Communications

The interdisciplinary future of mathematics curriculum

SUSAN STAATS

For the Learning of Mathematics has a long history of addressing the complexities of teaching contextualized mathematics. The journal has been at the forefront of conversations on ethnomathematics; writing to learn mathematics; connecting mathematics to narrative and poetry; and sociological dimensions of teaching and research in mathematics. Interdisciplinary mathematics—drawing a context from another discipline authentically enough to support learning in both disciplines—continues to pose teaching and research problems that FLM could productively address in the future.

In my University of Minnesota college algebra class, which includes many future teachers, I ask students to model Minnesota graduation rates by race and by income, to learn basic disproportionality analysis (Bollmer, Bethel, Munk & Bitterman, 2011), and to study three perspectives on educational disparities: Oscar Lewis's theory of the culture of poverty; the funds of knowledge approach led by researchers at University of Arizona, and Lisa Delpit's perspective on structural racism in schools (Delpit, 2012; Lewis, 1966; Moll, Amanti, Neff & Gonzalez, 1992). I ask students to comment on their mathematical models from the perspectives of these different educational theorists. This project leads to significant professional knowledge for future teachers in Minnesota because our educational disparities are among the most pronounced in the country.

Interdisciplinary teaching is difficult because teachers must guide explorations that are critical and non-routine when viewed from the standpoint of a partner discipline. For example, a mathematics teacher may be learning about theories of educational disparities alongside students, and may feel uncomfortable assessing students' work when it merges with a field of study outside of mathematics. Research on interdisciplinary teaching, learning and assessment can provide substantial support for teachers working across disciplines.

When a student demonstrates integrated, interdisciplinary understanding, their writing offers balanced insights drawn from at least two disciplines and employs an integrative device, "a metaphor, complex explanation, or bridging concept—that brings together disciplinary insights" (Boix Mansilla, Dawes Duraisingh, Wolfe & Haynes, 2009, p. 344). Consider, for example, the following student's commentary:

> Delpit would want to change the standards that students are held to. Just basing it on graduation is a rather low standard and she might ask students if they created a passion, set and met goals, *etc.*, through a students education [...] In both the groups I predicted did increase by 2015, but the gaps between minorities and majorities and lower and higher class isn't closing.

A teacher could assess this student's commentary positively because it represents accurate learning from two disciplines. The student has considered the increase in graduation rates critically, suggesting that there are alternative mathematical interpretations of her graph, and that Delpit might find weakness in the entire assessment. This type of integrative thinking corresponds to the interpretation stage of mathematical modeling, "to interpret mathematical results in extramathematical contexts" (Maaß, 2006, p. 116). The student has demonstrated learning in mathematics and in the discipline of education. The suggestion of student involvement in assessment forms a bridging concept to some extent, although it is not expressed explicitly.

Another student interpreted the increasing trend in graduation rates differently:

> The whole culture of poverty has its own sense of discrimination and racism in it. Basically saying that people living in poverty adapt and *DECIDE* to stay in poverty. But my result in the "mx +b" equation I got suggested an increase in graduating students, the number getting higher. Refuting it tremendously.

This student uses her mathematical model to critique an influential perspective in education; the idea of prediction seems to be an integrating concept for her. This student considers that Lewis's culture of poverty theory predicts stasis, in contradiction to data trends.

The next two selections are based on students' research on personally-engaging issues. These first-year students demonstrated interdisciplinary thinking through the use of novel integrative metaphors. They treat the slope concept as a poetic foundation for restoring human experience to aggregate data.

Valerie Klingberg represented her research on international children's issues with a poem that occupies the graphical space of her regression line (Figure 1, overleaf). Here, the integrative metaphor is the visual correspondence of the line of an equation and the line of text. It is a balanced interdisciplinary statement: the poem values both mathematical and humanistic knowledge; both are necessary but neither is sufficient to understand a refugee's experience.

