Taking the Patch Perspective: A Comparative Analysis of a Patch Based Participatory Simulation

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Abstract: In this paper we explore the implementations of an activity designed to engage students in an embodied simulation of an artistically expressive Agent-based modeling environment. We compare how two facilitators implemented the same activity, analyzing how they co-developed differing substrates with their students. We argue that instructors facilitated different embodied agent-based perspectives, which led students to develop considerably different conceptualizations of how these agents interact and how to code in this environment.

Introduction

Agent-based modeling (ABM) offers a powerful representational infrastructure for simulating and understanding emergent phenomena and complex systems. However, it *also* provides an expressive medium for creating computational art of various kinds. In the constructionist tradition, a single movable agent (turtle) has been used in environments such as TurtleArt (Bontá, Papert, & Silverman, 2010) and more recently Scratch (Resnick et al, 2009) as a means of exploring artistic expressivity focused on a single agent. In this paper, we extend this line of work into a multi-agent environment, NetLogo (Wilensky, 1999), focusing initially on the expressive visual potential of a large grid of immobile agents (patches), which can be thought of in terms of the panels of a quilt or the pixels of an image. As computational agents, patches have Cartesian coordinates, can change color, and can hold variables. In using the NetLogo patch grid as a medium for visual art, we have found students encounter conceptual challenges and opportunities in learning to use the environment expressively. In some senses, these challenges mirror those found with artistic uses of single and multi-turtle programming, where physical, embodied simulation have provided critical entry points for learners (e.g., "playing turtle" (Papert, 1980) for single turtle concepts, and engaging in "star people" activities (Resnick & Wilensky, 1998) for multiple turtle concepts). We hypothesized, however, that learning to conceptualize patches would require different mappings from social structures to computational phenomena. Engaging in design-based research to explore this area, we were interested in how a group of learners new to ABM could use coordinated social enactment to build familiarity with multi-agent patch programming as an expressive medium. We developed activities that invited participants to physically embody patches as an assembly of social beings that can each interpret and respond to code. We designed activities to foster understandings of how these agents function computationally and what visual effects they can produce. However, we found that teacher facilitators implemented these activities in ways that promoted different conceptions of patch agents, even when these activities were highly specified in professional development and curricular materials. In our study of two cases of implementation these differences appeared to be consequential, opening up two distinct ways of using patches, both of which were powerful and expressive but in different ways. In particular, we found that taking slightly different embodied perspectives as patches could contribute to the development of considerably different conceptualizations of how these agents interact and how one codes in this environment. Thus in this paper we explore the following research question: How do facilitation choices in these socially embodied simulations shape the image that emerges for participants of how one programs in a multi-agent environment?

Study overview

In this paper we report on data collected from the Computational-Thinking And Mathematics Play Spaces (CAMPS) project, a design based research project created specifically to look at how computational thinking and mathematics could be explored simultaneously with middle school learners in an expressive, artistic ABM environment. As the acronym suggests, this project took the form of a summer camp. The first design iteration consisted of a one-week (five-day) free summer camp for middle school students, held in a middle school in a southeastern U.S. city. The camp was titled "Code Your Art," and was advertised as a camp involving computer programming and art for rising 7^{th} and 8^{th} graders (although a few rising 6^{th} graders asked to participate and attended). Code Your Art camp consisted of two groups each with 16 students. Each group was co-facilitated by two middle school mathematics teachers; Tracy and Isabel were in room 1 and Kiara and Neil were in room 2. Six researchers and two undergraduate computer science students rotated between the rooms to collect data and provide technical and facilitation support as needed.

Over the course of the five-day camp, students created digital works of art in NetLogo to present and share on the final day in each class' art gallery. We conceptualized using NetLogo to create digital art by thinking of pixels as computational agents (patches). To do this, we had students import images from the web into NetLogo so that they could use this computational environment to manipulate different parts of the image, changing pixels based on color, location, or both. Since we conceptualized images as being composed of computational agents (pixels) it made sense for us to introduce NetLogo from the patch perspective, having students' first introduction to NetLogo be in the context of what a single pixel/patch would interpret in the context of creating a larger composite image. Thus students' first introduction to NetLogo was not on a computer, it was in a series of participatory simulations we referred to as the Stadium Card Activities. We took inspiration from a sports arena phenomenon in which spectators are given one or more colored squares of paper. When held up in a coordinated manner the entire stadium creates a composite image (Figure 1).

