ORIGAMI IN STEAM

ALEXIS LEIGH BOISVERT

SPRING 2021

A thesis submitted to the Honors Program at Southern New Hampshire University to complete HON 401, and as part of the requirements for graduation from the Honors Program

Reviewed and approved* by the following:

Dr. Adam Gilbert

Associate Professor of Mathematics

Faculty Mentor

Dr. Chris Matthews

Associate Professor of Global Business and Leadership

Honors Director

* Electronic approvals are on file.

Southern New Hampshire University

Manchester, NH

Abstract

This thesis explores origami's past, present, and future applications. Inspired by the Between the Folds documentary from PBS, we survey a wide variety of state of the art technologies which are possible because of origami. Throughout this thesis, readers will learn about the history of origami, it's place in mathematics, and it's potentially surprising applications in medicine, science, technology, engineering, arts and mathematics (STEAM). We make the case that there are great opportunities to use origami to supplement various aspects of STEAM topics in the early childhood, elementary and middle school curriculums. In addition, we provide sample origami applications for use in the kindergarten through eighth grade classroom which provide fun hands-on learning experiences and could inspire future scientists, mathematicians, doctors, engineers, and/or artists.

Keywords: Origami, Paper folding, Science, Technology, Engineering, Art, Mathematics, STEAM, Early childhood education, Elementary education, Middle school education, Math education, Science education, Medicine, Education

Introduction

Origami, also known as “paper folding”, was first introduced in Japan in 1603 ("BETWEEN THE FOLDS | History of Origami | Independent Lens | PBS", 2020). Within a few hundred years, paper folding was used for fun and for formal uses ("BETWEEN THE FOLDS | History of Origami | Independent Lens | PBS", 2020). By the 1800’s, kindergarteners in Japan and England were learning origami ("BETWEEN THE FOLDS | History of Origami | Independent Lens | PBS", 2020). Now, origami has many interesting applications. Origami can be used to model and create anything and everything from skyscrapers, and bullet proof shields to miniature planetary explorers and ingestible robots that can perform basic surgeries. Origami can be used for explaining how chromosome folds are linked to genetic mutation. Recently, origami has been used to model and design a star shade (Gent, 2018). This is a form of technology that works with telescopes by blocking out surrounding stars in space so the telescopes can see planets better (Gent, 2018). National Aeronautics and Space Administration (NASA) engineers are currently using origami practices to create a new rover that can be sent to explore planets (Gent, 2018). This rover is predicted to be better than the Mars Rover because it will be able to explore smaller/tighter places on the planets, adjust to the terrain more simply, and it will travel with more ease (Gent, 2018). Origami can also be used to model a “flat fold”. This type of fold can be used when working with cars and satellites. In terms of mathematics, Origami is useful for finding perfect triangles, uneven number of folds (ie. thirds, fifths, sevenths, ninths, etc) and much more. Even though origami is an old tradition, it has many unusual and striking applications to today's world and inventions. As laid out, origami certainly has natural applications spanning every aspect of STEAM (Science, Technology, Engineering, Art and Mathematics).

This thesis is a survey of origami past, present and future applications. Techniques from origami and insights gained have helped us learn more about advancements that are critical to space travel, microtechnologies, genetics, and much more. We make the case that origami could be embedded naturally into primary school and middle school lessons. One of our main objectives is to foster learning through ingenuities discovered from simple items and tasks, like folding a sheet of paper. We provide an appendix which includes supplemental activities that can be used in the kindergarten through eighth grade classroom. Origami has the potential to inspire future engineers, doctors, mathematicians, scientists and artists. In the appendix, we provide relevant projects to enrich students' learning, and which we hope will spark student's curiosity around the power and relevance of origami.

A Short History of Transformations of Origami

Origami has been around for centuries and has a riveting history. Whole books could be written on it's history. For the purpose of this paper, we will explore the history of the transformations of origami. The true origins of origami may never be truly known. However, it is a common belief that paper was invented in China in 105 A.D. Many cultures engaged in some form of paper folding, but it is believed that the Japanese were the first to do what we know as origami. Origami was previously known as "orikata" which means folding shapes. It wasn't until the late 1800s when it became formally known as origami. The name origami was formed out of the combination of two Japanese words, "oru" meaning to fold and "kami" which means paper. Theorists believe that this name was chosen because it was easier for young children to learn, remember and write. Since 105 A.D, origami has served many different purposes and grown to be very popular. (Hinders, 2019)

Before paper was mass produced, origami was only available to people who were wealthy, for religious and formal purposes. The group of people who did the most origami during this timeframe was monks. As monks did origami for religious events. The other most common use of origami towards the beginning of it's time was for weddings and gifts. Typically, when a Japanese couple got married they would have origami butterflies on the bottles at the reception. In other types of ceremonies, origami was given as a gift. Commonly, the origami would be given with a very valuable and expensive gift. This gift and paper-folded figure represented, "sincerity and purity". At important ceremonies, origami was given as a certificate of authenticity. Origami was very prestigious and formal during this time. (Hinders, 2019)

Origami became a more common practice when paper was being mass-produced. People started doing origami for fun (Hinders, 2019). Origami was used as gifts and cards (Hinders, 2019). Public schools taught kindergarteners and other school-aged children origami in the 1600s (Hinders, 2019). The creators of Waldorf, Montessori and a design school incorporated it into their curriculum in the 1900s (Robinson, 2021). Poets, authors and playwrights spoke of and wrote about origami starting in the early 1600s (Robinson, 2021). Mathematicians applied mathematics to origami and studied it since it first began (Hinders, 2021). In the 1980's, many mathematicians studied origami, it's properties and the intersection of it with mathematics (Robinson, 2021). Origami and mathematics were used in designing pop-up cards and pop-up books in 1998 (Abel et al., 1998). It was through all this, that helped the practice of origami spread to all of the countries.

