Math + $(A)^{rt}$ at the Winnipeg Art Gallery

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Abstract

We present our experience working as mathematical consultants for the Math + Art exhibition at the Winnipeg Art Gallery, with special attention to the educational programs. The creation and goals of the show are detailed, as well as a selection of the artworks in the exhibit and the activities used with our school programs. We discuss the challenges and successes of teaching mathematics in an art gallery, and the lessons we learned from this experience.

Introduction

I served as a mathematical consultant for Math + Art, a show that ran at the Winnipeg Art Gallery (WAG) from December 2013 to April 2014 in the province of Manitoba, Canada. This paper will explain the goals of Math + Art, my contribution to the project, the specific school programming that was offered, and a brief description of the successes of the show.

The idea to create a show on math and art came from one of the members of the education department, Rachel Berg, who served as curator for the exhibition. At the time, the WAG already offered school programs on mathematics in art, but they were not very popular and did not connect to the mathematics curriculum. The exhibition was created with education in mind, giving us the opportunity to reinvent the mathematics and art program and bring more students into the gallery. The show was meant to attract both mathematics and arts classes. As the focus was on education, we had more freedom than usual in creating the exhibition.

Figure 1: Mark Kelly's *Ginger*

As a mathematical consultant, I was included in the process from the beginning, before the artwork was chosen. Working with the curator, I was able to help choose works that fit the goal of the show, rather than being forced to find mathematics with pre-selected works. My experience leading school tours at the WAG was valuable, as I was familiar with the mechanics of giving a tour as well as what activities are likely to be successful. Essentially, this boils down to knowing the attention span and the level of engagement that you can reasonably expect to have with a group of students.

A public art institution will hold different types of exhibitions, which can be roughly classified by the ownership of the artwork involved. Math + Art is a collection exhibition, which means that every piece in the show was in the permanent collection of the Winnipeg Art Gallery. This impacted our ability to choose works that were mathematically motivated.

Creation of the Show

The school programs offered by the museum are generally interactive, in that the students participate in activities that actively engage them with the artworks. Often these activities do not center on art appreciation, but focus on social studies, english, or contemporary issues raised by the art. The goal of Math + Art was to allow students to recognize curriculum outcomes from their math classes in a gallery setting. Personally, I hoped to create a program that would also allow students to see mathematics as creative and interesting. It was also expected that the exhibition, and the relating school programs, would foster interesting artistic discussions.

In order to meet the objective of finding works that related to the curriculum, the natural first step was to examine the mathematics curriculum in Manitoba. The curriculum is divided into different areas, called strands, each of which has a variety of desired outcomes. For example, the shape and dimension strand has the outcome that grade five students should be able to

> Perform a single transformation (translation, rotation, or reflection) of a 2-D shape, and draw and describe the image.[2]

We ranked the learning outcomes by their suitability for in-gallery activities. Promising learning outcomes were recorded, and artworks were found in order to make activities for the curriculum outcomes.

Math + Art is organized into three themes, shape and dimension, number and relation, and symmetry and pattern. These are similar to the strands found in the mathematics curriculum. These themes helped keep the show more focused, and promoted a consistent artistic narrative to the public. Once the outcomes had been chosen, the next step was to sort through the collection and select artworks. It was quickly apparent that the collection of the museum was not sufficient to only include artworks which were explicitly created with mathematics in mind. However, this was never the point of the exhibition, and we were careful to avoid any implication that mathematics served as a direct inspiration for all of the artists in the show. Instead, the artworks were chosen in order to allow the creation of useful activities, and it was hoped that the end result would be a cohesive show.

The didactics and curatorial text could not deviate too strongly from the informal rules of art curation and have little mathematics contained in them. However, we were able to create several math-art cards which gave further insight into the mathematics behind some of the works, and contained mathematically themed activities for the general public. For example, Bertram Brooker's drawing *Four Dimensional Cube* (see Figure 2) had a math card explaining the concept of dimension and questions about the dimension of several different spaces, including more abstract ones such as color spaces. These cards allow a more interactive experience with the exhibit, as well as reassure the viewer that there really is math behind the art.