Figure 1. Stadium cards in increasing scale from left to right.

Since we were neither in a stadium nor in the digital world of NetLogo, but rather in middle school classrooms, we created our own physical computational environment by tapping into the cultural syntonicity (Papert, 1980) between stadium cards in the arena and patches in NetLogo. We taped out a 2 x 8 grid on the floor (one square unit for each participant/patch) and instead of giving participants a single colored card, like in the arena events, we gave each participant five 15" x 15" colored squares (one each of black, red, orange, green, and blue), each labeled with a number on one side (0, 1, 2, 3, 4, respectively), and attached by a binder ring so that students could flip through all five colored squares. Although the numbers and colors did not correspond to the same color system in NetLogo (e.g. in NetLogo red = 15 not 1), they still allowed participants to respond to code that referred to colors either by name or number, and produced an opportunity to think about modular arithmetic (e.g. what happens when you are asked to increase your color by 7).

In the context of the camp, a series of three Stadium Card Activities were used each day to introduce new computational concepts in NetLogo: patch color, patch location, and turtle movement. For this paper we will focus our analysis on the first activity, which we used to introduce NetLogo on day one of the Camp. This activity focused on patches (with color as their primary property), and basic syntax and computational concepts (e.g. brackets, "ask patches," if/then, colors named and numbered, loops, and randomness). This activity was co-designed with the instructors who taught the camp, using pilot enactments during four days of professional development to change the original researcher-designed activity. Through these conversations with instructors two consequential changes were made. (1) Someone embodied the Observer. We even dedicated a special location in the room for the Observer to stand and give commands. This created a "Simon Says" feel to the activity that the instructors thought would be something students could easily understand, taping into the ego syntonicity (Papert, 1980) between the agents (patches) as beings that can interpret commands and make decisions and the participants themselves who have these human abilities. The instructors suggested that this would also support students in eventually becoming the Observer themselves. (2) A slide deck with all of the agreed upon NetLogo commands for instructors to read as the Observer, along with a translation into English on each slide (e.g. "ask patches [if pcolor = black [set pcolor red]]" and "Ask all patches, 'if your color is black set it to red'"). This change allowed instructors to make connections for themselves about NetLogo syntax, such as relating brackets to quotation marks when "talking" to patches as the Observer. By the end of the professional development days, a Google slide deck was created for the instructors to use on the first day of camp. Although both teams of instructors had access to the same professional development and the same slide decks, when they ran this activity during the camp they made some changes. Although kids in both rooms playfully engaged in this social ABM environment through their embodiment of agents within the system, the changes instructors made resulted in significant differences in students' understandings of how to use NetLogo.

Theoretical framework

As seen in the two groups during Code Your Art camp, when groups work together, they develop their own micro-cultures that shape their understandings as they learn together (Fine, 1979). This development can be traced through an analysis of co-operative action (Goodwin, 2018). Goodwin describes human interaction as a process in which participants draw upon interactional components from a "substrate" of their shared history and reuse them with modification, transforming these resources in ways afforded by the semiotic system to which they belong so that they serve emergent interactional intentions. Substrates consist of shared resources for interaction that change as time unfolds and interactions continue. Goodwin defines a substrate as follows:

> It is visibly a form of action that organizes simultaneously 1) the *past* as something relevant to the present by not only incorporating, but transforming, the materials it emerged from; and 2) the *future* that will immediately follow from it by providing a constrained but open-ended framework for subsequent action (Goodwin, p. 32, 2018).

