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The Role of Body in Goal Negotiation and Adoption During a Collective Modeling Activity

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Abstract: This paper aims to explore how goal negotiation in collective embodied modeling activities can support sense-making and learning. We develop an Embodied Divergent and Convergent Learning Mechanism coding scheme and apply it to identify critical moments in students' goal negotiation and adoption. Interaction Analysis is utilized to understand the body's role at those moments. We argue that the body is integral to students' learning and that body both alongside and independent of speech offers unique insights into students' goal negotiation and thus sense-making. We conclude with suggestions for classroom teachers and designers.

Purposes

This study explores student's collective embodied modeling of particle behaviors in three states of matter in the Science through Technology Enhanced Play (STEP; Danish et al., 2020) mixed-reality (MR) environment. The present analysis focuses on two activities, one where students were given an open-ended goal of simply exploring the MR simulation (exploratory), and one which offered students a more specific goal of trying to create a predetermined state of matter in their model (structured). Informed by the Learning in Embodied Activity Framework (LEAF; Danish et al., 2020), this study recognizes that individuals who are working together to produce a collective embodied model are constantly aware of both their individual goals and experiences as well as the shared goals and experiences of the collective and that continually attending to these interrelated perspectives influences their learning. We developed a new coding scheme to help understand how students' experience of embodied modeling is different when engaging in either exploratory or structured activities. In applying this coding scheme, our goal is to understand not only how students' experiences differ, but how this impacts their learning opportunities. To accomplish this, we applied the coding scheme to two classroom activities to answer research questions:

1. How does a facilitator impact students' goal negotiation and adoption in an exploratory activity and in a structured activity?
2. What role does the body play in the process of students' goal negotiation and adoption in a collective embodied activity? How does this make the opportunity for learning visible?

Theoretical Framework

This study is rooted in Cultural Historical Activity Theory (CHAT; Engeström, 1999) and guided by the Learning in Embodied Activity Framework (LEAF) which extends CHAT into embodied learning contexts (Danish et al., 2020). CHAT is built on Vygotsky's (1978) idea of mediation, which is depicted as the triad of subjects, mediating artifacts/tools, and objects (Witte & Hass, 2005). The subjects are those who engage in mediated actions to achieve an object or goal. Mediated action refers to the process through which mediators such as tools or ideas can transform one's engagement with their goals, other people, or even other mediators. In the present study, students (subjects) engage in embodied simulations mediated through MR technology (a tool) to learn particle behaviors through modeling states of matter (the object). The object can be specific or flexible; in this study, one group was given the flexibility to explore the simulation while the other was asked to achieve a predefined collective object (a particular state of matter). To account for social interaction in mediated activity, Engeström (1990) expanded the

mediational triangle to include community, division of labor, and rules. We define the community as including the facilitators and peers present. The division of labor accounts for the different roles students take on (some students observe and provide feedback to peers who model as particles). Rules refer to the explicit expectations of the classroom that the facilitators might enforce, and the implicit guidelines that participants follow.

As students recognize the object of the collective activity, they develop individual goals and perform individual actions which may contribute to or be contrary to the achievement of the collective object (Wertsch, 1981). LEAF acknowledges that individuals move continually between individual goals/actions and the shared object of collective activity by elucidating the role of *embodiment* in learning through identifying the impacts of different components of an activity at individual and collective levels and interconnections (Danish et al., 2020). In our present analysis, we explore the significance of the body in how students pursue different goals collectively in embodied activity, and how negotiating those goals supports learning.

Methods

Embodied Divergent and Convergent Learning Mechanisms Coding Scheme

The Collaborative Learning Mechanism Framework (CLM, Fleck et al., 2009) was developed to examine the students' collaborative learning in pursuit of a predefined collective goal, illustrating actions as complementary to verbal discussion. Tissenbaum et al. (2017) proposed the Divergent Collaborative Learning Mechanism Framework (DCLM) to expand the CLM framework. It sought to identify patterns in participants' collaboration and learning in informal and open-ended exploratory environments. They revealed that participants in an exploratory informal learning environment experienced productive collaborations and gained insights that would not be possible in a more formal structured environment where they could not on occasion diverge in their goals (Tissenbaum et al., 2017). Therefore, DCLM is an appropriate starting point to capture students' interactions in activities with exploratory and/or predefined goals. As we analyzed video data through the lens of the DCLM, we adapted the scheme to reflect the unique characteristics of our classroom-based embodied learning context relative to the museum context for which the DCLM was developed. We aimed to highlight the role of the body by separating codes into speech and embodied dimensions to allow us to explore how each, or the two in interaction support students' coordination (Table 1). This process was emergent and conducted amongst all authors while iteratively analyzing the video data.

