Exploring students' divergent interpretations while studying ecosystems in an embodied mixed reality environment

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Exploring students' divergent interpretations while studying ecosystems in an embodied mixed reality environment

Mengxi Zhou, mz13@iu.edu, Indiana University Bloomington
Nitasha Mathayas, mathaya2@illinois.edu, University of Illinois Urbana Champagning
Joshua Danish, jdanish@iu.edu, Indiana University Bloomington
Morgan Vickery, moravick@iu.edu, Indiana University Bloomington
Selena Steinberg, ssteinb@iu.edu, Indiana University Bloomington

Abstract: This paper aims to understand how elementary students interpret the goal of a collective embodied modeling activity and how different interpretations influence their sense-making about an ecosystem. We conducted Interaction Analysis (Jordan & Henderson, 1995) to identify students' interpretations of modeling goals compared to the facilitator's framing. We analyzed how those interpretations were demonstrated in their embodied interactions and confirmed in the debrief. We also present how those interpretations contributed to students' modeling activity. We conclude with recommendations to teachers and designers on the importance of leveraging students' interpretations to foster more inclusive learning experiences.

Purpose

Researchers have examined how different modes of play-based learning, such as game-based and cooperative-based/collaborative-based environments, support students' learning of academic concepts (DeLiema et al., 2019; Ediger, 2010; Tu et al., 2019). A key insight is that all forms of play support students' learning, but different rules in these environments shape their inquiry pathways with different flexibility levels (DeLiema, 2019). However, most of these studies investigated student learning in cases when students' goals appeared to *converge* with the goals of the activity design. Fewer studies have investigated what happens when students' goals *diverge* from the design. For example, in one game-based environment, students opted to disengage from a gaming situation that they perceived as competitive (Ediger 2010), and in a one purposeful open-ended inquiry modeling environment, students' individual goals emerged and drove the modeling activity (DeLiema et al., 2019). Meanwhile, researchers have indicated divergence as valuable for learning (e.g., Gutierrez et al., 1995; Tiseenbaum et al., 2017). Therefore, it is crucial to consider students' interpretation of activity goals compared to the designed goals and how those interpretations impact their adoption of roles and rules for learning. This paper explores elementary students' individual goal adoption and learning of an ecosystem when participating in a collective embodied modeling activity supported by Mixed Reality (MR) technology. It aims to understand how the pursuit of individual goals influences students' adoption of activity rules and their sense-making of the ecosystem. We asked the following questions:

1. How did students act in response to the activity goal framed by the facilitator? And what does this suggest about the goals they were pursuing?
2. How did students make sense of differing goals during the post-modeling debrief?

