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Mathematical Dispositions and Student Learning: A Metaphorical Analysis

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Mathematical Dispositions and Student Learning: A Metaphorical Analysis

Purpose

One of the most striking facts discussed in national reports on mathematics education is the large number of high school students who avoid taking advanced mathematics courses. Generally, these students fail to enroll in advanced math classes because of their negative mathematical disposition or because of their perception of their future career opportunities, rather than because they lack innate ability. According to NAEP, in grade levels 4, 8, and 12, students who agreed that they like mathematics and who think mathematics is useful for solving problems scored higher than students who disagreed on those items (Silver & Kenney, 2000). Yet even among those students who expect to become scientists, less than 75% believe that advanced mathematics or science courses are necessary for their future careers (e.g., Ma, 2006). In order to improve students' learning of mathematics, we have to face the challenges of changing students' attitudes toward mathematics.

To effectively nurture students' mathematical disposition, it is necessary to understand how students view mathematics. The purpose of this study is to use metaphorical analysis to understand students' mathematical disposition, and also to explore how their mathematical dispositions are related to their mathematical achievement.

Theoretical Considerations

In Greek, the term metaphor means "carry something across" or "transfer," and usually refers to a comparison between two things, based on resemblance or similarities. Metaphors have been widely used in everyday life to describe complex concepts and to express a person's thinking. A striking metaphor can often prompt deep understanding and reveal underlying meanings that otherwise would be difficult to grasp. Cognitively, a metaphor is a mental construct that helps us structure our experience and activate our imagination and reasoning (Lakoff & Johnson, 1980). Metaphors can evoke powerful imagery to help organize and interpret information, decide what is important, what to attend to, and what to ignore. Often, a metaphor has been used as a basic means to make an abstract thought more accessible (Lakoff & Núñez, 2000).

In mathematics, it is a usual practice for mathematicians to use metaphors to represent and think through mathematical problems and make connections (Sfard, 1994). Pedagogically, metaphors can be effective instructional aids in making sense of mathematics. Many metaphors have been used to teach mathematics, but for a metaphor to be effective, one needs to be familiar with the construct to which the new knowledge is being compared. Because of this, some metaphors may be more appropriate than others (English, 1997). In fact, the power of a metaphor lies in its ability to help a person make sense of new conceptions in terms of already existing conceptions (Lakoff & Johnson, 1980; Presmeg, 1992). Thus, metaphors, used appropriately, can facilitate both conceptual understanding and problem solving.

In recent years, there has been an increased interest in using metaphors as a research tool to understand the processes of thinking and problem solving (e.g., Borgman, 1999; Cameron, 2002; diSessa, 1993; Hsu, 2005; Martins & Ogborn, 1997; Pimm, 1981; Sfard, 1994). For example, using semi-structured interviews, Chiu (2002) examined the way novices (middle school students) and experts (students in a master's program who completed at least two years of college mathematics) solved three problems involving negative numbers. He found that both novices and experts used metaphors to reason, understand, and solve these problems. However, the experts articulated more metaphors and used them more selectively, while the novices used metaphors less skillfully but more frequently. These studies showed that metaphors can be a powerful tool to understand the processes of thinking and problem solving.

Researchers also used metaphors to understand teachers' perceptions of mathematics and the teaching of mathematics (Bullough, 1991; Cooney et al., 1985; Miller & Fredericks, 1988; Munby, 1986; Sfard, 1998; Wolodko, Willson, & Johnson, 2003), and public images about mathematics (Lim, 1999). Bullough (1991) used metaphor analysis to engage pre-service teachers in an examination of their conceptions of teaching. The metaphor analysis helped pre-service teachers realize that thinking of teaching as gardening, coaching, or cooking can make a great deal of difference in the way they teach. Also, whether one thinks of children as clay to be molded, as players on a team, or as travelers on a journey makes a great deal of difference in one's approach to teaching (Bullough, 1991; Connelly & Clandinin, 1988). Lim (1999) used metaphor analysis to explore the images of mathematics held by a group of adults from the United Kingdom. The analysis of the metaphors revealed that this group of adults viewed mathematics as a journey, a skill, or a game/puzzle.