Applying the Coding Scheme to STEP: Particles

Participants and Settings. The present modeling activities occurred using the STEP system, an MR environment for students to explore complex science phenomena (Danish et al., 2015; 2020). The particles curriculum involved 22 first and second-grade students from the Midwest engaging in seven thirty-minute class sessions to explore particles' behavior in three states of matter (Danish et al., 2020).

Data. Our prior analysis demonstrated that students learned about the states of matter content using a multiple-choice test focused on particle behaviors in different states (Tu et al., 2021). The present analysis builds on this work to contrast students' activities on day three and day six of the implementation. These days were chosen to highlight the differences that arose between exploratory and structured tasks. On both days, students moved around the classroom embodying particles, and saw themselves in the projected STEP environment as particle avatars, which were connected via lines with different colors, thicknesses, and length to represent the strength of the bonds in the different states. However, on day three (Figure 1), students were encouraged to freely explore the simulation with little guidance regarding which state of matter they should be demonstrating. During day six (Figure 2), students were provided a background (i.e., ice world, pond, and desert) within the simulation and tasked with demonstrating how particles would behave in that environment. We refer to the day three activity as the "exploratory" activity and the day six activity as the "structured" activity.

Data Analysis. We analyzed two five-minute episodes of video data from both classrooms. Each video was segmented into 10-second clips. Two authors jointly coded six 10-second clips and collaboratively revised the codebook for clarity. The two coders coded the rest of the video clips and achieved consensus regarding codes with disagreement. The codebook was iteratively revised during collaborative sessions among authors. Authors then identified moments in which codes indicated that students' orientations towards their goals shifted. Interaction Analysis (Jordan & Henderson, 1995) was used to analyze those moments.

Results

RQ1: The Facilitator's impact

We report a frequency count of Collective Embodied Modeling (CEM) codes in Table 2. In line with previous studies, the concurrence of codes "facilitation" and "goal construction" demonstrates that the facilitator helps students converge on a goal by offering scaffolds that encourage coordination and enforce the activity goals (DeLiema et al., 2019). Additionally, we noticed differences in the facilitators' verbal scaffolds' focus in two activities as summarized in Table 3 and illustrated in examples below:

Exploratory Activity. Facilitator's verbal scaffolds more frequently addressed students' coordination. For example, the following scaffold, "*What happens when you move together? Try to notice something."* encouraged students' coordination and facilitated students shift from an independent exploration to collective exploration, as evidenced by the tight clump in Figure 1. The coordination help students become aware of their peers' actions, which is essential to interpreting models in a collective embodied modeling activity.

Structured Activity. Facilitator's verbal scaffolds focused more on reorienting students' attention toward the intended goal. "You can't just decide what you want to be, you have to look at the background and think about what a particle might be like in a place that's got really cold and there's snow." This facilitation happened when suggesting a different goal (modeling gas) from the simulation environment (an ice world) was accepted by other peers through moving further apart to embody the far distance in gas particles. This deviation from the predefined goal (solid) was corrected by facilitation as evidenced by students' response, "ah, ok" and by holding hands and standing in a circle to represent the closer distance and strong attraction in solid particles (Figure 2).

RQ2: The Body's role

Moments of goal negotiation and adoption were identified through codes, "goal construction", a marker of students' goal shifting. However, we noticed goals were usually explicitly called out in a structured activity, whereas goals were implicitly embedded in an exploratory activity. Therefore, we collaboratively watched moments coded as "accepting a suggestion," which can be a marker of goal adoption in the exploratory activity and identified moments when accepting a suggestion leads to goal shifting. A further investigation of body's role at identified moments revealed that body can be utilized either alongside or independent of speech:

Exploratory activity. We provide an instance showing the body's role in making and accepting suggestions (Figure 3). Oliver suggested peers move further apart by gesturing towards a location and physically pushing peers apart which is accepted as evidenced by them stepping backwards as guided. This episode illustrates a pattern which became visible: students' early participation in the exploratory activity was defined by a lack of coordination and a general disregard for their peer's actions (moving at different speeds, bumping into each other, etc.). Moments in which students offered and accepted suggestions were used to signify a willingness to adopt others' ideas and the beginnings of a convergence of students' goals. Students' awareness of others' actions is crucial to the comprehension of collective models. This episode also represents a moment where the coordination provoked the class to observe that the embodying students were being projected as particles in the simulation (which was not previously specified).

