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Metaphors and Mathematical Identity: Math is Like a Tornado in Kansas

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Abstract

Mathematical identity is an individual's concept of who he or she is mathematically. In this paper, metaphors for mathematics from elementary education majors are compared to metaphors created by secondary mathematics teaching majors. The analysis demonstrates a basic difference in the mathematical identity of the two groups, with the latter group having more holistic conceptions of mathematics than the first group. Elementary education majors describe mathematics as an ongoing struggle in which the mathematics is active, and they are the victims. The secondary teaching mathematics majors describe mathematics as an ongoing struggle in which they are active.

1. Introduction

Mathematical identity is an individual's concept of who he or she is mathematically [23]. It might include a person's concept of their own mathematical ability; their comfort level with mathematics; their sense of what mathematics is; or their concept of the worth of mathematics [13]. Students' mathematical identities can aid in understanding why some students are attracted to the field of mathematics and others are not [2, 4, 18].

Elementary teaching majors differ from secondary mathematics teaching majors in their main motivations for choosing their careers. Elementary teaching majors tend to choose their careers because they want to work with children [26], while secondary mathematics teaching majors tend to have a love of mathematics, along with wanting to teach [7]. Students who major in mathematics are directly influenced by their mathematics ability, the courses they have taken in mathematics, and their belief about themselves as mathematically capable [25]. Students who major in elementary education tend to have quite high levels of math anxiety [16]. Thus, it is likely that secondary teaching mathematics majors have more affection for mathematics than do elementary education majors.

Society portrays mathematics as something that only a small number of people are able to do. "Mathematics holds a privileged status in our society as an elite activity for the smartest of citizens. That assumption supports a view of mathematics as out of the reach of the common' man and thus disconnected from and inaccessible through everyday experiences" [18, page 226]. Much attention has been given to showing the public that mathematics has a wide array of applications and mathematical ability is something that is not solely for the chosen few. The aim is to convince those who do not identify as being "mathematical" that they are capable of learning and doing mathematics.

In this paper, metaphors for mathematics from elementary education majors are compared to metaphors created by secondary mathematics teaching majors. Our main finding is a clear, basic difference in how members of the two groups identify with mathematics. An implication for how society might convince more people that they are capable of doing mathematics will be offered at the end.

2. Definitions: Mathematics, Identity, Metaphor

2.1. Definitions of Mathematics

First, let us consider how mathematics is defined. The way that an individual defines mathematics may reflect the individual's attitudes about mathematics. How one views mathematics is thus part of the person's mathematical identity.

Some research in mathematics education has attempted to identify what mathematics is, although not with a lot of consensus. Both elementary and secondary students often have little to no idea what mathematics is beyond what they do in math class (e.g., work arithmetic problems), and secondary students often conclude that mathematics is something that "others" do [14].

Perhaps easier than defining *mathematics* is defining, more particularly, *school mathematics* or *everyday mathematics*. Elementary teaching majors reacted quite negatively when describing mathematics in general, but much more positively when describing the mathematics they encounter as part of their everyday life [5].

Some researchers have abandoned the attempt to answer the question of *what* mathematics is but instead focused on answering the question of *where* mathematics is. That is, does a given activity amount to mathematics or not? Is there mathematics in the activity, and according to whom? Young students identified mathematics as occurring in dressmaking, playing pool, knitting, playing chess, and making a robot [8].

2.2. Mathematical Identity

Mathematical identity is a "set of reifying, significant, endorsable stories about a person" [23, page 14] and about how that person relates to mathematics. It has been suggested that a person's mathematical identity reveals something about that individual as an individual; something about one's very being [13]. The relevance of mathematical identity is particularly appropriate when asking such questions as, why do particular individuals like mathematics? Why do particular individuals engage in mathematics? [23]

It is our position, however, that one's mathematical identity is not a given and not static. Rather, like other parts of one's identity, it is constructed and always under construction. This construction is influenced by a number of factors, including teachers one has had, courses one has taken, performance in math courses, and society at large.