Like Valerie, Xue Xiong used poetry (overleaf) to give voice to a graph, in this case, to consider issues of identity development among immigrants. Xue researched California's immigrant population over the past several decades and found a strongly linear relationship, with a slope of 330,002 people per year. Xue's integrative metaphor is an outcome of algebraic thinking. He uses the algebraic terminology of increasing and decreasing to explore a young immigrant's sense of uniqueness, collective awareness and forgetting. Both students' interdisciplinary writing, for me, expresses an authentic and affecting sense of productive disposition towards mathematics.

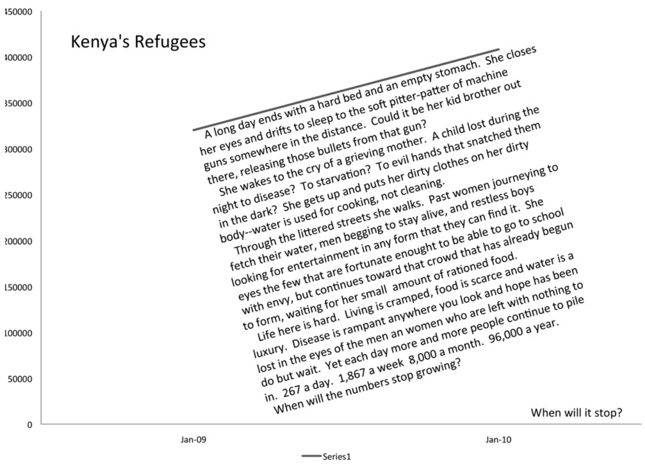

Figure 1. Kenya's Refugees: A Graphical Poem

I am me

I am me.
I am free.
I am different but that what make me unique.
I am not from here.
I came from a land of war and death seeking for peace and quiet.
You can say I have black hair.
You can say I am short.
You can say I like math.
You can say I speak ching chong ling long.
You can say I eat rice with anything.
But what you can't say is you don't like me because you have to be in my shoe to understand me.
But you can say I have changed because I have forgotten who I am.
I am not myself anymore; I have changed.
I am not free; I am struggling to succeed in this land.
I am not different because I have grown a custom to this land; I am not unique anymore because the uniqueness inside of me has return home.
I am from here now.
I came from a land of war and death seeking for peace and quiet but in return I have only found hate and shame.
There is more of my kind out there today, even though we grow bigger every day.
There are less of us who are still who we are.
There may be more of us but there are always many more of you guys.
There are less of us who are still who we are.
There may be more of us but there are always more of you guys.
There may be less us but always more coming.
There are many of us but there is only one of me.
By 2020, there will be over 14.2% of my kind but it takes more than as eye to find me.
I had been through life and death.
I had seen enough of fight and war.
I had run from my fear to find it will never leave me.
Working day and night for low wages, this is how my kind has tried to survive here.
Here is what we call home but we live day by day trying to survive.
Things get harder each day because we couldn't speak your language.
We lost our custom because we been here too long.
We eat turkey on Thanksgiving, give presents on Christmas day and celebrate July 4th.
Each year we lose our own custom because we have forgotten who we are.
Each day I speak less of my language because I need to succeed in my life.
Each day I learn something new and forget something old.
Each day I am becoming an American.

These four writing samples highlight variation in approaches to integrating learning. The first two students demonstrated knowledge of educational theories and mathematics, and they introduced bridging concepts that, perhaps, were only partially realized. Valerie and Xue developed more robust integrative writing devices. In these selections, I have touched on only two of several central issues in interdisciplinary teaching: that the teacher must be able to identify evidence of important learning in a partner discipline as well as in mathematics, and that stronger student writing will rely on an explicit, carefully-expressed and developed integrative device.

These algebra assignments were inspired by critical, social justice and interdisciplinary mathematics curriculum, but they were also designed to support students' development of professionally relevant mathematical knowledge. Making these interdisciplinary connections while in a mathematics class allows students to troubleshoot areas of mathematical weakness while working with a mathematics educator, rather than with an instructor in a partner discipline who may hold a more traditional view of mathematics and of mathematical learning.

My interest in interdisciplinary mathematics teaching is grounded in my position as the teacher of a service course that many students take as their final mathematics class. The dilemmas that I feel over choosing students' last formal mathematics activities may also be felt by teachers in other educational systems at the upper secondary level.

