This symposium contributes to our understanding of the nexus of personal embodiments and collaborative engagement through designs of and with body technologies. While embodied ways of learning and understanding are powerful, they can also be somewhat ephemeral—critical in the moment of insight, but fleeting. Further, embodiment is highly personal and subjective; communicating experienced physical phenomena is challenging enough in medical settings when the topic is immediate (Heritage & Robinson, 2006), let alone metaphorical and situated in a domain like math or science. Now, however, new technological developments in wearables, motion sensors, health trackers, and a host of other devices hold the tentative promise of making embodiment visible, sharable, archivable, aggregable, and analyzable for both individuals and groups (Lee, 2015). In this symposium we bring together various projects involving "body technology" to promote embodied learning in a *collaborative* context. Body technologies in our work include GPS, movement-trace games and simulations, health monitor devices, and wearable/programmable e-textiles. Some of our projects are based on individual learners with personalized, single-user technologies but who experience their use as a collaborative experience with peers. Others are individual learners creating collaborative or linked products together. Still others are pairs or groups of learners engaged in a collaborative experience with a body-sensing technology for multiple users at once. This session explores the designs, epistemologies, research methods, and outcomes of all these different, but related, models by addressing the following questions: 1) What are the affordances of body technologies designed for individual versus collaborative use, and what challenges exist for researchers in trying to design for personal and social learning when using these tools? 2) What is the relationship between individual insight from embodied experience versus social meaning from shared experience or enactment? What are the roles of body technologies in these phenomena? 3) What kinds of learning in this research are more individual, more collaborative, both, or neither? How do we know? How do we study learning in these ways? What does learning mean in these contexts? 4) What are implications for the design of embodied learning, when we consider how learners can collaborate and construct both personal and social meanings?

Objectives

Together, these contributions aim to provide a single venue for advancing understanding of embodiment with body technologies in collaborative contexts. The papers included in this session consider ways that embodiment facilitates collaboration as well as ways to design intentionally for collaboration with tools that promote embodiment. The papers consider a number of types of body technologies productively utilized for collaborative learning, such as personal medical technology used to manage everyday family practices (Lee et al.); mobile technologies that facilitate nontraditional forms of collaboration (Taylor et al.); and the tool designs that create opportunities for social dependencies and synergistic gestures (Lindgren et al.). Two papers explicitly consider the role of embodiment in students' designs of technologies, including collaborative, motion-sensitive electronic textile designs (Lui et al) and game designs that rely on playtesting (Litts et al.). One paper compares two different technological/representational systems to understand the "social" affordances of different collaborative embodied learning environments (Danish et al.). This symposium will provide opportunities to examine similarities and differences in approaches to body technologies that facilitate collaboration.

Session format

To promote active and productive discussion and future collaborations, the symposium will be conducted as an interactive demonstration. The chair will begin by introducing the theme of the session, sharing considerations of theory and design in embodiment and collaboration. Brief (1-minute) teaser introductions followed by posters and, where possible, body technologies will provide attendees ample opportunities to examine and discuss the varied designs and approaches of the presenters, and to synthesize with attendees' own expertise in a way that traditional talks do not allow. The symposium will close with an open discussion period, in which the discussant, an expert in embodied learning, action and inscription in a variety of educational contexts, will synthesize ideas around the main themes and areas of interest that emerged during the session and provide questions for the final discussion between authors and audience.

Data records from children with Type 1 diabetes: Objects for conversation and family sense-making

Victor R. Lee and Ilana Dubovi

New technologies are making bodily activity more accessible as objects for inspection in designed learning spaces (see Lee, 2015 for examples). The value of using records of bodily activity as objects of inspection presumably taps into embodied understandings that youth already have and can be connected to disciplinary ideas and practices. Yet beyond these deliberate designer-driven uses, there are also cases where archives of bodily experiences produce records for inspection and sense-making that are not directly tied to a priori learning goals but still lead to consequential learning and collaborative sense-making discourse and interaction. One of those, to be discussed in this presentation, is the work a family does to manage the health of a child who has been diagnosed with type 1 diabetes (T1D).