This analytic construct makes shared interactional resources visible as influencing future interaction by emphasizing how substrates evolve over time through interaction. Components of a substrate can include discourse, material tools, gestures, the physical environment, and anything else that can ground human interaction. An analysis of the substrates developed in the enactment of the Stadium Card Activities focuses on the social nature of the design through the collective embodiment of an ABM environment. During the Stadium Card Activities, relational metaphors, students position on the grid, and the order in which code was translated were the three primary components of each room's substrates that differed, constraining participants' respective open-ended possibilities for interacting with NetLogo as their computational understandings began to develop. In analyzing the different pedagogical choices instructors made when enacting this activity, an analysis of these substrates allows us to begin to understand how different choices constrained the possibilities for interaction.

Methods

In both rooms, the first Stadium Card Activity lasted about 40 minutes, starting with (1) a discussion about stadium cards as real life examples, (2) going through a sequence of commands with an instructor as the Observer, and (3) ending with students taking on the role of the Observer. The Stadium Card Activities were video recorded using four cameras situated around the periphery of the classrooms. Researchers observed this activity and took notes while watching. In both rooms the second author walked in during the activity and participated as well. This paper reports initial findings from our review and analysis of recordings of the first Stadium Card Activity. Using Interaction Analysis (Hall & Stevens, 2016; Jordan & Henderson, 1995) we have developed grounded theoretical categories to describe similarities and differences in the substrates (Goodwin, 2018) present in each room, looking specifically at facilitation and pedagogical choices instructors made and how they related to how students made sense of new computational concepts in this socially embodied ABM environment as they began to explore the expressive potential of the system.

Analysis

The Stadium Card Activity provided students with an accessible entry into an ABM environment that invited expressive play and allowed for participants to productively grapple with computational concepts. Although all four instructors participated in same pilot enactments of the Stadium Card Activities and had access to the same slide deck, both pairs of instructors made changes to the activities when facilitating them during the Camp. Three primary instructional choices created significant differences in how the first Stadium Card Activity was enacted in each room: (1) how the Observer was described and positioned, (2) where students stood on the grid, and (3) the order in which NetLogo code and English interpretation were translated. These differences affected the development of the substrate for the activity and thus how students interacted with each other, the materials in the room, and the instructors, and ultimately how students began to understand what it meant to use NetLogo as evident in how students took up the role of the Observer at the end of the activity through their participation in this socially, embodied ABM environment as they explored visual effects within this computational system.

Three instructional choices that created substrates for student learning

Establishing the Observer-patch relationship

Embodying agents in an ABM environment provided participants with easily understandable relational metaphors for the Observer-patch relationship. Facilitators' descriptions of their role as the Observer cued different relational metaphors, emphasizing different aspects of this computational environment. While facilitators in both rooms began by equating patches to pixels in an image, they positioned the Observer-patch relationship differently. In room 1, Tracy introduced the Observer as having authoritarian rule over patches:

> One of us [instructors] is gonna be the Observer. So right now this is gonna be the Observer box. I as the Observer have the privilege of being able to change you as patches. Ok? So I can speak to you, give you a command, and then you HAVE to follow my command.

This stance positioned the Observer as being in control over patches, who did not have a choice in their response. In response to this utterance, the students jokingly groaned and laughed and Tracy quickly chuckled as well. The groans and laughter indicated how Tracy's positioning of the Observer-patch relationship was an exaggerated or satirical depiction of the teacher-student relationship, a relationship the students were all too familiar with. In this moment, Tracy explained how she planned to embody a figure with complete control over these students: what they could do, when they could do it, and how they could do it. Here, the computational agents (patches) were depicted as subservient to an all-powerful ruler (Observer). Computationally one might argue that this is an accurate depiction because unlike humans, computational agents cannot think or choose or express agency, they can and must perform the actions commanded by the code they receive.

In room 2, Kiara positioned the Observer as a messenger to the patches, communicating the request (code) of another being, who could be anyone:

> And so then, I'll be the Observer and I'll be standing in the Observer box and later on you could be the Observer. And so what it's asking me, it says, "ask the patches," that's you guys. In a moment I'm gonna ask you to do something. So we always, the Observer always tells the patches what they're supposed to do.

