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PK 12

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Speculative Design for Mathematical Modeling and Belonging

AUTHOR NAMES:

Flavin, Eunhye; and Flavin, Matthew T.

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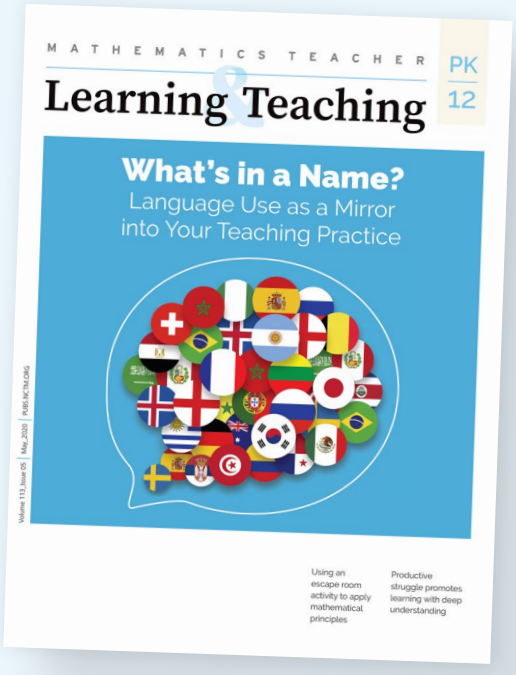
CONTACT: mtlt@nctm.org



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SPECULATIVE DESIGN FOR Mathematical Modeling & Belonging

3D modeling empowers students to envision and articulate aspirational futures for their communities.

Eunhye Flavin and Matthew T. Flavin

A sense of belonging in mathematics—feeling accepted and valued in the field (Good et al., 2012)—is a powerful predictor of student success. However, many students, particularly those from marginalized backgrounds, often lack this feeling as a result of limited representation in curricula and school cultures (Barbieri & Miller-Cotto, 2021). This article explores how a mathematics curriculum using 3D modeling as a speculative design tool supported students in expressing visions for their communities. Rooted in speculative pedagogy (Garcia & Mirra, 2023), an approach to envision alternative realities through creative works and activism, this project connected creative expression to 3D modeling. Our tasks are aligned with 6.RP.A.3 (ratio and rate reasoning), 6.G.A.2 (volume reasoning), and 7.G.A (scale drawings) (National Governors Association Center for Best Practices & Council of Chief States School Officers, 2010). We highlight moments when students' senses of belonging in mathematics visibly grew.

SPECULATIVE AND COMMUNITY-BASED MATHEMATICAL MODELING MODULE

The driving question of the curricular module is, "If you could build one building in our downtown, what

should it be?" This module starts with helping students make sense of the present, specifically, a downtown revitalization plan and its impact on communities. Then, students use Google SketchUp, 3D modeling software, to visualize buildings.

Analyzing the Past and Current States: Community Asset Mapping

Session 1 started with reviewing the downtown revitalization plan presented by the City Council. The plan included a current land use map and proposed zoning for the development of commercial and residential buildings. Students discussed changes they noticed in their gentrifying city and identified urgent issues like housing insecurity. Framing the mathematics classroom as a space that values students' community knowledge appeared to foster engagement, generating excitement about upcoming mathematics activities.

In Session 2, we used a community asset mapping activity to teach ratio-scale concepts (CCSSM 6.RP.A.3). Rather than emphasizing community deficits, the activity focused on existing assets (e.g., banks, hospitals, and parks). Students measured the distance between a church and city council building on a printed city map using a ruler, then converted it to actual distance using the map's 1:2000 scale (Figures 1 and 2).

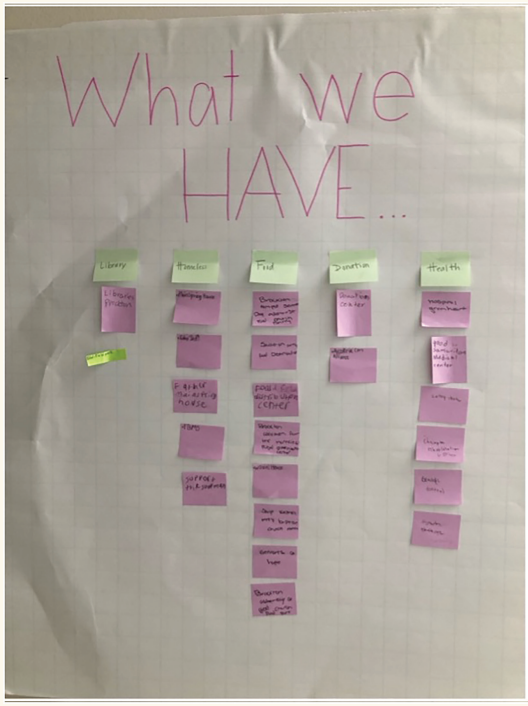
Example prompts:

1. Take a look at the Downtown Google map. Measure the distance between the church and the city council on the map. The distance is _____ inches.
2. The scale of the map is 1:2000. Each inch on the map represents an actual distance of 2,000 feet. What is the actual distance from the church to the city council? Explain your reasoning.