Living with T1D involves monitoring of blood sugar levels, deliberate decision-making and planning for diet and exercise, and regular introduction of artificial insulin into the bloodstream. Because it is a chronic illness, it serves as a disruption in practice and routine that necessitates introduction of quantification practices. It serves as a context for expansive learning (Engestrom & Sannino, 2010) that necessitates the creation of new representational infrastructures by families and caretakers (Hall, Stevens, & Torralba, 2002). The work described in this presentation is an accounting of how data related to the management of T1D are stored and mobilized for everyday sensemaking activities by families and youth.

In this study, data were obtained from 5 families with children under the age of 12 who had type 1 diabetes through meetings and visits ranging from one and three times for each family (Lee, Thurston, & Thurston, 2016). For four of those families, we conducted observations and interviews at the home of those families and photo-documented artifacts that were used in their diabetes management. One finding was the development of custom data logs as one form of representational infrastructure that four out of five families used to track blood sugar levels as measured from glucometers and from continuous glucose monitors (see Figure 1).

Figure 1. A glucometer being used to get a blood sugar reading (left), a continuous glucose monitor (center) and a homemade data logging system (right).

For two families that will be discussed, these logs served as important supports and motivators for discussions about the child's health and what was influencing changes in blood sugar readings. This representational form served as a source for investigating measurement discrepancies and supporting claims. In one family to be discussed, the two parents had both logged that they had administered the same amount of insulin for their child on different days, yet they noticed that the resulting blood sugar levels were quite different. This led them to question how they were dosing and the eventual discovery that they were measuring the meniscus (i.e., fluid curvature in a measurement vial) of insulin in different ways. In another family, the logs served as a guide for a parent to select meal options when the other parent, who typically did the family meal planning, was unavailable. In addition, that family used the data they stored in their handwritten log of digitally obtained data as justification for certain intuitions that they had about the impact of certain foods on the child's blood sugar levels.

In both families, the child was reportedly more adept at early numeracy skills. The parents spent a substantial amount of time teaching their children to recognize numerical readings of their own blood sugar data and to notice trends such as blood sugar "going down" or "going up", through spontaneous quizzing as part of monitoring. Through studies like this one, we gain some insight into what families do to retain and respond to personal data and how disciplinary ideas and practices—such as numeracy, logging, measurement, body systems, and nutrition—are established and drawn upon for coordinated action as a result of the disruption of disease diagnosis.

Collaborative design of wearable technologies: How embodied gestures support computational learning and creativity

Debora Lui, Lindsay Lindberg, Deborah A. Fields, Mia Shaw, Gayithri Jayathirtha, and Yasmin Kafai

While much existing embodiment research focuses on the *use* of wearable technologies for learning, there is less work that highlights the role of embodiment within the *design* of these body-based technologies which incorporate sensors into clothing or other wearable accessories in order to make them interactive. Here we position embodiment as an essential component within a student-centered, collaborative design process of developing wearable technology. The distributed nature of cognition (Hutchins, 1995) will be taken up with the perspective that physical gestures structure thinking and action during meaning making (Goodwin, 2000) as we share instances of youth collaboratively designing and constructing wearable body technologies such as light-up hoodies or music-playing gloves. Blending semiotic resources, including computational design and conversation, with physical embodiments as tools for sensemaking (Kirsch, 2011), we ask about the role of physical body movement and collaborative sensemaking in supporting student understanding of computational concepts, with the development of personalized, computational artifacts.

The study took place during a four-day summer STEM program at a local science museum. Four groups consisting of 3-4 high school students and 1 adult co-designed interactive musical wearable artifacts using an Arduino-based Circuit Playground electronic textiles kit and a piece of clothing (e.g., hoodies, gloves). Drawing upon artifacts, interviews, and video recordings, we developed four case studies of the groups highlighting their design process. Through an inductive analysis, we developed coding themes based on how students used embodiment to understand computational concepts in the design of their interactive wearable artifact.

