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Exploring the role of observers in shaping embodied modeling activities

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Abstract: This paper explores the role of observers in collective embodied modeling activity towards shaping modelers' goal evolution and scientific sensemaking. We conducted interaction analysis (Jordan & Henderson, 1995) to identify the emergent goals of observers and modelers, along with evidence of goal emergence. We then organize the evolution of these goals in relation to students' sensemaking of a scientific model through progressive modifications. Our findings indicate that students' progressive modifications of an initial model in pursuit of emergent goals enhance their understanding. More importantly, observers who played a peripheral role in the embodied activity were crucial in shaping modelers' goals and model modifications.

Purposes

In formal classrooms, while teachers set shared learning goals, students decide how to adopt and pursue these goals, which can enhance learning through individual exploration and multiple perspectives (Langer-Osuna, 2018). Previous research has found that students' conceptual understanding improved when they pursued their emergent goals within collective embodied activities (Zhou et al., 2024a; Ma, 2017). In an earlier study involving elementary students embodying ecosystem models, within a mixed-reality learning environment, we found that students who modeled with their bodies pursued different types of individual goals through their whole-body movement that complemented and in fact, enhanced the shared learning goals of the classroom (Zhou et al., 2024b). Meanwhile, observing students supported the modelers from the sidelines by pursuing learning goals in a different way. In this study, we investigate the observing students' emergent goals to see how they contributed to the scientific inquiry. We asked the following research questions:

1. What emergent goals are there in collective embodied activities?
2. How do observers and their goals impact scientific inquiry through model modifications?

Perspective

This study is informed by Cultural Historical Activity Theory (CHAT; Engeström, 1999), which emphasizes students' goal-directed actions within collective activities and where individual (*subject*) goals are integral to the group's shared *object* (Leont'ev, 1981). CHAT highlights how students' emergent and shifting goals are mediated by *tools* (artifacts), *rules*, *division of labor*, and *communities* (peers and teachers). In this study, students role-played as mice (*rules*, *division of labor*) trying to survive in an embodied mixed-reality model of a garden (*tool*). However, model changes (e.g., characters' energy depletion) or interactions of modelers and observers could lead students to shift towards other goals as new interests develop.

Students structure and achieve their emergent goals to develop their conceptual understanding (Saxe, 1991; 2002). One way to examine this development is to trace how they transform the forms and functions of artifacts as they use them as means to accomplish emergent goals. In this study, we examine students' learning by tracing how they transformed an initial model to pursue their emergent goals, focusing on observers' contributions in particular. Initially, students may interpret the model as a game, prioritizing their character's survival. Later, they may modify it to achieve their survival or emergent modeling goals (Tu et al., 2019). We connect students' goals with their model modifications, viewing these progressive changes as evidence of learning.

Method

The present model uses the GEM-STEP mixed-reality environment (Danish et al., 2022). Students experienced a garden ecosystem model to construct a food ecosystem by adding/removing organisms in the model. Initially, they interacted with a simple ecosystem featuring a food chain with one hawk, two veggie gardens, and mice (controlled by students). Next, students were shown an image of the entire garden ecosystem with more organisms; and invited to explore organisms' roles in the food web by making modifications (size, organism numbers etc.) to the model (Figure 1).

