Real Collaboration with a Virtual Peer: Results from Co-design in an Early Elementary Context

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Collaboration provides unique affordances for learning in exploratory environments. However, despite these benefits, the characteristics of collaboration that provide so many cognitive and social advantages may also hinder learning if they are not sufficiently scaffolded. Virtual peers have the unique capability of supporting children in collaboration during exploratory learning, as they can adaptively address problematic issues in collaborative learning while maintaining the productive peer-centered social environment that collaborative learning necessitates. We argue that to be maximally effective, VPs must leverage our understanding of social learning and use models of real student behavior to be accepted by the target population as an aspirational role model. We describe our initial results of classroom observation and co-design sessions exploring how collaboration is perceived and supported in two inner-city schools and where problems may arise, as well as propose a response to these issues using virtual peer technology.

1 Introduction

Collaboration among young students can provide unique educational benefits by allowing children to propose ideas, talk through alternate hypotheses, mediate disagreements, and constructively critique different solutions [1,2]. These advantages are particularly strong when children are able to participate in exploratory talk [3], where students engage critically but constructively with each other's ideas. Through dialogue, children are able to notice discrepancies in partners' work and attempt to resolve these inconsistencies [2] and build off their partners' ideas to synthesize new material and understanding [4]. It is in large part the peerness of this paradigm that contributes to its success, as it is a fundamental tenet of collaborative learning that students learn better from others in their zone of proximal development [5]. The cognitive conflict that arises as peers produce contradictory hypotheses about the world results in learning as students adapt and organize their own knowledge [6]. In addition, social psychology literature theorizes that humans are generally more influenced by members of their in-group; that is, peers who share their own traits and qualities.

Despite these benefits, however, there are many places where collaboration among young students fails, and the dialogue ceases to be productive. It is not guaranteed

that this beneficial exploratory discourse will always occur in a collaborative learning environment, as student talk can also be characterized by competition, asymmetrical participation, and can be focused on finishing the task instead of understanding of concepts [7]. Scaffolding children through the process of collaboration, then, can improve current and future learning. In the field of computer-supported collaborative learning, technologically advanced adaptive tutoring systems (e.g., [8]) and even pedagogical agents (e.g. [9]) have been successful in mediating the collaborative process. These systems often take on the role of an expert mentor in order to provide students with advice on how to collaborate more effectively.

However, given the known benefits of peerness in collaborative learning, there exists an exciting opportunity to employ technology that instead provides students with *partners in learning,* rather than expert tutors. This becomes particularly desirable within exploratory education environments, where students should feel free to explore, test, question, and experiment. Under scrutiny of an expert tutor, children may be more cautious with their curiosity than they would be with peers, thus hindering the opportunities for learning through exploration. To address this issue, we propose virtual peers (VPs), embodied conversational agents that are designed to play the role of a child similar to the target user, which have been successfully used to support collaborative learning among students [10]. To achieve this success, agents must not only just incorporate the best theory on collaborative learning, but also leverage our understanding of social learning. We must design virtual agents such that students accept them as part of their in-group, who express recognizable traits and qualities to mark them as members of the target population while providing an aspirational role model that can influence students' behavior. While virtual peers have been developed previously (e.g. as described in [9]), most are not based on an analysis of the real behaviors of their target demographic, and as such may limit the social benefits of collaboration. It is only through a thorough understanding of the context in which the collaboration occurs that we can build an intervention to effectively address the areas where children struggle and design agents who bond with the target children.

We propose that for VPs to be most effective, the agents must be based on an understanding of the behaviors of children in the target population, and the agent must be designed in close collaboration with both the teachers and students. In this paper, we describe a situated application of these recommendations through our design of a virtual peer to model classroom talk (specifically science talk and dialect switching), and present initial results of our co-design process that lead us to propose five design recommendations for virtual peer solutions to address typical problems in collaborative learning among students.