Kiara began this introduction by telling the students that although she would play the part of the Observer at the beginning, they would get a chance to play the part later. This pedagogical move emphasized accessibility of the role as something students would be able to succeed at during the activity. The transient embodiment of the Observer also distanced the role from the person, describing a different power dynamic than Tracy constructed. Distancing the person from the role was also evident when Kiara said, "And so what it's asking me, it says, 'ask patches,'" here Kiara depicted the Observer as a messenger, relaying a message (asking patches) for someone else. Computationally, this foregrounded the role of the coder as separate from a computer/Observer that relayed code to computational agents, placing agency in the coder and not the Observer.

By positioning the Observer differently in each room, the instructors contributed to the creation of different substrates in their respective rooms, drawing on two different relational metaphors—rulers and messengers—that turned out to influence students' own relationships with this computational structure and thus their understandings of how to interact in this environment and imagine differing possibilities.

Positions and perspectives on the grid

Physically standing in for patches on the grid provided students with a point of accessibility into the role and perspectives of this agent. The students in each room stood in different places on the grid (Figure 2), which provided students with different agent-based perspectives. In room 1, students stood inside the grid, such that each student was a patch and held their colored squares for the entire duration of the activity. This meant that these students experienced "the patch perspective" in which they could not see the entire image created by the group, only their neighbors were directly visible. In room 2, students stood outside of the grid facing inwards, meaning that unlike a digital patch, students could see the entire image created by the group. This difference meant students' perspectives on and visual access to the overall picture were different in each room.

In room 1, students embodied an intrinsic patch perspective. This arrangement created "constrained but open-ended" (Goodwin, p. 32, 2018) possibilities for student and instructor interactions during the activity. From this intrinsic perspective students could not see the composite image made by all of the patches, which meant that it was not necessary from the students' perspective to show their patch color uniformly. It is important to note that these students held their colored squares for the entirety of the activity and all presented them in some manner after they responded to the Observer, which was easily understood as part of their role as patches. As shown in Figure 2, students in room 1 did not present their colored squares uniformly. There are three students visible in Figure 2 that all presented their colored squares in different spatial orientations, as if to different audiences. The first student (1) held her patch in her left hand, presenting the orange square on the other side to someone standing on her right. From the camera's perspective it looks like she is presenting a red square, however, her rightward gaze indicates where or to whom she was presenting her colored square. The boy to her right (2) held his colored square above his head, presenting an orange square towards the instructor or Observer and the girl to his right (3) held her orange square facing outwards from her chest. While all three of these students held their colored squares orthogonal to the ground, some students even held their squares above their heads, parallel to the ground, visible from a bird's eye view. This meant that it was hard for participants both intrinsically and extrinsically to easily see the color of each patch or the resultant image. This also meant that it made it more difficult for students as patches to look to their neighbors for clues as to how to respond to a prompt, something that patches cannot do either. Similar to the conflation of person and role with respect to the

Observer as described in the previous section, in room 1 the person and role of patch was also tightly coupled due to the students' physical location inside the grid standing in as their patches for the entire activity.

Figure 2. Students stood in different places on the grid, which afforded different visibilities and perspectives.

In room 2, students stood outside of the grid, which meant that they had to take an intrinsic perspective (to think like a patch) while standing in an extrinsic position in which they could see the entire image (something that a patch could not "see"). From this position students in room 2 did not hold their squares the entire time, but they still intuitively understood their relationship to the colored squares, manipulating them when asked by the observer and then setting them down in the grid. This meant that the composite image created by the students in room 2 was visible (Figure 2), which made it possible for the group to evaluate their image. Had all of the students in room 2 (Figure 2) responded to the Observer correctly the resultant image would have been two stripes. In Figure 2 it is clear that one of the students in the orange stripe had her colored square blue instead of orange. This visible difference became a point of discussion for the class, prompting Neil to talk through interpreting the code with the student and later led Kiara to ask her what had been confusing. It is also important to note that visual designs were visible in this small grid to the extent that patterns (e.g. stripes) were easily accessible to the group. The group began to manipulate and see the visual effects transform the gridded canvas in a way that emphasized that the image consisted of individual programmable agents (patches).

