Math in the Studio

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Abstract

In this article, we describe an interdisciplinary mathematics and studio art course taught at Kenyon College in the spring of 2017. The course was designed for the general liberal arts student and was team-taught by a studio artist and a mathematician. Focusing on three main content areas (pattern and symmetry in the plane, linear perspective, and fractal geometry), students learned the formal elements of art and design while gaining a mathematical understanding of notions that are central to art. Coursework consisted of art projects culminating in class art exhibitions as well as homework assignments and examinations that involved problem solving and the use of the language of mathematics.

In the spring of 2016, the authors received an *Expanding Collaboration Initiative* grant through the Great Lakes Colleges Association to fund the development of an interdisciplinary art and mathematics course titled *Math in the Studio*. We met twice a week the following summer to design the syllabus, assignments, projects and individual lessons, and we ultimately taught the course in the spring of 2017. As the title might suggest, the class met in the Studio Art classroom, where students learned the formal elements of art and design while gaining an understanding of mathematical notions central to art. The only prerequisite for the course was precalculus, and it enrolled 16 students having a wide range of backgrounds. Some were senior art majors who had never taken a college-level mathematics course. (*Math in the Studio* could be used to satisfy Kenyon's quantitative reasoning requirement.) Others were sophomore mathematics majors with no studio art experience whatsoever. Several students had very little experience in either mathematics or art but were interested in exploring the intersection of the two fields. One student (an art major and mathematics minor) had extensive experience in both.

Course Overview and Rationale

The course consisted of three main blocks of material: pattern, linear perspective, and fractal geometry - and we used the notion of dimension as an organizing theme throughout. Emphasis was placed on the creation of artwork, focusing initially on drawing, before moving into other processes such as collage, small-scale sculpture, and site-specific installation. Assignments varied in nature, with some involving the creation of artwork and others making use of the language of mathematics. There were three large art projects serving as the capstones of the three blocks of material, two examinations focusing largely on the mathematical ideas, and about twenty smaller assignments which varied in their length and nature (about half were heavily mathematical). Students gained familiarity with historical and contemporary artists who have employed mathematical thinking in their work, and each student was responsible for giving a 20-minute presentation about one such artist.

We developed the course with the hope of dissolving the many misconceptions that exist surrounding the disciplines of mathematics and art. For example, many people declare math is "left-brained," characterized by linear, logical thinking, while art is "right-brained," involving creativity and lateral thinking. Many believe that mathematics is black-and-white, while in art, anything goes. Such beliefs are not only inaccurate, they are limiting to the development of a creative thinker, because they discourage one from making the effort to develop valuable skills believed to reside outside of these artificial boxes. By including (approximately) equal amounts of studio and mathematical work and clarifying the important connections residing between math and art, we hoped to reach students who would otherwise avoid math or art out of a fear of failure.[1] We designed the course to provide a safe, supportive middle ground, while encouraging students to venture outside of their comfort zone.

While we spent approximately equal amounts of time on each of the three blocks of material, page constraints on this article do not allow us to address all three blocks of material in appropriate depth without cutting out images of student artwork (which we believe are the highlights of our paper!). Hence, we will focus our discussion on the first block of the course and touch only briefly on the other two. The rhythm and nature of our course as a whole is represented well by block one.

The First Block: Symmetry and Pattern

The first four weeks of our course was devoted to the understanding and creation of symmetry and pattern in the plane. Inspired by the book "Patterns" in *Discovering the Art of Mathematics* [4], we started class on day one with the question: What is pattern? Recognizing that the term is ill defined, the discussion moved toward the roles that patterns play in the mathematical and art worlds. The discussion was cursory at first, but it grew deeper in the weeks that followed. The class looked at imagery that exemplifies how pattern has been utilized by historical and contemporary artists – from classical Greek vases and Japanese woodblock prints to Henri Matisse's collages to the mixed media work of the contemporary artists Mickalene Thomas and Yayoi Kusama. We discussed pattern as an enriching design element that adds movement, rhythm and visual texture to works of art. We also examined the work of M. C. Escher, illustrating how his passion for tessellations and patterns inspired by his visit to the Alhambra had such a great impact on his compelling artwork.