Mathematical identity is critical to understanding the level to which an individual perseveres, achieves, and engages in mathematics [2, 4, 18]. Mathematical identity can also explain if students view themselves as members in a practice. That is, there are people who are able to do mathematics, and they are active participants in the practice of mathematics. Unfortunately, most people do not view themselves as members in the practice of mathe-

matics; but rather, they view mathematics as something that "others" do [14, 17].

Research on people's mathematical identity is increasing, with interviews and the writing of mathematical autobiographies serving as common tools [3]. In this study, we examine a particular component of mathematical identity, and that is the way in which an individual defines mathematics and one's personal relationship to it. Simply asking the question "what is mathematics?" is problematic at various levels. It seems to result in trivial answers (e.g., "mathematics is math," "mathematics is arithmetic") from most people. As we have seen in this study, asking people to write metaphors for what mathematics is proves to be a bit more successful.

2.3. Metaphors

A metaphor uses easily understood ideas from one concept to illustrate a second concept that may be more difficult to describe. Thus, metaphors are used to explain something less understood in terms of something that is more understood. Using a metaphor can contribute to a new understanding of an old topic [6, 12].

When metaphors are used by students to describe how they feel about learning mathematics, the students' attitudes towards mathematics are often part of the metaphor [11, page 41]. The process of creating a metaphor forces a person to actively search for one's own meaning [1, 10, 19, 22]. "If a picture is worth 1,000 words, a metaphor is worth 1,000 pictures! ... A metaphor provides a conceptual framework for thinking about something" [24, page 102].

Nearly 100% of elementary education majors described mathematics as arithmetic when asked to write down what mathematics is, but all of these same students described mathematics as something other than just arithmetic when asked to write a metaphor [14]. Other studies have revealed that secondary students had "well developed and complex views about mathematics" when they used metaphors [21, page 326]. Strong negative emotions were shown by ninth through twelfth graders when using metaphors [10]. Mathematics teacher candidates in Turkey created metaphors for mathematics that described mathematics as limitless, interconnected, needed, or fun. In addition, their metaphors revealed that mathematics "requires effort and permanence" [9, page 298].

2.4. The Relationship Between Identity and Metaphor

One's mathematical identity is at least partially dependent on whether one views oneself as a member of the group that does, likes, and succeeds at mathematics, and, in turn, how one defines mathematics is dependent on holding this membership or not. Previous research has worked with mathematical identities, but attempts to define mathematics directly as part of an interview or autobiography do not work well, especially for non-mathematics majors. When asked to provide definitions, students struggle with describing numbers and number operations (e.g., adding, multiplying). Because metaphors force the participants to search for personal meaning (instead of attempting to find the "correct" definition), using a metaphor for mathematics is identifying with mathematics in a particular way. Thus, in this very specific way, the metaphor is the identity.

3. Methodology

The present study was conducted through a sociocultural lens; that is, we assert that an individual creates one's own mathematical identity by engaging in mathematics in a social context, which by necessity has culture.

This study compares metaphors written by two sets of majors at a comprehensive university in the Midwest, those majoring in elementary education and those majoring in secondary teaching mathematics, to see if there are fundamental differences in the mathematical identities of the two groups.

The following research questions guided the study:

1. What are the mathematical identities of the secondary teaching mathematics majors?
2. In what manners do the mathematical identities of the secondary teaching mathematics majors differ from those of the elementary education majors?

3.1. Sample

One of us teaches undergraduate mathematics courses to elementary education majors and secondary teaching mathematics majors at a mid-sized university in the Midwest. The samples used in this study were all students in those courses: one class of elementary education majors ($n = 93$ during fall 2013) and two classes of secondary teaching mathematics majors ($n = 21$ during spring 2014 and $n = 17$ during fall 2014).

3.2. Data and Analysis

Students in a section of *Mathematics for Elementary Education Majors* and in two sections of *Foundations in Mathematics* (a required introduction to proofs course for secondary teaching mathematics majors) were all asked to write metaphors to describe what mathematics is. The two of us separately coded the resulting metaphors.