Not only was the composite image visible, but student manipulation of colored squares was visible as well. It was clear when students were changing their patch color and when they were done (Figure 3). This meant that instructors could tell which patches thought they were being talked to and which were not, leading them to reiterate what "ask patches," meant ("ask ALL patches"). Similar to the way Kiara positioned the Observer as a messenger, patches in room 2 consisted of a system of students separate from their colored squares. This consistent social structure made processes and creations visible, which is not afforded in the computational environment of NetLogo. In both rooms, the relational metaphor of the Observer-patch relationship was further embodied by where students stood on the grid, continuing the development of differing substrates which influenced how students interacted with the Observer's code and the squares they manipulated.

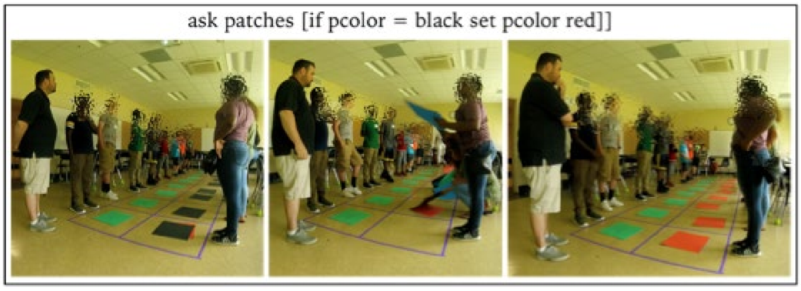

Figure 3. In room 2, it was clear which students responded to a prompt and how they responded.

Order of translation

The differing substrates in each room were also influenced by the order in which facilitators translated between NetLogo code and colloquial English when presenting code for students to interpret as patches. This led to the development of different frames for enacting code. Tracy used an *encoding* frame: she began with colloquial English and then translated her commands into NetLogo code. Kiara used a *decoding* frame: she began by asking students to interpret NetLogo code and once it was performed she translated it into colloquial English.

In room 1, Tracy began by describing the first command to the patches as a desired process in plain English words and praised students for quickly understanding the code, although she had not yet discussed the specific syntax needed for the computational patches in the computer to respond:

> So as the Observer, I might be thinking that I want to ask you all if you are black set it to red. So that might be something that I want to say and so since you all are, *((students manipulated their colored squares))* since you guys are all so smart and know both English and how we speak when we code, you guys already knew that if you were black you went ahead and set it to red. Did anybody not set it to red? No? All right, so the way we might ask this in coding language is, as the Observer, so I'm the Observer right now, I would say, "ask patches [if pcolor = black [set pcolor red]]"

Again, Tracy began by unifying herself as the Observer and commander, "I might be thinking I want to ask you." It was Tracy's agency as a human Observer that dictated what the students as patches had to do, the idea came from her. The students quickly responded by changing their colored squares to red, although nobody questioned whether they had started with black squares. Students were initially handed their squares with black on one side; however, students explored flipping through their colored squares on their own so by the time Tracy called out this command not all students had their colored squares in the same orientation—another challenge due to their location and position in the grid. It is also unclear how Tracy quickly asserted that all students correctly changed their colored squares to red, but her assertion, "since you guys are all so smart and know both English and how we speak when we code, you guys already knew that if you were black you went ahead and set it to red," was a pedagogical move in which Tracy gave students early, low-entry-level success evident in their quick manipulation of their colored squares. Speaking in an English translation of the NetLogo code at first and asserting students interpretations as a correct positioned students as successful from the beginning before they started to encode the NetLogo translation of the same command.