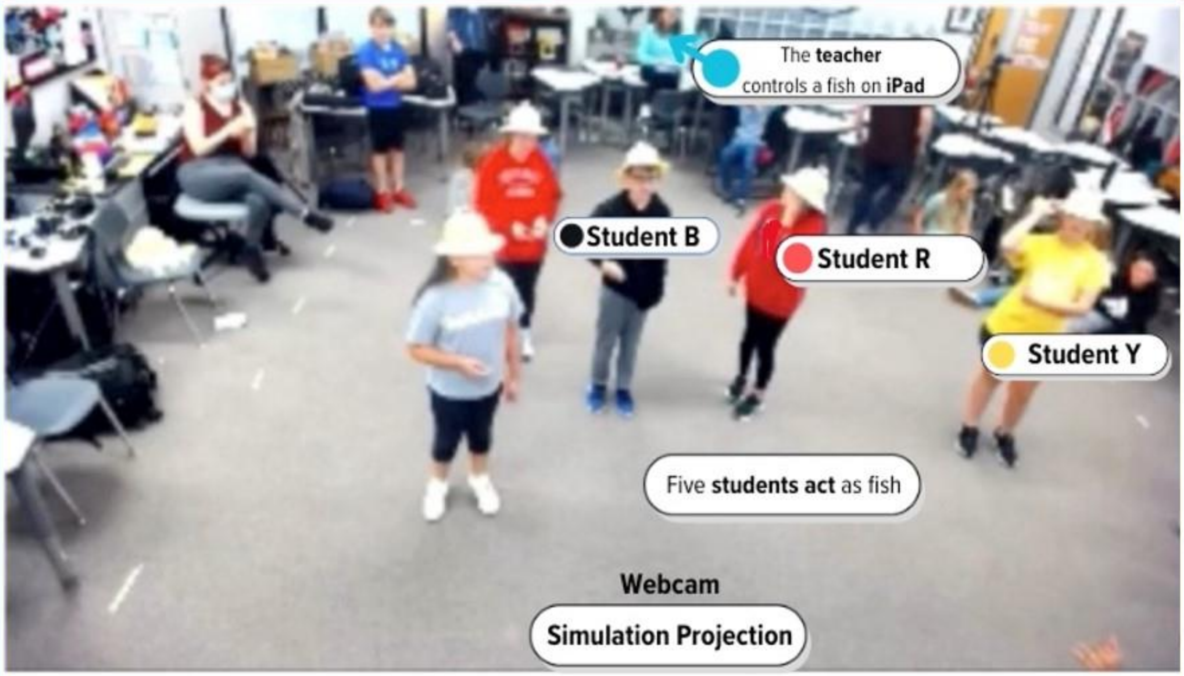
Theoretical Framework

This analysis is rooted in the Learning in Embodied Activity Framework (LEAF; Danish et al., 2020), which bridges sociocultural perspectives (e.g., Cultural Historical Activity Theory; Engeström, 1999) and individual perspectives (e.g., Lindgren et al., 2019) of embodied learning. This analysis privileges social dimensions, though we highlight the importance of individual experiences in those social interactions. We draw on LEAF's interpretation of activity as mediated by objects, tools, communities, division of labor, subject, and rules as we consider how individuals in collective activity concurrently pursue individual and collective goals. While the overarching activity object may remain stable, individuals' goals can emerge and evolve over time. From a CHAT perspective, previous research on the different modes of play investigates how activity rules shape students' activity goals (DeLiema et al., 2019). However, activity goals also simultaneously impact what rules are salient to students. Therefore, we need to consider a situation where students' interpretation of the activity diverges from the designed goals, how divergent interpretations shape students' choice of which rules to follow, and how these dimensions are interrelated to impact students' learning. LEAF informs us to think about how these rules originated from an individual and/or are collectively taken up to structure students' embodied actions (Danish et al., 2020).

