Origami Teaching to Improve Math Education

by

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Thesis Statement:

Origami can benefit many students as it is a motivating teaching tool for mathematics and can produce positive attitudes in a class setting.

Abstract:

I explored the relationship between origami and mathematics. Throughout the school year, I had access to a class titled The Art and Math of Origami that I was able to observe and survey. I believe that origami can benefit all types of learners. Origami is a great way to teach mathematical concepts. Through the production of origami, one's spatial awareness tends to improve. Within the survey answers, the students have specified that origami had improved their spatial awareness and they are able to imagine what a model could look like prior to making a fold. Many of these students decided to take this course due to their negative attitudes towards math. There is a potential for origami to improve attitudes towards mathematics as well. An innovative way to learn math concepts can be through origami which can help with student's negative math attitudes.

Chapter 1. Introduction

"When will I use this in the future?", I used to hear this saying since elementary school. Math is everywhere, so when I would hear this, I was always shocked. Children are not excited about math anymore. Some feel like it is the worst thing in the world when it should be exciting. I used to think of math problems as puzzles, which I still do to this day. The United States has placed 35 out of 72 countries in the math portion of the OECD's Programme for International Student Assessment (Jackson 2016). This test is given every three years to 15-year-old students worldwide. The scores reflect children's attitudes.

Students with or without disabilities often experience difficulties with abstract math concepts. (Sze 2005) Making math more enjoyable in classrooms could definitely improve a child's attitude towards math, as well as allowing children to be comfortable around math concepts. Origami is a creative way to change students' mindsets about math.

First, I will be talking about the connection between origami and mathematics. As well as look at past research on this topic and seeing where origami can be incorporated in math. I also have the opportunity to observe a class called The Art and Math of Origami. I am one of the student learning assistants for the course. This is a new course that satisfies the State University of New York requirement to complete a mathematics course in order for college students to graduate. Though not all the students would be classified as math-phobic, for the most part, students chose this course instead of standard math courses such as precalculus, statistics, and programming.

Chapter 2. What is Origami?

First, where did Origami come from? Origami has a rich and complex history that spans throughout cultures, class, and geography. (Lang 1988) Origami first originated in Japan. Due to its origins, Origami is most strongly associated with Japanese culture. The word origami comes from ori-, which means to fold and –kami, which means paper. Paper itself was invented in China but was brought to Japan by Buddhist monks in the 6th century A.D., the first origami folds date from this period. At this time paper was hard to obtain and was primarily used for ceremonial purposes. Most of these folds were very simple and sometimes used some cuts. Cuts and glue are frowned upon in modern origami. Few of the origami designs were passed down from generation to generation. It was easier to pass down the simpler ones since they were easier to remember. Some of the earliest instructions are contained in the *Sembazuru Orikata or Folding of 1000 Cranes* which printed in Japan in 1797. (Lang 1988)

It is very rare that a person has never made origami. Children from a young age often make paper planes, boats, and even hats. Origami is art made through paper. It is very easy to participate in this art. Animals, flowers, and many other things can be made by folding paper in different ways. Different types of origami patterns can take a few minutes and others can take a few hours. Some people even paint the paper to give it an extra pop. Origami is construction by geometric operations formed by folding a piece of paper, using raw edges of the paper, as well as crease lines, and points created while folding. (Sze 2005) This form of art is very inexpensive. All a person needs is paper. Even used paper works well and is an excellent way to recycle.

Chapter 3: Types of Learners

Origami is a hands-on activity that can benefit and be enjoyed by many different kinds of students, with different learning styles. According to Learning Styles and Their Importance by Ellington, Shannon & Benders, David, there are three types of different learning styles; visual, auditory, and kinesthetic. Most people have a mixture of all three types, but they learn mostly through one of these styles.

Visual learners see the world by constructing and remembering mental images. People in this group like to learn through reading, observing and displays of data. Students who show a preference for a visual learning style should be given instructions with visual aids. They perform better when given the appropriate materials. Origami is a great way to teach math concepts to visual learners.

Auditory learners prefer to learn through sound, by listening. These students would feel more comfortable to learn through lectures, seminars, discussions, and tapes. These students prefer oral tests rather than regular exams. Auditory learners can prosper when teachers use keywords, this can maximize the information retained by a student.