Across all four groups, we found that students' uses of physical gestures were central to the creation of their musical wearable artifacts and tightly intertwined with their engagement with computational concepts and one another. Introducing materials like gloves and hoodies (objects intended for functional use and movement) privileges physical, embodied participation with computational strategies by both instructors and students. Students' gestures could be categorized in three ways. First, students employed gestures to help *envision the design of their wearable artifact.* During the brainstorming phase, students acted out different series of possible 'trigger' gestures for teammates (e.g., waving hand) and verbally described different possible resulting actions ("now the lights blink"). Here, the gestures allowed students to simulate abstract computational sequences, to ideate upon new creative possibilities of computational action and also communicate their ideas to other peers. Second, students used gestures to *solidify their understanding of a computational concept*. This included, for instance, hand movements first demonstrated by the instructor and later taken up by students while programming a motion sensor to help concretize abstract ideas, such as quantifying space in terms of the three dimensions, determining conditional logic or system inputs and outputs. Finally, gestures were also utilized to help *calibrate parts of their computational design,* particularly programming motion and light sensors, where the degree of movement determined the threshold values for sensor activation. Collaboratively, students performed motions that activated sensors repeatedly (whether flipping a hood off their heads or waving their hands) as part of the process of calibrating their readings and programming these into their artifacts.

Moving beyond the individual, the embodied actions above served as tools for collaborative sensemaking and provided communicative and ideational support in service of creating a wearable technology. An understanding of how embodiment can serve these dual roles is especially timely because of the increased efforts to bring digital fabrication tools into schools (Peppler, Halverson, & Kafai, 2016), where students are not only users but designers of wearable technologies. We illustrate how privileging intentional physical movements in service of computational design can support collaborative work during the brainstorming and computational phases of development, thereby expanding opportunities for physical and cognitive participation, engagement in computing, and expressive agency.

Collective embodied activity and how different concepts map to social exploration

Joshua A. Danish, Noel Enyedy, Megan Humburg, Bria Davis, and Xintian Tu

In our work, we have developed a Learning in Embodied Activity Framework (LEAF; Danish et al., under review). 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 the sociocultural nature of individual learning and the unique characteristics of collective group activity into a combined framework. Within this framework, we view embodiment as supporting learning for both individuals and collective groups, and we believe it is important to explore how these two levels influence each other; individual experiences inform and are informed by collective activity. We are particularly interested in supporting collective embodied activities where participants coordinate their actions to learn about complex phenomena.

We believe collective activities are important because they place the role of social interaction as central to the embodied modeling process. The opportunity to include multiple participants within embodied activities also paves the way to supporting whole-class activities in ways that are often elusive for designs that only support individual students or dyads. For example, our work with the Science through Technology Enhanced Play (STEP) mixed reality environment has explored how students learn about states of matter (Danish, Enyedy, Saleh, Lee, & Andrade, 2015) and honeybees (Danish, Humburg, Tu, Davis, & Georgen, 2018). In the case of the states of matter unit, students took on the role of water particles and embodied their motion relative to each other. The STEP system tracked students' movement and fed it into a projected simulation so that students could see virtual particles moving as they moved. Importantly, their speed and distance relative to each other produced different states of matter: being near and stationary produced ice; slightly closer but moving produced water; moving fast and far apart produced gas. The simulation displayed each state, helping students to engage in inquiry about the relationship between particle motion and state by moving around and with each other (Danish et al., 2015). In the bees unit, students behaved as honeybees searching for nectar around the hive, with bee avatars that flew around a field of flowers in the simulation, mirroring students' movements around the classroom. As the students-as-bees visited flowers, they discovered whether there was good nectar. Through iterative experimentation, students came to appreciate that they could most efficiently collect nectar if they coordinated their activity with other bees and shared the location of good nectar (Danish et al., 2018).

The goal of the present analysis is to contrast these prior implementations with an eye towards unpacking how the different content areas afforded different forms of collective action, placing interaction and social interpretations into distinct but complementary roles within the inquiry process. For example, students in the particle simulation had to continuously attend to each other's behavior and motion in order to achieve a specific result. Their every embodied movement influenced their relative position, potentially changing the state of matter being collectively created and thus making it crucial for them to be continuously aware of their peers. Planning in this context took on a unique tenor as students had to continuously coordinate their ongoing activity. In contrast, the honeybees could spend extended periods of time ignoring their peers. However, the moments in which coordination became necessary were far more salient and crucial. This led to alternative forms of planning, and very different reflective practices as students had to attend to a few salient interactions with peers rather than continuous ones. In this paper, we further unpack how these different content topics provide unique opportunities for connecting the individual and social dimensions of embodied cognition and suggest implications for the design and analysis of future systems.