While metaphorical analysis can be an insightful way to study teachers' perceptions about and teaching of mathematics, little work has been done using metaphorical analysis to study school students' mathematical dispositions (Authors, 2011; Gibson, 1994). Gibson used cars as metaphors to help high school students think and write about their views of mathematics and themselves as learners. In an exploratory study, we attempted to use metaphorical analysis to assess students' mathematical dispositions. We found that the use of metaphors is quite accessible for students to describe their dispositions toward mathematics. Metaphors not only provide a richer context and expanded vocabulary for students to express and communicate their dispositions toward mathematics, but they also provide a means of showing various degrees of affection toward mathematics.

In this study, we used sets of two familiar objects—food and animals—as potential metaphors to probe students' mathematical dispositions. We investigated what this potentially powerful assessment tool revealed about students' mathematical dispositions, and as well as the relation of their mathematical dispositions to their learning.

Method

Subjects

The data were from a large research project that examined the differential effect of reform and non-reform mathematics texts on students' algebraic thinking ability. Nearly 1300 9^{th} grade students participated in the study. Male and female students were approximately evenly distributed. About 60% of the participants were African Americans, 19% non-Hispanic white, 16% Hispanic, 4% Asian, and 1% Native Americans.

Data Collection and Analysis

Each of the 9th graders was asked to complete six mathematics assessment tasks and a metaphor survey. Figure 1 shows the Metaphor Survey Instrument. In this instrument, each of the student was asked to use food and animals as metaphors to show their dispositions toward mathematics. Students were instructed to think about the questions and describe how they truly felt about mathematics. Most importantly, students were also asked to describe how the specific food and animals they chose mirrored their dispositions toward mathematics.

We are interested in learning how you think and feel about mathematics. Please consider the following questions and tell us how you truly feel. There is no right or wrong answer.

If Math were a **food**, it would be______________because___________________________________

____

____

If Math were an **animal**, it would be_________________because____________________________

____

____

Figure 1. Metaphor Survey Instrument.

The metaphor data were analyzed both qualitatively and quantitatively. In the qualitative analysis, each student metaphor was categorized by type of food or animal chosen. The purpose of the qualitative analysis was to specifically show what kinds of metaphors students used and why. Through analyzing their metaphors, we aimed for an in-depth understanding of their feelings about mathematics as well as an understanding of why they have developed such feelings about mathematics.

In the quantitative analysis, a holistic scoring rubric was developed to score each of the students' responses using a 6-point scale (0-5). Table 1 shows the scoring rubric. In the quantitative analysis of metaphors, we coded the two metaphors using food and animals as an integral whole. Such an analysis is desirable and possible since generally an individual student displayed similar feelings about mathematics using each of the two metaphors. If a student showed opposite feelings toward mathematics in their two metaphors, then that student was assigned a disposition score of 3 (ambivalent/neutral). In a few cases, a student's metaphors showed two different degrees of disliking (1 and 2) or two different degrees of liking (4 and 5) mathematics. In these cases, the students were assigned disposition scores of 2 and 4, respectively.

Table 1.
Scoring Rubric

Disposition Level	Score Description	Examples
0 Indeterminate	Student indicates no feelings, so it is impossible to determine disposition.	• Pizza: it's a pie and they use them in the math books.
1 Very Negative	Student indicates strong feelings of disfavor, using words or phrases such as "hate," "disgusting," "very bad," "really dislike," "scary," "nasty," etc.	• Math and lizards disgust me.
2 Moderately Negative	Student indicates moderate feelings of disfavor, using words or phrases like "dislike," "bad," "irritating," etc. Words like "hard" as well as the phrases "bad for you" and "don't need it" are interpreted as unfavorable unless qualified by something favorable like "…but I like it" or "I need it."	• I dislike math like I dislike broccoli. • Math gets on my nerves, and it is also irritating.
3 Ambivalent/ Neutral	Student indicates ambivalence or neutrality. This includes the case where a student indicates positive feelings in one response and negative feelings in the other.	• Noodles: Sometimes I love noodles and other times I hate it. • Math is okay. • Vegetable: I don't like it but I have to have it.
4 Moderately Positive	Student indicates moderately favorable feelings, using words like "fun," "like," "good," "delicious," etc. Words like "easy" or the phrases "good for you" and "need it" are interpreted as favorable unless qualified by something unfavorable like "…but I don't like it" or "I don't need it."	• Puppies are fun to play with just like math is fun to do. • Tacos are good and math is good for your brain.
5 Very Positive	Student indicates strongly favorable feelings, using words like "love," "awesome," "best," "favorite," "really like," etc.	• I love math. Math is my favorite subject and pizza is my favorite food. • Dogs to me are the best animal and math is the best subject.