Structured activity. Moments from the structured activity are quite different in that we see several students acting in ways that appear to contradict the shared goal or suggesting alternatives through their embodiment. Once students acknowledge the predetermined goal, we see students' goal construction happens only when the simulation environment changes to a new background, leading them to re-establish what state of matter they should work towards collectively. However, students have diverse embodied approaches to realizing the goal and demonstrating their understanding of how the states work. For example, one moment involves four students reacting to a change in the simulation from a pond to a desert (indicating a change in the target state from liquid to gas) (Figure 4). Ivy and Barry instinctively began running to represent the gas particles' relatively faster speed to that of liquid while Hazel prompted the group to spread out to represent the relative farther distance between particles to that of liquid. This suggestion is communicated verbally ("let's spread out") and with the body via a "separating" gesture with arms. Ivy and Grace accepted this suggestion as evidenced by stepping back in the direction indicated by Hazel. Barry hesitated to watch the simulation, which afforded them an opportunity to see how the simulated particles behaved. This episode portrays how students instinctively orient towards different characteristics of gas particle behavior (i.e., fast speed, far distance, and weak attraction) while still attending to the collective goal (modeling gas). This moment illustrates how students are willing to adopt others' approaches and forgo theirs to achieve the collective goal.

Implications

These findings provide insight into how students negotiate and adopt goals in two collective embodied modeling activities. Our findings demonstrate that students often express intention and ideas through embodiment, which is distinct from those communicated verbally. We recommend teachers and designers closely attend to students' embodiment in such activities to recognize the ways in which students navigate coordination with peers to pursue the activity goals and the emergence of individual agenda.

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Table 1: Embodied Divergent and Convergent Learning Mechanisms Coding Scheme

Codes	Definition	Speech Indicators	Examples in Students' Speech	Embodied Indicators	Examples in Students' Embodiment
Neglecting peers	Evidence of children disregarding/neglecting each other and the lack of awareness. It can take the form of prioritizing one's goal/actions over another or simply working towards their individual goal.	Moments when children stop another's actions by saying it out loud or arguing.	-"No, don't do that, you're messing me up. I'm trying to do this. Do not mess me up."	Moments when children move around on their own or protect themselves from being affected by others through actions.	- accidentally bump into each other without a shared attention.
Rejecting	Evidence of children rejecting others' suggestions.	Moments when children reject a suggestion / goal by words.	-"No! I don't want to."	Gestures to supplement rejective talk	- hand waving - refuse to hold hands
Making a suggestions	Evidence of making a suggestion and giving opinions to other members. We view suggestions at the level of an explicit action/behavior as a distinction from suggesting a goal.	Moments when children verbally make suggestions, introduce knowledge, and offer solutions.	- "Closer." -"You have to move."	Moments when children make a suggestion through gestures and movement. Certain gestures/movements convey its intended purpose as a suggestion. Otherwise, we pair speech with embodiment to know it is a suggestion.	-some aggressive suggestions can be making a suggestion, but they are context sensitive, such as physically moving someone, pushing someone, holding them back. -iconic gestures (i.e., pointing)

Accepting a suggestions	Accepting the information, opinions, solutions offered by other peers.	Verbally accept explicit suggestions from their partner.	- “Move fast!” “Yes!”	Acting on behalf of others guidance/suggestion	Moments when children act as recommended.
Emulating	Replicating someone else’s movement without any explicit invitation (suggestion) to do so.	Verbally indicating emulation.	In this activity, emulating takes the form of embodiment.	Following and copying a leader’s movement and/or actions.	Moments when a child stands behind and follows another child’s movement/actions.
Goal construction	Moments when children suggest a goal, expressly adapt or change their goals. We view the goal as the general model rather than particular behaviors.	Moments when children communicate a goal or intention to the rest of the group. It includes repeats, deviations, rephrasing, etc. of the original goal.	“Let's make gas!”	Moments when child(ren) shift their behavior in response to a some changed stimuli (auditory or visual cue i.e., change in projection)	Moments when children go back to a circle and stand still as the simulation environment changes into an ice world from a desert.
Clarification - requesting clarification	Clarification is explicit discussions among children and/or between children and facilitators, aiming to disambiguate questions about technology, modeling, etc.	Children verbally request clarification from others. It may take the form of a child asking questions to others.	“And now we are solid in liquid?”	Children describe confusion by body movement or exhibition of physical actions.	- shrug - look towards facilitators - point to the simulation and verbally express a question