Our lessons in this block ultimately culminated with the understanding and creation of wallpaper patterns, but we took small steps to get there. In the first week, we built the students' understanding of translational, rotational and reflective symmetries in the plane, weaving together mathematical exercises with activities designed to develop drawing skills. Mathematical exercises required students to identify various types of symmetries in a given two-dimensional pattern, including the location of rotation centers (aka "rotocenters") and axes of reflection or glide reflection. The book *Groups and Symmetry: A Guide to Discovering Mathematics* [2] by David Farmer was a good source for exercises and examples. Drawing activities in the first week focused on observational contour drawing, which is a technique that captures the form of an object with a traveling (pencil or pen) line. These exercises allowed the students to become more adept at capturing accurate proportions within an object and to draw precisely what they see and not what they assume to be the structure of the object in front of them.

At the end of week one, we introduced a tessellation project in which each student was required to create an Escher-like tiling of their own, exhibiting one of three possible symmetry patterns. (We restricted the possibilities to just three of the seventeen, so that we could better manage the process.) Students were given explicit instructions on how to create their tiles, starting with a parallelogram drawn on a sheet of graph paper. To carry out a tiling with a glide reflection, for example, we instructed students to create a polygonal path along the bottom side of the parallelogram and to create the same path along the top edge but reflected about the vertical. In a similar way, they created a polygonal path defining the left boundary of the tile and then reproduced the same (translated) jagged path on the right side of the tile. The students used their imagination when designing the interior imagery of their tiles. They were told that the tiling could represent creatures within their habitat (e.g., lizards in the desert); or perhaps they could incorporate two different tile designs within a tessellation to reflect a dichotomy or duality of sorts (e.g., night and day, fire and water, good and evil, etc). As in all artwork, the craft and originality were emphasized as crucial elements of the tessellation. Six examples of student work appear in Figure 1.

[1] It's worth noting that the fear some math students exhibit over drawing is as great or greater than the fear exhibited by art students over math!

