Engaging Community Through the Integration of Art and Mathematics

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Abstract

We believe that all students should have the opportunity to confidently and creatively engage in mathematical thinking in the classroom. We design experiences that integrate art and mathematics, and hence, foster a strong sense of ownership and investment inside and outside of the math classroom. We will share lessons from our practice over the last seven years in engaging school and local communities through these integrative experiences. Furthermore, we will guide participants in creative lesson design that can be introduced into their curriculum.

Introduction

In 2009, I, Ellie Balk was an artist in resident at The Williamsburg High School of Art and Technology and tasked with developing an arts integrated project for Algebra students. In preparation I found myself sitting in the back of a 9th grade algebra class experiencing all the anxiety and fear of my own high school math experiences. In an effort to understand what was being taught, I began to create a visual language for the lessons and found a connection to share with the students. I have been building upon these principles ever since and have taken the mission further to focus on using art as a tool to create community both inside and out of the school. In this partnership, we have completed over 15 public art projects visualizing mathematics. Through our projects, we have seen students that are struggling to come to school, become leaders. We see "outsider" students make friends. We see students that were not confident in math, showing greater interest in the subject.

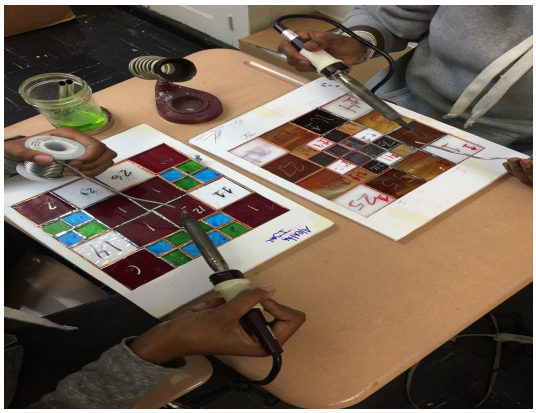

Figure 1: *WHSAT students soldering stained glass panels in a geometry class.*

Figure 2: *Entrance to WHSAT transformed by stained glass panels created by students.*

The mathematics are simple and come from a creative approach. I am not a mathematician. I am learning with the students as we use the art as a tool to make complicated math concepts more accessible. I have been collaborating on these public art projects with WHSAT math teacher Tricia Stanley and we have seen students not only be able to access mathematics in new and creative ways, but also develop confidence and a sense of community inside and outside of the classroom. We believe that "certain arts activities promote growth in positive social skills, including self-confidence, self-control, conflict resolution, collaboration, empathy and social tolerance" [1]. During this time we have transformed the front of the school with a stained glass project visualizing geometric transformations, Figures 1 and 2. Bringing power-tools into the math lesson, we challenged the students to understand systematic processes through an installation of two-point perspective painting on wood panels, Figures 3 and 4. We have taken the students outside the classroom and into the community to create a series of murals visualizing the number Pi on their streets in Brooklyn, Figures 5 and 6. Connecting students to understanding algebraic functions, we created multi-media mosaic installations on tables, Figure 7.

Figure 3: *WHSAT student using power drill to create two point perspective wood cut.*

Figure 4: *Two point perspective wood cut created by WHSAT students.*

Figure 5: *WHSAT students painting Visualize Pi One Point Perspective Mural.*

There is power for the students to see their art work on the path to school and down the hallways they walk everyday. This sense of ownership has created a strong school community. The experience of participating in these public art projects allow students to gain confidence in mathematics and connect to each other, making strong bonds.

Equity, Access, and Community Building

As a math teacher, I, Tricia Stanley want students to feel confident and use creative tools to think mathematically. I believe that the mathematical lens sharpens students' views in many areas of their lives, and therefore, their mathematics education should feature the student as an active agent within the community. In order to provide access to this lens, I have collaborated with artist Ellie Balk to develop not just projects but experiences that integrate artistic creation and mathematics instruction. We want the development of mathematical practices to reflect integrative associations that live both inside the classroom and outside in the community.