School Programs

Making math more appealing to students by creating activities that use art to teach mathematics is not a new concept, and we drew inspiration from previous attempts. We knew, however, that attention spans in

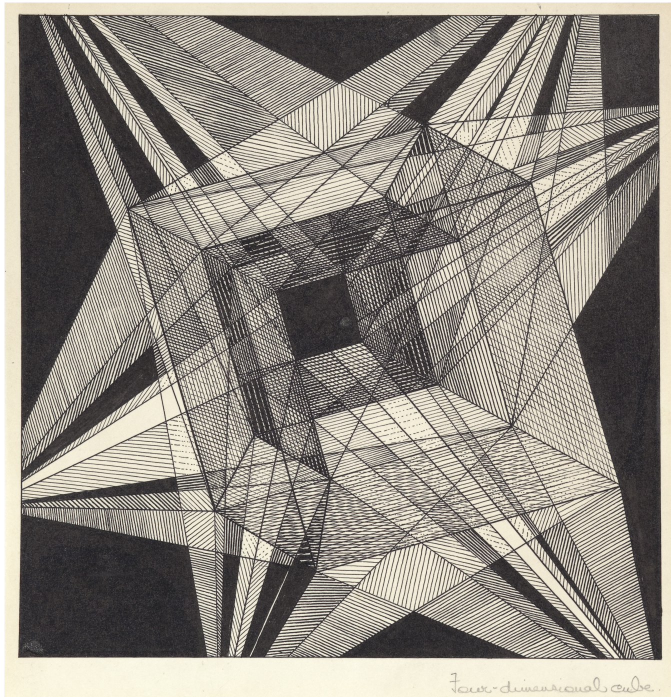

Figure 2: Bertram Brooker's *Four Dimensional Cube*

a museum tour are limited compared to a classroom, and that teachers and students expect to see most of the exhibition in a tour. These factors reduce the amount of time that can be spent on one activity. Also, a guide will have little knowledge of what the students have covered in class, so a variety of activities must be devised. Luckily, by having activities for all ages, it is easy for the guide to adjust the level in order to suit the class.

With Math + Art, we especially tried to avoid the creation of activities that are completely unrelated to the artwork. At least one museum has a math program which features activities where the children must search for certain numbers in the didactics, find geometric shapes in the architexture of the building, or other similar activities that could be completed without looking at any art.

This occurs not only in arts education but also in areas such as literature. Children's literature professor Perry Nodelman advises teachers to avoid activities that are not employed by adult readers [3]. Translating this idea to visual art, we tried to create activities that would be enjoyable to math and arts enthusiasts, such as Bridges Conference attendees. Even though the majority of artworks in Math + Art are not inspired by mathematics, they naturally prompt mathematical questions, or "art" questions that are math questions in disguise. Also, every activity requires the student to look at the artwork. What follows is a selection of artworks and activities for each thematic section of the exhibition.

Symmetry and Pattern

Symmetry and pattern was an obvious thematic choice, due to their extensive use and study in both art and math. Unfortunately, the WAG's collection of art does not include many pieces with wallpaper patterns, nor enough works from one art movement that was inspired by symmetry. As a result, the symmetry section of Math + Art is diverse, including an op-art painting, sculptures, tiles, and prints. However, this turned out to be a blessing, as it clearly demonstrates that artists from a variety of cultures and periods have used symmetry. Clearly, this begs the question: "Why do such a variety of artists care about symmetry?" This can lead to rich discussions of the varied roles that symmetry can play in art.