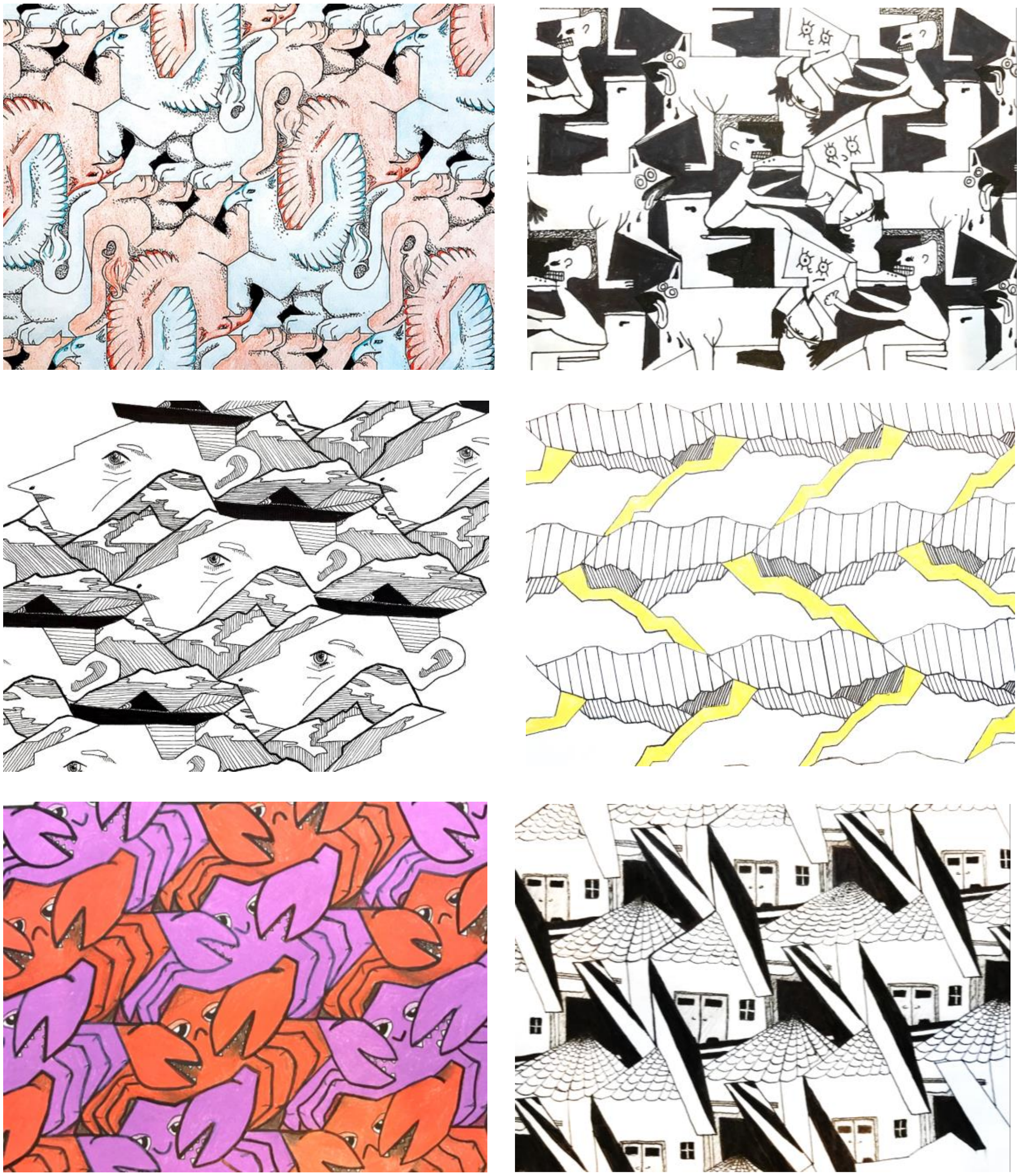

Figure 1: *Samples of student work; artists listed from left to right: (top row) Michaela Orr, Aaron Salm;(middle row) Justin Sun, Brent Matheny; (bottom row) Olivia Biel, Truda Silberstein*

To continue this block on pattern, we began a longer-term project in which students used drawing and design skills to create 7' x 2' wallpapers. We motivated the project by introducing the class to imagery of wallpaper created by renowned artists. We focused on contemporary work such as that of John Baldessari and the political artist Ai Wei Wei. See Figure 2 below. We discussed the basics of group theory and presented Evgraf Federov's famous 1891 result that there are only seventeen distinct wallpaper groups (and therefore seventeen possible wallpaper symmetries). Students were asked to identify elements in the symmetry groups of the wallpaper patterns we encountered and then classify the type of planar symmetry from among the seventeen possibilities.

Figure 2: *Wallpaper patterns of artists Ai Wei Wei (left) and John Baldessari (right)*

Students began the wallpaper project by refining observational contour drawings of objects. Once they were confident with these skills, they began the wallpaper design. They were asked to select two objects having a unique conceptual or formal relationship. In Figure 3 the umbrella and jellyfish have a formal relationship in their structure and a conceptual one in their connection to water. The pattern on the right illustrates a formal relationship between a stylized drawing of Elvis Presley and a soft-serve chocolate-covered ice cream cone. Less obvious is the connection between the hands and the okra on the left. This pattern was created by a student from Nepal where a common variety of okra is known as "lady fingers."

