From Doodles to Designs: Participatory Pedagogical Agent Design with Elementary Students

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ABSTRACT

Participatory design practices create informed designs by bringing stakeholders into the design process early and often. This approach is a powerful tool, especially when the designer and the intended user are very different. This paper reports on work in which researchers co-design pedagogical agents to support collaborative computer science learning with elementary school students using an iterative drawing methodology. In the open drawing phase, students drew what they believe good collaboration looked like. Next, researchers analyzed those drawings under the requirements of the broader project and created a drawing scaffold (similar to a coloring book page). In the scaffolded drawing phase, students ideated within the more focused context. This process resulted in actionable design guidelines for the appearance of pedagogical agents.

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KEYWORDS

Elementary students; participatory design; pedagogical agents

PARTICIPANTS

This study was conducted at a public school in the southern United States with 22 fourth grade students. Participants included 13 females and 9 males between the ages of 9 and 11. A majority of the participants were Caucasian (59%), 18% were African-American, 14% were multi-racial, 5% were Hispanic, and 4% were Asian. Participants in the study were enrolled in one of two science classes, each instructed by the same teacher. The classes were both 50-minute sessions.

LEARNING TASK

Students completed a learning task to reinforce a science concept previously covered in the class. They worked in pairs to code simulations of adding or removing energy to water and displaying the resulting state of matter. They were guided by one of the graduate researchers on this project.
After the three-day learning task experience, we informed the students that we wanted their help designing "buddies" in the coding interface. We told the students that the "buddies" were meant to help them as they learned computer science.

INTRODUCTION AND RESEARCH CONTEXT

Participatory design is a powerful methodology that has been successfully applied to education, such as building personas for technology-enhanced libraries [5] and designing virtual badges [8]. Participatory design experiences improve not only the quality of the resulting design but can also empower the co-designers [3]. However, a significant challenge arises when supporting ideation of children in collaboration with adult designers due to the power differential children perceive between themselves and adults [4], which could lead to children not feeling a sense of ownership within the design process [8]. Including all perspectives equitably is a central goal of participatory design [9], and a central challenge for the research community is innovating on design practices that achieve this goal more effectively.

Among the many ways researchers gather input from children during participatory design, drawings provide a rich visual representation of a child's subjective view of design issues, gather insight into children's classroom experiences [7], and are an accessible form of input for nonverbal communicators [14]. Typically, students are given a drawing prompt and researchers aggregate the drawings for thematic analysis. That process results in a set of themes and codes that show commonalities between how the students view a topic (e.g., in the case of learning, the importance of a teacher in a classroom) [7]. However, extracting actionable feedback from a child's drawing can be difficult. In work by Sheehan and colleagues [13], children were asked to draw new ideas for computer programs. However, many of the children drew images of games that were unrelated to the software, resulting in feedback that was difficult to integrate.

In this work, we are applying an iterative drawing methodology to co-design pedagogical agents with elementary learners. Pedagogical agents are effective but variations in their design have substantial implications on how effective they are for different groups of learners [12]. Currently, most pedagogical agents are designed by researchers and are informed primarily by literature [6], but do not consider students' perspective in the design. The ultimate goal of this work is to create pairs of virtual agents that collaborate with each other and with children in elementary school classrooms as the children learn computer science through coding. The use of student drawings will aid in the iterative development of the pedagogical agents by providing an insight into perspectives on teamwork and collaboration. Although computer science is a relatively new topic in elementary classrooms in the United States, it is common to pair students within a collaborative paradigm known as pair programming [15]. However, children do not intrinsically have strong collaboration skills [11], and helping them build these skills is an important research challenge. The pedagogical agents we are designing will support desirable collaboration practices for pair programming in elementary school.

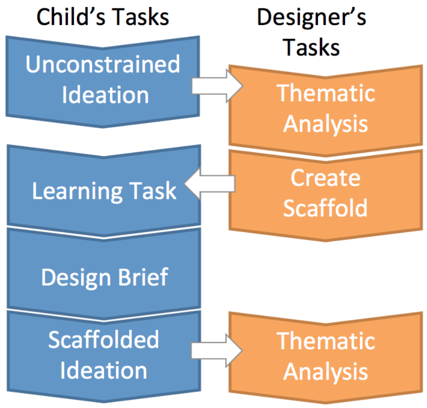

Figure 1: The drawing design process followed in this work.