A metaphor has a topic (in our case mathematics), a target (what mathematics is compared to), and a ground. The ground describes how the topic and target relate [20]. We read each metaphor and grouped metaphors that shared a common ground. We then each created a name for each group. For example, one of us named one group "up and down" (that is, mathematics is a process with ups and downs), and examples of metaphors in it were "*Math is like a roller coaster*" and "*Math is like going up and down hills*".

At the next step, we compared category names. At this point, we did not discuss which metaphors were placed into which categories, but only the names of the categories that we had developed. Obviously, it does not matter what each researcher named each group if the meaning is the same. Once groupings were understood, each metaphor was compared to see if it was placed in the same group. Before discussion, we had 100% agreement on the groups, and 98% agreement on which metaphors belonged in each category. After discussion, the agreement on which metaphors belonged in each group was 100%. A note should be made here that analyzing metaphors is a rather subjective process. Although having both authors separately examine the metaphors adds to the validity of the process, by its nature, there will be disagreement on the emergent categories if other researchers were to repeat the process.

The categories from the secondary teaching mathematics majors cannot be directly compared to the categories from the elementary teaching majors. Rather, we compare themes that emerged from each group. An example might serve as an illustration. The category of "puzzle" was included in the elementary education majors group, but not included in the secondary teaching mathematics majors group, although that group also used the term "puzzle" at times, although not as often. Elementary education majors used the term to describe the process of mathematics, but included a negative dimension or difficulty to it (e.g., "*Math is like a puzzle, there is always a lost piece.*"). The secondary teaching mathematics majors used the term to

describe a process that the participant completed (e.g., "*Math is like a puzzle; many smaller pieces that I put together to make up the entire masterpiece.*").

Categories are illustrative within a group, but we did not stop there. Once the groups were formed and agreement was reached, we examined the groups to see what themes were revealed. It was the resulting themes from the elementary education majors that were compared to the themes from the secondary teaching mathematics majors.

4. Results

4.1. Elementary Education Majors

The metaphors from the elementary education majors revealed two main themes. First, 43% of the metaphors were categorized as viewing mathematics as an up and down process that the students felt little to no control over. For example, one elementary education major wrote, "*Mathematics is like riding a roller coaster.*" One can argue whether riding a roller coaster is fun or not, but the up and down nature of the roller coaster is evident. More importantly, the rider is not controlling the roller coaster, only riding it.

Second, 25% of the metaphors described mathematics as very difficult and unpleasant. One student wrote, "*Math is like trying to walk on water, very difficult.*" Another, "*Math is like walking through a field of bombs I don't want to set off.*" And another, "*Math is like a tornado in Kansas.*"

The remaining metaphors were distributed across four different categories: mathematics is a puzzle (11%), mathematics is necessary (9%), mathematics is easy and pleasant (8%), and mathematics is a language (4%). We report more details on individual metaphors in our article "Math is like a lion hunting a sleeping gazelle" [15].

4.2. Secondary Teaching Mathematics Majors

Three themes emerged from the groups of metaphors written by the secondary teaching mathematics majors. First, 55% of these majors viewed mathematics as a way of thinking. Mathematics was not so much any particular content, but a process that one must enter into and try to navigate. The process requires thinking on the part of the participant. For example, one student wrote, "*Math is like baking a cake. It's a process that takes*

lots of ingredients and requires lots of patience to get it just right." Another example is "*Math is like a giant never ending puzzle, all the pieces are interconnected but the challenge is to get the pieces all together to understand the concepts.*" Similarly, one respondent wrote, "*Math is like building with LEGOs, you have all the pieces you just have to find out how to make it.*"

The metaphors in the thinking category describe some process (e.g., baking a cake, building with Legos, running a marathon, playing the piano) with which the participant must be actively, profoundly, and enduringly engaged. All the metaphors representing this theme suggest that it takes a good deal of effort to continue to work with the process.

