How Embodiment Helps Students Explain Their Ideas within an MR Environment and Content Interviews

Xintian Tu, Megan Humburg, Nitasha Mathayas, Mengxi Zhou, Joshua Danish
Indiana University
tuxi@iu.edu, mahumbur@iu.edu, nmathaya@iu.edu, mz13@iu.edu, jdanish@indiana.edu

Abstract: In this paper, we explored young children's embodied representation of states of matter after engaging in a mixed-reality environment where students explored states of matter by acting as particles (Danish et al., 2020). To examine how embodiment may play a role in helping students' explanations, we analyzed students' performance in assessments to explore how embodiment helps young children represent their ideas and found they were able to use a combination of talk and embodiment to provide more detailed explanations. Then we further explored how students formed these conceptual understandings in the MR environment and applied interaction analysis to analyze how embodiment played a role in the process. The results showed that gestures students used in the post-assessment emerged through their collective embodiment in the classroom.

Introduction

Embodiment has been viewed as a crucial part of cognition and learning (Abrahamson & Lindgren, 2014), prompting scholars to explore how to use embodiment to support students' learning (Danish et al., 2020). Previous studies demonstrate how engaging with conceptual ideas through movement improves students' target content understanding. Embodied motion and gesture have also been shown to serve an important role in students' communication and knowledge construction (Broaders, et la., 2007). As the role of embodiment in learning and knowing continues to be studied, there remains little scholarship exploring the role of embodiment in assessment in addition to instruction.

Many studies use multiple choice questions or content-focused measures of learning after embodied activities that reflect traditional beliefs about learning and do not keep pace with our current understanding of the repertoires of embodied expression children utilize during learning. Novices, in particular, might have ideas about target science content that they cannot show in the traditional assessment context. Therefore, there is a need to incorporate embodiment into assessments that measure students' learning after engaging in embodied learning activities. Previous research also suggests that embodiment offers an alternative way for elementary students to explain their understanding of concepts that they're less familiar with (Salehet al., 2015). This suggests that embodiment can offer a broader picture of what concepts students understand and how deeply they understand them. However, questions remain about how to reliably draw out students' embodied understandings in an assessment context. Therefore, in this paper, we focus on students learning states of matter within the Science through Technology Enhanced Play (STEP) environment as a case study for how the body can play a role in supporting sensemaking across learning and assessment. In prior studies, we found that students were able to understand complex science concepts such as the particulate nature of matter while engaging in the STEP environment (Danish et al., 2020). In this study, we designed two forms of instruments to assess young children's understanding of states of matter: a multiple-choice test and an individual interview. In the interview, we encouraged students to use their bodies to show how particles behave in different states of matter. We also provided manipulatives for student's opportunities to "act out" ideas. We then explored the following two questions: 1) How did embodied prompts help students to represent their ideas in an assessment context? 2) How did students form a conceptual understanding of particles' behavior and connection to macro-level state within the STEP environment?

Design

This study was built in the Science through Technology Enhanced Play (STEP) environment (Danish et al., 2020), a MR environment that uses Kinect cameras to track students' movement and map them to digital avatars. As students move in the space, the simulation shows their movement as particles interacting and changing into solid, liquid, and gaseous states on a shared screen in front of the classroom. The learning targets were (a) understanding and demonstrating particle behaviors in three states of matter and (b) depicting the connections between microscopic and macroscopic representations of matter. While students moved to represent particles moving, STEP depicted particle speed, distance, attraction, and particle trajectory according to real-world physics, enabling students to discover these underlying rules through their collective movement.

Method

Participants and Data source

Twenty-two students from a first and second-grade mixed-age classroom in a mid-western elementary school in the U.S. participated in this study. Students participated in a 7-session STEP activity; each session included 30 minutes of activity in the STEP environment and 30 minutes of supplemental activities without the STEP software in another classroom. Students participated in multiple-choice pre-tests and then one-on-one interviews the week before the project started, and the multiple-choice post-test was followed by individual post-interviews after the class engaged with all STEP activities. The interview included 26 questions, and during the interview, students were encouraged to use body movements to demonstrate particle behavior. All classroom activities and interviews were video recorded for analysis.

Data analysis

We applied a paired t-test to examine students' overall understanding of particle behavior We coded the pre- and post-interviews with a coding scheme used in previous iterations of STEP (Danish et al., 2020). Three research assistants coded the interviews and achieve 81% agreement on coding. We also looked into the interview data to find how embodiment helped them to demonstrate their understanding of the particle's behavior. All authors re-watched students' interviews videos and focused on students' verbal and embodied responses in the videos to explore how they articulated their ideas in the interviews. Based on our review of the interviews, we found that students used gestures in the post-assessment to supplement their demonstration of understanding, especially for challenging ideas such as micro-macro connection. Then we went back to the classroom videos and applied interaction analysis (IA, Jordan & Henderson, 1995) to see how concepts explored in students' interviews were developed through their in-classroom activities.