Interdisciplinary teaching and learning is complex, and there are many unanswered questions, particularly in the areas of curriculum design, assessment, and intentionality in our choice of curriculum (Staats, 2007; Staats & Johnson, 2013). It creates dilemmas for the mathematics teacher who becomes responsible for explicit learning goals outside of mathematics. Some questions for further research in interdisciplinary mathematics include:

- What approaches to curriculum design provide significant learning opportunities from the perspective of a partner discipline?
- What curriculum design approach will support a mathematics teacher who must lead class activities as a co-learner in a partner discipline, not just as a mathematical expert?

- What curriculum can support students' future learning in partner disciplines?
- What methods help mathematics teachers respond to student work that incorporates ideas from a partner discipline?

Interdisciplinary curriculum is different from a mathematical application. It's different from mathematics in context. A mathematical perspective alone is not sufficient to design curriculum or evaluate student work, because the curriculum fulfills obligations to the partner discipline as well as to mathematics. Greater awareness of the scholarship of interdisciplinary pedagogy can make teaching across disciplinary boundaries manageable for a wider range of mathematics teachers.

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Intentional play-spaces for teaching|learning mathematics with young children

LYNN M. MCGARVEY

Preschool pedagogy is now calling for educators to be intentional with regards to mathematics teaching and learning. In this communication, I provide an alternative conception of *intentionality* in which both children and adults act as teachers|learners within a play-space. I begin with an excerpt from an early childhood setting involving Martin, a 4-year old preschooler, and myself, as a teacher-researcher [1].

Learning and teaching: reciprocal responsibilities

During centre-time, I sat down at a table and poured out a bucket of coloured polygons. Martin (4 years, 10 months) sat down next to me, and Kiera and Taryn took the other two chairs. At first, we all independently began sifting through the shapes and putting them together. I looked at Martin's design and asked, "What have you got going there?"

"It's a traffic light. Now, I'm adding colours" (see Figure 1). I copied Martin's design so that I also had a red triangle, yellow hexagon, and green triangle traffic light. We agreed they looked the same.

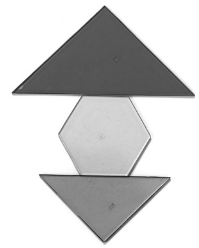

Figure 1. Martin's initial image of a traffic light.

I suggested we play a game where one person makes a design and the other person tries to copy it (see Figure 2). We each had a turn, but Martin was not particularly interested in playing. Instead, he continued putting two or three shapes together to see what they made. Martin then pushed two red trapezoids together: "This is a stop sign!"

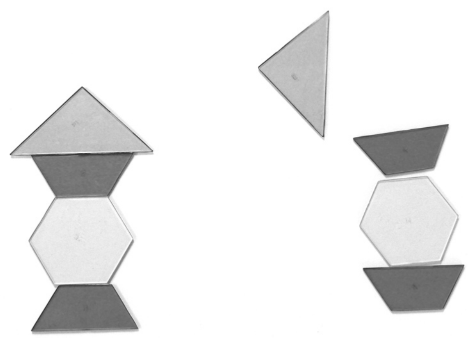

Figure 2. Game of copying designs.

"Hmmm … well … not quite. You've made a hexagon. Like this." I covered the two trapezoids with a yellow hexagon. "A hexagon has six sides. See ... one, two, three, four, five, six. A stop sign has eight sides" (see Figure 3).

"Where's a stop sign?"

"I don't think there is a stop sign here." We searched briefly through the polygons. I was well aware of Martin's fascination with traffic lights, stop signs, yield signs, and all other forms of traffic signs.

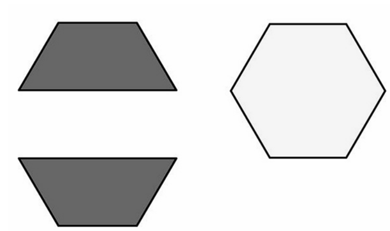

Figure 3. Two trapezoids congruent to a hexagon.