



## Reflections on the Teaching of Mathematics with Art

Education Notes

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I recently created a virtual museum which I have called the Museum of Art in Math Teaching<sup>1</sup> showing examples of the work I have done with my students in undergraduate mathematics classes using art to explore, develop, apply, reflect on, or assess mathematical concepts. The intent of this virtual space, which I will continue to expand and refine, is to inspire mathematics teachers at all levels to explore the possibilities that exist at the intersection of mathematics and art as enriching pedagogical tools. In the museum's Hall of Reflections, you can listen to a student who graduated from Rockhurst University in 2012 reflect on the impact of having experienced art as part of his undergraduate learning of mathematics.<sup>2</sup>

I have used art in the teaching of undergraduate level mathematics in a variety of classes. For example, inspired in the Math Horizons paper on Fibonacci Mobiles by Alison Frane and Susan Goldstine<sup>3</sup>, I created a semester long project for Calculus 2 that lead students through the design and construction of a mobile while studying areas, centers of mass, sequences, and series.<sup>4</sup> The mobiles were displayed in our building's main hallway at the end of the semester. I directed an undergraduate research project in measure theory in which students created art pieces to further their understanding of concepts after every chapter of readings and exercises related to measure theory.<sup>5</sup> We showed the pieces at two venues at the end of this project. During the pandemic, while working with my students fully online on Calculus 1 and considering how to create meaningful assessments that could minimize dishonesty while creating opportunities for conversations with students, I developed a half semester project in which students wrote and illustrated a story book aimed at 5<sup>th</sup> graders and based on a calculus concept. The stories went through a few iterations of revisions before the final draft was turned in as part of the final exam, and the illustrated versions were read to 5<sup>th</sup> graders.<sup>6</sup>

In spring of 2020, I started teaching a class called Math in the Modern World (MMW), which is our university's version of Mathematics for Liberal Arts. The class has a different focus depending on the faculty member teaching it, and I designed the class to engage students in mathematical reasoning through art. MMW: Art consists of a collection of very hands-on modules which have varied from class to class, spanning concepts like symmetry, tessellations, polyhedra, 2D to 3D and back, fractals, perspective, knots, and visual presentation of data.<sup>7</sup>

From the beginning, I perceived a higher level of mathematical anxiety in students in MMW: Art compared to what I was used to from teaching mathematics to STEM majors. To understand better the situation, I introduced a few surveys to gather data about students' mathematical anxiety and their attitudes towards mathematics. I have collected information about mathematical anxiety from 82 students in four classes which fluctuated in size between 15 and 31 students per class<sup>8</sup> (not all students participated in the surveys). In the data collected, 50% of students reported not having a good relationship with mathematics including 35% of this subset who reported high levels of mathematical anxiety. Slightly less than one in six students expressed both a good relationship with mathematics and that mathematics does not create anxiety for them.

Capturing if there is any change in students' perception of mathematics from the beginning to the end of MMW: Art has been a challenge I continue to pursue. I have gathered some quotes with regards to how this class, which focuses on teaching mathematical reasoning through art, has changed how students think about mathematics. Here are three representative quotes.

*“My understanding of math has changed significantly. I say this because now I don't think of math as something solely found at schools and STEM major careers but it's all around us in nature and in our everyday life. I think this was because the class focused on everything to do with math but not in the standard way, it made me feel like maybe I wasn't as bad at math as I thought.”*

*Jocelyn Garcia-Flores*

*“This semester I learned that math can be different than solving equations and that it has an art side to it.”*