Methods

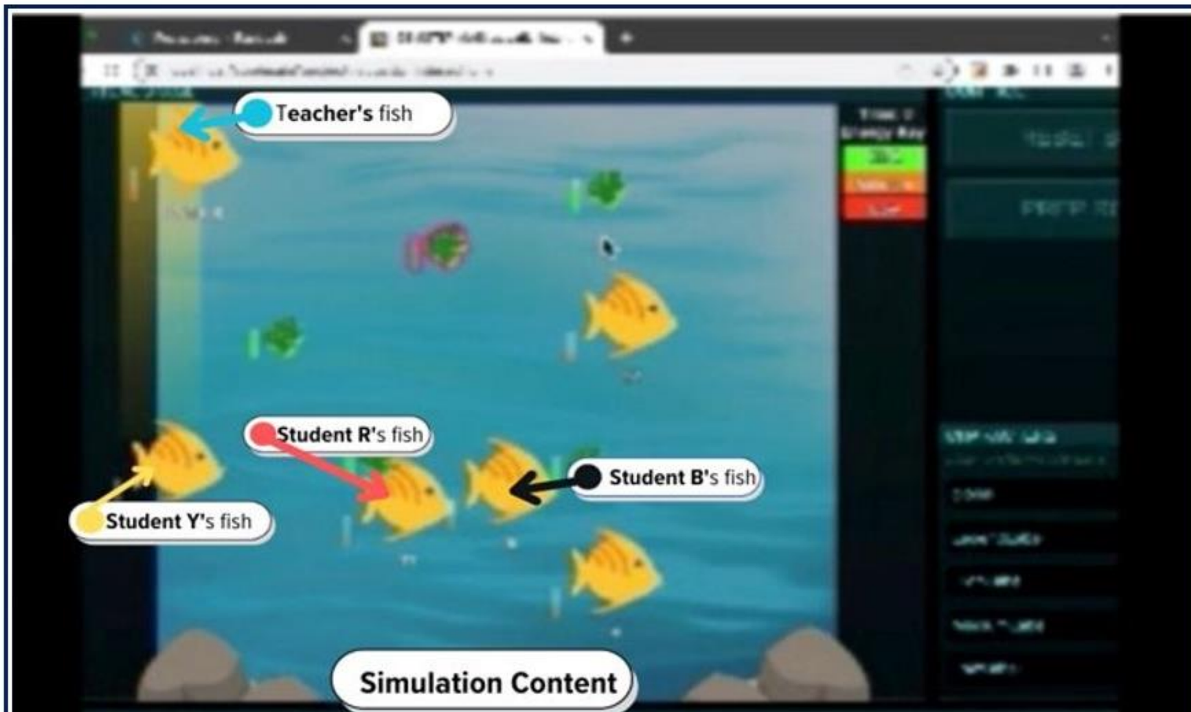
Design

The present modeling activity occurred using the mixed-reality embodied learning environment GEM-STEP (Generalized Embodied Modeling to Support Science through Technology Enhanced Play) (Danish et al., 2022; https://embodiedplay.org), which integrates a motion-tracking computational modeling simulation to mediate elementary students' playful exploration of agent-based models of ecosystems. Students assume the role of an agent (e.g., fish) as their movements are tracked and mapped onto a projected simulation of the ecosystem (e.g., pond) to explore how agents within the system interact with each other (Figure1&2).



Students assume the role of an agent (e.g., fish) and move around the designated tracking space. They can see how their movements are tracked and mapped onto a projected simulation of the ecosystem sitting in front of the classroom.

Figure 1. Three students in group one. Their letter label is picked based on their clothes color.



The projected simulation of the ecosystem

Figure 2. Three students and the teacher's fish in the simulation.

Table 1 summarizes the theoretical application of LEAF to this context with the analysis focus italicized.

Table 1: An application of LEAF into the present study context.

Mediators	**Applications in the present study**
Subject	The subject of the present study is *individual students who participate in collective embodied modeling activities*.
Tools	Tools encompass *conceptual and material artifacts* (i.e., the simulation).
Community	The community consists of *all individuals* involved in the activity.
Objects	The overarching object of the modeling activity is to *ultimately improve students' understanding of interdependence and how energy flows in the ecosystem*. However, since individuals pursue individual and collectively determined goals simultaneously (Engeström, 1999), *the modeling goal can be either to have a sole fish survivor or achieve a balanced system where all fish survive.*

Rules	Rules include explicit and implicit norms regulating participants' interactions with others and tools (Engeström 1999):
	• *Classroom rules* require students to obey preexisting behavioral norms (e.g., noise level) while embodying an agent in the simulation and responding to the simulation feedback on their movements.
	• *Simulation rules* include moving within the designated tracking area as agents. The simulation is pre-programmed to react to students' behaviors to highlight science. Yet, there is still agency to what aspects students take up:
	    ▪ If students as a fish touches the algae, the algae will lose energy until it eventually dies.
	    ▪ Students can develop their own behavioral rules for how long they stay at algae depending on whether they want to avoid eating it all (so leave some for others).
	• *Scientific rules*: students' progressive understanding of the scientific model
	
	Those behavioral rules are individual, but students also can negotiate them and encourage their peers to take up specific rules meant to align with their shared object. This process and its impact on learning is our focus.

