# Between the Two Cultures: Teaching Math and Art to Engineers (and Scientists and Mathematicians)

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## Abstract

In 2022 I helped develop and team-teach a class on "Sculpture and the Geometry of Three Dimensions". The goal of the class was to show students the interplay between art and math with a focus on having them make physical objects. Most math and art classes I know of focus primarily on introducing liberal arts students to mathematics. In a STEM context, we wanted to instead build on the mathematical knowledge that our students already have. We intended for students to use their existing mathematical (and perhaps artistic) knowledge to reinforce new artistic (and perhaps mathematical) experiences. Ideally, the knowledge and experience gained would increase their appreciation for both the beauty of mathematics and the importance of art.

## Introduction

C.P. Snow famously categorized modern intellectual life as being split between the culture of the sciences and the culture of the humanities and said that solving the world's problems requires bringing these two cultures together. Math and art classes inherently try to do that. However, most math and art classes I know of focus primarily on introducing liberal arts students to mathematics. In the Spring Quarter of 2022, Alan Bundza and I team-taught a different sort of course in mathematics and art at the Rose-Hulman Institute of Technology.

Rose-Hulman is a private, undergraduate-focused institution, all of whose students major in engineering (predominantly), science, or mathematics. We wanted to build on the mathematical knowledge that our STEM students already have with a focus on having them make physical art objects. Alan is an art professor specializing in mixed media with a focus in drawing and painting. I am a math professor interested in the mathematics of fiber arts such as embroidery, knitting, crochet, and weaving. Our goal was for students to use their existing mathematical (and perhaps artistic) knowledge to reinforce new artistic (and perhaps mathematical) experiences. Ideally, the knowledge and experience gained would increase their appreciation for both the beauty of mathematics and the importance of art and help them prepare for productive lives solving the world's problems.

## Description of the Course

The course, titled "Sculpture and The Geometry of Three Dimensions", was taught in the Spring Quarter of 2021–2022. My co-instructor, Alan Bundza, is an adjunct professor in the Department of Humanities, Social Sciences, and the Arts (HSSA). As mentioned, Rose-Hulman has no art majors. However, every student has to take a number of HSSA courses in order to graduate. We also have a relatively new Art Minor which has become fairly popular. The goal was to develop a class involving art and mathematics which would count toward both the HSSA requirement and the minor, while not requiring any prerequisites in either art or mathematics. The course did not count for any mathematics credit.

As background, I taught a similar art and math class at Rose-Hulman in 2019 [2] with a different art professor. Like the 2019 class, the 2022 class was planned for 12 students and filled up quickly. Unlike the

2019 class, many students had no previous art experience at the college level. Some of these students had some informal experience with sculpture, notably with the Rose-Hulman MakerLab club or other makerspaces. Since every student at Rose-Hulman should complete a year of calculus by the end of their first year, we knew that we could expect at least some calculus knowledge from our students. As it happened, all of our students had already had three quarters of calculus and at least two other mathematics courses.

Because of the registration process, the final class list consisted of 9 fourth-year students, 3 third-year students, and 1 first-year student. The first-year student was our only art minor, which gave her a special registration status for the course. We had 5 Computer Science majors, 4 Mechanical Engineering majors, and 1 each from Biochemistry, Civil Engineering, Engineering Design, and Optical Engineering. Two of the Computer Science Majors were students from Germany spending a year at Rose-Hulman as part of our International Computer Science joint program with Technische Hochschule Ulm. Twelve of the students identified as male, and one identified as female.

The course was based around a series of individual student projects, each of which was intended to focus on a different kind of math and a different sculptural technique. Each project followed a similar path, starting with introductory lectures on the sculptural and the mathematical principles. This was followed by several class days of guided work time, including generating designs, having them approved by the instructors, construction, and finishing. The last day of each project was a brief quiz on the mathematical terminology and basic concepts, followed by a critique session based on a traditional art class. In the critique, each student was expected to describe their project along with the notable successes and challenges that they had experienced, using correct artistic and mathematical terminology. Other students were then invited to respond with their own reactions to the piece and the process. Before the second and last projects, students were required to write a short essay in which they chose a work by a professional artist in a medium relevant to the upcoming project and reacted to it.

## Course Projects

After much discussion, Alan and I settled on three projects. The first was for each student to choose a complex polyhedron and build a cardboard model measuring 1 foot or larger on one side. This was intended as a warm-up and introduction to the steps of the sculpture process. We required that the model demonstrate some craftsmanship, incorporating clean edge and planes. Students picked a variety of shapes and finishing techniques, as shown in Figure 1. Some students chose to use a laser cutter which Rose-Hulman has available, while others cut the cardboard by hand.

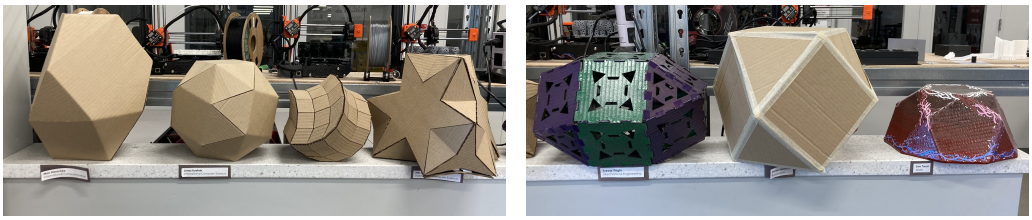


**Figure 1:** *Examples of cardboard polyhedra made by the class.*

The second project was probably the most complicated and the most difficult for the students. We asked the students to design and build a piece of furniture juxtaposing wood and 3-D printed plastic forms. Furthermore, the plastic form should incorporate a layer symmetry [1], a three-dimensional extension of wallpaper symmetry incorporating reflections (but not translations) in the third dimension. Many students had issues working with the two media simultaneously, and very few produced an end product that successfully integrated the two forms. Nevertheless, some quite striking pieces were produced. Figure 2 shows a selection

of the best.