SensEscapes: Learning and making public history in mobile collocated interactions

Katie Headrick Taylor, Adam Bell, Erin Riesland, Maria Hays, and Deborah Silvis

Mobile devices are antithetical to "promoting collaborative interaction in varied contexts" (CSCL Conference Theme, 2019), or so recent news stories would have us believe (e.g., Bowles, 2018). Those tiny screens inhibit a shared gaze on activity, distance users from the places they inhabit, and *im*mobilize bodies to statues posed with heads down, hands gripping edges of a phone. So designing "collocated interaction" or copresent technology use toward a shared objective, seems like a lost cause.

It is within this design space that we offer a more nuanced, perhaps optimistic, version of mobile collocated interaction for teaching and learning public history in an undergraduate course. While our designed activity, that we call "SensEscapes," encountered the kinds of obstacles to collaboration mentioned above, we also saw *openings* for novel relationships between bodies, local histories, places, and tools. These openings, we argue, are untenable when seated at a desk, in a classroom, and without a mobile device in hand.

Our design of SensEscapes is guided by theories of embodied learning (e.g., Lindgren & Johnson-Goldberg, 2013) and learning on the move (e.g., Taylor & Hall, 2013). SensEscapes invited students to engage their senses (ie., smell, sight, hearing, touch) for learning about the neighborhood surrounding their public university, and the histories that moved institution and community together and apart over time. Small groups of approximately five students used a mobile mapping application, Siftr ™, to find locations within a six-block area, read a short history about each location, then create a geotagged digital artifact at each spot. Siftr allowed for student groups to encounter past histories and document multi-sensory experiences using (analog and digital) mobile tools. After visiting and completing tasks at five locations, students returned to the classroom to share stories and photos mapped to a base layer of the neighborhood.

In our analysis of video records of student participation during SensEscapes, we found that mobile collocated interaction took the form of *static collaboration*. By static collaboration we mean that the typical social cues of "good" collaboration upon which the learning sciences place high value—gestures, shared eye gaze, touching and pointing to the same representation—were absent. However, evidence of effective and high levels of collaboration took other forms. While individuals kept their eyes on their own smartphone screen, they verbalized clarifying questions about the task as a bid for assistance from other members of the group. Upon reaching a location, groups frequently stood in a tight U-shape on the sidewalk, moving only for postural tuning to help a co-participant or get clarification from a neighbor's screen. With the visual field occupied, it was not uncommon for students to note fleeting smells or sounds while working on their phones. Students achieved focused interactions (e.g., Goffman, 1963) largely without looking at one another or seeing the same thing at the same time.

Our design of SensEscapes intended to teach students about their university community through embodiment, so our initial analytic lens was ill-equipped to see inertness as a legitimate state of collaborative learning in place. Using more typical qualities of collaboration from an interaction analysis frame, students' participation in SensEscapes looked divorced from place and one another *because of* the mobile devices. Yet, we knew from students' reflections after the activity that learning and engagement were high. We resituated our analytic lens to the context; by paying close attention to convergent talk and device use, and postural tuning to allow for quick glances to a neighbor's screen, it was evident the mobile device set up micro-mobilities (Luff & Heath, 1998) important for building shared understandings of the place, on the move. Still, our findings also point toward redesigns in both the mobile application and the overall activity that diminish the time spent in the digital world and increase time spent with the landscape.