2   Virtual peers to support classroom science talk

Our VP of interest is Alex, a virtual child who acts as a model for children to improve their ability in such classroom talk skills as scientific process dialogue [11] and appropriate dialect-switching based on social context [12]. While Alex has effectively improved children's classroom talk in these two areas in agent-single child interac-

tions [13], we are currently working to develop an Alex adaptation to support small-group collaboration to achieve the pedagogical benefits described above.

We propose that virtual peers can provide unique affordances in the guiding and modeling of collaboration. While the theoretical underpinnings of a technological intervention can benefit from the extensive literature on collaborative learning, the unique qualities of a virtual peer who participates in the conversation, acting at once as a novice and expert, as well as a friend, is a novel environment that will need new guidelines for design.

3   Needs-finding in inner-city classrooms

Co-design in education is a bottom-up approach to design that emphasizes the teacher's equal role in design, and requires understanding the classroom context from the teacher perspective, as well as the student perspective [14]. In our first stages of co-design, we worked with two independent charter schools (A and B) that report 99% free and reduced-price lunches with 100% African American students. Within these schools, we collected results using three methodologies within the co-design framework: teacher interview, teacher story-boarding, and classroom observation. In this paper, however, we focus on our classroom observations, which recorded child and teacher data in natural classroom settings in three primary areas listed in Table 1: collaboration, science talk, and dialect. Two trained researchers observed eight 2nd – 4th grade science classes, and we present the results from these qualitative analyses that bring to the literature additional data about how language is used in elementary classrooms.

Dimension	Evidence collected
Collaboration	Manner of collaboration between students (imposed by teacher or selected by children), missed opportunities for collaboration; references by teacher to collaborative work
Science talk	Teacher use of science talk during instruction as defined by *FOSS* framework; student use of science talk; differences in science talk expected during small-group interactions; how children model science talk usage from peers
African American English	Child and teacher use of AAE features; teacher correction of student AAE use; differences in dialect during full-class activities and small-group activities; how children pick up AAE usage from peers; differences in teacher AAE correction when students are in small groups

Table 1. Three dimensions of observations and the evidence collected for each

3.1   Science talk

We analyzed students' science talk using the *FOSS* educational framework, which focuses on students making observations, integrating new information with prior knowledge, forming hypotheses, and drawing evidence-based conclusions [11]. By using this inquiry-based science talk framework, we were able to form representations

of where our target children were already using this type of language, and understand where the language breaks down.

At School B, the 2nd grade students successfully produced science talk along many of the dimensions of the FOSS framework, including making observations using multiple senses, and also making conclusions relating to previously learned material. For example, during a lesson on magnetism where the students collaborated to make magnetic "fishing poles" to determine which objects on the floor were magnetic, the following exchange took place:

Student to teacher: I can't pick up the paper clip

Teacher: So what does that mean about the paper clip?

Student: It must not be made of loadstone, because things that have loadstone in it are, are magnetic.

This is an exemplary exchange, which demonstrates the abilities of students at this age to produce successful science talk. It stands in contrast, however, to the talk produced by the same student when interacting with his peers moments earlier, which lacks the hallmarks of scientific process and thought:

Student 1: This one isn't picking up

Student 2: None of them were working before.

Student 3: Yeah. Try this one now.

Student 1: No, that one won't pick up either.

Student 3: Okay.

This exchange demonstrates one of the key problems with peer learning. Children do not always engage in exploratory talk without intervention, leading to claims without evidence, lack of hypothesis formation, and agreement (or argumentation) without thoughtful critique. With a virtual peer, we can model this type of science talk in the discussion naturally, while the teacher can monitor the exchange without disrupting the peer discussion.

More alike to the peer talk in School B, we found that 4th grade students at School A had difficulty forming conclusions based on evidence, and applying what they had learned to answer new questions. They also had difficulty comparing and contrasting two different samples, or describing a sample using concise, descriptive words that uniquely identify the stimulus, even with the support of the teacher, e.g,:

Teacher: What is the difference between these two samples?

