Moving Forward: In Search of Synergy Across Diverse Views on the Role of Physical Movement in Design for STEM Education

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Abstract: Inspired by the current embodiment turn in the cognitive sciences, researchers of STEM teaching and learning have been evaluating implications of this turn for educational theory and practice. But whereas design researchers have been developing domain-specific theories that implicate the role of physical movement in conceptual learning, the field has yet to agree on a conceptually coherent and empirically validated framework for leveraging and shaping students' capacity for physical movement as a socio–cognitive educational resource. This symposium thus convenes to ask, "What is movement in relation to concepts such that we can design for learning?" To stimulate discussion, we highlight an emerging tension across a set of innovative technological designs with respect to the framing question of whether students should discover an activity's targeted movement forms themselves or that these forms should be cued directly. Our content domains span mathematics (proportions, geometry), physics, chemistry, and ecological system dynamics (predator–prey, bees).

Introduction

Inspired by the current embodiment paradigm turn in cognitive science (Barsalou, 2008; Wilson, 2002), researchers of STEM teaching and learning are seeking to understand implications for educational theory and practice. In particular, design researchers are developing domain-specific theories that implicate the role of physical movement in conceptual learning (Abrahamson & Lindgren, 2014). These scholars conjecture that learning disciplinary content is contingent on enacting particular situated movement routines for participating effectively in the performance of socially constructed tasks in material–virtual settings. And yet two decades since the pioneering movement-based design studies (Nemirovsky, Tierney, & Wright, 1998), our community has still to agree on the specific role of movement in STEM learning (Hall & Nemirovsky, 2012; Lee, 2015). In particular, although embodiment theories hold sensorimotor activity as constitutive of learning, knowing, and reasoning, the field has yet to agree on a conceptually coherent and empirically validated design framework to leverage and shape this resource in education (Abrahamson & Sánchez–García, 2016; Kelton & Ma, 2018). Thus, as the embodiment dust begins to settle on the fertile design-research meadows of the learning sciences, this symposium convenes to ask, "What is movement in relation to concepts such that we can design for learning?"

We all seek a cohesive theoretical framework for conceptualizing the fundamental role of physical movement in content learning. Also, we all believe that fine-grained ethnographic accounts as well as high-resolution data-mining analyses are necessary for providing empirical evidence for the validity of arguments grounded in embodiment theory. Collectively, we furnish diverse evidence supporting an implication of physical actions as critical catalysts in the emergence of new forms of reasoning. Where our designs differ, however, is in their study rationale and procedure with respect to why, when, and how students should enact these movements. Our most striking dimension of variability pertains to students' agency in determining the movements. Some of the designs espouse a "bottom up" view, where students freely explore the space of movement possibilities to discover the activity's targeted dynamical forms, whereas other designs espouse the antipodal "top down" view, in which students are cued to perform certain forms. It is intriguing that these mutually exclusive positions can co-exist. But what if these views are complementary? That would point to potential synergy in theory and design, moving forward. Moreover, the transparency of physical movements, as compared to covert reasoning in traditional sedentary activities, may enable us to revisit enduring problems of pedagogy with respect to the value of guided discovery learning (Abrahamson & Kapur, 2018; Klahr, 2010).

The session will open with introductory words. Six paper contributions then follow, spanning content domains of mathematics (proportions, geometry), physics, chemistry, and ecological systems (predator–prey, bees). Our Discussant, Dr. Oskar Lindwall, will then draw on ethnomethodology principles to interrogate implicit theoretical assumptions underlying the contributing researchers' respective design architectures and data-analysis methods. Regardless of specific techniques for fostering new movement, each activity appears to breach familiar interaction practices. Much of what we call skill learning could in fact be characterized as teachers and students negotiating new discursive routines and establishing what is learnable within the respective contexts. Illuminating this "dark matter" of STEM education could enhance the quality of design.

An ecological dynamics view on movement-based mathematics learning: On the emergence of sensorimotor schemes in sociocultural settings

Dor Abrahamson and Arthur Bakker

A multiyear research collaboration between UC Berkeley and Utrecht University is pursuing the multimodal embodied roots of mathematical concepts. Complementing clinical data with action logs and eye-tracking input, we have been able to implicate subtle micro-processes in the emergence of new sensorimotor schemes anticipating effective problem solving of tablet-based manipulation tasks. In particular, we have demonstrated student construction of *attentional anchors* (Hutto & Sánchez-García, 2015), information-invariant constellations of environmental features facilitating the situated enactment of complex, dynamical physical actions. Our empirical work has been centered on better understanding the role of attentional anchors in conceptual development. Being design researchers, we are conducting this investigation via further developing and evaluating an educational artifact, the *Mathematics Imagery Trainer* (Abrahamson & Trninic, 2015).