Kinesthetic students learn through the environment, by feeling and doing. People that prefer to learn through this method are very hands-on which helps them create and develop what they have learned.

I truly believe that origami is a great way to display math concepts, not to only visual learners but to all types. It is clear how hands-on and visual origami can be. It can also be helpful to auditory learners. (more on this further down)

Chapter 4: Math Phobias

Many students tend to have a bad attitude when it comes to math. To the point that their attitude towards math can become a phobia. This phobia is an academic sickness whose virus has not yet been fully diagnosed for an effective treatment in the class and the symptoms of this phobia are usually expressed on the faces of mathematics students in their class. (Nwoke & Ugwuegbulam 2016) This can be related to personality characteristics, negative attitudes towards mathematics, mathematics avoidance, poor mathematics background, poor teaching behavior, achievement levels, lack of confidence, and negative experiences in school. Tillfors defined phobia as learned emotional responses, which causes frequent, severe, and intense anxiety. (Nwoke & Ugwuegbulam 2016) Many students' negative attitudes affect their approach to solving math problems which may result in a phobia and poor performance in the subject area. When students tend to fall behind in math, the anxiety accumulates over time. This anxiety will cripple students' performance in the classroom leading often to them falling behind their peers. As a result, students will try to catch up but while trying to do so students can feel helpless.

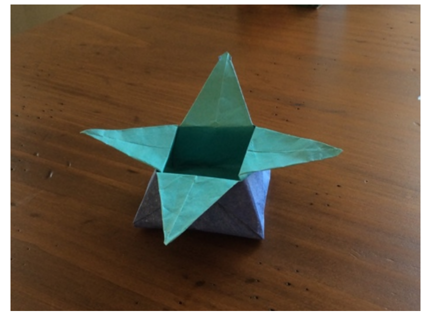
A study conducted on 110 secondary school teachers titled Causes and Solutions of Mathematics Phobia Among Secondary School Students where teachers were asked what the causing factors of math phobias were as well as what are some solutions. Some recommendations were suggested, such as having a good student-teacher relationship so that teachers can know the problems that the students are facing and there should be a counseling unit in secondary schools to re-direct students thinking about mathematics by letting them know the importance and usefulness of mathematics in their everyday life. Another suggestion is that math teachers should be re-trained periodically in order to have ideas of innovative approaches of teaching mathematics to avoid phobia among students. Tying back to origami, origami is a great teaching tool to get students excited about math and more willing to participate.

Chapter 5. What is the connection between math and origami?

Origami can assist with many areas of math education, including math concepts and spatial visualization. Being able to have a spatial visualization is the ability to mentally manipulate 2-dimensional and 3-dimensional figures. Spatial visualization is an incredible skill to have for mathematics, especially when studying topics like geometry, algebra, and symmetry. Spatial visualization is an integral part of the K-12 geometry curriculum. The National Council of Teachers of Mathematics (NCTM) has emphasized that children should be given the opportunity to explore and develop their understanding of shapes and structures through hands-on activities to build their spatial skills. As students use their fine motor skills to fold and crease the paper, their spatial reasoning skills improve. (Sze 2005) "Constructing and deconstructing math concepts by folding and unfolding a piece of paper which eventually leads to a three-dimensional product" (Sze 2005), is spatial visualization at its finest.

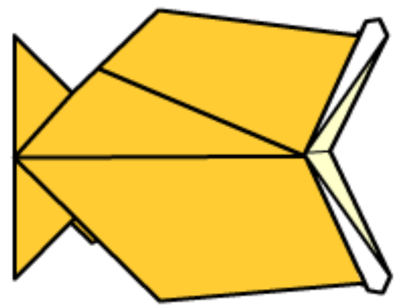
Paper folding, in general, is mathematics in action. When one is folding paper, she or he is playing with mathematical concepts like perpendicular bisections, angle bisections, or properties of right isosceles triangles. These are just a few of the mathematical concepts that are connected to paper folding. (Wares) In many models, there is a constant symmetry that would be an example of a math concept that can be taught through origami. Angles, triangles, intersections are just some examples of more concepts. Teachers can teach basic folding that will be useful for teaching geometry concepts. (Sze 2005) Making origami allows students to create and manipulate geometric shapes with ease. (Budinski, Lavicza, & Fenyvesi 2018) Origami is useful to teach platonic solids as ell as 3- dimensional shapes, vertices, edges, etc. Origami can also be used to teach different properties such as properties of polyhedrons.