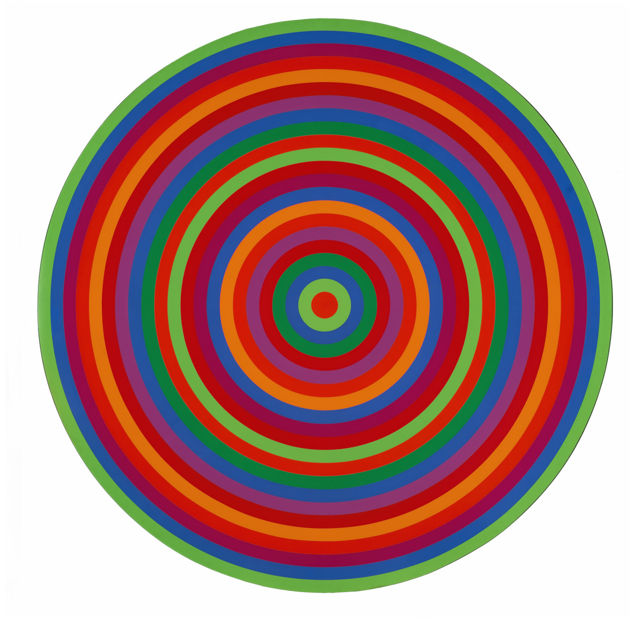

Figure 3: Claude Tousignant's *Accelerateur Chromatique*

Our mathematical goal in this section was to demonstrate the connection between symmetries and transformations. First, we ensure that students can recognize line symmetry using *Ginger* by Mark Kelly (see Figure 1). Often, students will remark that "the artist just flipped the picture", leading to a discussion of the relation between reflections and line symmetry. The slight assymetry in the top of the photo is noticed by many students. The brightly colored concentric circles in Tousignant's *Accelerateur Chromatique* (Figure 3) create a strong visual effect, and the work is popular with students. We ask them if they would be able to notice if we rotated the work, again linking the concepts of transformation and symmetry, this time with rotational symmetry. Color relativity, whereby the same color looks different depending on the colors surrounding it, is quite evident in this work and is a popular topic with students.

An activity for younger students has them investigating Max Dean's conceptual work *tool/loot*. On the left side is an aluminum plate with the word tool, and the right side is a mirror image of the left, only on paper. This work is meant to represent the lithography process, since the right side could be printed by the plate on the left. By having both the stone (here aluminum) and the finished print as the final work, Max Dean draws our attention to the process of making the work. Guides start by having the students notice the symmetry in the work, ignoring the color of the background. Students often recognize tool as loot spelled backwards (and nothing more) so we have them write tool on the paper with a palindrome like racecar underneath. Looking through the paper from the reverse side, they notice that they can easily read loot but racecar has 'backwards' letters in it. Students are then asked to find all letters in the lowercase alphabet that are valid letters when seen in a mirror, which corresponds to the curriculum outcome of performing and recognizing transformations. After noting that all the letters in tool are on this list, students are asked to come up with other word pairs like tool/loot. Teachers and students are encouraged to repeat this activity with rotations as a take home activity. This activity is partly inspired from Kormolova's work with students and symmetry [1].

Artworks provide a great opportunity to check that students have a firm grasp of a mathematical concept. One of the most successful activities in Math + Art is also one of the simplest. The guides split the students into groups and have them list all works that have line symmetry, and all works that have rotational symmetry. This forces the students to look at the art carefully, while promoting group dialogue and mathematical persuation. Having the students make a list leads to questions such as: “Why are some works on both lists but others only have rotational symmetry (or line symmetry)? What keeps the work from having line (or rotational) symmetry?” In the creation of the lists, students ask questions, such as: “Does color count? This work has a small flaw, should it count as symmetric?” These observations show that the students are observing the works closely and thinking about the questions asked in a precise and careful manner. Since every work must have some flaw, we can question if any of the works is really symmetric. This can lead to a discussion on the relationship between our world and the mathematical world. Sometimes a group of students is fooled by Jessie Oonark’s *Magic Circle* (Figure 4), which is not symmetric. This work is not inspired by mathematics, but shows how transformations can be used to create interesting designs from one basic shape. In fact, a large portion of her work features designs that are symmetric or use transformations and repeated shapes to form the composition.

Figure 4: *Magic Circle* by Jessie Oonark

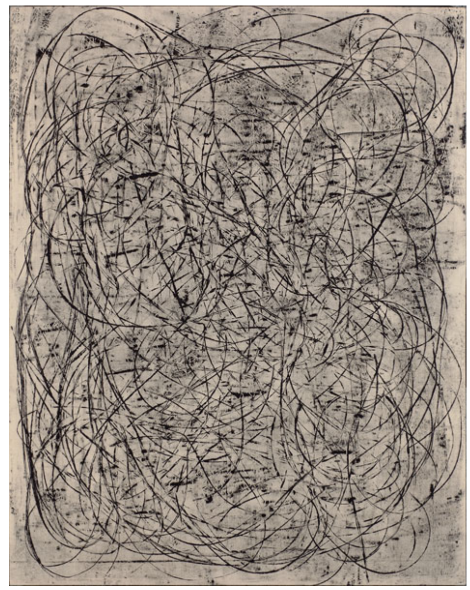

Figure 5: *Quarter Mile of Clothesline* by Gerald Ferguson

Number and Relation

The works in this section are varied, but are connected in some manner with number and relation. Gerald Ferguson’s *Quarter Mile Of Clothesline* (see Figure 5) was created by coiling a quarter mile of clothesline on the floor of his studio and then using a frottage technique to create the resulting painting. Hiding the title from view, we ask the students to estimate the length of the clothesline used in this work. The estimation itself is a good example of putting mathematics into practice. Their guesses are often inaccurate, and the students agree that this is not a good way to represent a quarter mile of clothesline. The merit of using numbers to convey information is immediately apparent when looking at this work.