Figure 1. A student invents and uses an emergent attentional anchor to guide the enactment of proportional bimanual movement: He focuses on an imaginary line between the fingertips of his left- and right-hand indexes, keeping this imagined line at a constant angle to the *x*-axis while moving the line to the right.

Figure 1 shows a sequence of stills from a video of a low-tracked middle-school mathematics student working on a bimanual control activity. In this activity, Orthogonal Plusses, the left hand moves a cursor up and down along a vertical axis while the right hand moves another cursor right and left along a horizontal axis. The activity's task objective is to make the screen green. Unknown to the child, the screen will be green only when the cursors' respective vertical and horizontal displacements from the bottom-left corner (the "origin") relate according to a ratio, here 1:2. The orange spots on the screen are post-intervention overlays of the child's eye-gaze foveal locations. This student is looking not at the fingertips of his left or right hands that are manipulating the cursors but rather at screen locations that bear no stimuli or contours at all. This dynamical pattern, his idiosyncratic and extemporized attentional anchor, is serving the student as a means of managing an otherwise overwhelming motor coordination task. The student explained that he is imagining a diagonal line connecting his fingertips (top-left to bottom-right); that he is sliding this projected percept along to the right, maintaining its angle constant relative to the screen base. In turn, note how operating this attentional anchor sends his foveal spotlight along a diagonal trajectory from the origin and up to the right along what amounts to a linear function corresponding to the ratio, $y=x/2$. This spontaneous invention of a new perceptual category, the imagined line, thus mobilized the child to construct new mathematical notions relevant to the curricular targets.

Our findings have thus empirically corroborated central theoretical constructs from Piaget's philosophy of genetic epistemology, such as reflecting abstraction, that is, an argument for the pivotal role of new sensorimotor schemes in conceptual development (Abrahamson, Shayan, Bakker, & Van der Schaaf, 2016). In so doing, we have also supported tenets from enactivist theory regarding the emergence of conceptual structures from spontaneous solutions to pragmatic problems of environmental adaptation: "(1) perception consists in perceptually guided action; and (2) cognitive structures emerge from the recurrent sensorimotor patterns that enable action to be perceptually guided" (Varela, Thompson, & Rosch, 1991, p. 173).

Drawing on complexity-science research in sports performance (e.g., Chow, Davids, Button, & Renshaw, 2016), we have imported the theory of *ecological dynamics* to the learning sciences. From this view, we model mathematical ontogenesis systemically as emerging from complementary contributions of embodied and sociocultural forces. Students develop proto-conceptual sensorimotor schemes by using available instruments to achieve contextual objectives specified in the social enactment of cultural practices, such as designed educational tasks. We are particularly interested in the pervasiveness of empirical cases where students themselves create these instruments ad hoc in a struggle to complete task objectives within fields of promoted action (Abrahamson & Sánchez-García, 2016). Given suitable design, students do not need movement direction.

Insight out: Embodied game play improves mathematical insight and proof

Mitchell J. Nathan and Candace Walkington

Grounded and embodied cognition (Barsalou, 2008; Shapiro 2014) frames intellectual behavior as grounded in situated action, mental simulation, and bodily states. Evidence is mounting that mathematical reasoning draws on the coordination of motor and language systems (Abrahamson & Trninic, 2015; Alibali & Nathan, 2012; Hall & Nemirovsky, 2012). Our theory of *Grounded and Embodied Mathematical Cognition* (GEMC) hypothesizes that cognition–action interactions can run forward (thoughts drive actions) *and* backwards (actions induce cognitive states) through a process of *action–cognition transduction* (Nathan, 2017). We investigated the empirical implications of GEMC for mathematical reasoning and proof performance in pre-college geometry. Justification and proof are fundamental to secondary and post-secondary mathematics education (e.g., Stylianides, 2007), but students struggle to develop effective proof practices (Knuth et al., 2009).