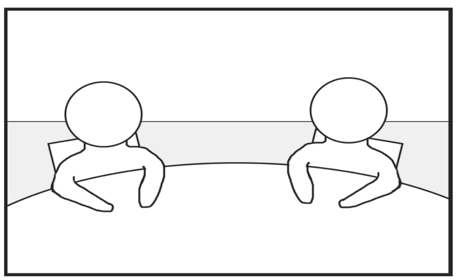

Figure 2: The scaffolded drawing given to students to focus their ideation on the pedagogical agent design.

COLLABORATIVE PEDAGOGICAL AGENT DESIGN PROCESS

In contrast to previous work, this paper synthesizes pedagogical agent design guidelines from student drawings in an iterative process, as shown in Figure 1. First, we held an open drawing phase of *unconstrained ideation* in which students were simply prompted to draw "good collaboration." We were aware that this phase would produce many designs that were not actionable in our software, but it was our goal to extract common themes from them to guide future stages of the work. Next, we conducted *thematic analysis of unconstrained drawings* to create the drawing scaffold. We went back into the classroom for this phase of the work, in which students *completed a computer science learning task* to ensure they had a concrete idea of the context for which the pedagogical agents were being designed. Next, they *participated in a design brief* in which researchers described some ways in which pedagogical agents could be integrated into the coding interface they had just used. After that, students completed the *scaffolded ideation* phase during which they were provided with a coloring page style sheet on which they made their drawings. Finally, researchers *analyzed these scaffolded drawings* to extract the actionable guidelines for designing the pedagogical agents.

Unconstrained Ideation Phase

During the first phase, our goal was to understand how elementary school students visualized good collaboration. Each student was given a blank piece of paper with the prompt "Draw or sketch what good collaboration looks like to you." After they completed the drawing task, we asked students to label some of their drawings to help us in our interpretation. Simultaneously, we conducted brief interviews with students about their drawings as they completed their drawings. These conversations with the researcher were recorded for the researchers to reference.

Thematic Analysis of Unconstrained Drawings

We conducted thematic analysis by using the unconstrained drawings themselves, corresponding student labels, and researchers' notes from the brief interviews as triangulating data. We utilized Creswell and Creswell's [2] data analysis spiral: memoing new ideas, classifying codes into themes, and developing interpretations. The themes were then combined into five categories: Actors, Actions, Communication, Affect, and Artifacts.

Figure 3: Subthemes of Agent Appearance.

Similar and Contrasting Characteristics. Drawings of agents were often depicted with levels of heterogeneity (such as matched gender or facial expression) (Figure 4). We also noticed contrast between the agents. Some pairs of agents had different shirt designs, accessories, and facial expressions. Another drawing depicted a devil sitting beside an angel (Figure 5), embodying two very different roles that agents might afford.

Gender Differences. The students gendered their agents, and some commonalities arose between the depictions of boys and girls. Accessories varied between the girl and boy agents (e.g., bows and hats), and girls frequently had longer hair, as shown in Figure 6. The color of the agents' shirts and accessories also varied. Only girls had symbols on their shirts (e.g., hearts, cats, stars), while boys had words written on their shirts.

Agent Facial Expression. We observed many different facial expressions drawn on the agents. Many of the expressions appeared joyful, but Figure 7 shows some examples of neutral expressions and crying, and another student created an agent displaying anger. The students portrayed these emotions using the agents' mouths, eyes, and occasionally eyebrows.

