Moving Between Experience, Data and Explanation: The Role of Participatory GIS Maps in Elementary Science Sensemaking

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Abstract: Constructing, sharing, and contesting models of the natural world is central to scientific inquiry (Latour, 1999) yet in K-12 science classrooms, students are rarely engaged in modeling processes of collecting data, authoring varied representational forms, and engaging in science argumentation. Science inquiry also tends to involve faraway locales, distant from students' extensive everyday knowledge of surrounding spaces and places (Barton & Tan, 2009). In this paper, we share findings from the most recent iteration of a larger design-based research project that directly engaged elementary students in modeling a local complex ecological system, the soil ecology underfoot in the schoolyard. We examine how 5th grade students used interactive GIS maps in whole class discussions, moving between their everyday experiences in the schoolyard, the data collection experience, and the classes' aggregated data in reasoning about complex socio-ecological relationships and explanations.

Keywords: participatory GIS mapping, elementary science, experiential knowledge

Constructing, sharing, and contesting models of the natural world is central to scientific inquiry (Latour, 1999) yet in K-12 science classrooms, students are rarely engaged in modeling processes of collecting data, authoring varied representational forms, and engaging in science argumentation. By skipping over these modeling practices, students are often left with distorted understandings of the purposes of science inquiry and weaker conceptual understandings of causal systems. Science inquiry also tends to involve faraway locales, distant from students' extensive knowledge of the surrounding spaces, places and people central to their daily experiences. As a result, science is often disconnected from youths' rich daily experiences beyond the classroom walls (Barton & Tan, 2009), limiting what forms of knowledge can be leveraged in science disciplinary learning.

Participatory Geographic Information System (GIS) mapping tools have shown potential in supporting youth integrating their first person experiences in everyday spaces as they reason with complex data about larger socio-political systems and processes (Headrick-Taylor & Hall, 2013; Rubel, Hall-Wieckert & Lim, 2017). Recent research has documented powerful ways in which digital mapping can support both critical conceptual learning and new forms of participation. Yet further research is needed to understand younger students' experiences engaging in participatory GIS mapping and how these digital spatial tools are used by students in collective classroom activity.

In this paper, we examine the most recent iteration of a larger design-based research project that engaged elementary students in participatory GIS mapping of an everyday socio-ecological system, their schoolyard and the soil ecology underfoot (Lanouette, Van Wart & Parikh, 2016). To examine how the interactive maps were used in classroom discussions, we draw on Saxe's framework for understanding cognition as process, with particular concern for how cultural forms come to serve specific functions in collective activity (Saxe, 2012). Using this framework, we focus on how students used the interactive maps as an intermediary form in their whole class discussions as they navigate between their everyday experiences in the schoolyard, their collection of field data, and their aggregated measures to reason about ecological systems (see Figure 1). We ask, how is the GIS map used in children's movement between everyday experiences, data collection experiences, and aggregated data as they construct, share, and contest models of a socio-ecological system?
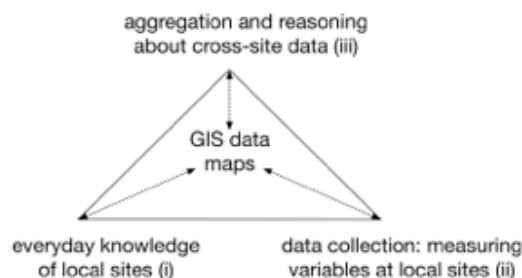

Figure 1. Potential of interactive GIS maps to serve as an intermediary form in collective activity.

Instructional design and context

This research was conducted in an urban public elementary school (K-5) in the Western United States. In this most recent iteration of the research project, we worked with one fifth grade class of 27 students. The lead author designed and taught an 18-lesson curriculum sequence, focusing students' inquiry on an everyday socio-ecological system, the soil ecology underfoot in the schoolyard. Across these class sessions, 5th grade students participated in two rounds of selecting sites for sampling, gathering data out in the schoolyard on both biotic (total invertebrate counts, earthworms, roots) and abiotic (soil moisture, soil compaction, soil color, soil composition) indicators, and collectively creating varied visualizations with the classes' aggregated data (bar charts, two way tables, paper data maps, digital GIS maps).

Throughout the curriculum, students used *Local Ground*, an interactive web-based mapping platform (Van Wart & Parikh, 2013), from early discussions marking potential schoolyard sampling sites to exploring relationships in the aggregated data maps. Three key design principles guided the iterative development of the tool design, including supporting (a) multiple data types, such as drawings, photos, audio recordings, and text notes in conjunction with quantitative data forms, (b) engagement in end-to-end mapping and data processes including designing protocols, analyzing data, and representing findings in varied formats; and (c) collaboration, where youth can collectively author the same map or create multiple variations drawing from the same collective data set.