Student: They're both, like… big.

From these observations, a virtual peer would need to be able to dynamically provide different levels of support to children. While children at School A may originally need substantially greater support, students in School B may be hindered by an domineering VP and more likely to benefit from a peer who simply modeled appropriate classroom talk without providing such explicit scaffolding. A virtual peer to support science talk in collaboration should get at the questions that real children are less likely to ask and answer without support: why does this work? What are the implications? What do we think will happen if we try something else? Why?

3.2 African American English

We also explored issues of dialect switching in the classroom. African American English, in contrast to Mainstream American English (MAE), is an accepted dialect of English that has a specific set of phonetic and morphosyntactic features that may be used by African Americans as a way of signaling identity [15]. Not all African Americans use AAE, or use it in all settings, and AAE may be used by people of all different racial backgrounds to signal identity. As this may be a key aspect of the cultural identity among our target population and yet is viewed by our teachers as an active problem in the classroom, we observed student use of AAE and teacher response to use of this dialect. Through both interviews and observations, we found that teachers perceived different amounts of AAE acceptable in the classroom in different situations, with it being *unacceptable* when speaking directly to the teacher and answering a question in class, *more acceptable* during small-group collaborations, and *completely acceptable* during primarily social interactions like lunch time and recess. However, teachers never made these perceptions quite clear to the students, leading to unclear siruations where children were only sometimes corrected for AAE use.

Schools A and B did not largely differ in the amount of African American English used in the classroom, and the students switched into AAE in similar contexts. In both schools, we observed that use of AAE primarily occurred when students were talking with peers – either when engaging in off-task discussions, or are working on a collaborative educational task. While there were still some examples of students using AAE in conversations with the teacher, they were less frequent, and the students typically switched into Mainstream American English when the teacher corrected them.

When students were in small groups, AAE became more frequent. During a 2nd grade small-group time-telling collaborative game, there were multiple instances of AAE used by each of the three participants while the teacher was out of sight. However, during instances where the teacher came around to check on the group, there was substantially less talk (and AAE) exhibited by the students. The dynamic of the group seemed to change, and the focus of the students' utterances seemed to take a more pragmatic turn, such as informing group members about whose turn it was, which was not done with such formality during the peer-only exchanges. We also observed that students would use more AAE during social exchanges with a peer, such as to console a student who was just chastised by the teacher, or to praise a peer who just shared an interesting story.

During a co-design session, a teacher explained that while she did not want students to use AAE in responses to her, she valued the importance of the students speaking freely during collaboration and said she does not correct students' language during collaborative learning. This distinction is important in the design of a virtual peer who must maintain the beneficial nature of peerness, as use of AAE can signal solidarity among our participants. This provides important insight into the dialect choices of virtual peer to best engage and motivate children, while also providing the best academic model in line with the teachers' classroom requirements.

3.3 Collaboration

Collaboration is brought up often in the classroom context, both as an instruction for an activity and as a reward ("you'll get to work with a partner on the next one if you are quiet and listen now.") Despite the emphasis on working together, teachers do not typically identify the roles or responsibilities for each student in these activities. The examples in Table 2 below show how children may be unsure of what it means to collaborate, or how to take responsibility for their partner's learning.