Calibrating personal gestures within a collaborative embodied STEM simulation

Robb Lindgren, James Planey, and Jason Morphew

Recent research has shown significant learning and engagement gains for single-user embodied simulations where a participant mobilizes their body to make predictions and structure their reasoning around a science domain such as planetary astronomy (e.g., Lindgren, Tscholl, Wang, & Johnson, 2016). In particular, our lab has shown benefits of a gesture recognition system that adapts to a learner's personal gestural representation of simulation functions (Junokas, Lindgren, Kang, & Morphew, 2018). At the same time, embodied learning simulations are often best situated within social learning environments such as classrooms and museums where there is an opportunity to work collectively and construct shared representations (Enyedy, Danish, Delacruz, & Kumar, 2012). Our current efforts are focused on embedding a scheme for personalized gestures within collaborative simulation tasks such that a learner keeps their ideas about STEM grounded in their own bodily but must still calibrate their actions with the simultaneous embodied expressions of other learners.

The current multiplayer version of our ELASTIC^{3}S simulation tasks require students to collaboratively problem-solve to explore complex dynamic systems such as the greenhouse effect, predator-prey interactions, and chemical equilibrium. Within the simulations, each student is able to control the rate of change of a variable which has an effect on the equilibrium of a system. In order to compare the effect of two simultaneously changing rates, students work collaboratively to reach and maintain an equilibrium point. We aimed to facilitate collaboration by providing each student with a portion of the information through the use of a three-screen projection system (Figure 2 middle and right). Information about the students' individual actions are projected onto the left and right screen, whereas information about the system threshold and equilibrium is displayed on the center screen (Figure 2 left). For example, within the greenhouse effect simulation pairs of students were asked to reach and maintain different levels of carbon dioxide in the atmosphere and to explore the effects on the global temperatures, sea level, and ice cap size. One of the individuals in the dyad controls the rate at which carbon dioxide entered into the system through increases or decreases in the number of factories, while the other student controls the rate at which carbon dioxide leaves the system though increases or decreases in the amount of photosynthetic biomass.

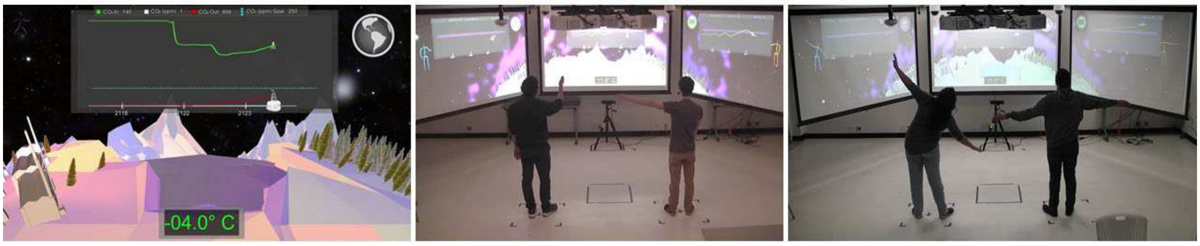

Figure 2. Left: Center sim screen showing change CO_2. Middle: Two participants controlling rate with an invented gesture. Right: Two participants controlling rate by showing a line slope with their arms.

Preliminary pilot sessions with the climate change simulation have demonstrated the potential to establish a collaborative environment that fosters communication while critically engaging with the science content. When presented with the tasks within the simulation, pilot participants have primarily taken one of two approaches, either initiating a collaborative dialog immediately after the task is presented in an attempt to plan and coordinate their inputs based on their understanding of the system, or immediately beginning to modify their inputs to the system separately with individual observations and struggles ultimately initiating a productive collaborative dialog. Both resulted in participants reaching their goal and reflecting upon their process.

Personalized embodied interactions can be a powerful approach to cultivating new, grounded understandings of complex domains, but new technologies should aspire to support these interactions in a collaborative context where dependencies are apparent and gestures can be synergistic.

Computing reality through collaborative, embodied debugging: How learners design and debug mixed reality games

Breanne K. Litts and Chase K. Mortensen

Embodied cognition (Wilson, 2002) suggests that humans often work out their thinking by interaction with the world through bodily or physical interactions. Mixed reality technologies (Milgrim & Kishino, 1994), which overlay or integrate digital objects or interactions with the real world, afford unique contexts to examine how learners engage in embodied cognition. Scholars (e.g., Lindgren & Johnson-Glenberg, 2013) not only recognize the potentially transformative impact of how these technologies afford *embodied learning*, but also encourage research and design considerations for such activities. At present, though, most of these efforts are thinking about how to design *for* learners, but we also see the value of thinking about how to equip learners to design *with* mixed reality technologies. Thus, in this study, we explore how learners engage in collaborative embodied learning when designing their own mixed reality location-based games.