Division of labor	• Groups of students interact with GEMSTEP through moving or iPad • Groups of students sit outside the tracking area to observe the modeling

Data and analysis

Twenty-two fifth graders from a public school in the Midwestern United States participated in nine 45-minute lessons to explore two ecosystems. Each day's lesson featured a facilitator's introduction, small group embodied modeling 'rounds,' and whole class debriefs. Each group round was organized into planning, modeling, and reflection phases. All lessons were video recorded, and content logged using ATLAS.ti.

The analysis involved an examination of content logs with attention to moments when students exhibited conflicting interpretations of modeling objects. Day 2 shows a recurring conflict about how students prioritized individual fish's survival versus collective survival. These patterns underwent an Interaction Analysis (Jordan & Henderson, 1995), including repeated video data viewing interspersed with researchers' interpretation and analytic memos. We iteratively watched students' embodied modeling activity to understand how different interpretations emerged. In analyzing students' discussions during the debrief, we looked for instances when students verbalized the target understanding of the ecosystem or provided insights for subsequent modeling exercises. We ultimately identified students' three interpretations of the activity goals described below.

Results

Our analysis showed that all consenting groups demonstrated conflicting goals about their activity while they modeled in GEM-STEP. Due to the space constraints of this proposal, we summarize the first group with the expectation of demonstrating analysis of all groups in the full paper. We conjecture that students' individual goals do/do not align with that of the collective and that these goals are made visible through students' embodiment and confirmed through verbalizing their perspectives during reflection.

RQ1: Three student interpretations

The facilitator framed the activity goal for group one as a collective goal by stating: "if you want to make this lake, *at least all of you to stay alive*, do you have, *as a team*, a strategy? ..." In response, the group chose not to discuss a strategy prior to the modeling round but reflected on their modeling in the round debrief.

Embodiment. We present the movement of the three students who described their experiences during the debrief in Figures 3-5, illustrating their embodied visiting route and description. We anonymized students based on their clothes color. All three students' visiting routes began with visiting the alga closest to them; however, they spent comparatively different amounts of time on their respective alga, with Y spending the longest time gaining energy. Because algae were pre-programmed with the same amount of energy reserves, spending longer time on an alga consumes more energy and leaves less for others. All students demonstrated seemingly meandering behaviors, with Y meandering at the end of the modeling round while R and B meandered during the modeling. Y and R consistently stayed within the group, yet B stepped away from the group toward the end of the modeling, which may suggest an *observer role*.