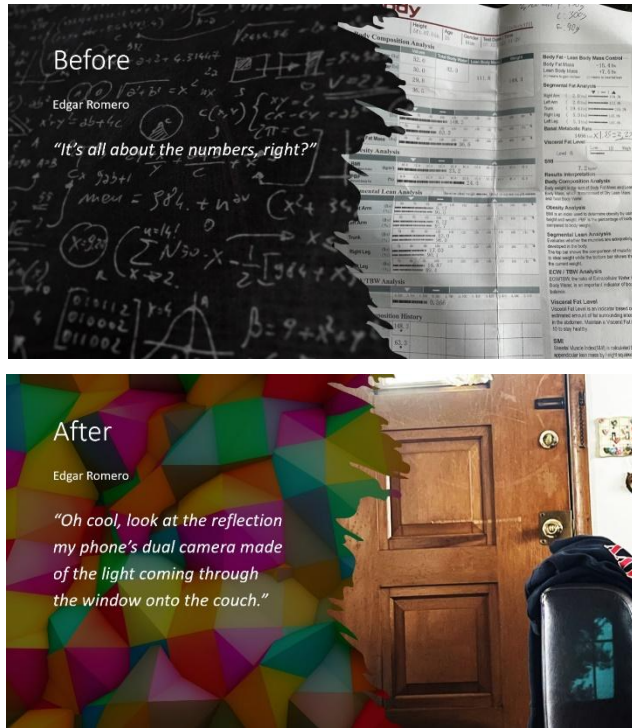
*Sarah Bernal*

*“I think just my concept of mathematics as a whole has changed. Before this class, I was very number oriented with my mathematical thinking, but now this class has shown me just how hands on and creative math can be.”*

*William Pender*

Though these comments reflect the sentiments expressed by many of the students, in the spirit of the class, I wanted to create a visual representation of their collective state of mind with regards to mathematics before MMW: Art, and after taking the class. I experimented with requesting that students submit a picture representing their relationship with mathematics at the beginning of the semester in the introductory quiz, and then again at the end of the semester in their final reflection. Figure 1 is an example of submissions by one student in the fall of 2021. I have annotated them with BEFORE and AFTER. The student, Edgar Romero, specifically commented on where he “sees” mathematics in each one of his submissions.

*Figure 2. Edgar Romero **Before** and **After** MMW: Art Fall 21*  
*Insert an IMAGE that describes your relationship with mathematics*



Combining all pairs of submissions (only students who submitted both images are represented) and using the images from Figure 1 as a background, I created the collages below. To be able to compare individuals within the group, every student's location on the collage remains the same on both images.

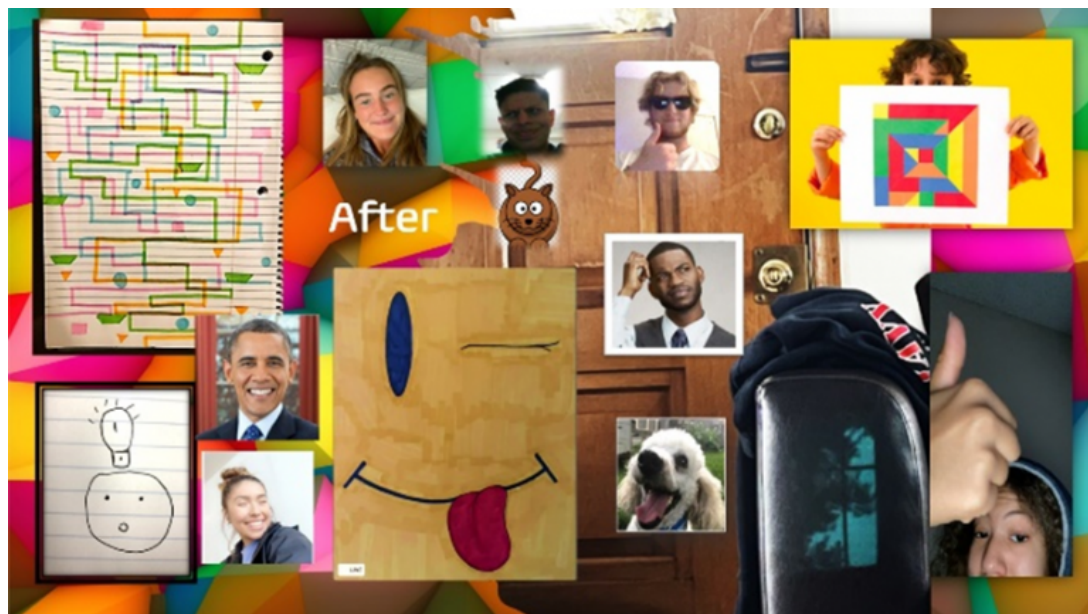
Figure 2. Insert an IMAGE that describes your relationship with mathematics

