Constructing Meaning through Making and Creating

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Abstract

Metaphor is frequently used in theatre to convey important messages to the audience. An interdisciplinary honors class used metaphor and theatre to teach students mathematics. Each group created a tangible object that was relevant to a mathematical principle of choice and that embodied a metaphor. Each tangible object was presented to the greater community at an art opening. Two of the projects will be discussed in this paper as well as results from a pre- and post-course surveys on students' perceptions of mathematics.

Introduction

The use of metaphor is a powerful tool to draw a comparison between two seemingly unrelated objects, or ideas. For example, Arthur Miller's The Crucible is about the Salem witch trials of the 1600s on the surface, but on a deeper level it is a commentary on McCarthyism, that is, the "witch hunt" for communists during the period in which the play was written. Metaphor is frequently used in theatre to convey important messages to the audience. An interdisciplinary honors class used metaphor and theatre to teach students—from a wide range of disciplines—mathematics. The goal of this paper is to discuss the class environment and to report pre- and post-course survey data on students' perceptions of mathematics.

Course Description

Invisible Theatre: Math and Metaphor as Actors on the Digital Stage was offered Falls 2014 and 2015. Data were only collected in 2015 so this paper discusses student work from that semester. The class had 18 Honors students: 11 identified as female, and 7 as male. These students were invited to join the Honors program because they had a minimum 3.5 high school GPA and minimum 1170 combined SAT score. There were 10 STEM majors (Biology, Chemistry, Physics, and Computer Science) and 8 non-STEM majors, but no math majors or minors. The students were a mix of sophomores to seniors.

The course was cross listed; depending on which section the student signed up for, s/he either received the general education requirement Quantitative Reasoning or Creative and Artistic Expression. The course was taught by two instructors: an Assistant Professor of Mathematics and the Technical Director of Theatre Arts. We met for 3 hours and 10 minutes once a week, for 15 weeks, in several different spaces: a computer lab classroom with tables conducive to group work and discussion (rather than rows which promote lecture) main stage, the theatre shop, and the Cabaret (which was usually set up with tables). The pedagogical backbone of the course was to engage students through active participation. There were very few lectures and the students spent most of the time exploring by playing (e.g. Torus-Tic-Tac-Toe), making (e.g. mathematical knots and theatrical knots), and creating (e.g. welded structures).

Mathematical Concept	Technical Theatrical Concept
Elementary topology (through explorations of the properties of the mobius and the torus) and hyperbolic geometry	Costume design and fashion, e.g. mapping the body with 2 dimensional objects
Conics and the cardioid	Optics and Acoustics
Elementary knot theory including mosaic numbers and cubic lattice numbers	Mechanical advantage and theatre knots
Tiling and Platonic and Archimedean Solids	Tension and Compression through building tensegrity models
The number and concept of Zero as a vehicle to discuss elementary set theory and elementary number theory	Metaphor

Table 1 : *Course Topics Related to Each Discipline*

Final Projects

The first 7 weeks of the course were devoted to exposing the students to the breadth of mathematical and/or technical theatrical topics (See Table 1). The rest of the class periods were devoted to studying a topic in depth in preparation for the final project. We had 5 groups and each group presented their proposals for their final project and created a prototype before fully constructing the final project itself. The goal of the final project was to build a tangible object that was relevant to a mathematical principle of choice and that embodied a metaphor. For the sake of space, only two projects are highlighted in this paper.

One group decided to make a dodecahedron infinity room. They first constructed a pentagon using only a compass and straight edge on paper to trace onto acrylic plastic two-way mirrors. They discovered that this method had flaws once they traced on the mirrors, so they chose a length and computed the interior angle of a pentagon and set the chop saw to that angle. In order to hold their dodecahedron together, they welded a base for it (See Figure 1). The top row of the figure shows the jig they created to weld the rods together. The bottom row shows the welded base and the completed project.

Figure 1 : *Dodecahderon Infinity Room Final Project*

The mathematical principles the students discussed in their project were infinities (countable and uncountable), and the theorized shape of the universe. The metaphor they used for the dodecahedron was the mind while the lights represented ideas, thoughts, and imagination. They claimed that, though physically bounded like the dodecahedron, "the mind is beyond any comprehensible boundaries." They accomplished this juxtaposition with the reflections of the lights inside the platonic solid.

Another group constructed a representation of a hyperbolic paraboloid. To create the negative curvature, the group used square dowels that are tangent to the surface of the curve. They used a compound miter saw to create the angles they needed for the dowels to join. The underlying structure that they used was a tetrahedron (see Figure 2). The dotted lines superimposed onto the left-side of the picture represent the dowels of the tetrahedron they removed once the tangent lines were secured into place. The final project along with three of the group's prototypes is on the right-side of the figure.

