Making Sense of Modes in Collective Embodied Science Activities

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Abstract: In this paper, we explore how students navigate collective mixed-reality embodied science activities in two contexts. We analyzed students' interactions using a mediated discourse analysis approach by creating bubble maps that captured modal density: the modal complexity (frequency and number of modes) and modal intensity (how much attention participants give to each mode) during embodied modeling and how these maps highlighted participants' engagement with science. We found that the content of the models shaped the modes that were relevant for participation and how the modelers interacted with each other.

Introduction and framing

In education, there has been increasing interest in understanding the role of bodies and movement in learning. We are particularly interested in supporting students' learning through *collective* embodied science modeling, or activities where students coordinate their actions in order to create an embodied model and to learn about complex science phenomena (Danish et al., 2020). In our work, students participate in these activities in mixed-reality environments; as they move around the classroom, they see themselves and their classmates projected as avatars on a screen. To an outside observer, these modeling sessions often seem messy and chaotic. They require that students move around and collaborate in a physical space, while also paying attention to how their actions influence the projected model. It is important to understand how students make sense of these activities in order to support their noticing of and engagement with target science ideas.

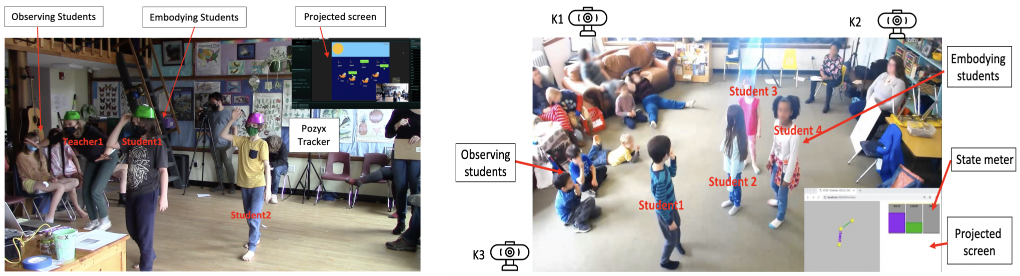
We explore these activities through the lens of mediated discourse analysis (MDA; Scollon, 2001). MDA is a framework that considers what actions are happening in a given site of engagement, and how discourse contributes to those actions. In MDA, the unit of analysis is a mediated action, or the things that people are able to do in a moment using available cultural tools. Central to this focus on mediated actions are modes, or systems of mediated action that "are part of the action that the individuals perform with others, the environment, and objects within" (Norris, 2016, p. 142). Wohlwend (2021) offers a modal categorization scheme, in which modes can be considered embodied (e.g.. gaze, speech, movement), environmental (e.g. color, layout, proxemics), or designed (e.g. image, music, shape). She argues that researchers may overlook meanings that children create because they are focused on fixed speech or print, rather than on actions in lived spaces. Mixed-reality embodied play activities are modally complex; they require students to coordinate multiple modes to be successful. In this paper, we explore how mapping the modal density of modelers' interactions, that is their modal intensity (how foregrounded or backgrounded a mode is for each modeler) and their modal complexity (how intertwined modes are with other modes), can inform our understanding of students' actions during embodied activities. We ask: how do students and teachers navigate modally complex multi-reality embodied play activities, and how does this impact what they notice and their participation in scientific modeling? We explore this question across two contexts where students engaged in embodied science activities: 5th and 6th grade students (ages 10-12) embodying energy transfer in aquatic ecosystems, and 1st and 2nd grade students (ages 6-8) embodying solid, liquid, and gas particles. In putting these contexts next to each other, we do not intend to compare them directly, but to explore the value of modal density for understanding modelers' participation across contexts.

Methods

Participants and data sources

Data for this analysis comes from two iterations of our projects on embodied science modeling: Science through Technology Enhanced Play (STEP) and Generalized Embodied Modeling: Science through Technology Enhanced Play (GEM-STEP). In these projects, students embody various agents (e.g. energy, particles, fish, worms, bees) in order to model complex systems. As they act as these agents, their movement is tracked and projected on a screen (Figure 1). Students generally model in small groups, while other students watch and make observations.

Figure 1
Students embodying energy in GEM-STEP (left) and students embodying particles in STEP (right)



<u>Context 1: 5th and 6th graders embodying energy transfer in aquatic ecosystems</u>
The first modeling activity occurred in the GEM-STEP environment, a platform that supports students to move between cycles of embodied and computational modeling (Danish et al., 2022). This iteration of the project took place in a 5th-6th grade mixed age classroom in a private school in the Midwestern United States. The students engaged in six one-hour long class sessions to learn about energy transfer within aquatic and garden ecosystems. The lessons were taught primarily by the research team, although the two classroom teachers were present and helped to facilitate, participating in the activities alongside students, and providing feedback on the lessons throughout the implementation. Data sources that were collected included video of the classroom implementation, screen recordings of GEM-STEP, and pre and post tests and interviews for each student. Because MDA relies on multimodal data, we focused on classroom video and screen recordings.