Initial Findings

Mathematical Dispositions

Students often used metaphors in striking ways to express their love or hate of mathematics. They used a large variety of foods and animals to express how they felt about mathematics. It was when they explained *why* they chose a food or animal that they revealed their inner disposition toward mathematics. Here are examples that show that they like and enjoy mathematics:

- *Tortas are very good. It's full of stuff that will fill you up. Math is the same because it's full of good stuff to fill your brain up with knowledge.*
- *Koalas are very interesting animal to know about. Math is also very interesting and good to know about.*

Similarly, students used metaphors to express their dislike for mathematics. For example:

- *Like chitlins, math is an acquired taste that most people, including myself, find disgusting and distasteful. I hate chitlins, I hate math. It's that simple.*
- *Dogs are horrible, and hard to understand why they act the way they do and that's similar to math.*

Gender and Ethnicity Differences

A Chi-square test showed that there were no differences in disposition levels due to ethnicity. However, we found a significant difference between the dispositions of male and female students (χ^2=0.16; $p < 0.01$). African Americans females, in particular, showed significantly more positive mathematical dispositions than African American male students (see Figure 2). Specifically, 35% of the African American female students showed Moderately Positive or Very Positive (levels 4 or 5) mathematical dispositions, but only 20% of the African American male students showed Moderately Positive or Very Positive mathematical dispositions ($z = 2.43$, $p < 0.01$).

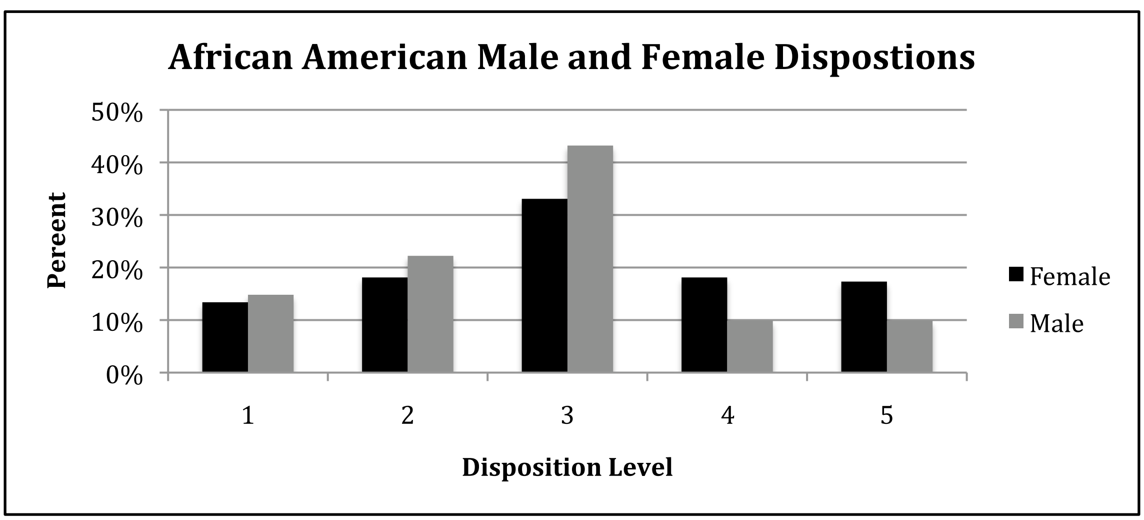

Figure 2. Disposition levels of male and female African American students.

Relatedness of Mathematical Dispositions and Student Achievement

In the full paper, we will use regression models to examine the relatedness of mathematical disposition to student achievement.

Significance

This study is significant not only because it provides an alternative means of examining students' mathematical dispositions, but also because it provides insights about the relatedness of mathematical disposition and learning.

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