Methods

In this analysis, we examined three student-led whole class discussions where 13 student pairs took turns presenting interesting or puzzling patterns in the class-level data using the interactive GIS maps. We selected these lessons because they involved students leading collective discussions about ecological relationships and explanations, with classmates' questions and counterclaims interspersed. As each pair presented, they controlled the *Local Ground* interface using a laptop computer next to a large projected screen (see Figure 3b). Data sources include two video angles of the whole class discussion, screen capture data, and audio recordings.

We engaged in two phases of analysis to examine how students were leveraging their everyday knowledge of the schoolyard and their experiences collecting data as they used the interactive GIS maps to reason about ecological relationships and conjecture possible explanations. In the first phase, we marked all instances of children's everyday knowledge and data collection and transformation experiences as the pairs shared and contested relationships in the data. This coding enabled visualizing not only the frequency of children's uses of these different nodes but more importantly, it illuminated how students were moving between these different nodes as they reasoned about key ecological relationships and processes.

In the second phase, we focused on how students used the maps within pairs' presentations. Findings from an earlier iteration of this design project documented students' shifting between the map, the data, and hybrid blending of the map features and the data (Lanouette, Van Wart & Parikh, 2016). In this analysis, we documented more subtle uses of the interactive maps as they emerged in conversation. For example, as students leveraged the spatial dimensions of the color photo map, we noted how it was used to serve different functions such as enabling children to gather more information about a particular spot (e.g., seeing if there were trees in a location) or to ground a specific recollection, memory, or experience in a location. Similarly, as kids worked with the aggregated data, we noted varied movements *within* the data, from examining just one variable to multiple variables, or focusing on just one site or several sites.

Findings

We first briefly describe students' experiential knowledge that surfaced as they reasoned about relationships in the data and conjectured possible explanations. We then present one vignette from a larger corpus of microanalytic moments that detail how students used the interactive GIS maps as they moved between different dimensions of their experiential knowledge and the aggregated data.

Children's experiential knowledge

Children's everyday knowledge of the schoolyard spanned ranged from particular moments in one location (e.g., "I used to pet bees there when I was in third grade) to considering specific locations across time (e.g., "That spot tends to flood in the winter months, when it rains a lot"). Children's knowledge also encompassed multiple modalities, from recalling sounds, smells, and physical pathways of movement to affective feelings rooted in particular places. It included detailed knowledge of the natural environment, such as knowledge of sunlight and shade patterns, areas prone to flooding and plant and animal distributions. Across the three lessons, students in these three lessons drew on their everyday knowledge 57 times, expressed in verbal utterances and accompanying

gestures that further elaborated dimensions of their knowledge (such as movement patterns, particular angles of sunlight, feelings in particular places). Children drew on their experiences collecting and transforming data, including first-person experiences at pairs' own site gathering data as well as general knowledge about data collection tools and processes for using these tools (e.g., soil compaction instruments and procedures for measurement). Children also drew upon their experiences transforming the data, as they moved from field note sheets full of sketches, text notes, and tally marks to symbolized and digital forms where several counts were collapsed into categorical ranges. Across the three lessons, students drew on their data collection and transformation experiences 28 times.

Interactive GIS map as an intermediary form

In earlier class discussions, students had been noticing a strong relationship between earthworm counts and soil moisture levels in the aggregated data but when Lena and Max presented, they offered a more complex conjecture: high earthworm counts occur in locations with moist soil, shade, and roots. With their initial data map view set to the garden and earthworm data selected (Figure 2a), Lena began talking:

> "So I am going to disagree with Mia, sorry. I think it [high earthworm counts at sites] actually has a lot to do with shade and stuff because worms need lots of moist soil and … shade too. See at the garden (pointing to the garden area), there is lots of shade because there are lots of trees. Now go to the pond (talking to Max, who adjusts the map), and so at the pond, as you can see there is a lot more sunlight (pointing to the sunny pond areas in a sweeping motion) and there is not a single eleven or more worms (pointing to data variables on right side of map) because there is so much sunlight and the soil isn't really moist, most of it is dry so I think shade and soil moisture have a lot to do with worms (see Figure 2b)."