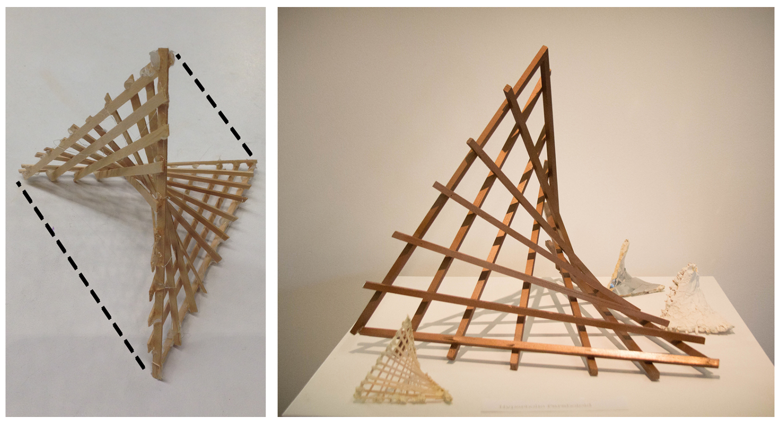

Figure 2 : *Hyperbolic Paraboloid Final Project*

Their project illustrated the mathematical principle of using tangent lines to approximate a curve. They also discussed saddle points. The metaphor that they connected their project to was a saddle at a local hike, Marshall Canyon. That is, the point at which a hiker can either chose to summit to either peak in one direction, or go back down in a different direction.

Data Collection and Analysis

Students were asked to complete a pre-survey and a post-survey. Survey items were taken from existing questions [1] [2] [3] and also created by one of the authors. The surveys had three free response questions, and 25 Likert items with a scale of 0-5. The pre- and post-surveys were identical except the post survey asked students to identify their genders and intended majors. Only the scaled items will be discussed.

A Wilcoxon Signed-Ranks Test indicated that the median post-survey scores were statistically significantly higher than the median pre-survey scores on three items (there were no items that were statistically lower on the post-survey scores):

- Taking risks is important in doing mathematics ($Z = -2.066,\ p < 0.04$).
- I feel confident when I am doing mathematics ($Z = -2.807,\ p < 0.01$).
- Mathematics is important in everyday life ($Z = -2.484,\ p < 0.02$).

A Spearman's correlation was run twice to assess the relationship between each of these items with the others: once with the pre-survey data, and once with the post-survey data. For the sake of space, only items that are significantly correlated with the Taking Risks item are reported in Table 2. Items are ordered from largest positive correlations to largest negative correlations.

Pre-Survey Correlations	Pre- r	Post- r	Post-Survey Correlations
· Doing mathematics involves creativity	0.55^*	0.70^{**}	· I can think of many ways that I use mathematics outside of school
· The best way to do well in math is to memorize all the formulas	-0.49^*	0.67^{**}	· Doing mathematics involves creativity
		0.61^{**}	· The mathematics that I learn in school is thought provoking
		0.60^{**}	· Mathematics is a very worthwhile and necessary subject
		0.57^*	· Mathematics helps develop the mind and teaches a person to think
		0.56^*	· Student's perceived ability in mathematics
		0.55^*	· Making connections is important in doing mathematics.
		0.54^*	· I believe studying math helps me with problem solving in other areas
		0.52^*	· In mathematics you can be creative and discover things by yourself
		-0.55^*	· The best way to do well in math is to memorize all the formulas

Table 2 : *Correlations for Taking Risks* ($^*p < .05$; $^{**}p < .01$)

Table 2 shows that the post-survey data were correlated with many more items that the pre-correlated data for these data; this was true for each of the items above. There are many correlations so we will only focus on a few, namely the ones that relate to creativity. Higher importance of taking risks in mathematics is associated with increased perceptions that a) doing mathematics involves creativity, b) making connections is important in doing mathematics, c) one can be creative and discover things on one's own in mathematics.

Conclusion

Students were challenged to use theatre concepts such as metaphor to form a deep understanding of mathematics that they generally would not be exposed to in their major curricula. Through trial-and-error, students created tangibles such as a dodecahedron infinity room and a wooden representation of a hyperbolic paraboloid. To help themselves and the audience to understand the mathematical principles of these projects through metaphor, one group made a connection to the mind, while the other to the geography of a nearby hike, respectively. Pre- and post-survey data suggest that higher perceptions of taking risks in mathematics is associated with a view that doing mathematics involves creativity.

References

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