Figure 3: *Wallpapers created by (left to right): Elvin Shrestha, Drew Meeker and Daniel Nolan*

We initially struggled in deciding how the students would fabricate their wallpapers. Certainly, symmetric patterns in the plane are best created on a computer where it is easy to replicate and transform images, but we wanted our students to create artwork *by hand*. In the end we decided on a hybrid approach. We required students to create the generating tiles for their planar patterns (i.e., the fundamental regions) by hand, but they would then scan and import their hand-drawn images into Adobe Illustrator, where the images could be reproduced, translated, rotated and reflected in various ways to create the desired pattern. We encouraged the students to be imaginative while expending effort on strong design and craft. Hence, they were thoughtful in choosing the color palette and symmetry pattern to convey their desired message in an effective manner. Art major and math minor Michaela Orr is featured on the left in Figure 4 drawing one of the several beetles she created before settling on her final design; her wallpaper, which couples Goliath beetles with vertebrae, is on the right.

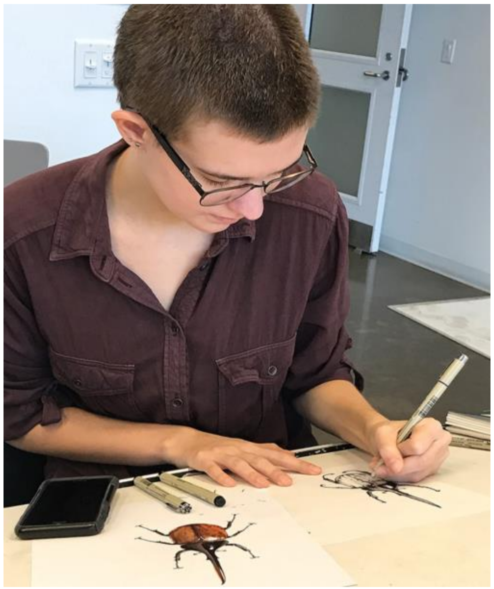

Figure 4: *Sophomore Michaela Orr (left) and her wallpaper pattern (right)*

Once students finalized their pattern within Illustrator, we printed the images on large-scale printers available in Kenyon's Studio Art building (Horvitz Hall). The students hung the printed wallpapers in the Horvitz Hall Fischman Lobby for display, and we advertised the exhibition to the campus. See Figure 5.

Figure 5: *The class exhibition of wallpapers in Kenyon College's Fischmann Lobby*

In the lesson following the opening of our wallpaper exhibition, we convened in the lobby to participate in a focused group critique where we discussed the wallpapers: the most compelling designs and concepts; the most effective use of symmetry; the different types of symmetry; the strongest drawings and use of color. In preparation, each student wrote a one-page reflection about their own pattern, addressing their choice of images, color and symmetry. They discussed the conceptual and/or formal connections between their images and their use and type of symmetry. Throughout the semester, there was an emphasis on developing the skills of informed discourse, with students articulating and defending their opinions with objective observations and analyses.

As it turned out, the wallpaper exhibition brought about an unexpected surprise. The owner of a local wallpaper business heard about the project and invited the class to visit his company, Wolff House Wallpapers, in Mt. Vernon, Ohio, and experience the printing (silk-screening) of one of his wallpapers. After living in the area for decades, neither author was aware of this niche business, which specializes in reprinting historical wallpapers for private customers, museums, and filmmakers across the United States and England. In Figure 6, Kenyon student Brent Matheny silkscreens a section of wallpaper. The class produced a single layer of color on the entire strip of wallpaper one section at a time by repeatedly silkscreening the same block of pattern, each time placing the screen further down the strip. What a delight it was to witness the wallpaper production process from start to finish!