Micah Lexier’s *All Numbers Are Equal (four ways)* (Figure 6) comprises four rows of nine prints, where each print consists of a digit from one to nine. The numbers are placed in the normal order, and the digit one is unchanged between the rows. Every other number is cut so that the surface area of the digit equals that of the digit one. The direction of the cut is consistent among all prints in a row. The activities used with this work depend on the grade level, but a discussion of the equality of the surface area between all of the numbers in the work is applicable to a surprising age range. We argue that the subject of this work is not the digits one through nine but rather the transitivity property of equality. For older students, there are a number of well motivated and interesting mathematical questions related to this work. How exactly did Lexier ensure that the surface area of the digit is the same for all of the prints? How can you calculate surface area? Is it even possible to cut the digits so that the surface area is equal, given that each digit was "cut" from a digital image make of discrete pixels?

Figure 6: Micah Lexier's *All Numbers are equal (Four Ways)*

We found that *All Numbers Are Equal (four ways)* also served as a good introduction to conceptual art. Students are usually good at recognizing and evaluating artworks that are representational. Abstract works are also evaluated and understood by students, as long as they can interpret, or recognize, the subject of the work. Conceptual works are more difficult to evaluate, and the difficulty lies in their inability to answer the question: "Why did the artist make this?" From experience, if we ask students whether they like Micah Lexier's *All Numbers Are Equal (four ways)* before explaining the work, only a few students will. The students are uncertain to like the work precisely because they don't understand why it was made. Micah Lexier's work is a great introduction to conceptual art because the idea behind the work can be easily explained. It is advantageous that the idea of equality is not political nor does it rely on cultural norms, except for usual ordering of the digits one through nine. Even though many students will not change their opinion of the work, they have been introduced to a new form of art.

Robert Hedrick's painting *Red White + Blue* (Figure 7) consists solely of triangles, each colored either red or blue, with the spaces between the triangles kept white. We ask the students how many ways the artist could have colored this work, given that each triangle can be colored either red or blue. High school students work out the general formula depending on the number of triangles, starting by enumerating small cases. *Red, White + Blue* contains 638 triangles, and the resultant possible color choices 2^{638} is a number with 119 digits. Once they understand the vast number of possible chocices, it becomes apparent that the job of the artist is to create a visually interesting work by carefully choosing the coloring of the triangles. They are encouraged to look for rules that the artist may have followed in order to choose the colors in the work. Upon close examination, it seems that Hedrick emphasized certain line segments by coloring all triangles on one side blue and all of the triangles on the other side red. Furthermore, when looking at the work from a distance, one is struck by how there appear to be many curved lines throughout the painting. Close up, it is clear that these seemingly curvy lines are in fact composed of many straight lines; the edges of the triangles. Thus *Red White + Blue* is a great visual demonstration of how a curved line can be approximated by a collection of straight line segments.

Shape and Dimension

The works in this section focus on form and shape in both three and two dimensions. Students consider the artistic differences between a painting and a sculpture by examining the works of Kazuo Nakamura, one a scuplture containing simple rectangular prisms connected by steel rods, the other a painting of a grouping of similar sculptures. Students are asked to create blueprint like drawings from the top, front, and side view of the sculpture. These drawings are compared with the painting, prompting a discussion on whether there is a best way to present three dimensional objects.