Clarification - providing clarification		Children verbally provide clarification for others. It may take the form of a child providing answers to others' questions.	"So, you are in a lake."	Children disambiguate confusion by body movement or exhibition of physical actions.	- demonstrating meanings through, performing with their hands/bodies
Joint attention and action	Evidence of at least two children working towards the same end and attending to a simulation together. It may take the form of jointly understanding the situation and/or solve a breakdown/conflict.	This involves verbal discussion about what is going on when children try to understand a situation or solve a problem jointly.	This takes the form of a conversation.	Moments when children attend to the same thing and act similarly in accordance with each other.	Body language (i.e., gaze, proximity, posture, position, direction faced) demonstrates the joint attention and actions.
Narration	Children describe their own actions and intentions, others' actions, and changes in the collective space that they observed with the purpose of keeping other peers abreast of current state of activity to facilitate group coordination.	Moments when children describe what they are doing, what they plan to do, what others are doing, or what is happening in the simulation.	- Facilitator: "alright I'm going to transport the particles to a new place." Modeler: "oh! it's liquid."	The physical actions and body movement (i.e., iconic gesture) accompanying narrations.	Iconic gesture, such as pointing to a change in the simulation.

Table 2. Collective Embodied Modeling (CEM) codes frequency counts

Frequency Counts	**Exploratory activity**	**Structured activity**
CEM- Goal construction	3	9
CEM- Joint attention and awareness	8	16
CEM- Neglecting peers	3	8
CEM- Emulating	8	3
CEM- Requesting clarification	5	3
CEM- Providing clarification	1	4
CEM - Making suggestions	8	17
CEM - Accepting suggestions	11	23

Table 3. Facilitators' verbal scaffolds in exploratory vs structured Activities

Exploratory Activity	**Structured Activity**
Actions and behavior (i.e., movement, physical contact, posture, proximity, etc.) Activity flow and focus (i.e., classroom management, attention staying on task, etc.) Limited mention of target content; moderating where students are focusing their attention to elicit ad-hoc observations Students positioned as learners and observers of a simulations with agency over the state of the model	Frequent mention of target content; student actions addressed in the context of the in-simulation consequences Moderating student behavior to be in line with the predetermined goal Students positioned as agents in a simulation who must subscribe to and act in accordance with the predetermined target state of the simulation

