

# Cyberlearning Community Report: The State of Cyberlearning and the Future of Learning With Technology

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- Fusco, J. Martin, W. Lane, H. C. & Chase, C. (2017). Virtual peers and coaches: Social and cognitive support for learning. In J. Roschelle, W. Martin, J. Ahn, & P. Schank (Eds.), *Cyberlearning Community Report: The State of Cyberlearning and the Future of Learning With Technology* (pp. 31-35). Menlo Park CA: SRI International.
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## 4. Virtual Peers and Coaches: Social and Cognitive Support for Learning



*By Judith Fusco, Wendy Martin, H. Chad Lane, and Catherine Chase*

### Design Description, Motivation, and Conjectures

Decades of research on expert teaching, human tutoring, and collaboration have established that the quality of a student's relationships with peers and teachers directly affects learning (Martin & Dowsen, 2009). Building on findings that show that people treat interactions with machines as a social experience (Reeves & Nass, 1996), cyberlearning researchers have investigated whether student learning could be supported through *pedagogical agents* (PAs). A PA can be an avatar that interacts with and helps teach learners. Unlike traditional computer-assisted learning systems, which simply provide feedback on user input, today's cyberlearning-based PAs draw on sophisticated artificial intelligence (AI) techniques and high-end animation systems to support both social and cognitive interactions. Whereas traditional systems used a mouse and keyboard for interactions, these new PAs often include speech, gesture, and other forms of input that are more like interacting with a person. These agents use verbal and nonverbal communication to establish a natural, welcoming learning environment. When implemented with appropriate pedagogies, such agents can

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#### ◆ **Computer science innovation:**

Computational models for complex, realistic social and cognitive agents

#### ◆ **Learning science innovation:**

Virtual peers and coaches that provide affective, cognitive, and social supports for learning processes

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increase learning (i.e., cognitive gains) while also improving motivation and student engagement (Schroeder, Adesope, & Gilbert, 2013; Schroeder & Adesope, 2014).

Intelligent virtual agents build on almost three decades of learning research (Johnson & Lester, 2016). This large literature has identified a range of *roles* for PAs, including as virtual peers, teachers, or coaches; teachable agents (for reciprocal teaching); mentors; and adversaries (in competitive games). There is no single best way to use a PA. Research also has found that the technology can be used poorly, for example, increasing cognitive load (the amount

## Virtual peer Alex recognizes and models verbal and nonverbal behaviors.



*Used with permission of Justine Cassell.*

of information a learner needs to keep track of). In a poor use, a PA may be an unwanted or unhelpful distraction. In this section, we highlight three recent successful examples of PAs in cyberlearning research that use AI innovations to put learning theories into practice.

### Examples of Virtual Peers and Coaches

The lab led by Justine Cassell at Carnegie Mellon University has developed a virtual peer named **Alex** (NSF #1523162), who is designed to be gender ambiguous. Alex collaborates with learners as they explain scientific concepts. Using models of effective social collaboration built on the basis of analysis of extensive peer-peer conversations, Alex can converse with a child in a normal manner. Alex's behavior can be adjusted to explore the effect of different interactions on learning, such as variation between standard language and dialect. This technology also

has been used to help children with autism, to integrate storytelling and learning, and to develop science reasoning and science discourse.

In an NSF Cyberlearning-funded project, Cassell's team is investigating how a virtual peer can build rapport with a human learner and what the effect of rapport is on learning. Rapport, which is informally understood as one's ability to have fluid, natural, and harmonious interactions with another person, is achieved computationally by building models that sense and attend to emotional and social cues during conversation (Zhao, Papangelis, & Cassell, 2014) and respond in kind. Building rapport is technically demanding, requiring multimodal sensing, which builds on recent advances in computer vision, signal processing, and machine learning, and multimodal generation of appropriate social strategies, which builds on new techniques in machine learning. In this project, the virtual peer automatically recognizes audio and visual behaviors during learner interactions and employs a decision