GEMC posits that body-based (nonverbal) forms of reasoning, as exhibited by gestures that show dynamic mathematical reasoning, can allow for key mathematical insights when reasoning about geometric relationships. When motor system activation is coupled with language system activation, in the form of dialog, self-explanations, or pedagogical cues, GEMC predicts that both insight and the formulation of valid proofs will be enhanced. We explored the implications for theory and learning environment design. Specifically, GEMC-based design principles led us to make *The Hidden Village*, a videogame where players must copy actions of tribal village members that sometimes model relevant geometric relationships in body-based form. Shape properties are then explicitly explored when players test and justify in-game geometry conjectures (Figure 2).

Figure 2. *The Hidden Village;* (a) Scene with full village map; (b) & (c) Directed actions turn green when players' actions match using Kinect™; (d) Conjecture multiple choice; (e) Tribal elder and earned shape.

We analyzed middle and high school players' (*n*=35) speech and gestures from 6 geometry conjectures presented in random order in *The Hidden Village*. Directed actions (2 factors: math relevant vs. irrelevant arm movements) and pedagogical cues (2 factors: explicit in-game links relating relevant actions and conjectures vs. none) were varied within subjects. Our scoring rubric for valid proofs looked for 3 defining criteria, from Harel and Sowder (1998): proofs exhibit operational reasoning about mathematical entities, a logical chain of inference, and generality. Insight scores reflected partial proofs addressing key relations.

Results support theory-based predictions about the processes linking action and cognition. Players' dynamic gesture productio predicts: (1) mathematical insight (Odds=8.1, d=1.2, p<.001); and (2) proof performance (Odds=11.5, d=1.3, p<.001). Predictions for the efficacy of our game-based intervention showed mixed support: (3) in-game relevant directed actions without pedagogical cues does not predict insight performance; however, (4) directed actions coupled with explicit pedagogical cues linking players' in-game actions to the math conjectures predicts players' production of dynamic gestures while justifying their proofs

(Odds=4.0, *d*=0.8, *p*=.001); (5) insight performance (Odds=3.1, *d*=0.6, p<.001); and (6) proof performance (Odds=4.7, *d*=0.9, *p*<.001). Most players reported no conscious awareness of the connection between the directed actions and the conjectures that were posed when receiving no pedagogical cues.

Our theory-based videogame design reveals the potential of GEMC to improve mathematical reasoning through action-based interactions elicited through game play. More broadly, embodied theories invite assessment of nonverbal behaviors such as gesture production, and interventions aimed at new forms of learning experiences through movement (Lee, 2015). Finally, we conclude that a design approach that cues explicit reflection on directed physical movements seems to be the most beneficial for learning of mathematical proofs.

Embodied explanatory control: simulations that prompt users to enact causal mechanisms

Robb Lindgren and David E. Brown

Common across theories of embodied cognition is the notion that thinking has "deep roots in sensorimotor processing" (Wilson, 2002, p. 625). Barsalou (2008) argues that cognition is grounded in simulations of perceptual and motoric experiences, and recent empirical work has shown that seeding learning interventions with designed physical activity (e.g., experiencing angular momentum by holding a spinning bicycle wheel) can lead to conceptual gains (Kontra, Lyons, Fischer, & Beilock, 2015). Indeed, much recent work in embodied learning has focused on ways to solicit meaningful bodily action in designed environments, especially technology-enhanced environments (Lee, 2015). There is significant diversity in this work, particularly in how the technology solicits body-action and what makes the activity meaningful. We argue that those decisions can be guided by theories that pertain to the particular kinds of learning and skills that an intervention seeks to cultivate. In our work, we are focusing on students' causal explanations of scientific phenomena (e.g., molecular interactions). We briefly describe how notions of explanatory reasoning have guided our design of an embodied simulation interface. Clement (2008) describes explanatory models as a type of scientific model that is created by scientists to explain the hidden structures and the unobservable mechanisms behind observable phenomena. We define students' explanatory models as imagistic models in which a student can visualize the interactions of unobservable elements such as molecules to explain why observable phenomena happen (Brown, 1993). Dynamic visualizations, such as computer simulations, allow a student to "see the unseeable," and with physically interactive simulations students have the opportunity to build metaphors that connect abstract mechanisms (such as molecular collisions) with sensorimotor experiences (feeling real-world objects colliding).

Figure 3. From left: The GRASP gas pressure simulation; Jada showing gas molecules hitting a wall; A "ghost hand" guiding the learner to make a fist and become the molecules.