Figure 6: *WHSAT students participating in Visualize Pi Two Point Perspective Mural.*

We have seen results consistent with Ruppert's appraisal that "the arts help create the kind of learning environment conducive to teacher and student success by fostering teacher innovation, a positive professional culture, community engagement, increased student attendance, effective instructional practice and school identity" [2]. When students participate in an activity that makes them feel academically confident and beautifies their school or their local community they become more invested in the places they interact, Figure 7. The ownership they have over their mathematical knowledge as well as

their contribution to the public art installation creates investment that not only leads to them becoming a more confident person. but a more empathetic citizen.

Figure 7: *Mosaicked table, stained glass panels, two point perspective wood cuts in WHSAT Assistant Principal and Guidance office.*

Coinciding with our collaboration, we have seen student test scores on the New York State's Algebra 1 Regents Exam increase by 12.5% over the last three years [3]. This finding corroborates Hardiman's findings that "the empirical classroom experience of arts integration subjectively suggests that carefully structured arts-based pedagogy can improve students' learning and academic experiences, resulting in demonstrably positive outcomes that include deeper engagement in subject matter and better retention of content" [2]. By "taking time" out of a more traditional mathematics curriculum to have students participate in these experiences, we have experienced growth on the traditional measures of mathematical achievement.

An Integrated Arts and Mathematics Curriculum

In our collaboration, we have designed four projects that integrate art and mathematics in the classroom: Transformations in Stained Glass, Two Point Perspective Wood Cuts, Mosaicked Functions, and a series of Visualize Pi murals. All projects are designed with Common Core Standards and Process Strands in mind. One of the strengths in our collaboration is that each project is designed based on a specific gap we have observed between where students are and where they need to be within the traditional curriculum. Each of these integrative experiences have been designed to place mathematical content

within the artistic process. The art serves as a permanent representation of the students' mathematical manipulations. It serves as a landmark in the larger community to commemorate mathematical reasoning.

The Transformations in Stained Glass project allows students to not only identify geometric transformations on the coordinate plane, but also create their own transformations in stained glass. After conducting an item analysis for the past Common Core Geometry Regents (the New York State exams), we saw that transformations were a high leverage topic that would appear often on the exam. It was important for us to focus on this topic in the project because it provided a meaningful manipulative for students to understand translations, reflections, and rotations.

Figure 8: *WHSAT students scaling Visualize Pi One Point Perspective in their local community.*

The "Visualize Pi" murals asks students to visualize a data set and to use appropriate tools as well as attend to precision when scaling the mural itself, Figure 8. In the creation of the mural students engage in the work by creating and solving proportions to create perspective. The skills that students need in order to scale the mural range from more simplistic, such as using a ruler and basic arithmetic, to creating iterative formulas in Excel to model exact proportions.

In the Two Point Perspective wood cuts project, students are guided in a specific process to attend to precision. When reviewing our diagnostics for this unit we saw that students had difficulty translating text to three-dimensional diagrams and drawing these figures accurately. Our goal in the design of this project was to not only help students develop a new skill of understanding two point perspective, but to help students feel more comfortable and familiar with drawing these figures. Two-point perspective

drawing can create something extremely precise and accurate if a specific process is followed. We believe that this idea translates to any mathematical content that requires students to understand and follow "process."

Workshop Details

In Mosaicked Functions, we want students to understand that a function can have multiple representations. Traditionally we teach that functions can exist as an equation, a table, or a graph. But for this project we want students to expand their idea of "visualizing a function." Instead of evaluating a function to graph it on a coordinate plane, students use the inputs and outputs to create a mosaicked design. The Common Core Algebra 1 curriculum emphasizes how each of these representations can identify the family of a function. In designing this project we noticed that students struggle with two aspects of this standard: one, that a single function can be represented in multiple ways and two, that each representation has its own rule or algorithm for determining its family. Our goal with these mosaics is to introduce a creative approach for students to recognize function family based on area of color. For example, Figures 9 and 10 show examples of linear and exponential functions visualized as mosaics. During class, students were able to categorize each of these functions within their designated family.

