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"Are you a match?": Coordinated embodied activity using multiple perspectives to support algorithmic solutions

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Abstract: Algorithmic thinking is the process involved in formulating a problem which can be represented by computational steps. We investigate the impact of students' perspective-taking during a mixed reality embodied activity and how the emergence of a blended perspective mixing agent and global perspectives has the potential to improve learners' algorithmic thinking by concretizing the computational steps.

Introduction

Algorithmic thinking is a cornerstone of programming and computational thinking (CT), that allows one to solve problems effectively across contexts (Shute et al., 2017; Grover & Pea, 2013). Algorithms are sets of precise steps commonly used in computational settings. Developing expertise in creating algorithms require planning, writing, and debugging processes. Algorithmic thinking can be challenging for novice programmers due to its abstract nature (Yadav et al., 2017). The use of embodiment to concretize abstract principles in computing education, shows promising results both for CT and STEM and deepens the understanding of the purpose of computing (Sung et al., 2017). In this paper, we investigate the impact of embodied activities in GEM-STEP (Generalized Embodied Modeling - Science through Technology Enhanced Play), a mixed reality environment, designed to encourage learners to take a first-person perspective while modeling. Specifically, we ask: How does perspective taking mediate the creation of algorithmic solutions in embodied modeling?

Background

Algorithmic Thinking and Embodiment

Computing education, particularly CT, is becoming increasingly important as technology is becoming more integrated in everyday lives and most fields. CT is broadly understood as a "universal attitude and skill set" that "involves solving problems, designing systems, and understanding human behavior" (Grover & Pea, 2013). Shute's et al. (2017) definition emphasizes that CT can be expressed through thinking and acting, and is exhibited using specific skills, including decomposition, abstraction, debugging, iteration, generalization, and algorithm design. Other researchers claim algorithmic thinking is a particularly hard task (Yadav et al., 2017).

A growing body of CT research highlights activities that involve the use of gestures to represent the abstract concepts associated with CT (Wang et al., 2021; Danish et al., 2020). Agent-based modeling also focuses on the benefits of body syntonicity: the connection learners make when imagining themselves as agents in a programming environment leveraging embodied roles or movement (Papert, 1980).

Perspective taking within Modeling

The embodied or syntonic connection that learners make with computational agents can support them in leveraging new perspectives to explore ideas. Scholars use viewpoints to delineate learners' perspectives: agent perspective (i.e., ground-level, or first-person agent) focus on individual contribution to the system; global perspective (i.e., top-level, or aggregated observer, with a third person or bird's eye viewpoint) focus on how the broader system-view affects the individual. Although it is a hard process to move between agent and global perspectives, moving between perspectives supports deeper and more complex reasoning (Lindgren & DeLiema, 2022).These benefits are further extended in embodied contexts. When the physical and symbolic worlds blend, it creates an in-between space where learners can reason about ideas and experiences, described as liminal blend. Such liminal blends help to concretize abstract concepts through perspective taking (Enyedy et al., 2015).

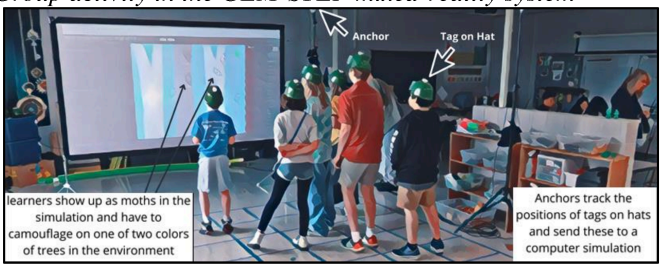
Methods

This study focuses on a group of 6 learners (1 Female & 5 Males), in a fifth-grade classroom in a southern middle school during 3 days (90 minutes) of a 9 day intervention. The curriculum leveraged the anchoring phenomenon of peppered moths to explore camouflage and adaptation. We focus on an activity that aimed to enhance students' CT, and specifically algorithmic design. This GEM-STEP model allows learners to control virtual moths by