While most students understood that two inches meant a distance greater than 2,000 feet, some struggled with the multiplicative reasoning. The instructor modeled proportional thinking using hand gestures and a ratio table (Table 1). When told the real distance was 4,000 feet, several students asked, "How big is a foot?"—linking mathematical abstraction to their perceived distance between the church and the city council. This activity made ratios feel relevant and personal by grounding them in a familiar community context.

While creating a community asset map, students shared experiences like waiting in a long line at a

Figure 1 List of Community Assets



Eunhye Flavin, eflavin@gatech.edu, is a senior research scientist/research faculty at the Georgia Institute of Technology. She develops and deploys pedagogical tools—such as intelligent systems—to leverage students' cultural experiences and intuitive knowledge in understanding abstract mathematical concepts.

Matthew T. Flavin, mflavin@gatech.edu, is an assistant professor in the School of Electrical and Computer Engineering at the Georgia Institute of Technology, where he leads the Flavin Neuromachines Lab (link online).

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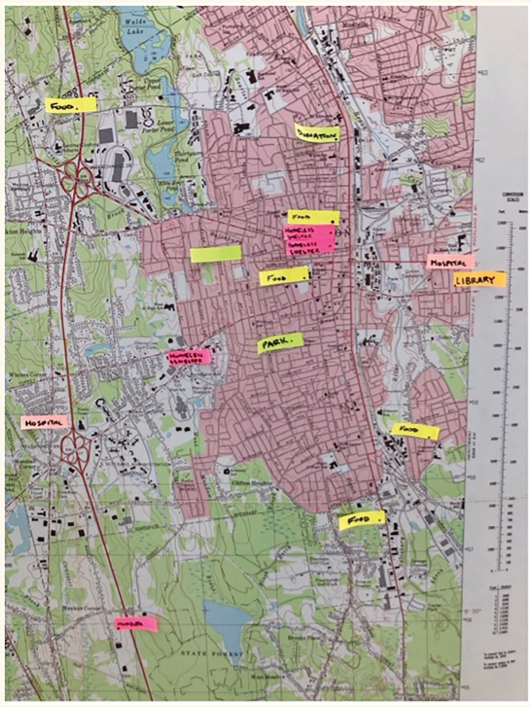
hospital. In response, Session 3 introduced a data talk comparing the number of health centers in Lake City, the location of this study, and River City, a similarly sized city (see Table 2; all names are pseudonyms). Students found River City had a much higher ratio of community health centers per person (0.01196%) than Lake City (0.00285%), identifying a lack of accessible care in their own city. This prompted a discussion reflecting both care for their community and critical engagement with data. The activity also reinforced ratio reasoning (CCSSM 6.RP.A.3) through a meaningful, real-world comparison.

Figure 2 Mapping Community Assets



Building a New Future: 3D Modeling

3D modeling software provides an intuitive interface and parameter settings, making it accessible for students. For this module, we used SketchUp (link online), a free, architecture-oriented 3D modeling tool accessible to K–12 students.

In Session 4, we introduced 3D modeling by demonstrating a house model and comparing 2D and 3D floor plans of a clinic. Students then drew 2D scale floor plans using provided measurements (Table 3 and Figure 3; CCSSM standard 7.G.A.1). With support during Sessions 5–6, they transformed their 2D floor plans into 3D models (Figure 4).

We scaffolded two key mathematics concepts using SketchUp: The first was **area vs. volume** (CCSSM 6.G.A.2). Students used the Push/Pull tool to extrude 2D surfaces into 3D forms, helping them visualize volume as layered and continuous (Panorkou, 2019), distinct from area.

The second concept was **scaling**. For this, they experimented with proportional resizing using drag-and-type functions, shifting their understanding from discrete map scales to continuous scale factors. SketchUp's scaling tool lets users input exact sizes or percentages (e.g., 200% = scale factor of 2.0). Students

Table 1 Ratio Scale

Map Distance	1 inch	1.25 inches	1.5 inches	...	2 inches	3 inches
Actual distance	1000 feet	1250 feet	1500 feet	...	2000 feet	3000 feet

Table 2 Comparative Data on Population, Health Care, and Socioeconomic Status

Location	Population	Number of hospitals	Number of community health centers	Average Rent	Average household income	Poverty rate
Lake City	105,446	3	3	$1,815	$77,290	16.7%
River City	117,090	2	14	$2,925	$112,565	7.4%