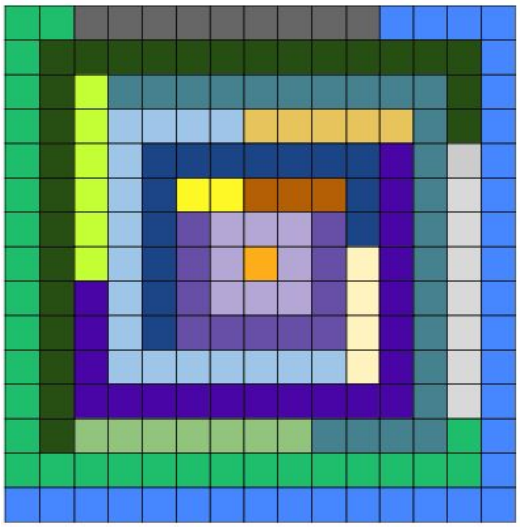

Figure 9: *Linear Function f(x) = 3x + 5 Mosaic Example.*

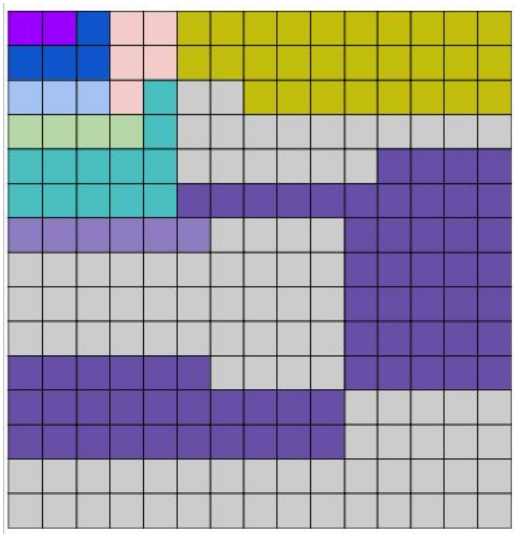

Figure 10: *Exponential Function f(x) = 2^x - 4 Mosaic Example.*

Our presentation will introduce participants to numerous creative approaches to teaching middle and high school level mathematics. We will share our projects and provide curriculum guidelines for implementation. Participants will learn how to use art as a tool to engage students to create a stronger school community.

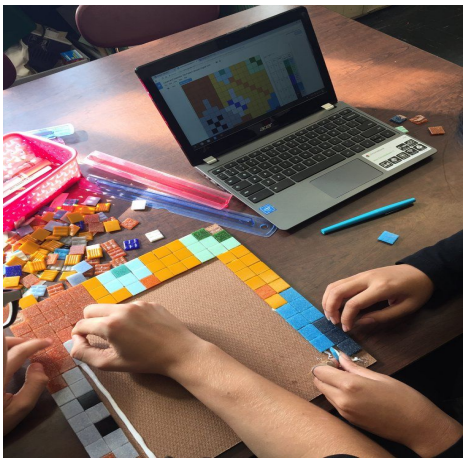

Figure 11: *WHSAT students using a digital template to create their mosaic.*

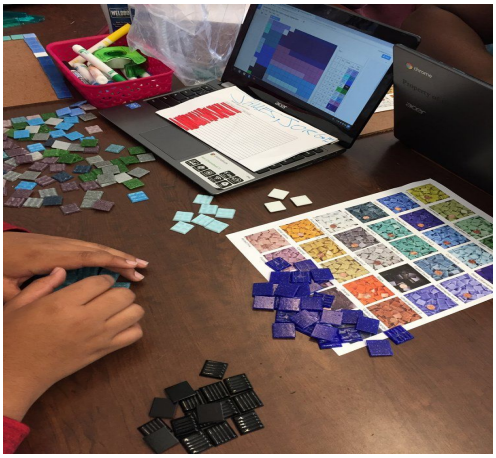

Figure 12: *WHSAT students using a restricted color palette to design their mosaic.*

For the hands-on activity, participants will collaborate to create a digital mosaic that visualize different families of algebraic functions within a 225 square grid template, Figure 13. We will lead participants through the following steps:

Step One: Each participant is asked to pick a set of adjectives that best describes them.