moving around the room, using tracking tags. The color of each moth was unknown to the group. The goal was to camouflage by matching their moth's color to one-of-two tree colors within 30 seconds (see figure 1). A match-meter goes up if a learner stands on the right color of a tree, and down if the learner moves elsewhere. The CT goal of the model was to develop a strategy for a Binary Matching problem through an embodied solution. Finally, as a group activity, this activity required students to collaborate to successfully design and enact the algorithm in the model. After the group participated in the embodied activity, we asked them to develop a strategy for a new group to be successful. The goal was to help learners shift from being agents in the model to taking a global perspective to make sense of and explicate the mechanism of the algorithm. To support learners, we asked series of questions: 1) 'What are the different situations you could be in? What is your position? What are the different actions that you can take?', 2) 'When you played, how did you decide what to do?' and 3) 'How would you explain to another group how they should act in this activity?' (Zipitría, 2018). The learners created a paper-based artifact to represent their strategy. After completing their own artifact, the group tried another group's strategy.

Figure 1

Group activity in the GEM-STEP mixed-reality system



In prior work (Ayalon et al., 2023), we identified the development of algorithmic solutions by comparing the learners' movement in the environment before and after a discourse on their strategy. Here, we focus on the hands-on activity designed to support the development of algorithmic thinking. Specifically, we examine the ways that students extend their embodied experiences through perspective taking as they negotiate and create an algorithm. Using Interaction Analysis (Jordan & Henderson, 1995), we developed a coding scheme (see table 1) to identify the perspective taken: Agent, Global and a novel perspective which we called *blended perspective*. The coding scheme considers ways in which learners may be taking perspectives both verbally and through gestures. When learners used the pronounce "I" to describe individual strategy or "you" to describe a single other, we coded it as an agent perspective. When learners used the pronounce "it" or "YOU" to describe a plural other or a generic moth, we codded it as a global perspective. We coded for a blended perspective when learners expressed ideas that leveraged both agent and global perspectives together. Specifically, when the following three events occurred: (1) talking about individual and group strategy in the same sentence, (2) talking about one moth while using hand gestures to refer to the entire system and, (3) switching the use of the word "You" & "YOU".

Table 1

Framework of discourse analysis about perspectives' indications (color coding for table 2)

Agent Perspective	Global Perspective	Blended Perspective
Individual strategy	Group strategy	Both individual and group strategy
One particular moth	All moths	Agent perspective dialog combined with Global perspective hand gestures
Limited, first-person view	Top down, bird's eye view	
"I" & "You"	A generic moth ("It" & "YOU")	"You" & "YOU"

While pronouns alone are not inconclusive evidence for perspective taking, triangulated with additional verbal and interactional cues they provide reliable indicators of a given perspective. Nevertheless, we acknowledge the limitations of this approach that integrates these observations with learner gesture, content of speech, and patterns of engagement.

Findings

The perspectives are expressed in three phases: the first round of the model, during the hands-on activity, and last round of the model. Below, we provide an overview of the learning trajectory while uncovering the perspective taking that occurred during the hands-on activity, focusing on blended perspectives in algorithmic design. During the hands-on activity, the facilitator prompted a discussion, asking learners to consider the different positions they may take in the model. The learners had a gradual shift in perspective taking, as learners first shared perspectives

across agent and global perspective then began to blend these as the strategy was concretized. Ahead (see transcript in table 2), we explore how this blended perspective emerged in three ways.

Table 2

Transcript of group discussion between learners guided by the facilitator.

All pseudonyms were selected by the learners, see color coding in table 1			
1	**Swaggy Muffin (SM):** Yes it's the way you can successfully do this, look at it, right?	12	**SM:** Two on each tree
2	**Crazy Wolf Love Pizza (CWLP):** Look at the match-meter is it right? Are you a match? Yes.	13	**PX:** Yeah, you're just two on each tree
3	**Facilitator:** But you have six moths that you need to look at, [at] the same time as the match-	14	**SM:** You're just look and see if you//
4	meter, how can you do it?	15	**PX:** //Faster in a//
5	**Luke (L):** You can do it like- you can do it like one or like two at a time maybe and go on a tree	16	**L:** //If you think about it, if all going on a tree//
6	and see if two matches go up.	17	**SM:** //It might be a bit faster, it's all
7	**Facilitator:** Okay, so you go, [by what] you suggest. Before PX suggested one by one	18	**L:** //Going on a tree it would be confusing. //
8	and you suggest[ed] let's do it two by two.	19	**PX:** If we go on one tree//
9	**L:** Like the whole group	20	**SM:** //How about//
10	**ProfessorX (PX):** Or three	21	**L:** //And then it would be confusing on what's not the match. Yeah.
11	**L:** Like the whole group? Like two on each tree		