In partnership with a local makerspace, we conducted two afterschool workshops with 19 middle school aged participants (3 girls, 16 boys, ages 10-13) in a rural city in the Western United States. Over the course of 12 hours (six 2-hour sessions), learners designed mobile, location-based games with mixed reality technology about local plants and animals. Learners engaged in a design process of research, storyboarding, digital construction, playtesting and debugging, including several iterations of outdoor collaborative debugging sessions during which learners playtested each other's games and exchanged feedback. We collected a range of data including in-process video and audio recordings, design artifacts, photographs, field notes from at least three researchers, and final reflective interviews with learners. In this paper, we focus our analyses on the outdoor collaborative debugging sessions across all participants. We constructed cases (Stake, 1995) from each session of outdoor collaborative debugging and compared across cases (Miles, Huberman, & Saldaña, 2013) to illustrate the ways in which youth engaged in and embodied designing *with* location-based mixed reality technologies.

Findings provide insights for how learners make sense of the mapping of game content and mechanics onto physical location and place through both experienced and observed embodiment. When playtesting others' games, learners experienced embodied design by moving around the physical world to collect digital items. For example, Peter, a 12-year-old Caucasian boy, playtested Doug's, a 12-year-old Caucasian boy, game, entitled "Wolf Quest", which challenges a player to "catch squirrels, like the lowest-ranking animal... you can use them to capture higher level class levels of animals" (Interview, 04/05/2017). While playing, Peter exclaimed "I'm drowning in squirrels!" and explained to Doug that he should change the game's algorithm to reduce the number of squirrels and make them spawn further from the player, because it was "drowning" the player making it too easy to level up. When others playtested their games, designers were able to observe how the player embodies their design. For instance, after a collaborative outdoor debugging session, Gracie, a 10-year-old Hispanic girl, reflected on observing others who sprinted around to try to play her game: "It's not working very way, it makes [him] go way waaay over there!... I made it too far" (Audio Recording, 03/16/2017). After debugging the issue, she explained how she leverageed this mechanic to increase difficulty in her game over time, "For the like three levels it's gonna be pretty easy, but then the items are gonna be harder to catch: it's gonna be further away from you, you're gonna have less time" (Interview, 03/30/17). Through observation and feedback, Gracie built an understanding of how players embody her design and how to leverage the development platform's computational algorithm to align with her design goals.

These cases illustrate how learners across the workshop embodied each other's location-based mixed reality games in collaborative outdoor debugging sessions, and how debriefing with feedback supported designers' computational and design understandings. This not only highlights how the collaborative moments shifted learners' designs, but also demonstrates the value of equipping learners as designers of mixed reality technologies, especially in support of embodied learning.

References

Alibali, M. W., & Nathan, M. J. (2012). Embodiment in mathematics teaching and learning: Evidence from learners' and teachers' gestures. *Journal of the learning sciences*, *21*(2), 247-286.

Bowles, N. (2018, October 26). A dark consensus about screens and kids begins to emerge in Silicon Valley. *The New York Times.*Retrieved from https://www.nytimes.com/2018/10/26/style/phones-children-silicon-valley.html

Chickering, A. W., & Gamson, Z. F. (1987). Seven principles for good practice in undergraduate education. *AAHE bulletin*, *3*, 7.

Danish, J. A., Enyedy, N., Saleh, A., Lee, C., & Andrade, A. (2015). *Science Through Technology Enhanced Play: Designing to Support Reflection Through Play and Embodiment.* Paper presented at the Exploring the Material Conditions of Learning: The Computer Supported Collaborative Learning (CSCL) Conference, Gothenburg, Sweden.

Danish, J. A., Humburg, M., Tu, X., Davis, B., & Georgen, C. (2018). *Modeling bees by acting as bees in a mixed reality simulation*. Paper presented at the Intl Conference of the Learning Sciences, London, England.