Ex. 1



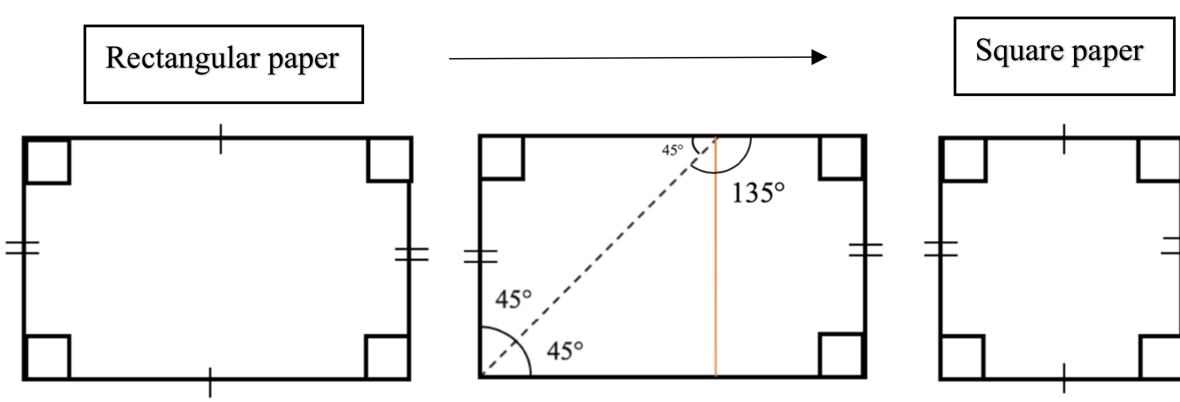
In the Art and Math of Origami class, Dr. Meyer showed how to calculate the final dimensions of several models, for example, the star basket. (Ex.1) We were also able to calculate of the size of the base of the star basket.

Ex. 2



There are several ways to determine how to fold an edge into thirds. This was an early step required for the kissy fish model. (Ex.2)

Something as simple as converting a rectangular piece of paper into a square piece can have so much math involved. (Look below) This step is often needed if an origami model requires an nxn size paper. When starting with rectangular paper one must first make valley fold (dotted line) and then unfold. This fold creates two 45° angles from a right angle. The orange line below displays another fold, we will need to make a cut along this crease for the final step. Prior to that let us look at the angles. Before folding we had a 135° angle which will change into a 45° angle and to a right angle. This is a great example of angular bisectors and the angles that can be found in origami.



Chapter 6. Findings from Past Research

We saw how origami has the potential to assist in math education, but does it work? Norma Boakes is an educator who has conducted multiple studies on the effectiveness of origami lessons. She used tests from the key of Factor- Reference cognitive tests (1976). The kit has 72 tests and is used to study reasoning, verbal ability, spatial ability, memory, and much more. Norma J. Boakes constructed a study: Origami Instruction in the Middle School Mathematics Classroom: Its Impact on spatial visualization and Geometry Knowledge of Students and used the paper folding test, card rotation test, and surface development test to conduct her study and a math achievement test. Boakes experimented with the results of origami lessons in addition to regular math classes. Her study involved 56 middle school students, the students were divided into two groups, a control and an experimental group. Each student received a pre/ post-test. Both the groups received regular math lessons, but the treatment group received an extra 20-30 minutes of origami instruction. Both groups did better in the post-test, but the experimental group did just as well or better. This demonstrates that origami can be a useful teaching tool. (Boakes 2009)

Norma Boakes also constructed a study that tested the impact of origami-mathematics lessons on college students. Her study, Origami mathematics lesson: Researching its impact and influence on mathematical knowledge and spatial ability of students was a very similar study as the previous study mentioned. She used the same tests as the previous study on a college course called The Art and Math of Origami, except for the math achievement test. The students involved in this study were aged 20-45. The course contained 27 classes and ten were dedicated to the tie of geometry and the folding process. Boakes concluded that 4 hours of Origami instruction received per week may very well have contributed to higher scores in the post-tests. Boakes, Norma. (2009)