Creating the Scaffolded Image

After gaining a better understanding of how elementary school students visualized collaboration, the research team met to discuss how the students' ideas and our research goals overlapped. In our work, we wanted the students to interact with a pair of near-peer agents. Since the students had drawn supervisor figures as standing and collaborating peers as sitting, we wanted to have the agents seated at a table together with the students, working toward their goal. Students had also drawn agents at circle tables talking with each other, while those at square tables worked individually. With these symbols in mind, we designed our scaffolded image to focus subsequent drawing effort by functioning like a coloring book page. As shown in Figure 2, we left plenty of open space for students to introduce new agents or items on the tables or walls.

Scaffolded Ideation And Thematic Analysis

After teaching the students computer science, we told the students that we were trying to make buddies for them to interact with when they were struggling with their code. We explained these buddies needed to be strong collaborators, and that we were not great artists and needed their support on our design. We emphasized that they could change anything about the coloring page they were given (the scaffolded drawing from Figure 2). Each student was given a blank coloring page, and colored pencils were placed at each table. Once we collected all the scaffolded student drawings, we replicated the same thematic coding processes described for the unconstrained drawings. The resulting themes were Agent Appearance, Agent Dialogue, and Agent Surroundings, whose derivation is described in this section. For this work in progress, we will focus on the Agent Appearance theme, exploring the codes that were identified.

Theme: Agent Appearance

The first major theme of the student drawings is how they chose to design either one or both of the collaborative agents. The Agent Appearance theme consisted of five codes: *agents with similar characteristics*, *agents with contrasting characteristics*, *gender differences between agents*, and *agent facial expressions*. These codes are discussed in Figure 3. We encouraged students to change anything they wanted about the scaffolded drawing. However, only two students chose to draw a single agent or introduce new agents, as shown in Figure 8. Another example of a change to the scaffold was to add an input box in which users could type their input to the agents.

Figure 4: Examples of Commonalities.

Figure 5: Examples of Individualities.

Figure 6: Examples of Gender Differences.

Figure 7: Examples of Facial Expressions.

Figure 8: Examples of Changes to Scaffold.

DISCUSSION

Involving children early and often in the design process can significantly improve the quality of the pedagogical agents we design, but it can be challenging to elicit student ideation that is directly applicable to the goals of a project. The drawing study reported here attempted to address that challenge with an unconstrained drawing phase followed by a scaffolded drawing phase. This process allowed the researchers to focus student ideation, determine design implications, and design the next iteration of user-informed designs (Figure 9).

In our initial open drawing phase, students displayed collaborators seated around a table with supervisor agents standing over them. Other work on virtual agents (such as those modeled as near-peers [10]) has taken this seated-agent approach. An important addition, however, is using the shape of the table as an indicator for whether the agents should be talking or working separately.

A popular approach to virtual agent design with multiple agents is to imbue these agents with distinct roles or functions (for example, an Expert and Motivator agent [1]). The children in this study sometimes drew the two agents as very distinct from each other, both in visual appearance and in persona. However, our student co-designers also frequently held some elements of the agent design constant (such as gender or materials around agent) giving them visual common ground. We believe that the student drawings shed insights on how to establish that the agents have personas and functions, but share a common goal, which will be essential in affording the correct types of interactions.

REFLECTIONS

Iterative student drawings facilitated a back-and-forth between the students and the researchers that resulted in actionable feedback. First, we started with an open drawing focused around good collaboration. Student drawings on collaboration allowed our team to discuss the overlap between the students' thoughts on collaboration and the software environment we had proposed. Then we returned with a scaffold, the outline of the two students at a round table. Analysis of those resulting drawings provided actionable guidelines to increase the fidelity of the agents' embodiment. This work can lead to a deeper understanding of how to best support children's learning with pedagogical agents. Our next step is to design several prototypes of virtual agents and return to the classroom for further studies. After the agents' appearances are determined, we will move forward with co-designing personalities, voices, and dialogue with the agents.

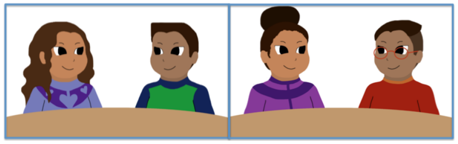

Figure 9: Examples of pedagogical agent designs inspired by student drawings.