Lena and Max then explain that their second sampling site near the playing fields shows this proposed relationship perfectly, with high earthworm counts, shade, moist soil, and lots of roots (Figure 2c).
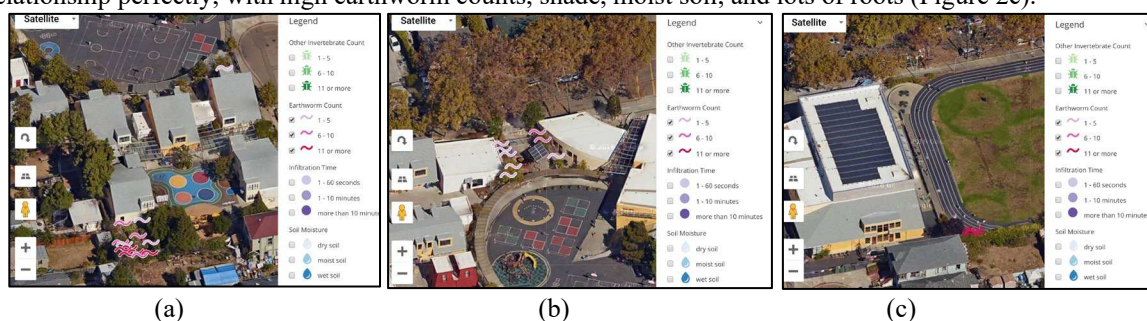

| (a) | (b) | (c) |

Figure 2. Screen captures of Lena and Max's shifting maps, including the garden (a), pond (b), and playfield (c).

Lena and Max then open up the discussion for questions and comments, with Marcel starting off: "So right now the cherry tree is really bare so there is still is a lot of sun there and that and you said that places where there is shade and so it is not providing barely any shade." Lena replies quickly, adding " Yeah but well, our lavender bush is creating lots of shade." Lena continues, using extended gestures to clarify her site location, showing how shade cast by the lavender bush by moving her cupped hand back and forth. Lena then turns abruptly to the map and says, "See this one [plant], right here… see, it is super full" moving the pointer stick and then her own hand to land on the site on the large map (see Figure 3a). Max simultaneously moves back to the laptop, zooming in the map to show their site's location and plants into closer view (see Figure 3b).
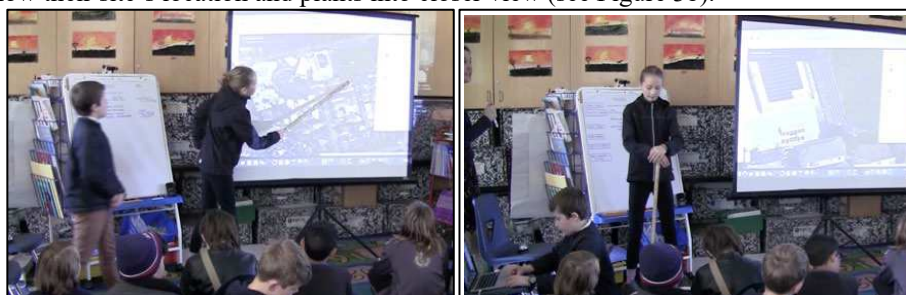

Figure 3. (a) Lena pointing to her sampling site, referencing the shade provided by nearby plants and (b) Max moving to the laptop computer that controls the map, using it to zoom into their exact site.

Another child, Ellis, is then called on by Lena and Max. He uses his group's site data and experience collecting data to refute Lena and Max's earlier proposed relationship. Ellis says: "Well so, I actually kind disagree with this because like, first of all, our group, we basically have the same circumstances as you… we have a lot of shade, we have moist soil, and we have roots down there too and we've only found one worm so far and we are in that tucked away corner in the garden." Ellis then moves up to the laptop, shifting the map view to his garden site, with relevant variables clicked on to include soil moisture and earthworm counts.

Throughout this short exchange, students used different aspects of the map to serve different functions in sharing and contesting potential relationships in the data and plausible explanations for these relationships. Lena and Max begin by showing earthworm counts in the garden and pond area before settling in on their second sampling site along the playing fields, moving back and forth between the spatial aspects of the color map and selected symbolized variables. Two counterclaims are raised, with students drawing on their everyday knowledge of the schoolyard, the data collection experience, and the interactive map in flexible ways. One child, Marcel, questions the likelihood that one variable, shade, was actually a factor at their location, drawing on his everyday knowledge of that space. Lena and Max respond, arguing that several plants at the site provide shade, using extended gestures and the color map to describe the particular site. A second child, Ellis, also contests Lena and Max's conjecture that high earthworm counts are related to soil moisture, shade, and roots. He draws on his own site data gathered in the garden and the first-hand experience of collecting data, changing the map to show his group's site and several symbolized data points.

Conclusions

Across these class sessions, children used the interactive GIS maps in flexible and inventive ways as they moved between their everyday experiences in the schoolyard, the data collection and transformation experiences, and reasoning about patterns and relationships in their abstracted data. Our findings suggest that by situating elementary students' science inquiry in everyday spaces and engaging them in modeling processes of observation, measurement, and collective discussion using participatory maps supports generative opportunities for learning. Details such as sunlight against a fence, shadows cast by buildings, and children's movement across the schoolyard were accessible and integrated into sharing and considering their peers' proposed relationships and explanations. In reasoning this way, children were able to leverage their vast experiential and everyday ways of knowing in grappling with the complexity of a local socio-ecological system.

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