Qualitative study: Geometry teaching via origami: the views of secondary Mathematics Teacher Trainees. In my opinion, this study is one of the more interesting studies that I have read. Teachers were the ones surveyed not the students. The teachers were asked questions such as: “What are the benefits of using origami in mathematics teaching?” The study collected their responses. The test concluded that origami is a beneficial instructional tool to be used in math lessons and teachers are suggested to use origami activities in math lessons. Mathematics teacher trainees stated that they had fun while doing origami, and origami transformed mathematics into fun lessons for students. The participants point out that origami is useful in understanding geometry. Origami activities have also improved the teacher trainee’s communication and collaboration skills. The study suggests that origami activities should be included in mathematics teaching.

Chapter 7. How does one make origami lessons?

For one to be able to create well-designed origami lessons, one should first consider what the outcomes of the lesson should be. By knowing what type of concepts and vocabulary words that you would want to incorporate will help you decide what type of origami model would be best to use. A teacher should be able to go through all the steps of an origami model prior to introducing it to the class. Practicing is a great way to decide where and when you would like to introduce certain keywords and concepts. Going through the folding process again this time writing down questions for the class will help one prepare. Answer your own questions to see how the class could answer. Having models to show the students prior to the lesson will motivate the students.

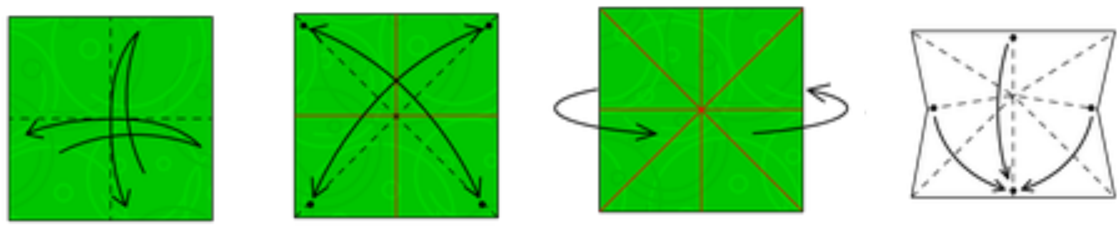
Having a good amount of materials available is necessary. A flat surface is always best, especially for new paper folders. I personally believe that larger paper is the best way to go when teaching a class. The students could use larger paper or use a smaller piece of paper. A good way of making steps a little more discrete is by drawing on the students' paper so they can see where creases would be created by folding on a line drawn on paper. This method will also work if one was to draw a dot where the paper should fold too.

Asking students to imagine what the paper would look like after a fold is made is good for their spatial reasoning. Having them unfold to see the patterns created is a great way to aid the understanding of what has been created.

Chapter 8. How I made a lesson

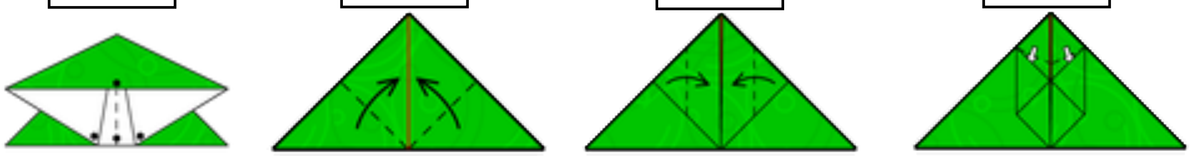
Taking what I have learned in chapter 6. I have constructed a lesson that incorporates origami. I was able to share this example with my math senior seminar class through a presentation. During my presentation, I did not go into too many details since the whole senior seminar class has taken high-level math classes in the past. I chose to teach the class a traditional and easy to follow fold, a water bomb. This fold has a lot of potential for math purposes. A professor at SUNY Purchase College, Dr. Irina Shablinsky, used this fold to teach another math general education class about platonic shapes. I have included the steps for the water bomb fold for easy to follow along with instructions. As well as points that can be made through the folding process.