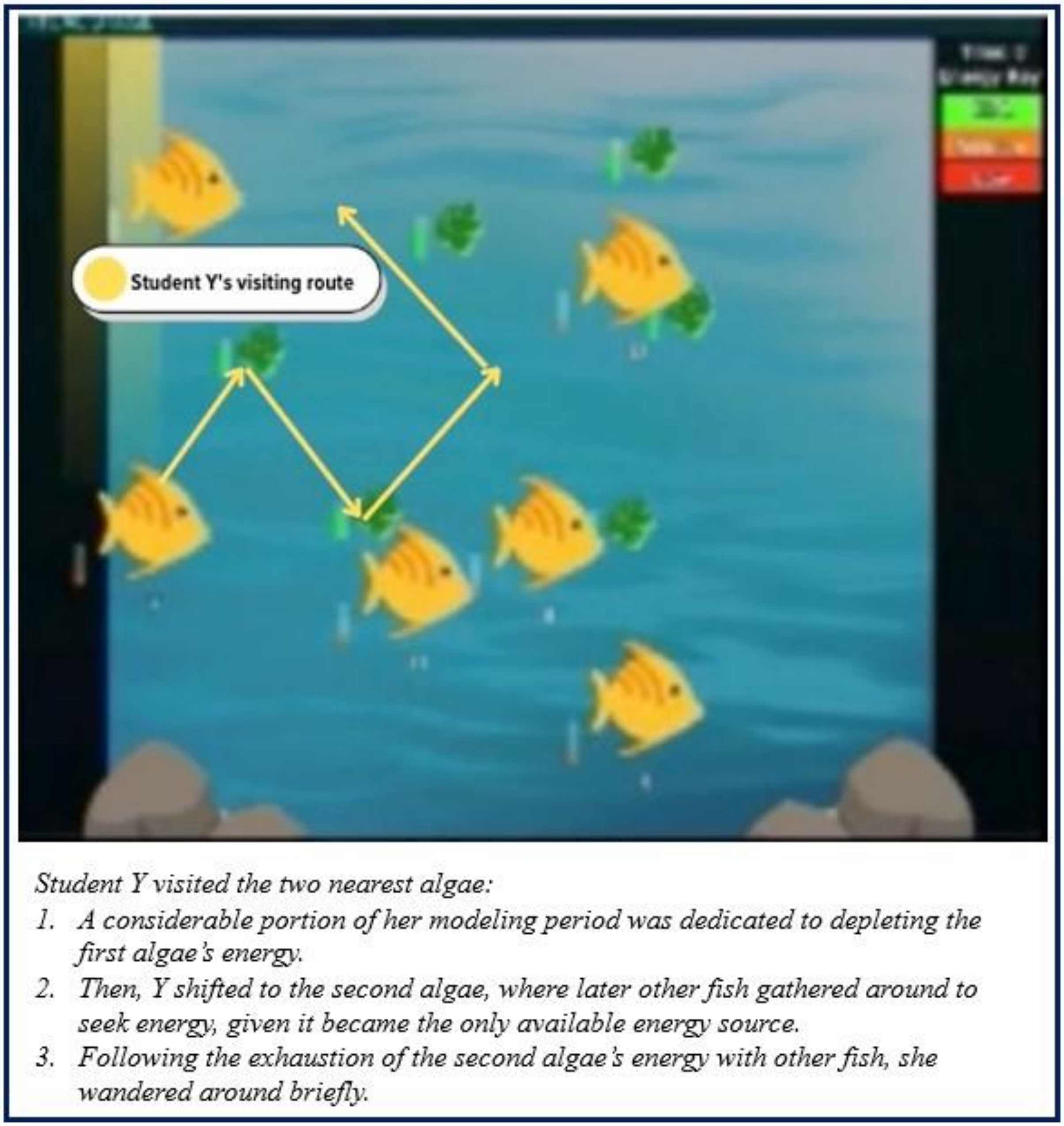
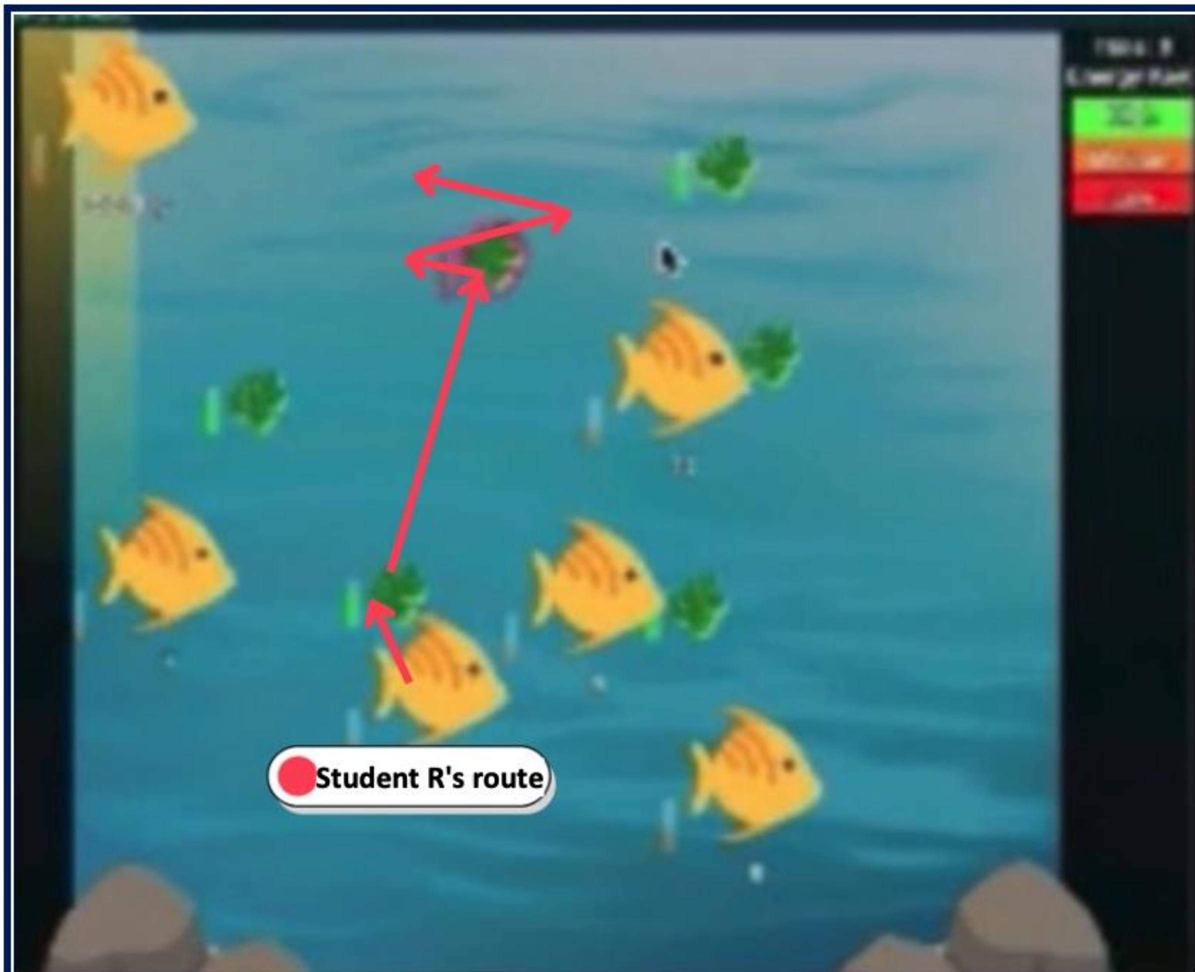
