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Researcher-Teacher Co-Design in a Mixed-Reality Science and Computational Thinking Curriculum

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Abstract: In this paper we argue that co-design was a helpful approach for studying the development of our participant teacher's views on agency, authority, and curricular goals. Using video data of a multi-day unit on moths that implemented augmented reality technology, our research team compared our 5th grade STEM teacher's participation from an earlier to a later iteration of the curriculum over the course of a school year. Findings showed that our teacher led us (researchers and teacher) in considering how to share agency with her students, enhanced her own epistemic authority as she became more familiar with our (the researchers') content, and then advocated for her own curricular goals in balance with our (the researchers') project goals. We provide design implications for researchers of science teaching in order to establish more expansive and equitable opportunities for co-design with science teachers.

Motivation

Research using emerging technologies such as mixed-reality (MR) are often introduced with little input from the teachers (Neira et al., 2017). As a result, schools face difficulties implementing emerging technologies into classrooms (Rogers, 2000). Research on defining and examining improved learning outcomes related to new teaching technologies is also lacking (Tofel-Grehl et al., 2017).

More recent research has shown mixed reality supports children's multimodal modeling skills: through embodiment, computer simulations, drawings, and discussions (Enyedy et al., 2015; Keifert et al., 2020; Tu et al., 2021). While modeling has become an important skill for children to develop as a result of national standards (NGSS Lead States, 2013), children's ability to juggle many different modalities to communicate their understanding also leads to more opportunities to engage in authentic scientific practices (Lehrer & Schauble, 2015; Pierson et al., 2021). However, teachers are often underprepared to support children in developing these sophisticated ways of thinking.

In this paper, we argue for researchers to co-design mixed reality enhanced curriculum with teachers in order to collectively support their students in developing multimodal modeling skills. Teachers are important partners in this endeavor because they have a deeper understanding of the classroom and community (Gutiérrez & Vossoughi, 2010). They develop relationships with children through care (De Royston et al., 2017) and trust (Vakil et al., 2016), which takes much longer than researchers usually spend in classrooms.

In the context of a classroom that leverages the mixed reality and modeling expertise of researchers with the relational skills of a fifth grade STEM teacher, we ask two research questions: (1) How do teachers help introduce new technology to students? (2) How does co-designing with teachers change how they facilitate activities with mixed reality?

Literature review

In this paper we argue that co-design is an approach to tackling teachers' "fear factor" associated with implementing new technologies and computational thinking into their classroom teacher (Rogers, 2000, p. 461). To combat this fear, we draw on literature that shows the relationships between co-design and agency, epistemic authority, and alignment of pedagogical goals between teachers and researchers.

Stroupe et al. (2018) argued that co-design allows for agency to be collective rather than individual, leading to new forms of participation. Given the barriers to technology that Rogers (2000) described, it follows that focusing on co-design and collective agency (i.e., shared between researchers, students, and teachers) would be a helpful tool for opening up new opportunities for implementing technology into classrooms. Barton and Tan (2010) also argued for the transformation of science teaching from a model where teachers instruct students on how to make sense of the world in canonical ways, to a format where students ideas are valued and followed. As a result, new learning pathways are forged and changes in disciplinary identity (i.e., seeing oneself as a tech person) are possible.

In their review of emerging technologies in education, Neira et al. (2017) found that students and teachers alike expressed concern in regard to improving their competence and confidence in implementing these

technologies. This skill was also reported to be considered important in tandem with 21st Century competencies such as creativity, collaboration, and critical thinking. While specific training and education could be one way to address this concern, Basu (2008) also showed that by taking a lead in enacting their own curricular ideas, students and teachers could enhance their domain expertise (epistemic authority) and their role in the community as an expert (positional authority). Therefore, our study looked at how authority could be shared and how co-design could lead to more equitable teaching practices (Farr, 2018).

Penuel et al. (2022) showed that co-design is also a helpful method for balancing curricular goals. The iterative process of implementation, reflection, and revision is especially helpful for refining these goals. Farr (2018) also argued for constant critical reflection in order to establish for more equal and balanced relational processes, in this case between researchers and teachers. With these themes from the literature in mind (i.e., agency, authority, and balancing of goals), the next section will describe our analysis of our co-design process in the context of the current study.

Methods

The data from this study comes from a design-based project (GEM-STEP) about how a mixed reality enhanced curriculum can teach scientific modeling and computational thinking skills. The mixed reality technology included Pozyx anchors and RFID tags which tracked children's location within the classroom when they are wearing the tags, and GEM-STEP software that transforms students' tracking information into an agent on a projector screen within a model of the phenomenon of interest (in this case moths and adaptation; See Figure 1)

Figure 1

Children playing as moths trying to camouflage with tree trunks

The data was collected at a public middle school, in a small suburban city close a large metropolitan area in the Southeastern region of the United States. This analysis focused on a STEM classroom, in which one teacher (pseudonym: Ms. S), worked with all students in each grade across the four quarters of the academic school year. This paper focuses on the fifth-grade class, when we implemented and video recorded a multi-day curriculum about moths and adaptation in Quarter 2 (Q2; 7 days) and in Quarter 4 (Q4; 9 days). We excluded Q1 and Q3 due to incomplete data collection as a result of COVID-19 restrictions that made it difficult for researchers to access the school. The days of implementation varied by quarter due to design changes that were made through our iterative process (Cobb et al., 2003).