Step 1 Step 2 Step 3 Step 4



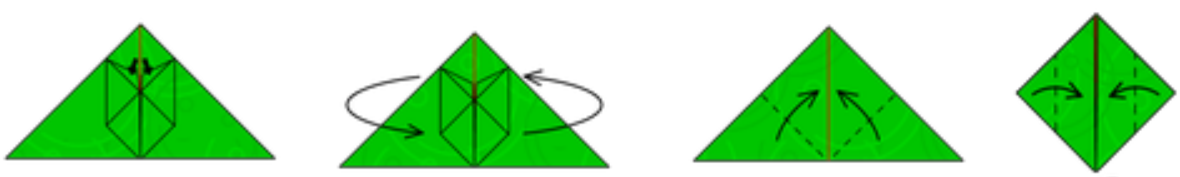
During these early folds, one can talk about the symmetry displayed, as well as fractions.

Step 5 Step 6 Step 7 Step 8



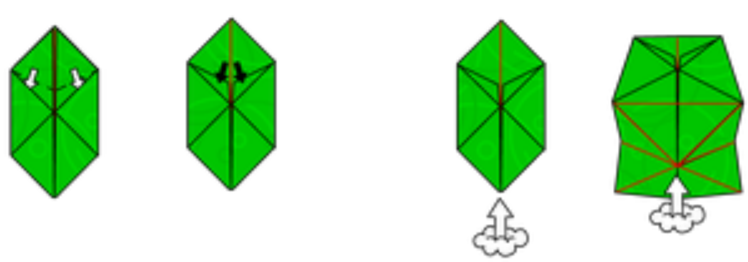
There is a clear demonstration of different triangles. Asking students to point out the different triangles is a great idea. There is still a constant symmetry.

Step 9 Step 10 Step 11 Step 12



Step 9 is a pretty difficult fold, especially for new folders. This fold requires to insert a tab into a pocket. From step 11 and on are mostly repetitive.

Step 13 Step 14 Step 15

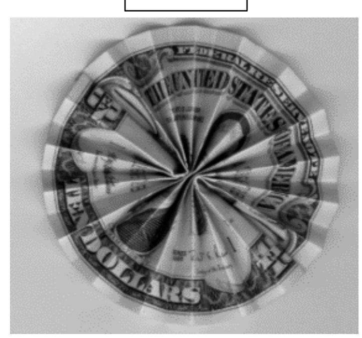


Now from step 15 is where it gets a little different. Before blowing into the hole at the bottom, asking students what they think the model would look like is great for spatial awareness. After creating the water bomb one can see that we have created a cube. A positive experiment can be remaking the waterbomb with a bigger $n\ x\ n$ size paper and checking to see if any of the angles change. We know that all the angle sizes will not, but it will be a fun hands-on experiment to learn about angles.

Chapter 9. The Art and Math of Origami Course

I was able to be a teaching assistant for a class called The Art and Math of Origami. I personally enjoyed and it was my favorite class throughout the semester. The teacher, Dr. Jeanine Meyer, has been doing origami for 56 years and views origami as mathematics. However, her initial reaction to being asked to develop the course was that the mathematics in origami may be too difficult. She realized that much of origami could be connected to basic mathematics concepts, including spatial relations. Professor Meyer took ideas she picked up from conferences, papers, and conversations. For example, she took the idea of students curating individual collections from an article and later a conversation with Norma Boakes. She decided that students would “get a peak” of more advanced mathematics. The class was combined with a Topics in Advanced Mathematics class for a lecture on the dollar bill rosette model (Ex.3) that includes the notion of iteration to improve an estimate and a category of prime numbers. Theorems on flat foldability were

Ex.3



presented with students making a simple bowl. Finally, students learned how to produce a five-point star with "one cut" with mention made of the general theorem on producing any polygon with just one cut.

This class met twice a week for an hour and forty minutes. Folding goes on in practically every class. The exception is when students give reports on history topics. Ideally, there is time to fold a model twice. Students are required to identify, learn, and teach a standard model and then a modular. There is an assignment to invent variations on models. A paper airplane contest provides a fun activity that relates to paper folding most people have already done.