The second theme that emerged among the respondents' metaphors was the view of mathematics as a struggle. This set of data suggests that secondary teaching mathematics majors do not find mathematics particularly easy or pleasant. None of the metaphors given by the secondary teaching mathematics majors describe a sense of natural ability. Their metaphors describe struggle. The metaphors also describe a nearly "love/hate" relationship to mathematics, with the love coming at moments in the struggle where success is temporarily reached. Then the struggle continues. The metaphors are multifaceted and rich in description, many taking up entire pages. Many of the metaphors emphasize the difficulty and awkwardness of learning mathematics.

- *Math is like growing a third arm; at first it is really awkward and an inconvenience, but then as you get used to it, you can do so much more and do more than you ever could before.*

In addition, the metaphors are often quite emotional:

- *Math is like your mother; has the power to make your life miserable, but if you do everything right everything is OK! Sometimes her rules are ambiguous and it is up to you to figure it out... Sometimes you choose right, sometimes you choose wrong.*

The final theme emerging from the secondary teaching mathematics majors is that mathematics is seen as an essential body of content. One needs mathematics for other disciplines, for everyday problems, and for the world to advance or mathematics is simply needed for its mystery, vastness, and beauty. The following pieces of data are illustrative of this theme:

- *Math is like a toolbox. You can use it to solve all sorts of problems.*
- *Math is like the language in which we describe the world we live in through physics, chemistry, and biology.*
- *Math is a beautiful rain forest that has so many interesting things just waiting for someone to solve their uniqueness and make advancements in the world today.*
- *Math is like the deep blue ocean so vast and unknown.*
- *Math is like the sun shining, intense, and full of comfort.*
- *Math is like an unending spider web.*

4.3. Comparison of Metaphors

The results of our study lead us to assert that if all of the metaphors were mixed together, and one was chosen randomly, it would be quite easy to guess whether an elementary education major wrote the metaphor or a secondary mathematics teaching major wrote the metaphor. They differ that much. In fact, after we had this thought, we actually attempted it, with 100% accuracy. In particular, three key differences emerged in the data. See Table 1 for a summary of the differences.

We found that both groups tend to view mathematics as a process. However, the secondary teaching mathematics majors describe mathematics as a thinking process. It is simply the nature of mathematics. The elementary education majors seem to think there is something about themselves that makes mathematics require too much thinking or work. That is, mathematics is so difficult to them personally that the whole process is one of an up and down nature: Sometimes it goes well, sometimes it goes poorly.

The difference is subtle, but quite profound. Both groups are seeing mathematics as a process with success and failure, but the secondary teaching mathematics majors describe mathematics in an active manner; the participant is actively involved (e.g., climbing a mountain). The elementary education majors give the activity in their metaphors to something outside of themselves (e.g., a storm, a roller coaster, or a hurricane). At a psychological level, the data give us an indication about the individual's locus of

Table 1: Main Differences between the Two Sets of Metaphors.

	Elementary Education Majors	Secondary Teaching Mathematics Majors
Locus of Control	Around 40% of the participants gave metaphors that view mathematics as being outside of one's self, and around 11% could be viewed as inside one's self.	Around 80% of the metaphors view mathematics as being inside one's self, with 0% of the metaphors clearly showing an external locus of control
Emotions	25% of the participants gave quite negative metaphors.	Most describe mathematics as a struggle, but the struggle is not negative.
Usefulness, beauty of mathematics	Around 9% of the metaphors mention the usefulness of mathematics.	About 45% of the metaphors mention the usefulness and/or beauty of mathematics.

control. Among the elementary education majors, in general, the mathematics metaphors suggest an external locus of control, which is to say that the individuals do not control what is occurring; they are at the mercy of outside forces. Among the secondary teaching mathematics majors, however, the prevailing message through the metaphors they offered is that they have an internal locus of control — that is, the individuals believe that they can influence events and outcomes; they have a sense of human agency.

The elementary education majors appear to feel more at the whim of mathematics. One metaphor given by an elementary education major was "*Mathematics is like a lion hunting a sleeping gazelle, and I am the gazelle.*" Although this is an active metaphor (a lion hunting), the elementary education major takes an inactive role. Another example is "*Mathematics is like a pigeon flying into a hurricane.*" One wonders if the pigeon or the hurricane is

taking a more active role, and if in fact, the hurricane (mathematics) is acting on the pigeon (the elementary education major). In the secondary teaching mathematics majors' metaphors, the role of activity always belonged to the one writing the metaphor. The individual is an active protagonist in the scenario suggested by the metaphor.