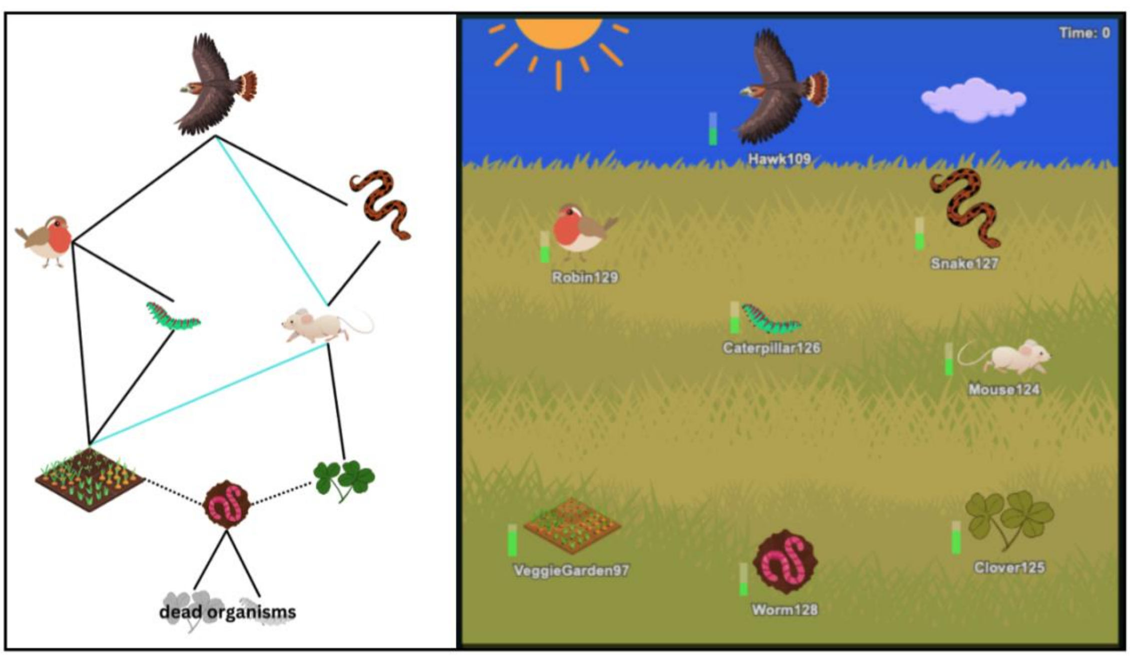

Figure 1: On left, the garden ecosystem food web, with the first simple food chain highlighted. On right, a screenshot of the Garden Ecosystem model with all organisms included.

The garden ecosystem model was situated in a three-lesson sequence over 5-days, focusing on food chains, food webs, and organism roles within an ecosystem. The class was divided into three groups. Each group cycled through a technology station (embodied modeling activity) and two non-tech stations. Students experienced 50 minutes in each station and an additional 50 minutes of whole-class discussions. This analysis focuses on observers and modelers in the embodied modeling activity.

We applied CHAT to this activity to consider the mediators of students' emergent goals. In the embodied modeling activity, each team was divided into modelers and observers (*division of labor*). Modelers moved in a tracking space, wearing tags that sent their location to a computer, allowing them to move their mouse in the model (*tool*). Observers stood on the sidelines and commented on interactions they noticed on the screen. The embodied activity unfolded in a sequence of rounds that began with the group picking a modeling goal (*object)* but that changed as new observations emerged. In this lesson sequence, the overarching *object* was to determine each organism's role in the food web.

In the case we present below, the group investigated the overarching goal by first understanding the robin's role in the ecosystem. Observers watched the model to identify the robin's interactions, while modelers moved in the physical space to control mouse characters. After each round of modeling, students shared new observations and reflections. They then addressed a new related goal or suggested ways to meet their prior goals if they did not fully succeed in the model run. The subgroups alternated so all students could participate in both roles.

Data and analysis

Twenty-two students across two fourth-grade science classes from a Southeastern elementary school participated in this study. The video data was content-logged and transcribed in InqScribe. We explored 20 minutes model runs on the fifth day with one group of students. Students' names are self-selected pseudonyms. The subgroups are: 1) modelers: *Goat*, *Savage*, and *Fier*; 2) observers: *Ronaldo* and *Chloe-Rose*. These episodes were selected because our initial content logging and interaction analysis (Jorden & Henderson, 1995) identified them as valuable to understanding students' collaborative inquiry tied to movements and unique to understanding observers' role in embodied learning. The first three authors also individually watched videos offline and took notes, which were organized to identify types of goals, evidence, and sensemaking.