1. Steady, constant, and straightforward.
2. Balanced and symmetrical
3. Fast-paced and boundless

Step Two: Participants are asked to find another person in the room who picked the same set of adjectives and together they will create a function based on their "personality." If they picked the first set of adjectives, they will create a linear function, if the second, a quadratic function, and if the third, an exponential function.

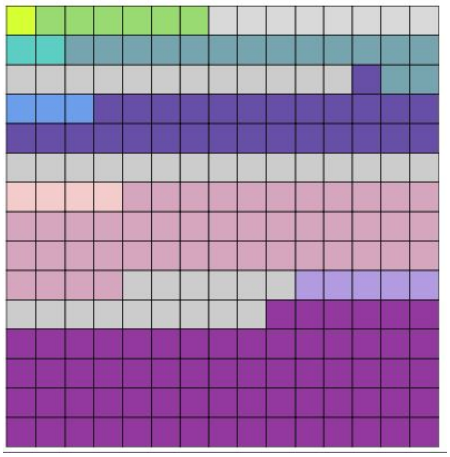

Figure 13: *A completed 225 digital tile mosaic visualizing a quadratic function. This pair used gray for their 50 negative spaces.*

$f(x) = 2x^2 + 3x + 1$

x	f(x)	SUM	x color	f(x) color
1	6	7	Lemon yellow	Chartr euse
2	15	24	Teal tint 2	Deep teal
3	28	55	Cyan tint 2	Deep cyan
4	45	104	Muted pink	Purple tint 2
5	66	175	Ultram arine tint 3	Deep ultram arine

Figure 14: *An evaluated quadratic function with aggregated sums and color choices.*

Step Three: Pairs will now access the mosaic design template through a shared google drive folder , Figure 14, to evaluate their function for input values starting at one. They will calculate the aggregate sum of their inputs and outputs. Because the template is exactly 225 squares, they can only visualize their function less than or equal to a sum of 225. If a pair's sum is less than 225, the "unused" squares will be filled in with a "negative space color" chosen by the pair.

Step Four: From a pre-selected color palette, Figures 11 and 12, pairs will then select specific colors for their inputs (x) and outputs (f(x)). For example, if a pair has five inputs and five outputs, they would need to choose ten different colors to represent their function and one extra color to represent their negative space. We will spend a moment talking about color and encourage participants to pick related colors for each evaluation set. This will strengthen the identification of the functions patterns in the visualization design.

Step Five: In order to design their mosaic, example seen in Figure 13, pairs will be asked to follow one rule. Each pair is allowed to organize their tiles in the design template in whatever order they like, but at least one input "tile" must touch at least one of its respective output "tiles" on the mosaic. Tiles are allowed to touch on corners or on sides. We will model this by showing examples from our students' designs.

Step Six: When the design is complete, participants will digitally "turn in" their mosaics so that they can be compiled by the facilitators to create a larger mosaic image.

A curriculum guide will be provided that outlines the process and gives resources for materials to take this project off the screen to create a ceramic or glass mosaic.

Summary and Conclusions

We have observed that integrating art into the mathematics curriculum creates a more confident, community minded, and academically successful student. We believe this is true because of our own experiences with high school students and their performance on state exams over the last seven years of our collaboration. The integration of art and mathematics is powerful because it creates access for students who have not been able to engage with the standard curriculum. Engagement with academic material and participation in public art installations allows students to have ownership over their education and investment in their community. We believe that the experiences we create inside and outside of the classroom allow students to see the integration of mathematics in multiple aspects of their lives, which creates a normalization of concepts that at first seemed inaccessible.

References

[1] M. Hardiman, Ed.D, S. Magsamen, G. McKhann, M.D. and J. Eilber. *Neuroeducation: Learning, Arts, and the Brain.* The Dana Foundation, 2009.

[2] S. Ruppert. "Critical Evidence: How the ARTS Benefit Student Achievement." *National Assembly of State Arts Agencies*, 2006.

[3] New York City Department of Education 2017 School Performance Dashboard: https://tools.nycenet.edu/dashboard/ - dbn=14K454&report_type=HS&view=City