The analysis process started by focusing on the first 10-15 minutes of each class session because those were the sections most collaboratively designed with Ms. S. We also compared across Q2 to Q4 to see changes in Ms. S's practice related to the three themes from our literature review: agency, authority, and curricular goals. Our research team started by content logging (Derry et al., 2010) each class video. An undergraduate researcher

then looked through field notes and content logs to summarize our collective observations based on the three themes: (1) Ms. S's moves that expanded or limited student agency, (2) Ms. S's comfort/familiarity with facilitating the mixed reality curriculum, (3) Ms. S's approach to framing the daily activities. The lead author went through video and research teams' notes to identify focal clips, which are described below.

Findings

We observed that Ms. S often led our research team on how to design for student agency by modeling this practice in her introductions to each day's lesson. For example, in Q2, she started each day with mostly lecture-based introductions, but in Q4 she gave students a lot more agency in that the discussion was more student-led. Ms. S took somewhat of a backseat as students excitedly discussed their results of the previous day's mixed reality activity game. The students' excitement to lead in Q4 rather than Q2 could have been the result of our change in design to have more mixed-reality activities on consecutive days, which provided more embodied experiences for them to wonder and inquire about. Another example of Ms. S leading us in designing for student agency was how she started to incorporate students' questions from previous mixed reality days in the "icebreaker" opening discussion practice. In Q4, one of the students, Crazy Wolf, kept dying as a white moth because all of the trees were gray, so he asked: "If you are the white moth, where are you going to live?" Ms. S thought that Crazy Wolf asked such a good question, she included it as the icebreaker question for the following day's introduction. We argue that students may have been more engaged in these discussions in Q4 because they saw their own thinking being represented up on the board as the discussion prompt. In order to connect the mixed reality environment activities to her own facilitation style, Ms. S modeled for us how important it was to co-design for student agency.

We also observed Ms. S's comfort with facilitating the mixed-reality activities increased and her authority over the content knowledge being taught increased. On Days 2 and 3 of Q2, Ms. S started to be more active than on Day 1 in facilitating the mixed reality activities. She solicited ideas from the students about what might be happening during the activity, but it started out as a more one-on-one approach in Q2 as compared to Q4 where she could field questions from students in groups. In Q1 we also noticed she would often ask researchers to answer students' questions about the mixed reality activities, but by Q4 she answered more questions and suggesting more ideas to help support their thinking (e.g., "If you were a moth, what would be on your to-do list?" as a metaphor for sequencing and computational thinking). These days showed us that Ms. S played a very active role in helping us design the activity flow, because she began to understand and (re)author our content goals together by Q4.

Ms. S also led us in balancing NGSS-aligned goals and our grant project goals. Although we were unsure of how to include the story about the peppered moths during the Industrial Revolution into our curriculum, Ms. S started the unit by briefly mentioning the historical moment. This practice is in line with phenomenon-based science teaching (Lee et al., 2019). She also brought back more standards-based practices such as collecting and interpreting data in Day 7 of both quarters. This consistency and persistence from Ms. S showed us that she was leading us in making sure we aligned the mixed reality technology with NGSS teaching goals.

Implications

In this section, we address how each theme could inform takeaways for when researchers are co-designing with teachers. We found that Ms. S often thought about student agency when co-designing our curriculum. As a result, we (researchers and teacher) planned for and facilitated discussions in ways that built on and followed student thinking. For example, we could continue to design activities that encouraged students to ask questions during activities and lead discussions about their questions.

Our second theme around teachers' epistemic authority leads us to consider how power relations impact research-teacher-student interactions. In Q2, we did not realize how often Ms. S was redirecting students' questions to us. And in Q4, we were more intentional in helping Ms. S feel more comfortable fielding students' questions by explicitly asking her to lead the lessons from start to finish.

And finally, we found that Ms. S was persistent in keeping researchers' goals aligned with NGSS and school district standards. Therefore, it is important to discuss goals early and often with our teacher co-designers. This practice will allow room for creative ways to incorporate phenomenon-based (research/teacher-designed) curriculum and also responsive (student-led/in-the-moment) teaching approaches in mixed reality classrooms.

In sum, we found that co-design was an effective method for increasing collective agency among researchers, teachers, and students; for developing our teacher's epistemic authority; and for balancing the goals of our teacher, her school, and our research team. We argue that these elements show that co-design could also open up more expansive ways of designing and teaching science and technology curriculum. Future research should consider how to further develop these more equitable design and relational processes in ways that continue to empower our teachers and students.

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