In room 2, Kiara and Neil gave the same command to their students' patches by first saying the specific NetLogo code and then decoding its meaning, framing coding as a process of interpretation:

> Kiara: So it tells me to ask the patches, so here goes, "[if pcolor = black [set pcolor red]]"
>
> Neil: What do you think pcolor means? Patch color. So if patch color equals black, does anyone body think they might have a patch color that is black? Right?
>
> Kiara: What would set pcolor red mean? What do you think you'd have to do?
>
> Student: Turn it red.
>
> Kiara: Turn it to the red.
>
> Neil: All right.
>
> *((Students manipulated their colored squares, one row changing their black squares to red.))*
>
> Kiara: So in everyday life we don't go around saying all the, all the people holding black just turn pcolor, turn the equal black now I want you to set pcolor red. Is that how we speak in everyday language?
>
> Students: No
>
> Kiara: No! That is our computer language, but if we translate that, what I actually said was "ask all patches," which is just this side right *((points to the row of students who changed their colored squares))*? All patches is just this side right?
>
> Student: No
>
> Kiara: NO! It's who?
>
> Student: All of these
>
> Kiara: All of you! But I was only talking to which color first?
>
> Students: Black
>
> Kiara: Black. So it says ask all patches, which I asked everybody first, and then I said, "if your color is black," so you immediately looked down to see if you had black and it, I said, "set it to red," and they changed their cards to red.

Kiara began again by positioning herself in the Observer role as a messenger to the patches, "so it tells me to ask the patches." This cued a syntax detail in the NetLogo code; "ask patches," which syntactically positioned what followed as a request or command spoken to patches to follow. Kiara and Neil continued by talking students through interpreting the new vocabulary and syntax. Right away, Neil chimed in asking students to interpret new vocabulary, asking them what pcolor meant and whose pcolor was black. Kiara continued by asking students what setting pcolor red might mean. Once the students had interpreted the code they then proceeded to perform it: all of the students whose colored squares were black turned them to be red. Breaking down the potentially intimidating code into smaller, digestible interpretative questions (e.g. What does pcolor mean? What does set pcolor red mean?) facilitated students' early success interpreting their first line of code.

Kiara emphasized that although NetLogo code is not how people normally talk, it is comprehendible from an embodied patch perspective, emphasizing the ego syntonicity (Papert, 1980) between students and patches. Through this translation process she made certain aspects of the syntax salient to the students, emphasizing that although not all students changed their pcolors, they were all spoken to because "ask patches" meant "ask all patches." Noting that the first step was to attend to noticing if one's patch color was black—"so you immediately looked down to see if you had black"—was an important embodied interpretation of the code, positioning *all* individual computational agents as needing to interpret the coded request. In room 2, not only was the instructor playing the role of the Observer treated as a messenger, but the students themselves were a distributed part of a patch-person-square-system as messengers to their colored squares. This decoding frame positioned students as interpretive agents translating NetLogo syntax into actionable English that they understood as humans in contrast to the encoding frame that developed in room 1 in which ideas were first expressed in English by the agentic instructor/Observer and then translated back into NetLogo.

Differences in students' subsequent activity

The different structural pedagogical moves that instructors made in each room created differing substrates in which two predominant student coding dispositions developed. Goodwin (2018) writes that substrates structure subsequent activity and thus students' participation as the Observer provides evidence that different substrates sedimented. Although students in both rooms engaged playfully as they took on the role of the Observer, they utilized the different frames that developed in each room. In room 1, students engaged in an *encoding frame* by first sharing complex ideas for the composite image that eventually over extended even the instructors' computational understandings, stretching the group's encoding abilities. In contrast, the students in room 2 engaged in a *decoding frame* in which they proposed much simpler code to the group, but communicated their code directly using discourse that more closely resembled NetLogo syntax. We argue that room 1 enacted an encoding frame for understanding code in which one started from open-ended possibilities that could be articulated in English and room 2 enacted an interpretive frame for understanding code in which interpretation of a new language was foregrounded. Not only were different dispositions for how to code developing in these two rooms, but the students that chose to participate as Observers differed in both rooms. In room 1, the most vocal students, three boys with coding experience, volunteered to play the Observer, while in room 2 boys and girls all of whom had no previous coding experience participated as Observers. The different substrates that developed in each room influenced the subsequent activity as evidence in students' enactments of the Observer.