The final project again incorporated wood, but this time as a frame for 3-D string art. Some student examples are shown in Figure 3. Students were asked to incorporate at least two different geometric forms into their frame, and to incorporate at least one non-flat string surface. Some students had a surprising amount of difficulty attaching the string to the frame, but this project was undoubtedly the most successful from an artistic standpoint.

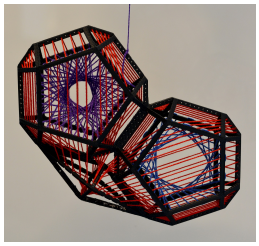
*Trevor Fagin*

*Maximilian Dierschke*

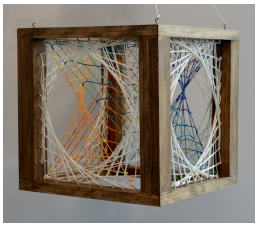
*Nils Engleder*

*Colin Beach*

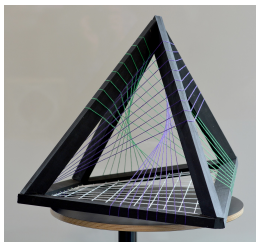
**Figure 2:** *Examples of furniture projects made by the class.*



*Nathan Lee*



*Isabel Haut*



*Nils Engleder*

*Colin Beach*

**Figure 3:** *Examples of string art projects made by the class.*

## Discussion

In the 2019 class, the overwhelming majority of the students had both artistic and mathematical experience, and the main challenge was leading the students to an understanding of how to synthesize the two. Synthesis was still a challenge in the 2022 class, but it became part of a larger challenge of working creatively under constraints. Many times, students came up with ideas which did not fit the project we had assigned. In some cases, it was difficult to nearly impossible to convince the student that their plan would not work.

A related challenge came up in the critiques. Students had a great deal of difficulty using either artistic or mathematical terminology to describe their pieces and their process. Much of each critique was instead conducted in a mix of vague non-technical vocabulary ("I thought these two things looked good together") and terms that the students had made up or adapted to describe their work ("the wedge-shaped piece cut out

of the bottom"). Students were also asked before each critique to comment on certain mathematical aspects of their work, and often had trouble remembering everything that they were supposed to include.

For the first two projects, the mathematical aspect was unfamiliar for many students, so I tried to keep the amount of analysis relatively low. In the first project, most students successfully named and classified their polyhedra according to regularity, convexity, and self-intersection. For the second project, most students demonstrated understanding of layer symmetry as a combination of two wallpaper symmetries. Several students made small mistakes in the identification of their wallpaper symmetries. In the future, I would try moving the quiz to an earlier date in order to encourage more practice with this.

For the third project, I asked the students to put a coordinate system onto part of their frame and to parameterize one of their 3-D string surfaces. I then asked them to eliminate the parameters and demonstrate that their surface was one of the standard three-dimensional quadric surfaces. The results were turned in as a memo in lieu of the usual quiz. This should have been a somewhat involved but basically straightforward problem from Calculus III. Unfortunately, my instructions on how to set up the coordinate system in order to get a clean final result were not completely accurate. One or two students had a simple enough frame to fully execute the procedure. Some more followed my instructions but were not able to get a final result. Others stopped in the middle without trying to finish, and a few never got started. The fact that this project came just before graduation for many students probably also played a role.

## Summary and Conclusions

Despite these difficulties, I think that the class was a success. Many good pieces of art were produced, and I think the students learned a lot about the process of designing and creating sculpture, especially in using creativity under constraints. I think we were less successful in getting the students to think mathematically about art, but I hope that we made a start on that process. The final grades in the course were 4 A's, 3 B+'s, 5 B's, and 1 C+. Seven students responded to Rose-Hulman's Course Evaluation at the end of the quarter. Five of the seven rated the quality of their learning as "Excellent" or "Very Good", and all seven rated the course overall as "Excellent" or "Very Good". Students commented on both strengths and weaknesses; for example:

> I really enjoy building in the class, and takes away from the stress of engineering while applying engineering concepts in building and assembly. It lets me explore a lot of creativity and design.
>
> Math components could be integrated a bit more smoothly - in particular by being cohesively merged into the conception phase of the second and third project
>
> I really hope this course will run again, it was an amazing experience

From Rose-Hulman's point of view, one drawback to the course was the use of two professors to teach only thirteen students. This was also the case in 2019; in the 2022 class my time was actually paid for by an Endowed Chair rather than through the normal budget. Because the course is offered for HSSA credit, someone with an art degree has to be involved, which complicates things. Hopefully these difficulties can be surmounted and more courses like this can indeed be offered in the future!

## References

[1] F. Farris. "Wallpaper Patterns from Looping Strands: The Layer Groups." Bridges Conference Proceedings, August 2, 2021, pp. 71–78.

[2] J. Holden. IA 399-01: Art and Mathematics, 2019. https://wordpress.rose-hulman.edu/holden/teaching/ia-399-01-art-and-mathematics.