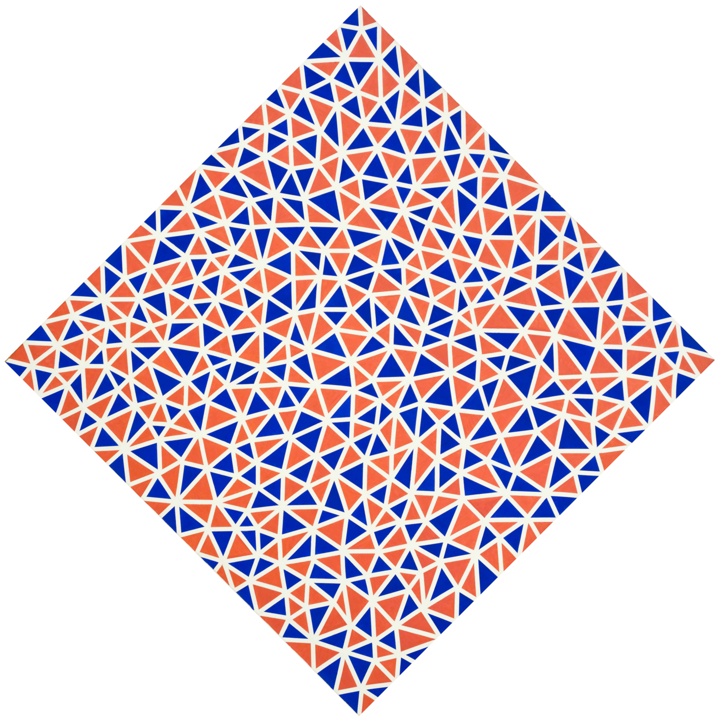

Figure 7: *Red White + Blue* by Robert Hedrick

In *Transformed Environment No. 1 - Dotscape* by Serge Tousignant, an undulating landscaping containing a regular pattern of bushes receedes into the distance The image is surrounded by dots forming the same pattern. Students can tell that the land is not flat precisely due to changes in the pattern. When we bring this to their attention, they realize that patterns change on curved surfaces and that patterns are distorted by perspective as well. Another Tousignant work, *géométrisation solaire carrée*, answers the question: “Can different three dimensional configurations of the same objects produce similar shadows?” in the affirmative. Four photographs, each showing a square shadow created by four sticks, with each photographing having a different configuration of the sticks. The futurist artist Cosimo Carlucci’s sculpture *Processualità Uccello* shows the progression of a bird in flight by a series of two dimensional slices. Guides explain how this enables Carlucci to depict motion, and compare this work to flipbook animation and movies.

The activities for this section also include the construction of a net for a cube and estimating the surface area and volume of a sculpture using idealized forms. These activities are directly linked to the curriculum, but are not as naturally related to the artwork. On the other hand, the questions in this section motivated by the artwork are not always related to the curriculum, but might lead to a greater curiosity in mathematics.

Evaluation and Conclusions

As a programs facilitator, I led many school groups through the exhibition. This allowed me to determine which activities worked better than others, as well as see how the students reacted to the program. Invariably, the students reacted best to activities that were most naturally motivated by the artwork. Activities in the symmetry section were consistenly successful and had a high level of engagement from students of all ages. There was great variance in the mathematical level of the students that visited, but happily the school programs were constructed with this in mind. The tour guides found it possible to choose activites that suited the interests and abilities of the students.

One of our greatest challenges in Math + Art was the instruction of the tour guides. Many of the guides are not math enthusiasts, and a successful tour depends on a knoweledgable and enthusiastic guide. At the WAG, the solution was to train the guides as much as possible on the new material, and to try to get them interested in the mathematics themselves. This proved to be fairly successful, however certain guides were only comfortable with giving tours to the younger grades. However, this phenomenon is not limited to our mathematical tours. Over time, the guides grew more comfortable with the tour as they gained confidence in their mathematical knowledge. At times, they would even forget to talk about the artistic side of the works, because they were so focused on the math. We found that tours were most successful when they struck a balance between the two subjects.

With respect to the stated goal, Math + Art was a success in that classes who visited the gallery interacted with the math from their curriculum through activities that were linked to the artwork. The ability to advertise the curriculum links was very helpful in attracting classes to the gallery. The feedback from the teachers has been very positive and the students seem to enjoy the tour as much, if not more, than our other programs.

With the benefit of hinsight, there are a couple of things that we would do differently if creating another show on math and art. We would limit the age range of the intended school programs. This would reduce the amount of training required for the guides. Second, we would ensure that all curriculum outcomes were very evident in the art, to ensure that no "pointless" activities are created. If possible, we would include work from artists not in the collection of the museum, allowing for a greater range of choices. It would be great to have work from mathematical artists such as those in the Bridges community.

It is our belief that it is worthwhile to create more programs similar in spirit to Math + Art. Most cities are not lucky enough to have a museum dedicated to mathematics, but many have art museums. An art museum is a non-intimidating place to investigate both mathematical and artistic questions, and school programs can allow students to see math in a new, and hopefully more interesting, light.

References

[1] B. Kamrlova, "How do Symmetries Come To Children, and Vice Versa?", Bridges 2013 Conference Proceedings, pp. 539-542.

[2] Manitoba Ministry of Education. (2013). "Kindergarten to Grade 8 Mathematics: Manitoba Curriculum Framework of Outcomes". `http://www.edu.gov.mb.ca/k12/cur/math/framework_k-8/full_doc.pdf` (as of Feb 1, 2014).

[3] Nodelman, Perry and Reimer, Mavis, "The Pleasures of Children's Literature", Allyn and Bacon, 2003.

[4] Weyl, Hermann, "Symmetry", Princeton Science Library, 1989.