First, as learners began to discuss their strategy efficiency, they would shift between expressing ideas on the individual and group strategy. For example, in line 2 of the transcript, CWLP says "Look at the match-meter is it right?" expressing a blended perspective when he refers both to another learner's ("Look") while talking about a generic moth in a global perspective ("it"). Another example are lines 16-18. In line 16, L is explaining what will happen "if all [group] going on a tree" (global perspective). He expresses a group level strategy when SM adds to it (line 17), expressing that "it might be a bit faster" to send multiple moths to trees than their strategy so far. L shifts back into the agent perspective when in line 18 he suggests that going all at once might be a bit confusing, reflecting that he is embodying the individual moth in the strategy. In both examples, the learners shifted between agent and global perspectives to balance goals of efficiency with simplicity in agent rules.

Figure 2

On left, hand gestures used during the group discussion expressed in lines 3-4 of Table 2. On right, hand gestures used during the group discussion expressed in lines 13-14 of Table 2.

Second, we observed that both learners and the facilitator expressed first person perspective in their speech while expressing global perspective in their gestures (i.e. motioning with their hands to create the borders of trees). In one example, PX and SM explore together the idea that learners could walk in pairs to discover matches more efficiently (lines 12-15). In the brief interaction, SM first repeats a suggestion made by another student "two on each tree", without use of pronouns which suggests a more global perspective. PX contributes by agreeing and repeating the idea but adding "you're", which centers the learner using an agent perspective (line 13). Adding to PX's statement, SM then begins to describe, from an agent perspective, what two moths at a time would physically do in the model (looking at the match-meter), "you're just look and see if you". As they both use the agent perspective to explain the strategy, they gesture with their hands, indicating trees in the model and the match-meter (see figure 2). From this shared communication and set of gestures, PX determines that this strategy is "faster" than if they go one by one (line 15, 19). In this example, learners used their embodied experiences and an agent perspective to make sense of a global strategy, which they expressed through gesture.

We observed a third expression of blended perspective, when the learners used the word "you" while discussing strategies (lines 1-5, 7-8, 13-14, 16). The conversation shifted frequently between you as one moth or

a player to YOU as the group or a general moth, reflecting a potential comfort between the shifts in agent to global perspectives. Moreover, “you” (you & YOU) was often a bridging pronoun that was used by students to shift between perspectives. For example, CWLP refers to both agent and global perspectives of ‘you’ as a moth by asking “are you a match?”. While asking another learner to identify their state, his word choice of “a match” indicates a bird’s eye view of the model; rather than ‘are you matching’, he asks the learners to attend to the match-meter. Throughout the discussion, learners continued to center themselves within the strategy and the designed algorithms, even while attending to global perspectives or outcomes of the system.

Discussion & Conclusion

In the study, we explore the impact of multi perspective-taking, using embodied activities, to enhance the development of algorithmic approach in the scientific context. The activity supported learners to switch from an agent perspective when they played in the mixed reality embodied simulation, into a global perspective, when we invited them to think of a strategy. The expected behavior could have been that the students will switch from agent to global perspective or maybe switch back and forth, However, analyzing their interaction revealed that the students were able to hold both agent and global perspectives **at the same time** and created a blended perspective. We argue that the embodied activity helped to concretize the abstract components of the activity and allowed a glimpse inside the algorithm. Moreover, a significant aspect of their learning was due to the invitation to think globally about the group’s strategy, and the creation of *blended perspective*.

We suggest that this coordinated embodied activity while changing between agent and global perspectives has the potential to improve the efficiency of learners' algorithms and support abstract concept-learning by concretizing them. The use of the body improves performance by taking a blended perspective, a space where learners can act simultaneously as a group and as individuals. We suggest that further research is needed on methods to design activities that encourage the blended perspective. In addition, another aspect of future work should test learners' algorithmic thinking assimilation over time.

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