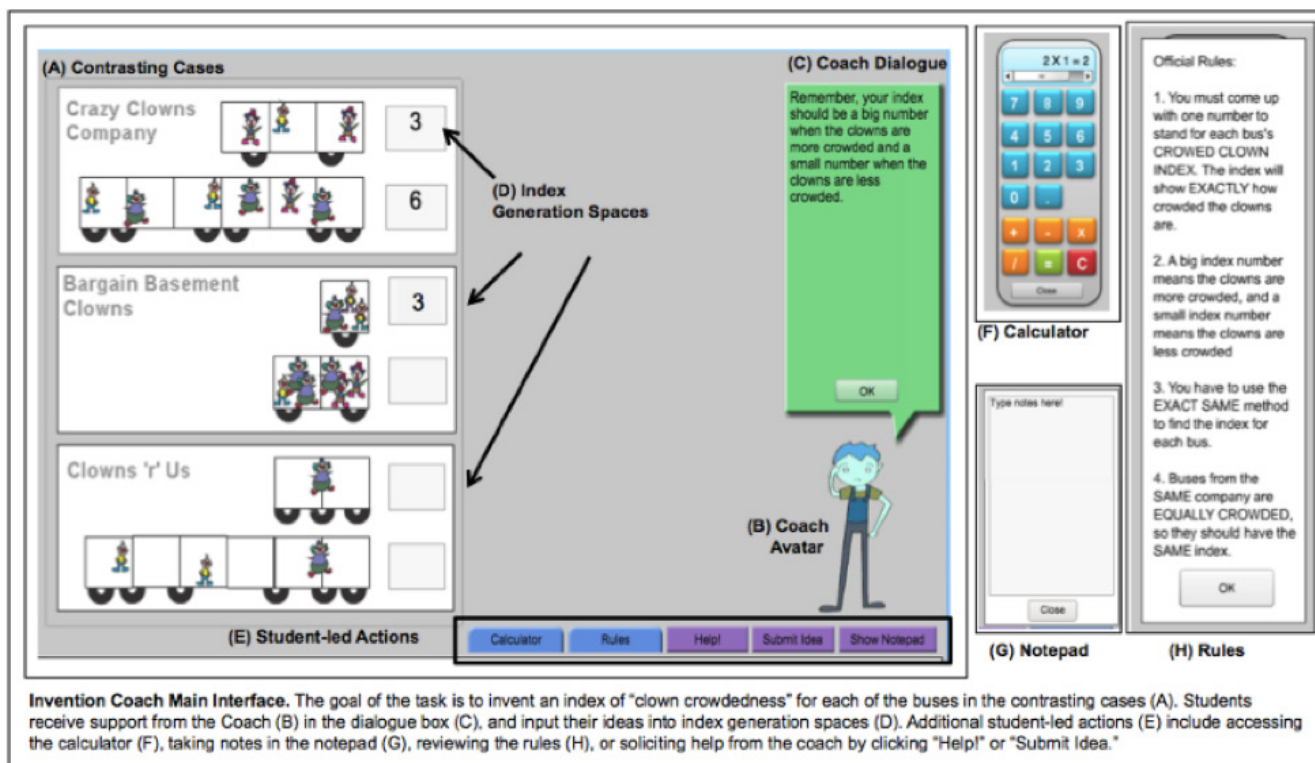
module to select from appropriate social and task moves during the dialogue (initial work reported in Madaio, Ogan, & Cassell, 2016).

The team also developed abilities for the virtual peer to communicate in multiple dialects and to switch among the dialects within a conversation with a student, depending on the context. In one project (funded by the Heinz Foundation), the virtual peer has been used to test hypotheses about how to best support students in learning to speak in appropriate “school English” when needed. For this work, Alex was augmented with an ability to speak in African American Vernacular English in addition to standard English or even to rapidly change (“codeswitch”) among the dialects at different times in their dialogue. Research with the virtual peer has demonstrated that using a familiar dialect builds rapport and that rapport mediates the relationship between dialect and

learning. Learners exhibited greater scientific reasoning in their contributions when they were able to speak in their own dialect (Finkelstein, Yarzebinski, Vaughn, Ogan, & Cassell, 2013). The research findings have broad implications, both for technology design and policy. They are relevant to practices in schools, for example, in determining whether teachers should require students to use only standard English or to support dialect switching.