Dewey, J. (1938; 2007 ed). *Experience and education*. Simon and Schuster.

Engeström, Y. (1987). *Learning by Expanding: An Activity - Theoretical Approach to Developmental Research*. Helsinki: Orienta-Konsultit Oy.

Engeström, Y., & Sannino, A. (2010). Studies of expansive learning: Foundations, findings and future challenges. *Educational Research Review, 5*(1), 1-24. doi:https://doi.org/10.1016/j.edurev.2009.12.002

Enyedy, N., Danish, J. A., Delacruz, G., & Kumar, M. (2012). Learning physics through play in an augmented reality environment. *International Journal of Computer-Supported Collaborative Learning, 7*, 347-378.

Goffman, E. (1963). *Behavior in Public Spaces.* New York: The Free Press.

Goodwin, C. (2000). Action and embodiment within situated human interaction. *Journal of pragmatics*, *32*(10), 1489-1522.

Hall, R., & Nemirovsky, R. (2012). Introduction to the special issue: Modalities of body engagement in mathematical activity and learning. *Journal of the Learning Sciences*, *21*(2), 207-215.

Hall, R., Stevens, R., & Torralba, T. (2002). Disrupting representational infrastructure in conversations across disciplines. *Mind, Culture, and Activity, 9*(3), 179-210.

Heritage, J., & Robinson, J. D. (2006). The structure of patients' presenting concerns: physicians' opening questions. *Health communication*, *19*(2), 89-102.

Hutchins, E. (1995). Cognition in the wild. Cambridge, MA, US: The MIT Press.

Junokas, M. J., Lindgren, R., Kang, J., & Morphew, J. W. (2018). Enhancing multimodal learning through personalized gesture recognition. *Journal of Computer Assisted Learning*.

Kirsh, D. (2011). How marking in dance constitutes thinking with the body.

Lakoff, G., & Johnson, M. (2008). *Metaphors we live by*. University of Chicago Press.

Lakoff, G., & Núñez, R. E. (2000). *Where mathematics comes from: How the embodied mind brings mathematics into being*. Basic Books.

Lee, V. R. (Ed.) (2015). *Learning technologies and the body: Integration and implementation in formal and informal learning environments*. New York, NY: Routledge.

Lee, V., Thurston, T., & Thurston, C. (2017). A Comparison of Discovered Regularities in Blood Glucose Readings across Two Data Collection Approaches Used with a Type 1 Diabetic Youth. *Methods of Information in Medicine, 56*(open), e84-e92. doi:10.3414/ME16-02-0047

Lindgren, R., & Johnson-Glenberg, M. (2013). Emboldened by embodiment: Six precepts for research on embodied learning and mixed reality. *Educational Researcher*, *42*(8), 445-452.

Lindgren, R., Tscholl, M., & Wang, S., & Johnson, E. (2016). Enhancing learning and engagement through embodied interaction within a mixed reality simulation. *Computers & Education,* 95, 174–187.

Luff, P., & Heath C. (1998). Mobility in Collaboration. In S. Poltrock & J. Grudin (Eds), *Proceedings of the 1998 Conference on Computer Supported Cooperative Work* (pp. 305–314). ACM: Seattle.

Miles, M. B., Huberman, A. M., & Saldaña, J. (2013). *Qualitative data analysis: A methods sourcebook*. SAGE Publications, Incorporated.

Montessori, M. (1917). *The Advanced Montessori Method.*.(Vol. 1). Frederick A. Stokes Company.

Peppler, K., Halverson, E., & Kafai, Y. B. (Eds.). (2016). *Makeology: Makerspaces as learning environments* (Vol. 1). Routledge.

Stake, R. E. (1995). The art of case study research. Thousand Oaks, CA: SAGE.

Stevens, R. (2012). The missing bodies of mathematical thinking and learning have been found. *Journal of the Learning Sciences*, *21*(2), 337-346.

Taylor, K.H. & Hall, R. (2013). Counter-mapping the neighborhood on bicycles*:* Mobilizing youth to reimagine the city. *Technology, Knowledge, & Learning 18*(1-2), 65-93.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic bulletin & review*, *9*(4), 625-636.