Findings

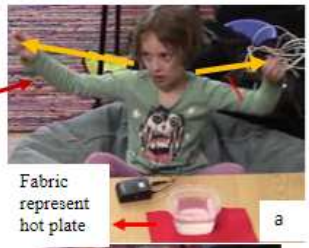
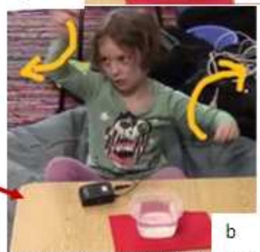
We ran a paired t-test on students' performance on the multiple-choice test and found there was a significant improvement from the pre-test score (M = 5.5) to post score (M = 11.2), t = -8.72, p <.01, which showed that students' overall understanding of the target content improved after they engaged within the STEP environment.

To answer our question: "How did embodied prompts help students to represent their ideas in an assessment context?" We focused on two sets of interview questions related to the challenging multiple-choice questions: 1) questions that encouraged students to use their body to act like particles and 2) questions that asked them about the micro-macro connection. We found that more students were able to answer the interview questions in post-interviews accurately when encouraged to use their body to represent particles' movement. For example, 57% of students were able to describe at least one characteristics of particles in Question 4 "Let us pretend you are particles in that water, can you act out with your body how particles are moving in the water?". Then for questions 12-15, which covered micro-macro connections, we found thirteen of the twenty-one students (61%) were able to elaborate on the mechanisms of particles' behavior. This was quite a difference compared to the 2 students who were able to answer the multiple-choice question covering similar content correctly. This suggests that students benefited from using their bodies to explain their understanding.

We present an example of a student gesturing to answer the question about particles moving in water. These questions asked how particles behave when there is a macro-level change (Table 1). Lily explained that with a macro-level change, the liquid would turn to gas (line 2). Then in the next question, she described changes in the distance between particles and the speed of particles with gestures (Line 4). She mentioned that "they will go farther apart, and go faster and have more energy," while pulling her hands far apart horizontally to show the increasing distance between particles in liquid as they get more energy. Then she used another gesture to demonstrate the speed of particles by making her hands into fists and moving them quickly in the air (Table 1, Figure b). Then she used the same gesture to describe the distance between particles as far apart. In her responses, her gestures were consistent with demonstrating certain characteristics of the particles' behavior (e.g. distance). In addition, she was also able to describe the changes in particles' speed, which is the concept she failed to answer in the multiple-choice test. On looking across the interviews, we found that this pattern of gestures and embodiment supporting more elaborate descriptions was consistent across the interviews analyzed. Therefore, the interview helped students to demonstrate ideas by allowing students to use gestures to represent ideas.

Table 1

Lily gesturing to demonstrate particle behaviors to answer question 12 to 14.

Turn		Verbal	Embodiment
1	Author 2	if the plate is really hot, what will happen to liquid water? [Q12]	 Fabric represent hot plate (a)
2	Lily	It turn to gas. [MMC1, macro change]	
3	Author 2	So, if the plate is really hot, what will happen to the particles in the water [Q13]	Student used gesture to show the distance between particles (figure a).
4	Lily	They will go farther apart, and go faster and have more energy [MMC4, Distance and Speed]	And then she used gesture to show particles will go "faster" (figure b)  (b)
5	Author 2	More energy. Okay, so why do you think the particles will do that? [Q14]	
6	Lily	Um.. Because gas has more energy and it goes apart.	When students talk about the particles go part, she used the gesture in previous answer (a) again to show the distance between particles.

RQ 2 How does students' understanding of particles behavior form in classroom activity?

To answer our second research question, we analyzed how students' embodiment helped them to form their conceptual understanding in classroom activity. We focused on how students' understanding of 1) characteristics of particle behavior (e.g. distance), and 2) micro-macro connection, were constructed during class activity. We identified two classroom activities on 1) students exploring particles behavior in a tank, and 2) students explore particles with changes of temperature when the concepts we outlined above were discussed.