Figure 6: *Brent Matheny silkscreens one layer of color onto a strip of wallpaper*

Blocks II and III: Linear Perspective and Fractal Geometry

Moving into the second block, we spent four weeks covering the mathematics and application of linear perspective. We started with a basic explanation of what perspective is and examined its historical development from Egyptian, early Asian, and Gothic artists' depictions of space to Brunelleschi's experiment and Alberti's Treatise. We spent a week immersed in mathematics, making good use of the book *Viewpoints: Mathematical Perspective: Mathematical Perspective and Fractal Geometry in Art* [3] and some of Annalisa Crannell's hands-on activities [1]. For example, tape on a window outlining a building can illustrate the two-dimensional realization of a three-dimensional object in the real world. By tracing the edges of the building with tape on the window, it is easy to show students how parallel lines in the real world translate into converging lines on the artist's picture plane. We covered one-point and two-point perspective from the mathematical point of view, and then students applied these ideas with several drawing assignments. They drew equally spaced railroad tracks and the interior of a hallway (based on observation). To reinforce their understanding of two-point perspective, they produced a drawing of 15 stacked boxes. We also examined the work of Paolo Ucello, Pietro Perugino, Richard Estes and Toba Khedoori, all of whom fully utilized these methods. The block culminated with a major drawing assignment in which students created a surreal interior referencing Rene Magritte's use of Magic Realism, in which objects and spaces are drawn realistically, but the scale and/or the surfaces and relationships are surreal. This drawing project was ambitious, requiring students to master techniques to create value (e.g., cross-hatching and stippling), and we offered several drawing lessons to target these methods, following up with several assignments to reinforce them. As was the case with block one, this block culminated with a class display of the surrealist perspective drawings and a critique of the student work. We include a sample submission in Figure 7.

Figure 7: "*Surrealist Interior" perspective drawing created by sophomore Michael Fisher*

In the final block, our discussion of dimension grew more rigorous and abstract. We considered the possibility of having objects of dimension $d > 3$ and explained how to visualize the fourth dimension (and the hypercube, in particular) using shadows and slicing. We discussed the relevance of the fourth dimension in the conceptual reformation of space known as Cubism and how Picasso and Braque attempted to represent the fourth dimension on a two-dimensional surface by creating highly fragmented objects and spaces. We then covered the notion of fractal dimension, which involved lessons on proportion and scale, perimeter, area and volume, and students created their own fractals using balloons [5], Lindenmayer Systems [6] and an online recursive drawing tool [7]. We examined the fractal imagery used by contemporary artists such as Maya Lin and Martin Puryear, and the class learned how to compute the dimension of fractal objects like the Sierpinski Tetrahedron, the Sierpinski Gasket and the Koch Snowflake. The book "Geometry" in [4] was a particularly helpful resource here. Finally, we examined how fractal dimension has been used in recent years to analyze work of Jackson Pollock to detect forgery [8]. The block (and semester) culminated with an art project in which students created a metaphorical fractal tree using a variety of materials (e.g., foam core, hot glue, wood, collage, paint, markers and ink). By repeating the same branching unit at varying scales, each student created a large, wall-hung tree-like pattern that was symbolic of an overriding message, possibly about themselves, the culture at large or social-political issues. The content was up to the student. A sample is provided in Figure 8 below.

Summary and Conclusions

A primary goal in teaching *Math in the Studio* was to encourage students to move beyond their comfort zone, gaining new skills and perspectives. We are pleased to report that many of our students did just that. Art majors who had entered the class with a fear of mathematics dug into the problem-solving and ultimately recognized the value of mathematics to their chosen field. One senior, for example, voiced appreciation on multiple occasions over her new-found understanding of tesselations; as a future designer, she saw the value of undertstanding the symmetries in fabric patterns. Additionally, math students without any prior training in studio art left the course with a greater level of confidence in their ability to create artwork. There were multiple comments in the course evaluations revealing the development of a growth mindset among the students. For example, one student wrote, "[the course] made me believe I could make art if I put in the time and effort." Another wrote "It was interesting and relieving to learn that artists utilize math in their art and not every artist was just some kind of perceptive genius."

More generally, the course evaluations were positive, indicating student recognition of the deep connections residing between mathematics and art. One student summed it up well: "Art and STEM are usually presented as polar subjects, and this [course] made me see that they're inherently linked."

Figure 8: "*Fractal Tree as Metaphor" created by sophomore Elvin Shrestha*

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