Results

Observers' emergent inquiry goals

Our analysis identified that observers' emergent goal was to understand the role of robins in an ecosystem, particularly the relationship between robins and caterpillars. This goal emerged through a group discussion before modeling activities. Table 1 illustrates how the goal emerged from interactions. The teacher prompted students to suggest organisms to add to the model for testing. Ronaldo suggested earthworms (line 1), likely driven by his real-life experience (line 4). However, the teacher countered this suggestion (line 4), explaining that earthworms primarily stay underground in this model, making it difficult to observe "bird pecking the ground to find the worm." Ronaldo then suggested caterpillars as a compromise (line 6). Goat added, "the bird" in the next turn. Consequently, Ronaldo hypothesized that, "the bird will eat caterpillar" (line 8), that the teacher adopted as the goal for the first modeling activity (line 12).

Table1. Transcript 1: Pre-modeling whole class discussion.

Line	Speaker	Transcript
The teacher mentions that they have added the snake and the robin, then prompts students to share ideas for what else they could add.		
1	Ronaldo	Earthworm
2	Teacher	Ok, so you want to add the earthworm?
3	Ronaldo	Yeah, because the bird tries to get it, the thing, and maybe the snake tries to get it.
4	Teacher	So, I will say, in this model, the bird - I know y'all brought some experiences from real life saying that the birds - I heard y'all say that the birds will peck the ground and find the worm. But this worm is really [motions down] underground and in this model, that model stays underground.
5	… Goat suggest acting as robin or snake and the teacher replied that they will do it in the future ...	
6	Ronaldo	Ok caterpillar, caterpillar.
7	Goat	The bird
8	Ronaldo	The bird will eat the caterpillar.
9	Teacher	Ok so you think the bird's going to eat the caterpillar.
10	Savage	Or if we add the worm.
11	Ronaldo	[turns to look at Savage with swag] It's too underground. [motioning down]
12	Teacher	We just had the conversation about the worm though. So, we could add the caterpillar because you're saying that means the robin would eat the caterpillar. Ok, we could try that...
13	Teacher begins transition to using the model, selecting Messi, Fier, and Savage to use model; Ronaldo and Chloe-Rose as observer.	
14	Ronaldo	I'm just watching the robin to see if it is going to eat the caterpillar.

Modeler's emergent survival goals

Our analysis identified that modelers' emergent goal was to maintain their character's survival. Modelers role-played as mice; to stay alive, they have to find food from veggie gardens and avoid predators (hawk and snakes). We observed a consistent pattern where all modelers went to veggie gardens for energy and avoided predators by bending down or moving quickly. These embodied actions mediated by their need for energy to stay alive, indicated students pursuing an emergent goal of survival. Additionally, we observed modelers helping each other to achieve this goal. Figure 2 exemplifies the embodied collaborations among three modelers. Goat's mouse was eaten by a snake, and Savage's mouse ran out of energy, leaving only Fier's mouse to survive. Instead of leaving the modeling space, Savage and Goat guided Fier to a veggie garden without explicitly communicating their new joint goal. Savage stood behind Fier, hands on his shoulder, guiding him to the left while directing him to look at the simulation screen. Simultaneously, Goat turned to Fier and said, "you are still alive." Then, Goat extended his arm toward Fier, gently "pushing" him toward the screen (the top veggie garden). This case demonstrates that modeler's survival goal extends beyond individual characters to the collective survival of the same species.