The fact that the course satisfies the SUNY mathematics general education requirement means that there are various students from different majors enrolled which have taken different levels of mathematics. All of these students had different levels of experience with origami and different attitudes towards math.

When asking the students why they took this class on the first day there were many different answers. Some were excited to learn how to make origami. Many of the students had not done any paper folding before. Many of them said they were too intimidated to take another general education math class and were excited to see connections between math and origami. Others took this course over pre-calculus or calculus because they were too intimidated. Many of the students saw the relationship between math and origami before even starting the class. Professor Meyer's main goal was to get all the students to think of math differently by the end of the semester. She also felt that taking students away from their screens was an important goal.

Allowing students to get more involved is always a positive thing. When students are able to create their own terminology, they are able to remember a step better. In origami, there are a lot of base steps. I personally refer to a common base as the diamond base. (Example 3)

During one of the classes, a student referred to a kite base as an ice cream cone (Example 2). This is where I believe that auditory learners can benefit from origami. There is an interplay between teaching and encouraging students to use the standard origami terms and math language while also encouraging students to invent their own jargon and recognizing and celebrating when they do so.

Ex. 4

Ex. 5

Chapter 10. Survey and Results

Due to lack of time, I wasn't able to perform any tests, but I was able to give out surveys to The Art and Math of Origami class. I wanted to know what were the last few classes the students have taken, and why they decided to take this specific course over other general education courses. Whether they believe their spatial visualization has improved and how they think math and origami relate to each other. Not all of the students were in class on the day I gave out the surveys. But I was able to get twelve out of sixteen students to complete said surveys.

Students have taken different math courses from high school algebra to calculus 3. It's interesting to see why students that have taken a lower level math classes and their reasoning to why they decided to take an origami class. Many students have said that they weren't good at math and didn't want the anxiety of a regular math class. Some of the students that are creative and, in the arts, have stated that they wanted to take a creative class because they wanted a fun and interesting class. While others decided on this class because they enjoy making origami.

Most students besides one said that this helped with spatial visualization. Said student said they "just weren't good at stuff like that." Three of the students have mentioned that they had pretty good spatial visualization prior to this course. One of those students said, "As a dancer, I already feel as though I have an advantage when it comes to spatial visualization and visual awareness so if anything, it just helped to further it.". Two other students had mentioned that being a visual artist has also given them advantages when it comes to spatial visualization. These students with prior spatial visualization do believe that origami did help improve it. Another student had indicated, "Definitely as a sculptor, I have to visualize everything I do in both two and three dimensions. Practice is always good. This class has helped me train my eye a bit more". The rest of these students excluding the four that I have mentioned have also said that they believe that their spatial visualization has improved. And throughout the class, their ability to think of folds ahead of time has improved as well.

After almost a whole semester of this course, it's interesting to see how the students still think math and origami relate to each other. The students have stated that within origami there are many angles, shapes, fractions, ratios, and origami relate to math through geometry and trigonometry. A student answered the question by saying, "Angles and length are what gives shape to origami creations". Another student answered, "formulas can be used for certain folds". Through the surveys, the students also mentioned that through different measurements and lengths of paper one gets different outcomes. Not too sure if they know if the angles stay the same. Throughout the class, the students were asked to do research on different origami related topics. One of the students learned that engineers use origami techniques. One student said, "I understand how it relates to geometry but personally the math aspect seems like over complicating things". Which is fair, every student has different opinions.

Chapter 11. Conclusion

Origami is an ancient paper art form, that enables hands-on learning, step-to-step instruction, schema building, spatial reasoning, and logical concept mapping. (Sze 2005) Origami should be used more often to get students interested in math education. It can be used to build spatial awareness and can be used to learn about shapes, geometry and much more. Origami can be a useful tool to fight math phobias by providing different ways to make math lessons more exciting.

The class that I was able to TA was not only fun, but I do believe my own spatial visualization skills have improved. Being able to fold origami helped but going around a classroom trying to guide students after a fold was incorrectly done improved it tremendously. Most of the students that I questioned have answered yes, they also agree that origami can benefit their spatial awareness. The students also saw how math and origami are connected. Most of the student in this course took this class due to their negative attitudes. I do hope that the students got a different perspective of math through The Art and Math of Origami.