Example 1: 3rd grade, Classroom 1	Example 2: 3rd grade, Classroom 2
Student 1: We're done!	Student 1: A___, how do you do this one?
Teacher: Why is your partner still writing?	Student 2: Ms. B__, I'm done!
Student 1: He's not done.	Teacher: You're all done?
Teacher: Then you're not done yet, are you?	Student 2: I didn't even need a calculator
Student 1: But I'm done.	Student 1: A___, how do you DO it …

Table 2. Examples of "collaborative" talk

Though teachers sometimes provided support for student collaboration, such as telling students how they could distribute the workload, teachers sometimes tried to encourage autonomous successful collaboration among students. This is demonstrated in the following quote from a 2nd grade teacher: "Work out with your partners what order you'll go in, and make sure everyone is getting a turn and contributing ideas. You have to work this out with each other though, you can't ask me for help – someone needs to go first, and someone needs to go last." While some groups had no problem determining order (such as a chivalrous young boy insisting "ladies first" to his two female partners), another group spent upwards of 10 minutes playing rock-paper-scissors to determine a "fair" ordering scheme without intervention from the teacher, who clearly wanted to students to figure out a solution for themselves. Despite the teacher's good intentions, the struggling group never did manage to complete the task.

4 Discussion and conclusion

Through qualitative analysis of our co-design sessions and the observations described above, we build on the collaborative learning literature to describe five concerns that came up in our classrooms, and how we can design virtual peers to support collaborative learning in exploratory environments.

1. **Students may not know the goals of collaboration.**
   In numerous situations, students seemed unsure of their role during the collaborative activity, and often did not take responsibility for their partners' success as is demonstrated by the examples in section 3.3. As misunderstanding teacher goals from provided instruction is a common issue in classrooms, particularly when teachers and students are from different cultural backgrounds [16], support in understanding the goals of collaborative learning is vital, Virtual peers should be used to model the behaviors appropriate for a particular educational setting, which

would allow the children to see a concrete instantiation of stated teacher goals. This may be able to address some of the cultural miscommunications that exist between teachers and students, with children being able to see how a peer from their own cultural background interprets teacher instruction.

2. **Students may not know how to move the dialogue forward to complete a task.**
When students didn't know how to progress in their own interactions, they often stopped to ask their teacher for help or inform her of their status. While the teacher typically was able to provide a hook for the students to then continue, as is demonstrated in section 3.2, her entrance momentarily broke the peerness of the interaction which we know is a beneficial factor in collaborative learning. Virtual peers can push a dialogue forward without interrupting this peerness the way a teacher's entrance might, while still modeling exploratory talk that is within the students' zone of proximal development.

3. **Students may not know how to work through their conflicting ideas.**
Like the students playing hand-games to determine a group order in section 3.3, many students were unable to productively come to a consensus on how to progress on a task when there was more than one outspoken student. A virtual peer can be used to demonstrate how to challenge ideas productively, while also modeling how to respond to their own ideas being challenged. Conflict is a key component of peer learning, and though teachers may be able to support students in their idea generation, it may not produce the type of beneficial *discussion* that can come out of peers creating opposing arguments for their own ideas.

4. **Students may not know how to manage their progress and stay on-task.**
From both our observations and teacher reports during co-design sessions, in the instances where students did get stuck, they often soon began to engage in off-task discussions which turned loud and disrupted the other groups. Virtual peers will be noticeably present in a collaborative group in a way a dialogue-only agent or other technology might not be, and as such, may be particularly situated to keep the students on-task by being a force that is able to mediate distractions. Additionally, the VP can be designed to monitor students' progress through the task, and ensure that the lesson moves in line with the students' abilities.

5. **Students may not understand differences in teacher expectations between contexts.**
Teachers perceive a different amount of AAE appropriate in different situations, and, as is demonstrated in [16], it may be difficult for students to understand these fluid expectations when they are not clearly communicated. Virtual peers can be designed to know how teachers expect students to interact in different social contexts, such as small-group situations and formal classroom presentations. The VP can demonstrate different behaviors, such as by using some AAE features in small-group situations as a way of engaging socially, but switching to MAE when presenting an answer to a teacher or writing down a final solution.

Employing virtual peer technology situated in a real classroom context and developed through co-design can address many problematic issues in collaborative learning, and the unique affordances of this VP approach can support children in gaining domain

knowledge, better understanding teacher goals, improving classroom talk abilities, and contributing to the development of critical collaboration skills.

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