Another cyberlearning project involving a pedagogical agent is the **Invention Coach** (NSF #1361062) developed by Catherine Chase and Vincent Aleven. This virtual coach supports students through invention tasks; research has shown that invention tasks prepare students to learn in the future (Schwartz & Martin, 2004). The system provides students with feedback to promote exploration. After the exploration phase,

### The Invention Coach’s main interface where a student works to invent an index of “clown crowdedness,” a proxy for density (mass/volume).



*Used with permission of Catherine Chase.*



the coach seeks to maximize the value of direct instruction (Marks, Bennett, & Chase, 2016). Because open exploration and discovery can be overwhelming for some learners, the Invention Coach system was designed to guide students through this often messy and iterative process.

The Invention Coach goes beyond traditional intelligent tutoring systems by supporting learners as they tackle *ill-defined* problems (Lynch, Ashley, Alevan, & Pinkwart, 2006), such as the process of invention. To address this challenge, an interdisciplinary team investigated what kind of guidance effective human coaches use to promote transfer from one learning task to another. They found that effective one-on-one human invention coaches asked questions and did not give answers, which is compatible with most studies of expert human tutoring in general. Further, the *more* explanations a coach gave, the lower the transfer test score for the student. These findings inspired the research team to develop an adaptive Invention Coach that avoids giving direct feedback or didactic explanations. Instead, the coach provides a balance of problematizing and structuring feedback, which

encourages learners to diagnose their own errors. A classroom study of the Invention Coach found that it led to greater transfer than no guidance and minimal guidance versions of the system.

A third example is research led by Kristy Boyer, Brad Mott, James Lester, and Eric Wiebe (NSF #1721160, #1640141, #1409639, #1138497). In working with educators, the researchers were inspired by the challenges of trying to design an educational game that appeals to girls. Together, they found a solution in using a virtual agent in the role of a learning companion. The companion, **Adriana**, takes the role of a younger peer. Adriana's backstory was that she was "the little sister" of a character in the game. Players consult with Adriana about how to succeed in the game world. As they converse with her, they simultaneously learn and gain an empathetic ally. The researchers found that by talking with Adriana, girls overcame initial frustration that had previously been seen to lead to a gender gap in gameplay outcomes. These results along with previous research suggest virtual agents may help in other areas and with a wide range of skills.

### Adriana, the learning companion.



*Used with permission of Kristy Boyer.*

## Contributions, Opportunities and Challenges

Cyberlearning research on PAs is pushing the frontiers of human-computer interaction and AI-based agents, as well opening new doors for learning sciences research. For example, research on virtual agents can give us a better understanding of the interplay between affect and cognition and lead to better support for learners. Improved scientific understanding of how to create empathetic virtual agents not only can improve learning outcomes in specific cases, but also has potential to help address equity issues in STEM learning. Further, designing computer agents that can establish rapport with a student will most likely be important for advancing human-computer interaction in general.

Investigating PAs also highlights important and difficult research challenges. An obvious challenge is the difficulty of translating what we know about human social and cognitive support into virtual systems — and also identifying what parts of the learning experience are best left to human educators and peers. Understanding the limitations as well as the strengths of PAs will improve the design of learning environments that combine the best of computer-based and human coaching.

Specific research questions can also be fruitfully explored with PAs as research tools. For example, the role of gender in mentoring interactions can be systematically explored by varying the gender of the agent. Likewise, personality factors can be systematically varied and effects on learning can be investigated. The value of storytelling as a component of how students learn science concepts can be investigated while also exploring how stories and social interaction may help improve attitudes toward STEM.

The technical dimensions of this research demand advances in methods. Cyberlearning researchers engaged in PA research are using multimodal data analysis (combining forms of data such as eye-tracking, gesture recognition, and speech recognition) to better monitor and integrate the emotional responses a learner shows. Further, modeling these data to improve tutor dialogue is driving new applications of research from natural language processing. As these approaches mature, PAs can integrate with the other genres discussed in this report to augment the human support available to learners to engage deeply and effectively.

## Resources

**CIRCL Primer: AI Applications in Education:** <http://circlcenter.org/ai-applications-education/>