Table 3 Measures of a 2D Floor Plan

Room	Transitional housing shelter	Community health center	What are the square feet (ft) for each room?
Lobby	8 ft × 15 ft	8 ft × 15 ft	120 square ft
Shared Sleeping Quarters	20 ft × 20 ft	Not applicable	400 square ft
Exam Room	Not applicable	20 ft × 20 ft	_____ square ft
Office/Learning Space	10 ft × 10 ft	10 ft × 10 ft	_____ square ft
Bathroom	3 ft × 5 ft	3 ft × 5 ft	15 square ft

Figure 3 2D Floor Plan of a Transitional Housing Shelter by Jake

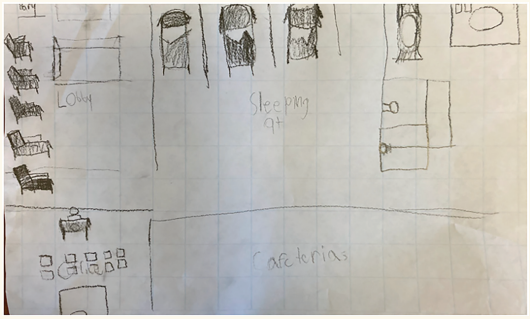
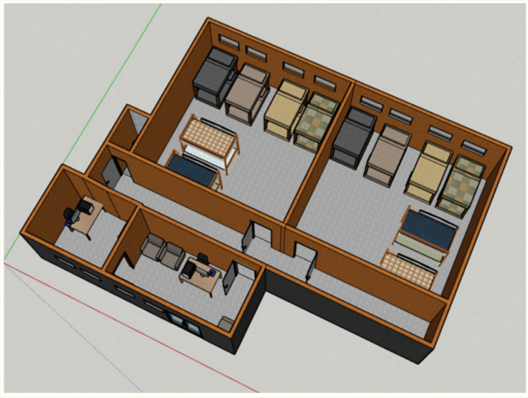


Figure 4 3D Transitional Housing Shelter Model by Jake



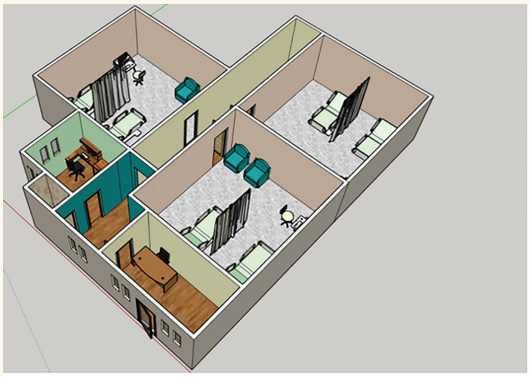
connected visual changes to scale factors and realized that, while the overall size changed, the model's proportions remained consistent.

In Session 7, students presented their building designs and reflected on their community impact and future goals. All the students showed their willingness to contribute to their community's well-being creatively. For example, Kamryn, who initially disliked mathematics, designed a transitional housing shelter model with a game station for peers who might live there, expressing newfound usefulness of studying mathematics for his community (Figure 5). Omya, once with a low mathematics self-efficacy, designed a community health center (Figure 6) and mentioned that this curricular module made her appreciate

Figure 5 3D Transitional Housing Shelter Model by Kamryn

mathematical measurements. These projects showed how positioning students as creators of narratives and artifacts who envisioned their future scenarios fostered a strong sense of belonging in the mathematics classroom.

Figure 6 3D Community Health Center Model by Omya



FINAL COMMENT

This article demonstrates how a mathematics curricular module helped students envision the future of a community. Designing a building model using 3D modeling software was joyful for students, and it served as a form of civic engagement. Previous research found that 3D modeling software is easy to use, and teachers often show proficiency in using it (Huang & Wang, 2022). Professional development opportunities for learning SketchUp (link online) are also accessible to the public. Given the benefits of a speculative design approach to mathematics in enhancing a sense of belonging, we recommend that teachers implement our task or explore our design principles in their classrooms.

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MATHEMATICS TEACHER Learning & Teaching PK 12

Speculative and community-based mathematical modeling module

MTLT TAKE AWAYS

Session 1. Intro to mathematics as a tool for understanding community	• Develop a critical understanding of how mathematics is used in real life by beginning with a community-based scenario.
Session 2. Community asset mapping	• Learn about map scale while engaging in mapping community strengths.
Session 3. Data talks about the community	• Collect and analyze data related to relevant issues (e.g., housing insecurity, health care, transportation, and food access).
Session 4. 2D scale drawings	• Create 2D drawings and compare them with 3D models. • Apply mathematics operations and reasoning to model community scenarios.
Session 5. Introducing 3D modeling software	• Engage in a few tasks using 3D modeling software, needed to create a 3D model, including area, volume, scaling, rotation.
Session 6. Creation and revision of 3D models	• Create a 3D model of what students think their community needs. • Critically assess initial mathematical models and revise based on feedback.
Session 7. Sharing and action planning	• Present findings and models to peers, teacher, or community members and plan actions and next steps.