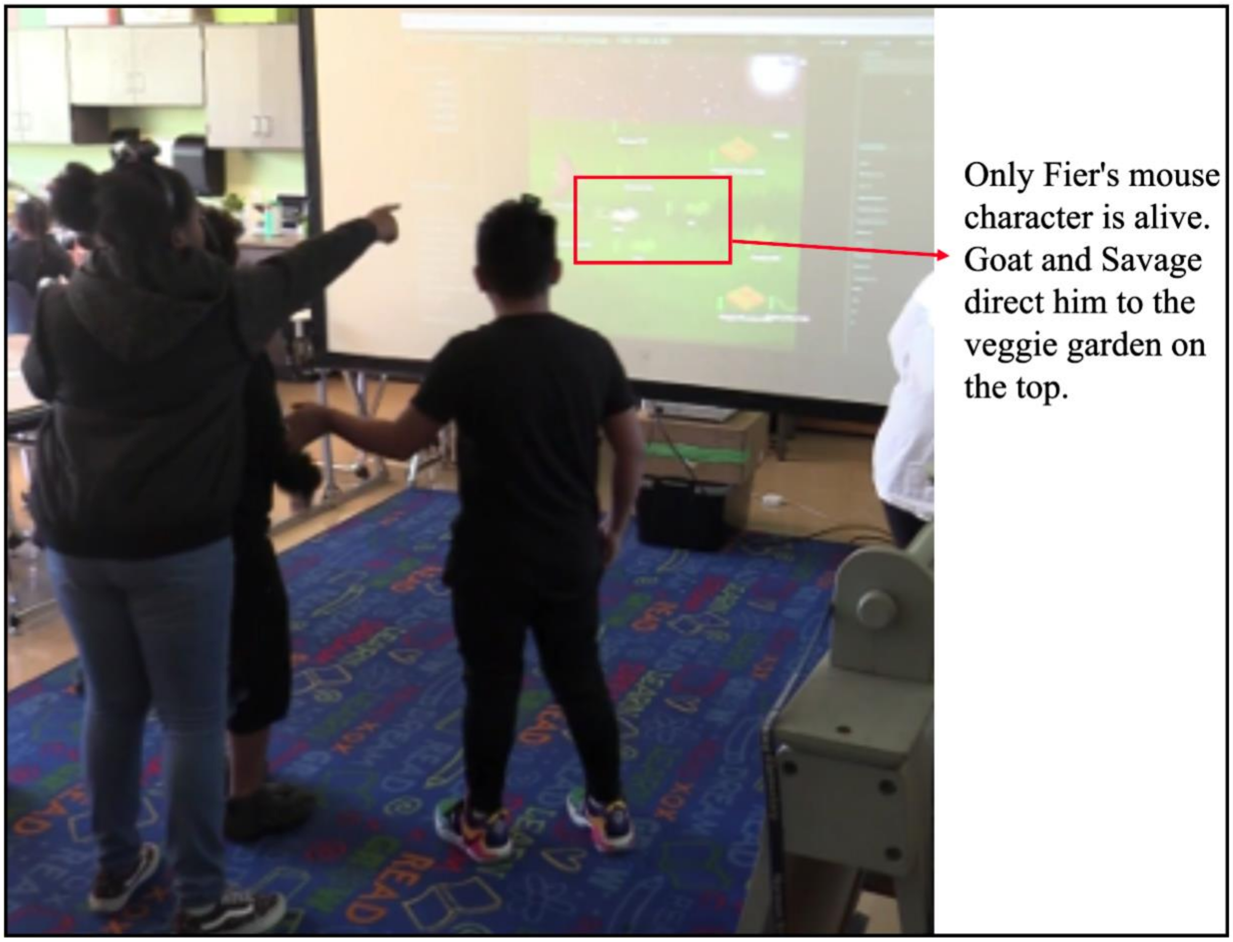

Figure 2: Goat and Savage help Fier's character to survive.

In contrast, the differences between modelers' and observers' emergent goals were salient: observers verbally explicitly expressed their goal mediated by curiosity, while modelers' goals were more implicit and mediated by the model design.

Goals evolution

On this day, we found that observers' goals to understand what the robin eats remained unchanged, while the modeler's goals evolved to converge with the observers. Initially, Goat pursued a survival goal, demonstrated by his energy search and avoidance of predators, which could be mediated by the model. However, his participation changed when a computer-generated snake ate his character. Subsequently, he shifted to observer's goal of understanding robins and caterpillars. He made significant observations about caterpillars, noting their energy level (dying out), energy source (veggie garden), and predators (hawk). Later, upon noticing Fier's surviving mouse, he shifted back to survival, first helping Fier and then mirroring Fier's movement as Fier attempted to survive. This moment exemplifies Goat' goal evolution and the primacy of collective survival in pursuing the survival goal.