Chapter 12. Suggestions for the upcoming course

The only thing that I would propose is that more math concepts and geometry be taught. That way students can see the connection between origami and mathematics in a better light. Some of the classes can solely be based on math. The class itself can be based on reviewing lessons that students had learned in high school that way students can relearn through a different perspective on topics that they might have had negative experiences with. It will be a great way to convert negative attitudes into positive ones.

During this study, I attempted to stay as formal as I could, but I highly recommend that a similar study be conducted with the incoming semester class. During the class, there weren't any tests given, but a test could be conducted prior to and after the class to the future students of The Art and Math of Origami class (experimental group) and another general education math class (control group). That way we can see if origami played as a positive role for educating the students in math as I believe it can. The tests could be similar to the ones Norma Boakes conducted. For example, the paper folding test, card rotation test, and surface development test could be used. Let's not forget to include a test that will evaluate their mathematical skills. Surveys could also be used again with some alterations such as changing or adding some questions. Asking what the students' majors are and what were the past grades in math classes would be a great addition. Most importantly the students will have a great time with this art.

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Appendix

Survey:

What made you decide to take The Art and Math of Origami over other math general education classes?

What were the last two math classes you have taken? (this includes classes from high school)

Being able to have a spatial visualization is the ability to mentally manipulate 2-dimensional and 3-dimensional figures. Do you feel like your spatial visualization improved?

How do you think math and origami relate to one another?

	What were the last two math classes you have taken? (this includes classes from high school)	What made you decide to take The Art and Math of Origami over other math genEd classes?	Do you feel like your spatial visualization improved?	How do you think math and origami relate to one another?
1	IB trigonometry and finance for the arts	I am not really good at math so I thought that taking an origami class would be easier than a regular math class because it relates to art as well	Yes ever since taking this class my ability to think of foods ahead of time have improved	Yes in my research for origami I learned that many engineers use origami techniques
2	Calculus two and three	I like origami	Probably not I'm bad with that stuff	Origami in my opinion is a type of math How the angles and Lengths relate to one another is what gives shape to origami creations
3	Math for contemporary life and algebra two	Any form of art involved with academics that I am typically not good at interest me plus origami seemed fun	In a sense yes but ultimately I personally just have a hard time doing that	Origami deff relates to geometry and algebraic formulas
4	College calculus and IB math	I was intrigued by the name and wanted to see what the class would be about	Yes knowing the ways to manipulate angles to make different objects has helped	The angles and measurements play a big role in the outcome of the fold
5	Art and math of origami financing The arts	They said it had little to no math	Sure	Origami revolves around mathematic principles, the whole art is based upon the math of angles. So very directly related.
6	Algebra two trig and calculus	It's seemed better than a normal math class because it would train the creative side of my brain as well as fuel my "step taking" brain	As a dancer I already feel as though I have an advantage when it comes to spatial visualization and visual awareness so if anything it just helped to further it.	The lines and angles often relate back to origami. Also formulas can be used for certain folders.
7	Financial arithmetic and AP macroeconomics	Financial arithmetic and AP macroeconomics	Yes.	Geometry as well as trigonometry
8	Algebra two and geometry from high school	Seemed more creative and interesting	Yes!	I believe that both are linked to geometry, planning and abstract thinking.
9	Statistics and trigonometry	Seemed like the easiest possible math course I can take specially since I really don't like math.	Yes even though I had a pretty good special visualization as I am a visual arts major	Origami has a lot to do with angles and shapes so it very closely relates to geometry
10	Algebra and advanced geometry	Origami was a subject that I was interested in previously, and I wanted to take related class.	Yes!	Math relates to origami in that the construction of highly detailed figures is relation consistent mathematical geometric and proportional trends throughout its building process.
11	Geometry and algebra two	It involved the least amount of math. Also, origami	Sure	I understand how it relates to geometry but personally the math aspect seems like over complicating things
12	Algebra one and two	I have always struggled terribly with math. It's a language that completely confuses me, to the point of bad anxiety. If I had to take another class... even coding or logic it would've been really unlikely for me to pass	Definitely as a sculpture I have to visualize everything I do in both two and three dimensions. Practice is always good. This class has help me train my eye a bit more.	Fractions and ratios, angles, etc.