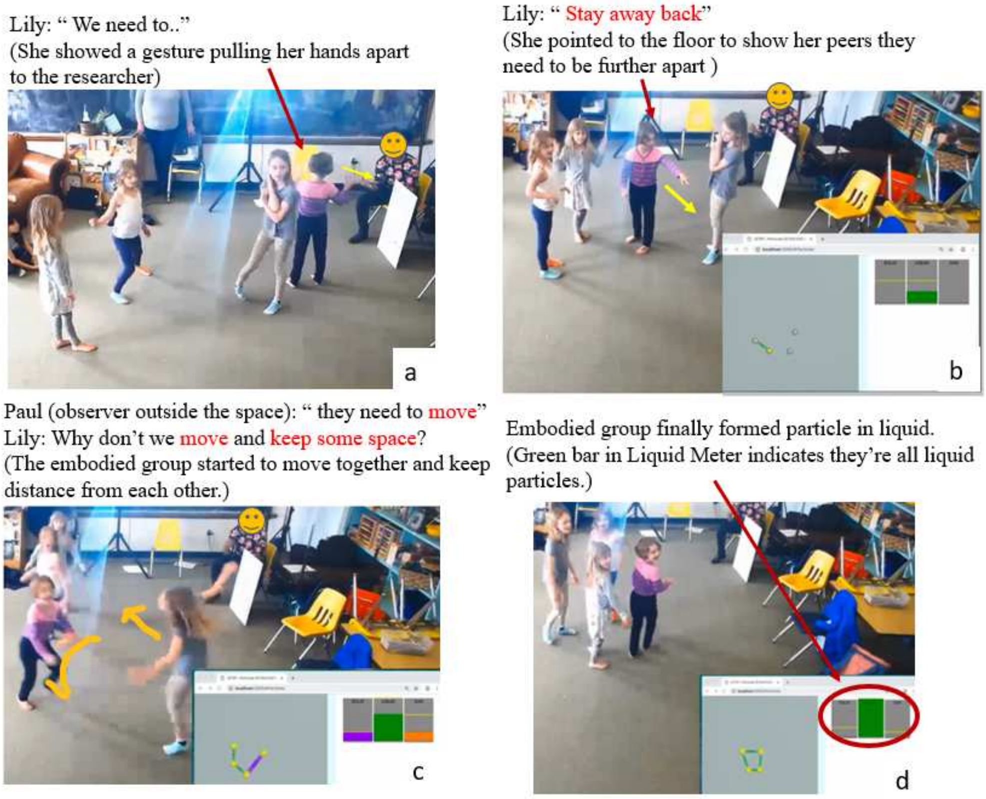
Exploring characteristics of particles in a tank

Our Day 3 activity focused on helping students to understand particle speed and distance in three states of matter. The physical positions of students were projected as particles on the shared screen and they needed to move collectively to form different states of matter. We present a segment of Lily's group collectively exploring how liquid particles move in Figure 1.

Lily's group went into the space with a goal to form liquid. They started moving freely in the space, and tried different motions (e.g., running, standing still) that would trigger the state meter in the simulation to indicate that they had achieved liquid state. Even though they were recognized as particles, there was no certain state shown in the state meter. So, the researcher in the space asked them what they needed to do to make liquid. Lily looked at the screen and used a gesture that pulling her hands far apart, indicating her group should be farther apart (Figure 1a). With encouragement from the researcher, Lily went back to the tracking area, pointed to the floor, and told her peers to stay away (Figure 1b). Here, Lily suggested the team to work collectively to adjust their relative *distance* between particles. Even though they moved away from each other, they were not recognized as liquid particles in STEP simulation. At this moment, Paul, an observer pointed out that the embodied group was not moving. Then the entire group started to move around without maintaining their distance from one another leading to no particular state of matter depicted by the state meter. Then Lily suggested, "why don't we move around and still keep some distance" (Figure 1c). At this moment, Lily was suggesting her team collectively adjust their *distance and speed*. In response, the embodied group walked in one direction to keep relatively the same speed and amount of space, and the team was recognized as liquid particles by the state meter (Figure 1d). In summary, this episode showed that students' understanding of liquid particles was formed through their collective embodiment. In post-assessment, when students were asked to demonstrate liquid particles, we also see a similarity between the gesture that Lily used here to represent particles' distance in the classroom and interview.

Figure 1

Lily's group exploring how liquid particles move.



Summary and Significance

In this study, we explored the role of embodiment in an assessment context contrasted with a more traditional multiple-choice assessment, and how students formed the conceptual understanding in classroom activities. We found that the individual interviews offered students opportunities to articulate their ideas with more detail through talk, gesture, and motion. Students frequently used gestures in the post-interview to demonstrate their understanding of particles' behavior. Then we analyzed classroom data to understand how young children made sense of the content when they embodied particles in the MR environment. By showing links between Lily's interview answer and her actions during classroom activity, we show how to construct embodied assessment questions that map to classroom learning. This suggests that, especially when students have learned concepts in an embodied learning context, assessments that capitalize on these embodied resources may provide greater insights into their emergent understanding of the concepts than traditional measures.

References

Abrahamson, D., & Lindgren, R. (2014). Embodiment and embodied design. *The Cambridge handbook of the learning sciences*, *2*, 358-376.

Broaders, S. C., Cook, S. W., Mitchell, Z., & Goldin-Meadow, S. (2007). Making children gesture brings out implicit knowledge and leads to learning. *Journal of Experimental Psychology: General*, *136*(4), 539.Goldin-Meadow, S. (2004). Gesture's role in the learning process. *Theory into practice*, *43*(4), 314-321.

Danish, J. A., Enyedy, N., Saleh, A., & Humburg, M. (2020). Learning in embodied activity framework: A sociocultural framework for embodied cognition. *International Journal of Computer-Supported Collaborative Learning*, *15*(1), 49-87.

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences, 4*(1), 39-103.

Lindgren, R. (2014). Getting into the cue: Embracing technology-facilitated body movements as a starting point for learning. In *Learning Technologies and the Body* (pp. 51-66). Routledge.

Saleh, A., Danish, J. A., Enyedy, N., & Lee, C. (2015). Assessing young Children's cognition through multi-modal interviews. *Proceedings of the 11th International Conference of Computer Supported Collaborative Learning (CSCL).*