In another case, we observed Goat shifting from pursuing the survival goal to adopting the observer's goal. He attempted to sacrifice his mouse character to understand the robin's role in the ecosystem by moving directly into its path to see if the robin would eat the mouse. This interaction occurred when the robin was about to die from hunger, preventing them from achieving the observers' goal. Instead of continuously focusing on his mouse character's survival, Goat sacrificed this goal to help achieve the observers' goal.

Model modifications

The modeling activity began with a goal of testing whether robin ate caterpillars, explicitly proposed by an observer, Ronaldo. However, modelers did not necessarily adopt this goal, as evidenced by their consistent actions of maintaining survival during modeling runs. After two model runs, Ronaldo suggested modifying the model because the hawk ate the robin almost immediately in the initial model, preventing further observation (Table 2, line 2). When Ronaldo suggested removing "stuff", Goat, a modeler replied to take out the snake (line 6), likely due to his survival goal being thwarted by snakes twice. Thus, Goat's suggestion aimed to sustain his mouse survival, not necessarily about achieving the observer's goal of testing whether robins ate caterpillars. Next, Ronaldo suggested removing both the snake and the hawk, which was collectively agreed by others. Unfortunately, this revised model was again inadequate, as the robin's random movement did not touch veggie gardens or caterpillars and died of hunger (Table 3). During the modeling, Goat shifted from his initial survival focus to the observer's goal by sacrificing his mouse to a robin, but the effort was unsuccessful.

Table 2. Transcript 2. Model revision discussion 1

1	Teacher	I want you to pause real quick. I heard something really interesting from Ronaldo that I want you all to listen in on. He has like a prediction and kind of a way to test it and I want to see if you all like think that this is a good idea. [Motions towards Ronaldo] Ronaldo do you, want to share this?
2	Ronaldo	So I was thinking that the hawk eats the robin too fast and when he gets hungry he does that. So I was just thinking we could take some stuff out to test if the robin eats the caterpillar.
3	Goat	We could take the snakes and the caterpillar so it is only the [holds up one finger]
4	Teacher	Just, he's saying that [points at Ronaldo] test the scenario the robin eats the caterpillar.
5	Ronaldo	Take some stuff out/
6	Goat	/So take the snakes/
7	Ronaldo	The snake and the hawk.
8	Chloe-Rose	The snake and the hawk.
9	Ronaldo	That's all
10	Teacher	Ok so take the snake and the hawk out?
11	Ronaldo	And then we can put them in later

Table 3. Transcript 3. Conversations during the modeling

Students test the newly revised model.		
1	Teacher	Ok, let's go. Alright, who is looking at the robin? [Chloe-Rose raises hand] Ok, who is looking at the Caterpillar?
2	Ronaldo	[inaudible] trying to get the [motions at screen] caterpillars.
3	Goat	[motions with both hands towards screen] It doesn't eat nothing.
4	Ronaldo	The robin eats nothing.

5	Goat	The robin eats nothing. He's dying [gestures both hands towards the screen]. He's dying.
6	Ronaldo	The robin dies and Ronaldo says, "bruh" and turns away from the screen.

In the following model modification (Table 4), Ronaldo suggested bringing the robin and caterpillar closer (line 4) because the current distance prevented their interaction before energy depletion. Next, Goat suggested adding more caterpillars because the single caterpillar at the bottom was not visible to the robin (line 9 -11). Both mice and caterpillars get energy from veggie gardens, so adding caterpillars could increase the chance of the robin meeting caterpillars and achieving the observer's goal but could also hinder the modeler's survival goal. Therefore, Goat's suggestion demonstrated a potential focus shift from survival to modifying the model to achieve the observers' goal. The teacher adopted both suggestions and the new model proved successful, as students finally observed the robin eating caterpillars.

