal underpinnings of these cognitive and affective benefits, as well as fine-tune our understanding of how we can optimize a pedagogical agent's design to craft learning experiences that are at once highly effective, engaging, and authentic.

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## References and Sources Consulted

- Arroyo, I., Woolf, B. P., Cooper, D. G., Burleson, W., & Muldner, K. (2011). The impact of animated pedagogical agents on girls' and boys' emotions, attitudes, behaviors and learning. In *Advanced Learning Technologies (ICALT), 2011 11th IEEE International Conference on* (pp. 506–510). IEEE.
- Baylor, A. L., & Kim, S. (2009). Designing nonverbal communication for pedagogical agents: When less is more. *Computers in Human Behavior, 25*(2), 450–457.
- Clark, R. E., & Choi, S. (2005). Five Design Principles for Experiments on the Effects of Animated Pedagogical Agents. *Journal of Educational Computing Research, 32*(3), 209–225.
- Clark, R. E., & Choi, S. (2007). The Questionable Benefits of Pedagogical Agents: Response to Veletsianos. *Journal of Educational Computing Research, 36*(4), 379–381.
- Cook, S. W., Friedman, H. S., Duggan, K. A., Cui, J., & Popescu, V. (2016). Hand Gesture and Mathematics Learning: Lessons From an Avatar. *Cognitive Science*.
- Craig, S. D., Gholson, B., & Driscoll, D. M. (2002). Animated pedagogical agents in multimedia educational environments: Effects of agent properties, picture features and redundancy. *Journal of Educational Psychology, 94*(2), 428.
- Heidig, S., & Clarebout, G. (2011). Do pedagogical agents make a difference to student motivation and learning? *Educational Research Review, 6*(1), 27–54.
- Johnson, W. L., & Lester, J. C. (2016). Face-to-Face Interaction with Pedagogical Agents, Twenty Years Later. *International Journal of Artificial Intelligence in Education, 26*(1), 25–36.
- Kim, Y., Baylor, A. L., & Shen, E. (2007). Pedagogical agents as learning companions: the impact of agent emotion and gender. *Journal of Computer Assisted Learning, 23*(3), 220–234.
- Kim, Y., & Baylor, A. L. (2016). Research-based design of pedagogical agent roles: a review, progress, and recommendations. *International Journal of Artificial Intelligence in Education, 26*(1), 160–169.
- Lester, J. C., Converse, S. A., Kahler, S. E., Barlow, S. T., Stone, B. A., & Bhogal, R. S. (1997). The persona effect: affective impact of animated pedagogical agents. In *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems* (pp. 359–366).
- Mayer, R. E. (2005). Principles for reducing extraneous processing in multimedia learning: Coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principles. *The Cambridge Handbook of Multimedia Learning*, 183–200.
- Mayer, R. E., & DaPra, C. S. (2012). An embodiment effect in computer-based learning with animated pedagogical agents. *Journal of Experimental Psychology: Applied, 18*(3), 239.
- Meij, H., Meij, J., & Harmsen, R. (2015). Animated pedagogical agents effects on enhancing student motivation and learning in a science inquiry learning environment. *Educational Technology Research and Development, 63*(3), 381–403.
- Moreno, R., & Flowerday, T. (2006). Students' choice of animated pedagogical agents in science learning: A test of the similarity-attraction hypothesis on gender and ethnicity. *Contemporary Educational Psychology, 31*(2), 186–207.

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## References and Sources Consulted (continued)

- Moreno, R., Mayer, R. E., Spires, H. A., & Lester, J. C. (2001). The case for social agency in computer-based teaching: Do students learn more deeply when they interact with animated pedagogical agents? *Cognition and Instruction*, 19(2), 177–213.
- Osman, K., & Lee, T. T. (2014). Impact Of Interactive Multimedia Module With Pedagogical Agents On Students' Understanding And Motivation In The Learning Of Electrochemistry. *International Journal of Science and Mathematics Education*, 12(2), 395–421.
- Plant, E. A., Baylor, A. L., Doerr, C. E., & Rosenberg-Kima, R. B. (2009). Changing middle-school students' attitudes and performance regarding engineering with computer-based social models. *Computers & Education*, 53(2), 209–215.
- Schroeder, N. L., & Adesope, O. O. (2013). How does a contextually-relevant peer pedagogical agent in a learner-attenuated system-paced learning environment affect cognitive and affective outcomes? *Journal of Teaching and Learning with Technology*, 2(2), 114–133.
- Schroeder, N. L., & Adesope, O. O. (2014). A systematic review of pedagogical agents' persona, motivation, and cognitive load implications for learners. *Journal of Research on Technology in Education*, 46(3), 229–251.
- Schroeder, N. L., & Adesope, O. O. (2015). Impacts of pedagogical agent gender in an accessible learning environment. *Educational Technology & Society*, 18(4), 401–411.
- Schroeder, N. L., Adesope, O. O., & Gilbert, R. B. (2013). How effective are pedagogical agents for learning? A meta-analytic review. *Journal of Educational Computing Research*, 49(1), 1–39.
- Schroeder, N. L., & Gotch, C. M. (2015). Persisting issues in pedagogical agent research. *Journal of Educational Computing Research*, 735633115597625.
- Tien, L. T., & Osman, K. (2010). Pedagogical Agents in Interactive Multimedia Modules: Issues of Variability. *Procedia - Social and Behavioral Sciences*, 7, 605–612.
- Top 10 Tips on How to Use Avatars in eLearning. (2014, August 17). Retrieved October 31, 2016, from <https://elearningindustry.com/top-10-tips-use-avatars-in-elearning>
- van Vugt, H. C., Konijn, E. A., Hoorn, J. F., Keur, I., & Eliéns, A. (2007). Realism is not all! User engagement with task-related interface characters. *Interacting with Computers*, 19(2), 267–280.
- Veletsianos, G. (2007). Cognitive and affective benefits of an animated pedagogical agent: Considering contextual relevance and aesthetics. *Journal of Educational Computing Research*, 36(4), 373–377.
- Wang, N., Johnson, W. L., Mayer, R. E., Rizzo, P., Shaw, E., & Collins, H. (2008). The politeness effect: Pedagogical agents and learning outcomes. *International Journal of Human-Computer Studies*, 66(2), 98–112.
- Woo, H. L. (2009). Designing multimedia learning environments using animated pedagogical agents: factors and issues. *Journal of Computer Assisted Learning*, 25(3), 203–218.
- Wouters, P., Paas, F., & van Merriënboer, J. J. (2008). How to optimize learning from animated models: A review of guidelines based on cognitive load. *Review of Educational Research*, 78(3), 645–675.