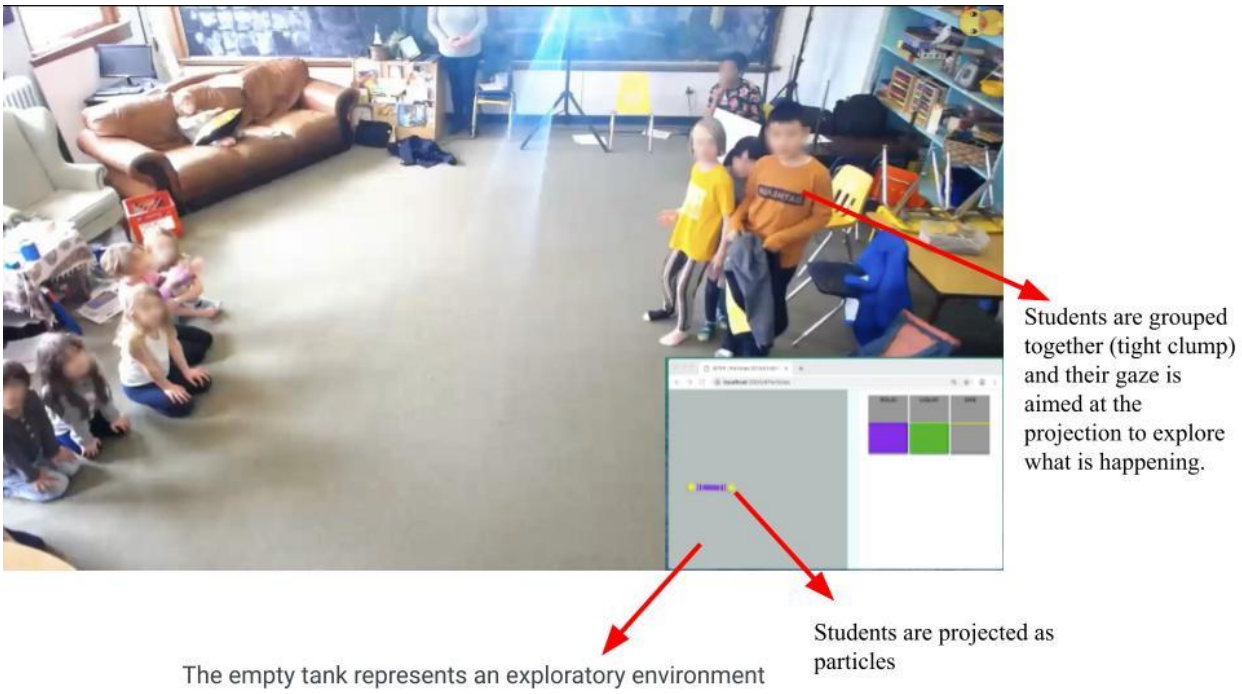

Figure 1. Students' collective exploration in an exploratory activity

Figure 2. Students hold hands and stand in a circle to model a predefined goal in a structured activity

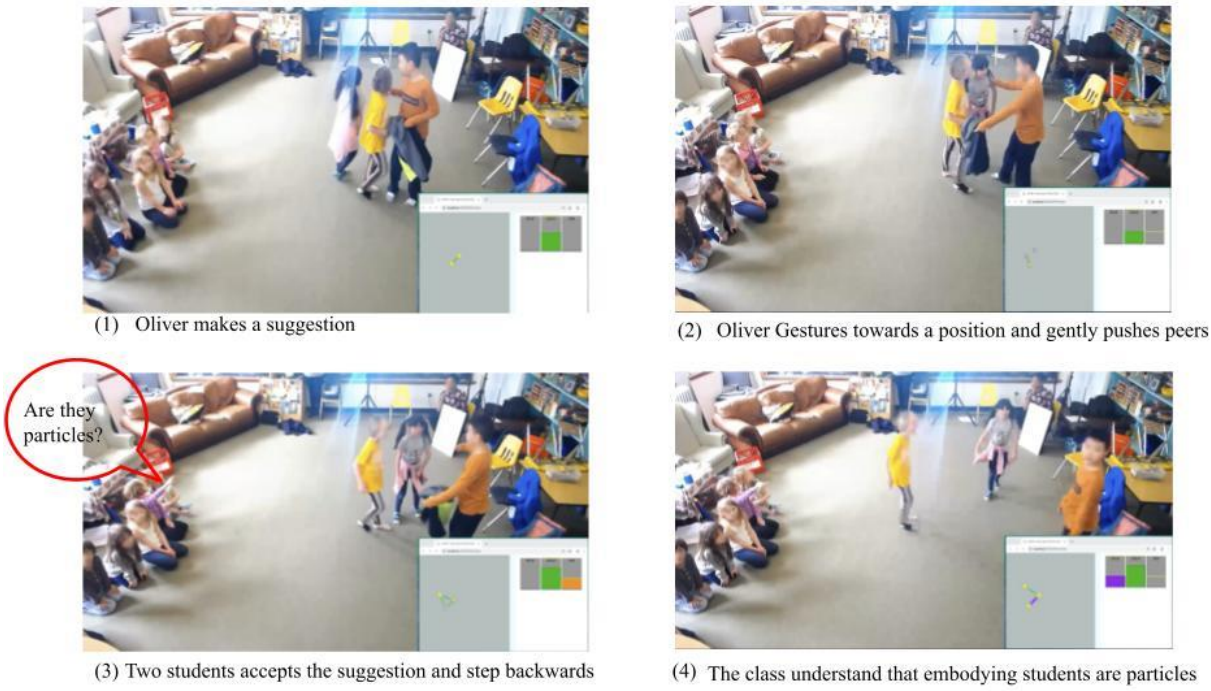

Figure 3. Students make and accept a suggestion through body in an exploratory activity

Figure 4. Students make and accept a suggestion through body in a structured activity