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Choosing, Imagining, and Changing as Agency in a Mixed-Reality STEM Learning Environment

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Abstract: We explore how student agency was enacted in small, medium, and large ways that impacted the emergent design of a technology-enhanced science learning environment. Small acts corresponded to students choosing how to participate, medium acts when students' imagination was supported, and large acts when students' ideas changed the curriculum. We analyzed video data from 21 class videos to highlight the design trajectory from the first iteration (one 5th-grade classroom; topic: moths and adaptation) to the second (four 4th-grade classrooms; topic: food webs). Our findings suggest that supporting choice and imagination led us (researchers and teacher co-designers) to make curricular changes to follow students' ideas (e.g., an activity about decomposition to figure out how plants get their energy). Future learning environment designs should be responsive to all three types of student agency.

Motivation and theoretical framework

Agency has been shown not only to enhance student motivation and engagement in STEM, but also to connect social change to disciplinary learning (Goulart & Roth, 2010; Basu, 2008). However, agency has been difficult to operationalize, and even within science education, scholars conceptualize agency differently (Arnold & Clarke, 2014). For Arnold & Clarke, agency was defined as "the discursive practice of positioning oneself or being positioned as responsible" (p. 751). The National Research Council (2009) has reported the temporal aspects of agency that may help teachers identify moments to encourage student agency: "A sense of agency or belonging can be experienced retrospectively when reflecting on past events, it can be experienced in relation to current activities, and it can be projected into the future through imaginative acts regarding what one might become" (p. 74). Agency has also been defined as the capacity to act on one's knowledge of science (Basu, 2008; Barton & Tan, 2010) or "a person's capacity to engage with cultural schemas and mobilize resources in ways that did not exist before, creating new contexts and practices" (Varelas et al., 2015, p. 517). This wide range of definitions (from responsibility based on how one chooses to position oneself, to acting from one's imagination, to the capacity to act) suggests the importance of understanding and conceptualizing sub-types of agency. From this range of definitions, we argue three contexts when agency is relevant for students: moment-to-moment interactions, dreaming about the future, and acting on the dream to realize a desired future or outcome.

In this paper, we propose three different types of agency that build up to students taking social action: choosing (small; Rodriguez, 2015; National Research Council, 2009), dreaming (medium; Carlone et al., 2015), and changing (large; Arnold & Clarke, 2014). We present empirical data from the Generalized Embodied Modeling and Science through Technology Enhanced Play (GEM-STEP) project about learning through embodiment in a mixed reality environment to provide examples of these three types of agency. These examples show how agency impacted children's learning and our iterative co-design process. Specifically, we ask: How does the co-design/co-facilitation process between researchers-teachers-students support student agency?

Methods

The data for this study comes from the GEM-STEP project, where students play within a system that tracks their location and shows them on a shared visualization as an agent within the scientific phenomenon of study (in this case, moth adaptation and terrestrial food webs). Our curricula leveraged embodied modeling technology that enabled students to appear as and control agents within a simulation on screen with their movement (e.g., a moth hiding from an artificial intelligence-controlled controlled hawk, a robin eating and gaining energy from an AI-controlled beetle, and carbon dioxide molecules that meet up with water molecules at an on-screen zoom-in of a plant leaf's chloroplast; See Figure 1).

Authors 1-3 time-indexed and content logged (Derry et al., 2010) 21 days of video (9 days of the moth unit; 3 days x 4 iterations of the food web unit) and iteratively watched these videos as an author team to refine hypotheses (Engle et al., 2007) about moments when students are engaging in small, medium, and large acts of agency. We noted moments when teachers and researchers give students choice as small agency moments (e.g., "Are we ready? Are we all where we want to be [in the tracking space]?"). When children asked creative questions

or made observations that required imagination, we noted those moments as medium agency (e.g., "I ate the garden, but I couldn't eat [another student's name]"). When students made a suggestion that led to real change in the activity design or curriculum, we noted those as large agency moments. We also tracked overall how our planned design decisions did or did not support all three types of agency, and what unplanned design decisions occurred in response to students' small, medium, and large acts of agency.

Findings

We identified planned and unplanned design decisions that impacted student agency in the moth and food web iterations. For example, within the moth curriculum, we planned for students to have choice (small acts of agency), but students surprised us and created their own moments of medium agency when they made up narratives about moths facing imminent death and the hawk "birdie" being broken. Because the moth iteration somewhat restricted students' agency to use their bodies to engage in the activity (i.e., staying still and hiding on a tree from the hawks was a popular strategy), we also intentionally designed the food web activities to require more movement in order for kids to engage (i.e., eat the moving beetles when you are a snake or robin). This design change opened up more opportunities for both small and medium acts of agency.

In the food web unit, we expanded the possibilities of students' imagination by designing the game so that children can take the perspective of multiple animals. Through the food web activities, students began to wonder and worry about the plants: Where do they get their energy from? In response to their concerns, we added a decomposition activity to meet students' desires to learn more about the connection between producers and decomposers. Although we saw large moments of agency the fewest amount of times than the other two types of agency, we plan to ask children, "Why should we care about food webs?" in order to understand what socio-environmental connections or changes children may suggest.

Future directions

Overall, because this project builds on the tradition of iterative design-based research, we are fortunate to make changes to our curriculum in real-time response to students' choices, imagination, and sociopolitical agency. We hope this inspires other science learning environments to design curricula and activities in a way that can be responsive to students' agency.

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