The metaphors, then, seem to suggest a basic identity difference between the two groups of majors. The secondary teaching mathematics majors view themselves as capable of doing mathematics. They identify as mathematics doers. The elementary education majors do not identify themselves as doing mathematics, but as having mathematics done to them, and, thus, being an outsider to the process.

We first noticed the difference in locus of control while examining the secondary teaching majors' metaphors categorized in the thinking category. Once we noticed that all of these metaphors were given in a very active manner, we reviewed all metaphors again to see if others referenced activity on the part of the person.

About half of the metaphors that secondary teaching majors gave in the usefulness category also showed an internal locus of control, as did metaphors that described mathematics as a struggle on the part of the participant. Some metaphors (such as, "*Math is like the deep blue ocean so vast and unknown*") did not seem to describe either an internal or external locus of control, and some (such as, "*Math is like a language that describes the universe*") seemed to us to be an internal locus of control, but that may just be the way we viewed it. So, we erred on underestimating the percent of metaphors that described an internal locus of control, and we give this percent as around 80%. The remaining 20% were not viewed as having an external locus of control, but only that we were not confident that an internal locus of control was described.

The situation was nearly an exact opposite when we re-examined the elementary education majors' metaphors. Nearly 40% very clearly showed that the locus of control was outside oneself (such as, riding a roller coaster). In addition, a few metaphors showed activity on the part of the person, but still somewhat beyond one's full control (such as, being in a storm). Around 11% of the elementary education majors described mathematics as a puzzle, and these may be viewed as an internal locus of control.

The second important comparison is that about one-fourth of the elementary education majors were extremely negative about mathematics. This is simply absent from the secondary teaching mathematics majors' metaphors. Although they describe mathematics as a struggle, this actually seems to be part of the delight of it for these majors. Note that this result might be stated in the opposite direction. That is, approximately three quarters of the elementary education majors were not negative about mathematics. Although only a small percent were quite positive, most of the metaphors were rather neutral. It is an important result that a quarter of the elementary education majors spoke negatively about mathematics (while none of the secondary teaching mathematics majors did), but it is not an overwhelming statement about the difference between the majors.

Finally, nearly half of secondary mathematics majors gave metaphors that describe mathematics as needed for its usefulness and/or needed for its great beauty. None of the elementary education majors gave metaphors that described mathematics as beautiful, although around 9% described mathematics as needed.

The differences between these two groups have been the emphasis of this paper. However, it should be noted that there are similarities between the groups as well. The difference regarding locus of control is where this paper can make a true contribution to the research base. At first, this too appears to be a similarity. Both groups describe mathematics as a process. This is in fact an unexpected result. Earlier research seems to describe elementary education majors are viewing mathematics in a more static manner [14]. Mathematics is a set of material that one must memorize, for example [5, 14]. But, in this study, both sets of participants view mathematics as a process. The difference, while subtle, is about just who is in control of the process.

5. Concluding Comments

Secondary teaching mathematics majors' metaphors describe mathematics as an ongoing struggle in which they are eager to be active. Elementary education majors describe mathematics as an ongoing struggle in which the mathematics itself is active, but they are the victims.

This study offers a recommendation for those who aim to convince more people that they are capable of doing mathematics. Rather than trying to convince people that mathematics is not a struggle, mathematics educators

should attempt to help people be more comfortable with the struggle and challenge the notion that who these students are mathematically is radically different than people who are successful at mathematics. The "membership rules" for being a mathematical person need to change to include those who currently do not view themselves as an "insider" mathematically. The use of historical stories of mathematicians, exposure to real mathematicians, and/or increasing the opportunities for students to discover mathematics or work with real-life mathematical situations are all possibilities that may help those who struggle with mathematics to still identify with mathematics, as struggle is not outside a mathematics student's identity.

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