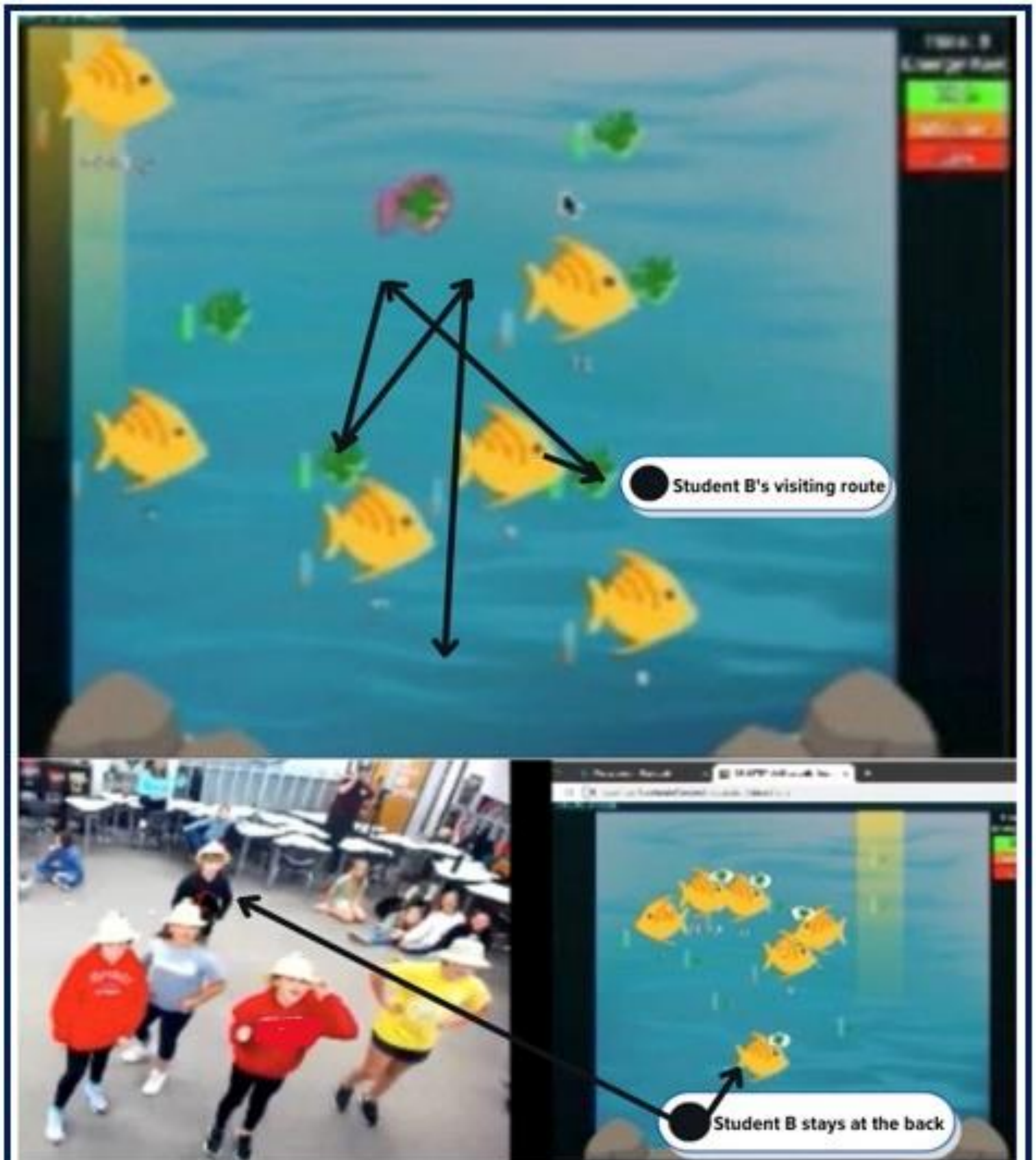