<u>Context 2: 1st and 2nd graders embodying solid, liquid, and gas particles</u>
The second modeling activity occurred in the STEP environment, a predecessor of the GEM-STEP that leverages students' embodied play as learning resources to understand scientific phenomena. Students' movement was tracked by three kinect cameras (labeled as k in Figure 1) and simulated as water particles on the screen. The present analysis focuses on an implementation of the particle curriculum in which 22 first and second-grade students from the Midwest participated in seven thirty-minute class sessions to learn about the behavior of particles in three states of matter (Danish et al., 2020). Three researchers, one classroom teacher, and student observers watched the embodied modeling and offered in-time feedback and questions. Previous analyses have shown that students made significant learning gains from the pre/post tests (Tu et al., 2021) and that the collective embodied modeling activities developed their mechanistic reasoning (Zhou et al., 2022). This current analysis uses multimodal interaction analysis to investigate how students' multimodal resources played out in their coordination and emergent scientific understanding.

Analysis
We engaged in multimodal interaction analysis (Norris, 2004) to understand how the modelers navigated the complex mix of modes and meanings as they engaged in a round of embodied activity. To begin, we selected one clip from each context that contained complex interactions between multiple modelers because we wondered about how modal density could shed light on the modelers' collaboration. In context 1, two students and one teacher embodied energy in an aquatic ecosystem in a 130-second-long round. The model included the sun, five algae, and five fish, which students could bring energy between. We selected this clip because we were struck by the sharp contrast between the way that the teacher used the mode of gesture, as she acted out energy, and the students' lack of engagement with acting, even though it was encouraged by researchers. In context 2, four students each represented a particle and explored how their speed controlled different states of matter in a 190-second-long round. We selected this clip because we were interested in how students worked together as they planned, tested, and refined an idea.

Next, we made bubble maps of modal density for each modeler (Norris, 2006; Wohlwend, 2021). To do so, we segmented each clip into ten second segments, and coded each segment for the modes that were present and absent for each modeler (frequency of modes). Next, we assigned values for which modes were foregrounded and backgrounded (attention), that is, which modes required conscious attention, based upon discussion among the authors. In this process, we included embodied modes (gaze, speech, movement, posture, gesture, haptic) due to our interest in modelers' embodiment, as well as proxemics (proximity to others) because we were interested in the modelers' collaboration with each other. We noticed that gaze was present and foregrounded for the majority of both clips, and so we split gaze into gaze towards the screen, gaze towards other modelers, and gaze towards the community (including observing students and teachers) in order to better understand this mode. Speech referred to anytime the focal modeler spoke, movement to their movement through the space, posture to a modeler standing still, gesture to hand movements that conveyed meaning, haptic to moments when touching something (like the hats) and/or other modelers was relevant, and proxemics when modelers seemed aware of or navigated around other modelers in the space. After creating these bubble maps, we explored the implications of a particularly foregrounded or backgrounded mode for participation. In context 1, we noticed that movement was foregrounded and frequent for all the modelers, so we tracked how each modeler's movements corresponded to their engagement with the science model. In context 2, gaze was heavily foregrounded but in different ways across students, and movement was foregrounded for everyone except for student 4, which was surprising in a modeling activity about speed. Thus, we rewatched this clip iteratively to understand how those modes informed students' coordination.