Table 4. Transcript 4. Model revision discussion 2

Model revision discussion 2		
1	Teacher	Wait he died. What did he die from?
2	Ronaldo	From hungriness [puts fist over heart].
3	Teacher	So then, What could we. If we are really wanting to see the interaction that happens with the robin, what do you think we should do?
4	Ronaldo	[inaudible] [motions, putting two pinched hands together.]
5	Chloe-Rose	Take out the veggie garden [motions with hands from center of body rotating outwards]
6	Goat	The snake
7	Savage	Take out the veggie garden.
8	Ronaldo	Put them close to each other, see what happens.
9	Goat	Let's put more caterpillars. [Ronaldo puts hands on head then moves closer to Goat and covers mouth with hands]
10	Teacher	Ohhh, put more caterpillars? Why?
11	Goat	Because it's only one and that's the only one and there are 4 mouses so he can see
12	Teacher	Oh, so he's saying, oh this robin is having a hard time seeing one so we could add in more. [Students say yeah] How many do ya'll want to add in?
13	Students propose numbers, like 5, 6	
14	Teacher	Let's have a happy medium, let's say add in/
15	Ronaldo	I want 4 [Fier raising four fingers]
16	Goat	3, 3!
17	Teacher	Ok, let's add in three.

Conclusion

This analysis presents different goals held by observers and modelers in collective embodied modeling activities and demonstrates shifts in modeler's goal as students collaboratively negotiate model modifications. Goat initially focused on a survival goal and suggested model modifications to achieve his goal. However, Goat gradually shifted to the observer's focus by sacrificing his mouse character to sustain the robin for observation and then risking mouse character' energy source to increase the chance of achieving the observer's goal. Ronaldo's persistent efforts in pursuing his observer goal by suggesting modifications drove the modeling activity and impacted modelers. This analysis reveals observers' contribution and highlights their active role in an embodied context where they are often in a peripheral position.

The full paper will further explore how observers in an embodied context shift and drive inquiry and examine changes that occur in transitioning roles.

References

Danish, J. A., Anton, G., Mathayas, N., Jen, T., Vickery, M., Lee, S., ... & Ryan, Z. (2022). Designing for shifting learning activities. Journal of Applied Instructional Design.

Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R.Miettinen, & R.-L. Punamäki (Eds.), *Perspectives on activity theory*. Cambridge University Press.

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

Langer-Osuna, J. M. (2018). Exploring the central role of student authority relations in collaborative mathematics. ZDM, 50(6), 1077-1087.

Leont'ev, A. N. (1981). The problem of activity in psychology. In Wertsch, J. V. (Eds.), *The Concept of Activity in Soviet Psychology* (pp.37-71). M.F. Sharpe, Inc.

Ma, J. Y. (2017). Multi-Party, Whole-Body Interactions in Mathematical Activity. *Cognition and Instruction*, *35*(2), 141–164.

Saxe, G. B. (1991). *Culture and cognitive development: Studies in mathematical understanding.* Hillsdale, N.J.: L. Erlbaum Associates.

Saxe, G. B. (2002). Children's developing mathematics in collective practices: A framework for analysis. *Journal of the Learning Sciences*, *11*(2-3), 275-300.

Tu, X., Danish, J., Georgen, C., Humburg, M., Davis, B., & Enyedy, N. (2019). Examining How Scientific Modeling Emerges Through Collective Embodied Play. In Lund, K., Niccolai, G. P., Lavoué, E., Hmelo-Silver, C., Gweon, G., & Baker, M. (Eds.), A Wide Lens: Combining Embodied, Enactive, Extended, and Embedded Learning in Collaborative Settings, 13th International Conference on Computer Supported Collaborative Learning (CSCL) 2019, Volume 2 (pp. 676-679). Lyon, France: International Society of the Learning Sciences.

Zhou, M., Mathayas, N., & Danish, J. (2024a). Elementary Students' Emergent and Divergent Goals in Collective Embodied Modeling Activities. In Lindgren, R., Asino, T. I., Kyza, E. A., Looi, C. K., Keifert, D. T., & Suárez, E. (Eds.), Proceedings of the 18th International Conference of the Learning Sciences - ICLS 2024 (pp. 1339-1342). International Society of the Learning Sciences.

Zhou, M., Mathayas, N., Danish, J., Vickery, M., Steinberg, S. (2024b). Exploring Students' Divergent Interpretations While Studying Ecosystems in an Embodied Mixed-reality Environment. A poster presentation at the Annual Conference of the American Educational Research Association (AERA).