Figure 3. Student Y's route.



1. *Student R visited two algae, beginning her visiting route with the nearest one. Unlike Y, R did not deplete the entire energy of the first algae, as evident by R's comparatively shorter time at the algae (all algae started with the same amount of energy).*
2. *Then, R proceeded to the second algae, where she spent even less time, after which she meandered around the algae.*

Figure 4. Student R's route.



1. *Student B initiated his modeling by visiting the nearest algae where he shared the energy with another fish.*
2. *He then proceeded to the upper pond area and subsequently visited the second algae where two other fish, including Y were gaining energy.*
3. *Following the energy depletion, he displayed a very brief period of meandering around the middle.*
4. *He moved toward the back of the classroom and distanced himself from his group.*

Figure 5. Student B's route & he stayed outside the group toward the end of the modeling.

Verbal responses and interpretations. Y shared the following, "How I won was I ate the algae, and then I went to the algae that has like ((mimic gesturing the energy bar)) the left, the food left. So, I was like regain my energy…I just like I have mine." We interpreted this response as indicative of an *individual survivalist* goal orientation mediated by mechanics within the simulation that was gamified by the student (i.e., the agent-specific energy bars). She adopted the behavioral rule of depleting algae and seeking any remaining to maintain personal health. This approach seemed to induce competition as it inhibited others from accessing energy from the same alga.

R shared her strategy: "I kinda eat something, and then I moved away. So, it could regrow." She expressed frustration about peers who did not wait for the algae to regrow, "... some other people, on top of the one that hasn't grown at all …. Why cannot we just go somewhere else and wait for it to regrow." We interpreted her modeling behavior as being *socially attentive*, exhibiting a collective ecosystem-focused strategy. She adopted the facilitator's activity goal of keeping all fish alive and the rule of leaving algae for other people. The simulation mechanics (i.e., algae bar) mediated her attention to leaving energy for others and waiting for energy regrowth. This approach seemed to feature a consciousness of others and collaboration.

