Balancing the Scales: Implications of Model Size for Mathematical Engagement

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Abstract: We discuss a constructionism-based geometry curriculum in which middle school students built models of tents, first at a full, large-size scale, and then at a small scale. We build on *body syntonicity* to analyze how students learn through relating abstract knowledge to the knowledge of their bodies. Using video data, we analyze the affordances and constraints for students' mathematical engagement in creating models. We conclude with brief implications for mathematics education and for CSCL research.

Introduction and background: Mathematical modeling and scale

Given the value of geometry learning for both educational and industrial applications, it is necessary to design pedagogical practices that support such learning in ways that are meaningful for adolescents (Ma, 2016). While math educational researchers have studied the use of a variety of tools and manipulatives including project-based math curricula (e.g., Galindo & Lee, 2018), it is not yet clear whether students working with differently sized artifacts has unique affordances for their understanding of geometry. Thus, we sought to understand a) what mathematical practices were made visible in students' engagement with model-making activities, and b) what were the particular affordances for mathematical engagement in building large-scale and small-scale models?

In this poster, we present initial findings from a project-based geometry curriculum implemented by middle school teachers, in which students designed and built tents at two scales. Our analysis is based on constructionism (Papert, 1980), in which learning is presumed to happen most effectively when learners create personally meaningful objects in social contexts. Furthermore, Papert (1980) argued that anything can be learned if it is coherent, 'in tune,' or compatible with the learner's knowledge of their own bodies (i.e., body knowledge). This is what Papert calls "*body syntonicity*" (1980, p. 68). For example, the abstract notion of the *height* of a triangle is in tune or related to the learners' knowledge about the height of their own bodies. Our analysis, guided by the concept of body syntonicity, showed that students engaged their bodies and target math concepts differently across the two scale tents. This points to implications for the design of collaborative learning environments, including how to structure the scaling up and down of model making within collaborative and project-based learning (PBL) curriculum.

Methods

This poster draws on data collected during a PBL math course that took place in a chartered public middle school with 72 students. The course was structured for students to design and build tents at two different scales: (1) large-scale structures that could fit a group of eight students and (2) small-scale models. The large-scale tent was built before the smaller, model-scale one, contrary to common practices where the model or prototype is built before a full-scale version. We focus on one small group of eight students as they worked across large- and small-scale structures, video-recording their work for qualitative analysis throughout the unit. We iteratively coded the videos to identify moments when students employed geometry concepts and practices based on state standards (e.g., triangle attributes, scale drawing, angle computation, Pythagorean theorem). Following the concept of body syntonicity and using interaction analysis (Jordan & Henderson, 1995), we zoomed in on particular episodes that involved geometry concepts and analyzed how student groups engaged differently with the math, tools, and materials in each small- and large-scale tent.

Findings

During the building of the large-scale tent, the focal students used their bodies as resources while engaging with math. They first marked the location of the five vertices of their pentagon-shaped floor plan, starting with the center point (C, see Figure 1). One youth, Tom, suggested they use some nearby PVC pipes as rulers because the metric tape was not available. The flexible pipes were long enough for the students to lay them flat on the grass and then lower their own bodies to the ground to visually place the pipes as a way to ensure a straight line between two points. With a protractor from point C, students measured 72 degrees between two imaginary lines (CB and

CD). However, the combination of makeshift rulers and a measurement error caused by using a small protractor when trying to identify point D led to them placing the flag for the third vertice outside the pentagon (Figure 1, left, point E). Thus, the segment BE ended up longer than the expected 8 feet (BD). As the students worked again to locate the right location for point D, Tom lay down, using himself as a 'ruler' to estimate the height of the triangle (distance CF) that needed to be 5.5 feet long (Figure 1, center).

Figure 1. Tom discovered segment BE is too long (left). Tom estimates the height (center). Area diagram (right).

Moreover, the use of the two different scales impacted tool selection, a notable difference in the division of labor, as well as the size and behavior of the materials due to their weight. For instance, in the large-scale tent, multiple students had to help each other as they placed the roof and used heavy tools when placing the wooden stakes to support the walls (Figure 2a). In the small-scale model, one student could cut and sew the canvas roof panels or use simpler tools such as glue guns to install the tent walls (Figure 2b). In fact, group work and collaborations were impeded more in the small-scale work than in the large building project.

Figure 2a. Large-scale tents afforded collaboration.

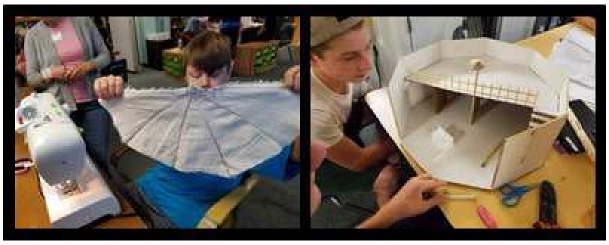

Figure 2b. Small-scale tents afforded one-person tasks.

Discussion

The order of first engaging with large-scale models before working on a smaller scale seemed to support students not only in repeated use of particular geometric concepts and practices, but also in allowing them to engage differently. For instance, students used their whole bodies to experience actual heights and lengths when lying down as "rulers" or simply by moving around and inside the tents (or watching others doing it). Students did not rely solely on "imagining" how long 5.5 feet looks, they collaboratively created non-standard units of measurement that anchored concepts to the world and to themselves. This points to important insights for the design of collaborative learning environments for geometry learning: Scaling-up before scaling-down may deepen mathematical collaborative engagement. It also points to ways that future computer-supported programs for digital model-making, simulation, and mixed reality might consider matters of scale. As for size changes, we need to pay attention to the impact on the type and use of the tools, the division of labor, and to the sensory information provided by the physical materials.

References

Galindo, E., & Lee, J. (Eds.). (2018). *Rigor, relevance, and relationships: Making mathematics come alive with Project-Based Learning* (1 Ed.). Reston, VA: National Council of Teachers of Mathematics.

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences*, 4(1), 39-103.

Ma, J. Y. (2016). Designing disruptions for productive hybridity: The case of walking scale geometry. *Journal of the Learning Sciences*, 25(3), 335-371.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic Books.