Student observers generated different prompts in each room

When students were given the opportunity to perform the part of the Observer in this physical ABM environment, students in each room consistently enacted the different coding frames that had developed in each room. Although both instructors asked students to try out their own ideas as the Observer, students in each room took this up either as *encoders*, sharing their ideas first in English, or as *decoders*, sharing their ideas first in NetLogo. In room 1, Tracy emphasized an encoding frame, telling each student Observer to first tell the group what he wanted to happen and then make the same command in NetLogo: "So Kevin, you tell us what you want to happen and then we're gonna help you translate it into a language that the patches understand." When student Observers shared their ideas in English, before attempting to encode them in NetLogo, student patches immediately started responding by manipulating their colored squares. When Charlie began as the Observer, he shared with the class, "Ok, so first I want you to pick a random number from 0 to 5," and students immediately began flipping through their colored squares. The social relationship between the Observer and patches was so strong that as soon as the Observer started uttering commands, the patches immediately responded. Tracy, however, quickly asked them to stop, "Ok, hold up patches, hold up. He was just telling in English first." Tracy's request that they wait for the official code ran counter to the students' understanding of their role, and emphasized that patches could only understand the specifics of coding languages. Tracy also wrote the NetLogo code on the whiteboard as students developed the code out loud, providing another representation of the code and emphasizing the official syntax as what patches could respond to. This sequence of action was dependent on the substrate that began to sediment throughout the activity as described previously.

Similar to how Tracy positioned the student Observers in room 1, Kiara also encouraged the student Observers to try out their own ideas with the group: "Are there any other ideas you want to try? Anybody want to be the Observer? *((One student raised his hand.))* Ok, you want to be the Observer? Ok, you go and I'll take your place. And you tell us what you want us to do." Kiara asked students to share their ideas, not specifying that they had to be in NetLogo or in English as Tracy had. The student Observers in room 2, however, all talked in a manner that resembled NetLogo code. Their syntax was not perfect, but it was also clear that they were not talking in colloquial English like the students in room 1. In contrast to student Observers in room 1, the students in room 2 spent about half as much time in the Observer box, quickly reciting their code to their peers. The barrier for entry seemed much lower in room 2 and although the ideas the student Observers tried were simpler than in room 1, students' ability to speak in this new coded language and decode it as patches was much more fluent. As substrates developed and sedimented in each room, students' understandings of how to code in this ABM remained consistent with the encoding or decoding frame they established, reinforcing these dispositions.

Discussion and conclusion

Facilitation of these Stadium Card Activities appears to afford a wide range of choices. Even with tightly scripted and explicitly documented materials, we found that our teacher partners could make divergent and separately coherent patterns of facilitation choices, that produced (a) distinct opportunities for student participants to experience intrinsic and extrinsic perspectives on their shared simulations, and (b) distinct images of the nature of agent-based commands. Though our analysis is preliminary, these different facilitation choices also appeared to be consequential for the kinds of creative agent-based programming ideas that students generated in the moment. In both cases, the activities succeeded in fostering creative expression, but there was a distinct flavor to each of the two rooms, resonant with the choices the facilitators made. The social and embodied performances of the infrastructure of an ABM environment was an accessible way for learners to grapple with important computational ideas with a lively tone that invited expressive play. In our next design iteration we hope to explore students' participation in a similar activity that allows students to leverage both intrinsic and extrinsic perspectives and explicitly acknowledges these the two frames for coding (encoding and decoding) that we saw develop in this first design iteration.

In addition, creating visual effects on an embodied patch matrix at a small scale provided learners with a "mid-level" (Levy & Wilensky, 2008) conception of expressive designs. The Stadium Cards provided an activity-type for thinking with patches, which addresses core ideas in that area. These activities can be seen as providing experiences that fill an analogous role to that played by basic work in turtle graphics, for turtles (movable agents). To fulfill an expressive function, patches must be thought of in groups, and recognizable visual forms only become coherent with an enormous number of patches (think of the unit of the megapixel), but a mid-level scale of patches is accessible to learners and gives them an entry point to think about dynamic, computational images as composed of a grid of individually programmable patches/pixels.

Endnote

(1) In these transcripts, whenever anybody read NetLogo code aloud we transcribed their verbalization as the written code itself. This was done to emphasize the syntactical differences between NetLogo code and colloquial English.

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