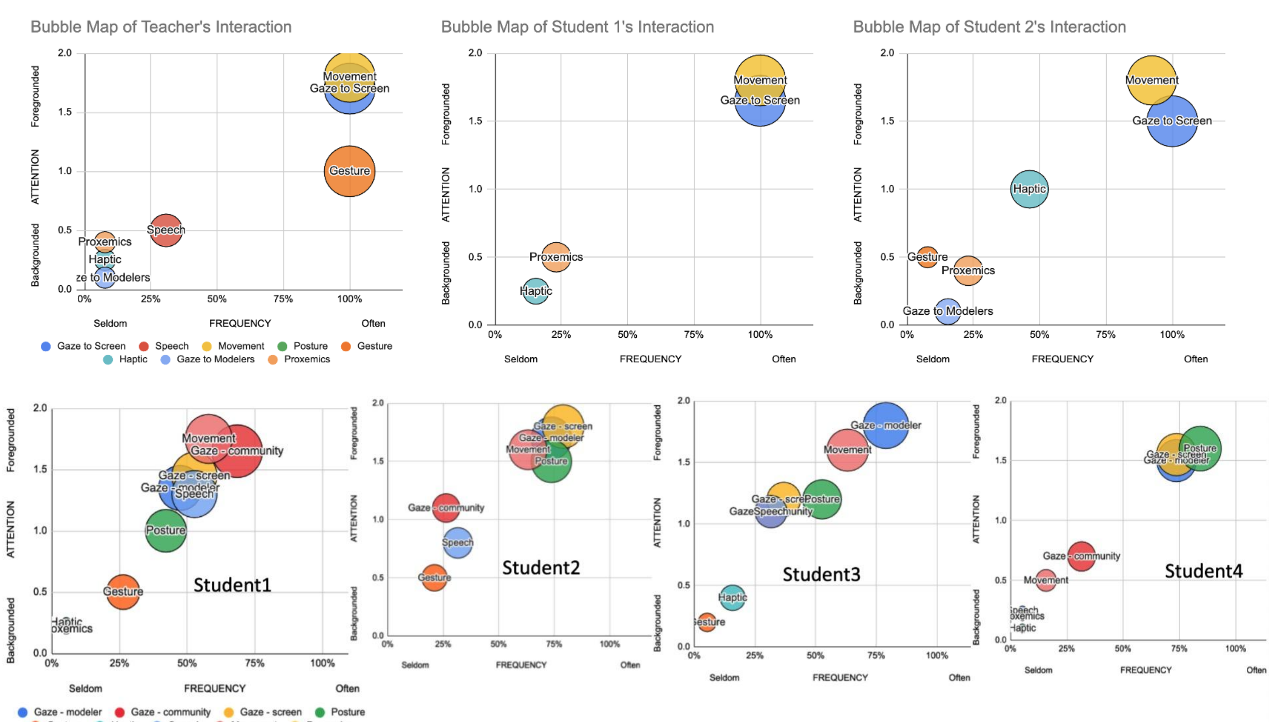
Findings and discussion

Context 1- 5th and 6th graders embodying energy transfer

The bubble maps for each modeler demonstrated that both movement and gaze to the screen were modes that occurred often and that modelers explicitly attended to as they made meaning (Figure 2). The modelers' actions were characterized by an intense, constant gaze towards the screen: they rarely looked at each other, yet only had a few close calls in terms of bumping into each other. There were distinct differences between the teacher and the students' modal interactions. The teacher used speech to coordinate with students: "talk to me people, who do I need to save?". She also engaged playfully through her hand gestures, a mode that drew negative attention from observers: "you look ridiculous". Instead, students seemed more focused on modeling through movement. Even though movement was frequent and foregrounded for everyone, they attended to the model through movement in different ways. The teacher often traveled far distances, ensuring that the fish and algae furthest away from the sun received energy, while the students attended to the fish and algae closest to them. However, they all seemed aware of which agent needed energy, as indicated by a red or orange energy bar, and only brought energy to an agent with a green bar once. All of the modelers were in nearly constant motion as they moved between the sun, algae, and fish. They attended to all of the agents, engaging in what looked like parallel play.

Figure 2

Bubble maps of modelers' modal interactions during a modeling round in Context 1 (top) and Context 2 (bottom)



Context 2- 1st and 2nd graders embodying particles

While gaze and movement were also foregrounded for the modelers in this context, they varied in where their attention was directed most often (Figure 2). Student 1 predominantly focused on the community, student 2 on the screen, student 3 on other modelers, and student 4 on both the screen and other modelers. Rewatching this clip iteratively as a team, we noticed that each student's bubble map related to their roles in the cycle of initiating/planning a goal, enacting/refining the plan, and starting a new plan. Student 1 initiated the modeling plan and addressed questions about the goal from the community, thus directing his gaze there. He assigned each student to move at still, slow, and fast speeds to correspond to the three states (solid, liquid, and gas). Student 2 was initially assigned to be a still particle and complied (as seen by foregrounded posture in the bubble map). Student 4 joined the modeling late and was not assigned a speed. As a result, she was often still and movement was backgrounded. Thus, students collaborated in this context; each students' modal density highlights their role (or lack of role) in the model.

Implications

The bubble maps helped us to attend to how each design necessitated and benefited from different modes. In particles, students needed to collaborate with each other to be successful: as such, their gaze was divided between other modelers, the screen, and the community. In energy transfer, students gazed almost entirely at the screen to make sure the algae and fish did not die, perhaps limiting collaboration. Using bubble maps to attend to these differences in gaze helped us to understand how the content areas and model designs facilitated different modes, leading to different ways of collaborating and engaging. Attending to different modes also seemed to afford different opportunities for engagement and learning. For example, proxemics were backgrounded for all of the particle modelers: students attended to speed and its relationship to the macrostates and had not yet determined that distance to each other mattered. In energy transfer, modelers' intense gaze to the screen enabled their movements to hold meaning– they moved intentionally between agents as they embodied an energy cycle. While we focused on the foregrounded modes in analysis, the backgrounded modes point to actions that may be important but are beneath notice, or to which participants are centralized or excluded from activity. Differences in bubble maps across participants also may indicate differences in experience, like the teacher's gestures during energy transfer or student 4's lack of movement in particles. Future research can explore how to design embodied activities that support specific kinds of modes and engagement.

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