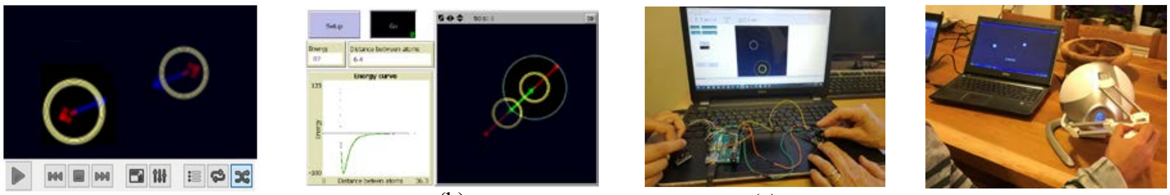
With our *GRASP* Project (GestuRe Augmented Simulations for supporting exPlanations) we have been faced with the challenges of how to build those metaphorical connections between student movement and computer simulations of science phenomena such as gas pressure. Previous "embodied" simulations have given students control of macroscopic elements, such as using gestures to move a virtual wall that changes the volume of a container holding a gas, which are often visualized as balls bouncing around inside the container. We refer to this type of control as *embodied phenomena control* (EPC). With EPC, the learner is able to either represent or manipulate some observable aspect of a physical system. But because our work is targeting the construction of explanatory models described above, we have focused instead on gestures that control the interactions of the molecules themselves (Figure 3, left). With *embodied explanatory control* (EEC) students use gesture to affect pressure by tapping their palm (representing the movable wall) with their fist (representing the molecules). Quick tapping leads to high pressure and slow tapping leads to lower pressure. This particular gesture emerged from preliminary interviews with students like Jada (Figure 3, center) who, when productively reasoning about gas pressure, started tapping her fingers at different rates against the palm of her hand. Leveraging these productive cases, we cued students to represent the causal mechanisms with similar gestures by employing interactive interface techniques such as "ghost hands" (Figure 3, right) and "fading" to facilitate the connection between the body and the visualization (e.g., the hand becomes the molecules). It is important to note that even at the molecular level it would be possible to give learners control by having them directly manipulate elements of the simulation (e.g., grabbing molecules and tossing them), but embodiment theories suggest that gestures more naturally connect with knowledge when they are enacting processes and simulating actions (Hostetter & Alibali, 2008). Thus, we let students' hands represent simulation elements rather than manipulate them. In our design-based research study over 30 students to-date have used the GRASP gas pressure simulations, and initial findings (Brown, Mathayas, & Lindgren, 2017) have demonstrated powerful effects of EEC in focusing student attention on the molecular mechanism for gas pressure. Simultaneous studies of other gesture-controlled simulations such as the causes of seasons are helping us to understand how EEC control can be used for other unobservable mechanisms such as the distribution of light rays on the Earth's surface.

The ELI-Chem Simulation: Grasping Chemical Bonding by the Hands

Asnat R. Zohar and Sharona T. Levy

This design-research project seeks to solve a fundamental problem in learning about matter: understanding the chemical bond as dynamic equilibrium between attraction and repulsion forces. Molecular phenomena cannot be experienced directly, so students learn about them in the absence of intuitions derived from their experience of the world (Taber & Coll, 2002). Therefore, the concept of chemical bonding is difficult to grasp precisely because there is no analogous physical experience of simultaneous attraction and repulsion. Moreover, mainstream curricula often mislead students by: presenting chemical bonds as different categories (e.g., ionic, covalent) without relating them on the basis of shared principles; and explaining chemical stability of molecular structures using the octet-rule heuristic (i.e. with eight electrons in the outer shells) rather than the more fundamental balance between electrostatic attractions and repulsions (Nahum et. al, 2007; Taber & Coll, 2002).

Students understand STEM concepts by grounding them in their intuitions (Clement, Brown, & Zietsman 1989; diSessa, 1993; Núñez, Edwards, & Matos, 1999). Drawing on embodied cognition theory, we conceptualize this grounding as resulting from purposeful actions (Dourish, 2004; Kirsh, 2013; Wilson 2002). Applied to education, embodiment theory implicates concepts as emerging from situated bodily interaction via reflection, discourse, and modeling (Abrahamson & Sánchez–García, 2016). The *embodied design* framework specifies how to create opportunities for students to develop new sensorimotor schemes and then shift into scientific reconceptualizations (Abrahamson, 2014), such as universal electrostatic interactions underlying chemical phenomena.



(a) (b) (c) (d)

Figure 4. ELI-Chem degrees of embodiment. (a) No motion (video), (b) mouse interaction, (c) Joy-stick interaction and (d) Haptic device.