LIMITATIONS

While this process produced useful design implications, there are notable shortcomings. First, while most students enjoyed working on their designs, some students chose not to participate. Some students also seemed embarrassed about their drawing skills and chose not to give us their drawings or scribbled out what they had made. One student told the researchers, "I'm a bad artist." In future studies we will try to more heavily emphasize how everyone's input is useful and that there are no bad drawings. It is also important to verify that this process is equitable.

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REFERENCES

[1] Amy Baylor and Suzanne J Ebbers. 2003. Evidence that multiple agents facilitate greater learning. *Artificial Intelligence in Education: Shaping the Future of Learning through Intelligent Technologies* (2003), 377–379.

[2] John W Creswell and J David Creswell. 2017. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Sage publications.

[3] Karen E Fisher, Katya Yefimova, and Eiad Yafi. 2016. Future's Butterflies: Co-Designing ICT Wayfaring Technology with Refugee Syrian Youth. In *Proceedings of the The 15th International Conference on Interaction Design and Children*. ACM, 25–36.

[4] Mona Leigh Guha, Allison Druin, and Jerry Alan Fails. 2013. Cooperative Inquiry revisited: Reflections of the past and guidelines for the future of intergenerational co-design. *International Journal of Child-Computer Interaction* 1, 1 (2013), 14–23.

[5] Helvi Itenge-Wheeler, Heike Winschiers-Theophilus, Alessandro Soro, and Margot Brereton. 2018. Child designers creating personas to diversify design perspectives and concepts for their own technology enhanced library. In *Proceedings of the 17th ACM Conference on Interaction Design and Children*. ACM, 381–388.

[6] Benjamin Nye and Donald M. Morrison. 2013. Towards a Generalized Framework for Intelligent Teaching and Learning Systems: The Argument for a Lightweight Multiagent Architecture. In *Artificial Intelligence in Education (AIED) 2013 Workshop on the Generalized Intelligent Framework for Tutoring (GIFT) (pp. 105-115)*.

[7] John Ow and Katerine Bielaczyc. 2013. "Drawing out" students' voices: Students' perceptions about learning science through Ideas First, a knowledge building approach. *Knowledge Building Summer Institute, Puebla, Mexico* (2013).

[8] Caroline Pitt and Katie Davis. 2017. Designing Together?: Group Dynamics in Participatory Digital Badge Design with Teens. In *Proceedings of the 2017 Conference on Interaction Design and Children*. ACM, 322–327.

[9] Janet C. Read, Daniel Fitton, Gavin Sim, and Matt Horton. 2016. How Ideas make it through to Designs: Process and Practice. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*. ACM, 16:1–16:10.

[10] Albert Rizzo, Eric Forbell, Belinda Lange, J Galen Buckwalter, Josh Williams, Kenji Sagae, and David Traum. 2012. SimCoach: an online intelligent virtual human agent system for breaking down barriers to care for service members and veterans. *Healing War Trauma A Handbook of Creative Approaches. Taylor & Francis* (2012).

[11] Barbara Rogoff, Barbara Radziszewska, and Tracy Masiello. 1995. Analysis of developmental processes in sociocultural activity. *Sociocultural Psychology: Theory and Practice of Doing and Knowing* (1995), 125–149.

[12] Noah L Schroeder, Olusola O Adesope, and Rachel Barouch Gilbert. 2013. How effective are pedagogical agents for learning? A meta-analytic review. *Journal of Educational Computing Research* 49, 1 (2013), 1–39.

[13] Robert Sheehan, David Haden, and Sara Metz. 2015. Using children's drawings to improve a programming app. In *Proceedings of the 14th International Conference on Interaction Design and Children*. ACM, 303–306.

[14] Roberta Tovey. 1996. Getting kids into the picture: Student drawings help teachers see themselves more clearly. *Harvard Educational Letter* (1996), 5–6.

[15] Laurie Williams, Eric Wiebe, Kai Yang, Miriam Ferzli, and Carol Miller. 2002. In support of pair programming in the introductory computer science course. *Computer Science Education* 12, 3 (2002), 197–212.