(a) Before and (b) After

Math in the Modern World: Art, Fall 21



a)



b)

The feel of these two images is quite different. I see two striking differences: color and expressions. The images seem to indicate a positive change in attitude with respect to mathematics which I would like to attribute to the hands-on-learning of mathematical reasoning through art. The word-cloud below, in which size reflects frequency of the word in the list, is a summary of the one-word description students used for the MMW: Art class.

Figure 3. Describe MMW: Art in one word<sup>9</sup>

I believe there is great potential for enriching mathematics classes at all levels using art as a pedagogical tool. This approach has been very rewarding and fun for me and my students, and it has been especially helpful in my classes for non-STEM majors which have large proportions of students with mathematical anxiety by creating more positive attitudes towards mathematics.

*Zdeňka Guadarrama is a Professor of Mathematics at Rockhurst University in Kansas City, Missouri. She has taught mathematics classes across the undergraduate curriculum, and used art as a bridge into the exploration, development, application and reflection of mathematical ideas.*

*She is the Department Chair of Mathematics, Analytics and Technology, and Director of Mathapalooza, a Mathematics outreach program which focuses on engaging people of all ages in mathematical explorations outside the standard K-12 curriculum. Because she believes that there is enough variety of mathematics out there for everyone to enjoy, and that play can help challenge conventions about what mathematics is and how it is taught, she is also the Co-founder of the social enterprise Math through Play.*

*Zdenka has written mathematics curriculum, given talks, designed workshops for teachers to help them bring mathematical inquiry into their classes, and created a range of programs to introduce the community to meaningful, beautiful, and enjoyable mathematics.*

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## Endnotes

<sup>1</sup>Z. Guadarrama, Museum of Art in Math Teaching: <https://app.cloudpano.com/tours/aOZK1V5Py>

<sup>2</sup>Video Serge Nevsky, Software Engineer, currently at Meta.

<https://drive.google.com/file/d/1MVbrDdokrnhqrU8bn2r3CF1ttuDzml3e/view>

<sup>3</sup>Frane, Alison and S. Goldstine (2008) Fibonacci Mobiles Math Horizons, 16(2), pp. 24–25.

<sup>4</sup>Art in Single Variable Calculus: <https://app.cloudpano.com/tours/aOZK1V5Py?scenelid=zgJok49ZU>

<sup>5</sup>Art in Math Undergraduate Research: <https://app.cloudpano.com/tours/aOZK1V5Py?scenelid=1YFJ76el4>

<sup>6</sup>Art in Single Variable Calculus: <https://app.cloudpano.com/tours/aOZK1V5Py?scenelid=zgJok49ZU>

<sup>7</sup>Some examples of student work from these classes can be found in Art in Math for Liberal Arts Galleries:

<https://app.cloudpano.com/tours/aOZK1V5Py?scenelid=tJj874hPg> and <https://app.cloudpano.com/tours/aOZK1V5Py?scenelid=kXdCwqKNt>

<sup>8</sup>Numbers of students who provided data by class and its modality: Spring 21 (25 students – fully online synchronous class), Fall 21 (23 students- hybrid class: one day on ground and one day online asynchronous), Spring 22 (20 students – online hybrid: one day synchronous and one day asynchronous), Spring 23 (15 students – classroom-based meeting two times a week).

<sup>9</sup>From end of the semester reflection, MMW: Art: Spring 21, Fall 21, Spring 22, Spring 23.

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