We designed and developed the ELI-Chem environment (Embodied Learning Interactive simulation-based environment, Zohar & Levy, 2015). The base of the learning environment is a chemical bonding computer simulation displaying the attractive and repulsive forces between two atoms and the resulted potential-energy diagram. Using a mouse, students interact as an atom with another atom, exploring changes of forces and energy. By connecting a joy-stick and a haptic device to the simulation, the ELI-Chem system offers sensory-motor experiences of the attractive and repulsive forces at four increasing degrees of embodiment (Figure 4). The study is framed as an experimental pretest-intervention-posttest design with four treatment conditions: animations, mouse-, joy-stick- and haptic-based participation in the model. The participants are forty-eight (n=48) 12th grade chemistry students, randomly assigned to one of the four conditions (12 in each). The independent variable is the embodiment level; the dependent variable is conceptual change, tested with a pre- and post-test questionnaire and using the activities' worksheets of 40-minutes work with ELI-Chem. Main concepts addressed were repulsive and attractive forces, chemical stability and potential energy diagram.

Our findings show that there is an increase in students' conceptual understanding in all four levels of embodiment, with significant higher learning gain in the haptic condition. From explanations based on the 'octet rule' depicting the atoms as static "touching" balls, students turn to consider the dynamic balance between attraction and repulsion forces. In the qualitative results we have seen four important differences between the forms of interaction: the modes of perception used to access information which become more varied as the level embodiment rises: from seeing, through active manipulation to feeling the forces. As these modes increase in number, the resolution of the information accessed and described increases as different parts of the parameter space become distinct. Since the new component introduced to the students' conceptual model involved repulsive forces, we can see how more scientific descriptions are provided at the higher levels of embodiment. Finally, multiple perspectives of the phenomenon are adopted by students who experienced higher levels of embodiment.

Complexity Learning via Elicited Movements: MMLA of Embodied Design

Alejandro Andrade, Joshua A. Danish, and Adam V. Maltese

A wealth of empirical findings suggest physical movement is considerably involved in all thinking and knowing (Barsalou, 2008; Wilson, 2002). Educational researchers have been investigating how physical movement could be harnessed in the service of content learning. Indeed, design researchers have demonstrated instructional interventions that foster student development of targeted movement repertoires, which in turn enable the grounding of STEM concepts (Abrahamson & Sánchez-García, 2016; Lindgren, 2015). Evaluating these interventions requires new research paradigms along with appropriate data collection tools. Specifically, *multimodal learning analytics* (MMLA, Blikstein & Worsley, 2016) research methods utilizing sensing technologies to capture, integrate, and interpret student perceptions and actions, can elucidate implicit processes of embodied learning. We report on results from implementing an action-based embodied design for complexity reasoning. These results were obtained by applying MMLA to explore patterns in fine-grained physical movements students performed as they engaged in a technology-facilitated activity. The patterns were inferred from low-level computer logs and then statistically analyzed through latent states and motion-sequence models. We chose the challenging subject matter of dynamically stable predator–prey ecosystems (Hmelo-Silver, Marathe, & Liu, 2007).

Figure 5. From left: Barchart dynamically shows predator and prey population count; a student remote-shadows the moving bars; then explains; automatically generated motion-logs show movement analytics.

Fifteen 3rd/4th graders (ages 8-10) were asked to observe and follow two moving population bars depicting predator and prey counts in a running simulation (Figure 5). Due to feedback loops in animal interactions, the two bars present an off-phased sinusoidal motion pattern, in which population counts do not always move in opposite directions. Students' hand movements are sensed by motion detectors and inscribed over time, through software translation, in the form of two corresponding line graphs. Thus, the line graphs show us, both in real time and as an electronic trace for subsequent reflection and analysis, not what the bars depict but what the students perceive and enact the bars to be depicting. Following each task, we asked students either to reflect on relations between their hand motions and the simulation content or to predict hand motions under various scenarios. These questions prompted the students to consider that at any given moment in the predator–prey ecosystem there are two forces acting simultaneously (i.e., negative and positive feedback loops). This activity abides both with embodiment theories that assign complementary roles to language and sensorimotor activity in conceptual growth (Alibali & Nathan, 2012) and exemplary embodied designs that often steer students to articulate the situated physical actions they have learnt to perform (Abrahamson & Lindgren, 2014).