B did not verbalize his embodied experiences during the debrief or exhibit overtly competitive/collaborative behaviors. Instead, he stated his observations in the post-modeling debrief. His *observer behaviors* could be motivated to understand others' behaviors and simulation feedback or refrain from consuming algae to support others' survival. His behaviors potentially revealed his goal of understanding the functionality of the ecosystem and adopting a scientific modeling rule of exploration/experimentation and reflection. This approach demonstrated attentiveness to the modeling ecosystem as a whole.

RQ 2: Students' sense-making

In the post-modeling debrief, students made an observation about the model that aligned with their embodied behaviors, contributing to modeling activity in the subsequent days. B (observation-focused) initiated, "The algae never regrew." This was an important observation for survival-focused and social-focused goals, which was taken up later in the model refinement. Y(survival-focused) believed that algae's spatial positions impact the chance of it to regain energy from the sun, "...the algae was too low." R (social-focused) argued that the spatial position might not be the sole reason, as she observed that the same issues occurred with the upper algae, "It is also below. … the highest one still did not grow even when the sun is over it."

In summary, we found that students' sense-making of the modeling was associated with their interpretation of the activity goal as reflected in their embodied actions and reflection. Adopting the scientific modeling rules of experimentation and observation, B, with the goal of understanding the functionality of the ecosystem, was the first to point out the key problem preventing their group from surviving. Adopting the rule of focusing on gaining energy for the individual, Y, with the goal of individual survival, visited the two nearest algae, and the position of the algae (located in the lower pond) oriented her to highlight the spatial position as a reason for that problem. Adopting the rule of leaving energy for others, R, with the goal of maintaining a group survival, wandered around the upper pond to wait for algae regrow, which attuned her that the problem occurred to the upper algae so that the spatial position could be a partial reason. Students built on each other's observations and decided to modify agents' positions (move algae up) and size (widen the sun) by changing the agents' underlying code in subsequent rounds.

Some students' frustration that emerged from competitiveness (R in group 1) and failure to adhere to an agreed-upon collaborative strategy (groups 2 & 3) prompted them to ponder simulation design refinement and modeling activity to remediate their attention toward the collective ecosystem health. They expressed apprehension about the unhealthy energy bar placed alongside their fish, and the fear drove them to consume more algae. Students in group 3 suggested replacing the energy bar with a more subtle indicator, for example, only denoting half health level. Students in group 2 pointed out that survival-driven motivation reflects a negative reality of "whoever stands the last wins." Alternatively, they proposed a more explicit goal, "keeping all fish alive for 1 minute." The subsequent modeling activity incorporated their suggestions, leading to an increased awareness of the collective ecosystem.

Conclusion

This analysis revealed three distinct individual goals from students in the same modeling activity: survival-focused, social-focused, and observation-focused. Our intention is not to claim the superiority of one goal over others. Rather, we argue that they collectively contribute to students' sense-making about the ecosystem. Competition can be negative in some senses; however, persistent collaboration is hard to maintain (Kao et al., 2008) and may lead to unnoticed yet valuable divergent insights (Gutierrez et al., 1995). We believe that students' individual goal is formed and enacted from the lamination of emergent dynamics among students (Hunicke et al., 2004), varied interpretations of the design based on their personal experiences, and the autonomy granted by the authority in the space. These findings underscore the existence of a spectrum of interpretations regarding collective goals. We recommend that designers consider these diverse framings from students' perspectives and plan spaces for them to share interpretations and leverage them as sense-making resources. Although teachers hold the power to frame and enact activity goals, empowering students' agency in framing and enacting the goal is valuable for fostering a progressive learning trajectory.

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