Comparison of student performance on pre-/post-assessments after this short tutorial shows increase in content understanding of the double feedback loops as well as notable increase in spontaneous gestures that resemble the elicited gestures. These co-speech gestures appeared to support students in ad hoc reasoning, not only in expressing ready-made inferences. They thus mark salient moments where students' understanding was developing. MMLA of student–computer interaction reveal five distinct movement patterns during the simulation activities, and these patterns correlate with different learning gains: (a) frequently pausing after each movement stroke predicted high learning gains; (b) enacting fluid movements predicted ceiling scores; and (c) lack of sync with the sinusoidal motion pattern predicted lower scores. Consequently, *students' movement patterns, as they engage with visualizations of quantitative models, can predict the quality of their content learning* (Gerofsky, 2011). We have thus validated both a learning design and a MMLA method. We also concluded that students benefit from elicited movement, provided they reflect on situated meanings of these movements.

STEP-bees and the role of collective embodiment in supporting learning within a system

Joshua A. Danish, Noel Enyedy, Megan Humburg, Asmalina Saleh, Maggie Dahn, Christine Lee, Xintian Tu, Bria Davis, and Chris Georgen

In our work, we have developed a *sociocultural framework for embodied cognition* (Danish et al., in preparation). Our goal in doing so is to build upon prior findings about how the body supports individual cognition (Lindgren & Johnson-Glenberg, 2013) and extend these with a theoretical framework—activity theory (Engeström, 1987)—which explicitly addresses both the sociocultural nature of individual learning and the unique characteristics of collective group activity into a combined framework that provides more robust insight into how we can design for and analyze embodied activity in rich sociocultural contexts. In doing so, we take a view of embodiment as activity that explicitly relies upon the use and movement of the body. We then explore embodiment (e.g., gesturing and moving within the space) simultaneously from the perspective of how it impacts the individual learner, how it impacts the collective activity in which a group of students are interacting, and how the two are interrelated. For example, in the current project we build upon the notion of play, which Vygotsky (1978) defined as consisting of both an imaginary situation and a set of rules. Engagement with the imaginary situation in play frees learners to explicitly explore and negotiate the rules of their social world (Elbers, 1994). Within STEP-Bees (see Figure 6), students take on these new roles through a combination of play-acting and movement through the physical and simulated space, a process through which they are able to articulate and revisit their ideas about the concepts they are embodying.

Figure 6. Students within the STEP-Bees classroom pretending to be bees (left) as they see the bees maneuvering through the virtual environment (right).

The design of the STEP-Bees environment leverages embodied activity as a tool for learning by allowing multiple students to coordinate their movements within the context of a mixed-reality participatory simulation. Two groups of 2nd grade students (N=16, ages 7-8) participated in seven days of activities, with each group led by one of their classroom teachers. The students each took on the role of a honeybee, physically moving through the space as a bee would, foraging for nectar and communicating flower locations with their peers via a waggle dance, and their movements were tracked using computer vision and translated into an on-screen simulation which was projected in the front of the room. The overall goal of the sequence of activities was to help students explore the patterns and connections within the complex system of a beehive through coordinating their physical movements with feedback. Classroom interactions were videotaped to examine how students coordinate their actions within activities; individual pre-post interviews measured their learning gains.

Students exhibited significant pre–post learning gains for all four learning targets: Communication ($t(15) = -12.199$, $p < .001$), Cycle ($t(15) = -3.159$, $p = .006$), Complex Systems ($t(15) = -5.217$, $p < .001$), and Pollination ($t(15) = -7.904$, $p < .001$). Analysis of classroom video reveals that students' embodiment provided opportunities for coordination with various sources of feedback (peers, simulation, teacher). As individual honeybees, students had to attend to their peers' waggle dances (represented by their body movements) to find flowers with good nectar, and peers, in turn, had to adjust their waggle dances in response to feedback that their communication was unclear. This coordinated cycle of communicating via physical movements and adjusting movement in response to peer feedback encouraged students to reflect on the interconnected nature of a beehive. Students' exploration of this complex system was further supported via a need to coordinate with the simulation, which provided additional feedback on how students should move through the space. Receiving nectar at a flower would draw other students towards that point in space, whereas the presence of a predator would steer students' movements away from that location. Our analyses reveal how the embodiment provided a powerful resource for individual students to think with, as did the ongoing feedback that they received from their peers and the simulation itself. Thus, the combination of individual embodiment, peer feedback, and feedback from the simulation provide a stronger set of resources for learning than any one component alone.

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