Origami arrived late to the United States of America. A very popular origami artist, Akira Yoshizawa who is known as the "Grandmaster of Origami", had an exhibit that caught the attention of Lillian Oppenheimer (Robinson, 2021). Oppenheimer played a vital role in spreading origami to American (Robinson, 2021). She opened the Origami Center of America in New York, used television to publicize origami, as well as published many origami books (Robinson, 2021). Oppenheimer also opened an origami foundation and taught courses in origami ("Video: Lillian Oppenheimer "My Life" Part I", 2021). Without Oppenheimer, origami wouldn't have come to the United States and become as popular. Origami has gone through major transformations throughout it's time. It is an amazing and beautiful art that throughout history and presently has applied to other art forms and subjects.

Origami and Art

In PBS's, *Between the Folds* documentary we learn that the origami was first used by Monks for religious purposes; At the time, origami was only available for the rich and wealthy ("BETWEEN THE FOLDS | History of Origami | Independent Lens | PBS", 2020). When paper started being mass-produced, origami quickly spread like wildfire internationally and became available to everyone. And just like that origami became an artform. Since then the art of origami has kept up with modern day technologies. Origami art was once a simple crane and now, artists are designing life-size elephants from a single piece of paper.

Sipho Mabona, a 41 year old south afraican origami artist, is using his origami to stand up for social issues (Stewart, 2017). For example, Mabona built a life-size elephant to raise awareness for the dangers of ivory trade (Stewart, 2017). Mabona also folded paper money to fold into locusts to tackle the issues of money and the symbolism of ambition and damnation caused joy and pain (Stewart, 2017). After fifteen years of making paper airplanes, Mabona began doing origami (Stewart, 2017). Mabona's origami designs range from abstract geometric shapes to designs with deeper meanings (Stewart, 2017). He competed in the Salzburg 2006 Red Bull Paper Wings World Finals and has designed pieces for the movie, "Origami in the Pursuit of Perfection" (Stewart, 2017). Mabona was an invited guest to the 2008 Japan Origami Academic Society and was the first foreigner on the cover of the convention book the same year (Stewart, 2017). His works can be seen in galleries in London, Vancouver, Tokyo, Berlin and more (Stewart, 2017). Some of Mabona's most famous works include a Life-sized Elephant from one piece of paper and Swarm of Locust made from money, which you can see below (Stewart, 2017).

(Jobson, 2014) (Yoo, 2012)

Dr. Jeannine Mosley received her Ph.D from Massachusetts Institute of Technology (Stewart, 2017). She was a member of origaMIT club (Newton, 2015). Dr. Mosley's origami is famous because of her use of nontraditional "paper" (Stewart, 2017). Dr. Mosley has designed many fractal origami pieces (Stewart, 2017). A fractal is a mathematical object created from repeating a pattern over and over. Her most famous piece, the Menger Sponge, was made from business cards (Stewart, 2017). See a photo on the next page. The Menger Sponge is a fractal that divides cubes in ninths and removes the center cube from each exterior face of the original cube as well as removes the center cube (Stewart, 2017). In total, seven cubes are removed from each larger cube on any given iteration. Dr. Mosley worked on the Menger Sponge fractal for eleven years (Stewart, 2017). She used 66,000 cards (Stewart, 2017). Since then, Dr. Mosley has created more fractal origami pieces (Stewart, 2017).

(Friedman, 2005)

Art is defined in the Merriam-Webster's dictionary as, “the conscious use of skill and creative imagination especially in the production of aesthetic objects” (Definition of ART, 2021). One artist we examined uses art to stand up for social issues, while the other creates never ending patterns out of irregular materials. As we can see, art has kept up with the modern day. Origami art could be taught in the kindergarten through eighth grade classroom because it’s cost effective, easy to clean and a traditional art form with opportunities to add a modern twist. Origami art has even grown to include small circuit lights (see activity), and motion. Origami art could be a fun new twist in the typical art class. Since origami allows for natural links to occur between art and other subject areas such as science, engineering, mathematics and even social studies, it opens up the door for meaningful lessons and activities that can greatly impact their learning. Rather than the same old shading and painting, students could be creating light up and motion origami pieces.

Origami and Technology/Engineering

Using origami in technology and engineering is both innovating and exciting. From starshades to creating buildings and setting them up with helicopters origami is transforming engineering and technology. Technology is ever-changing. Using origami in technology has allowed innovators to make the most of its shape and design. Origami, while relatively new to engineering, has impacted processes and acted as inspiration for many new inventions. Origami has inspired both technology and origami in many ways.

One emerging technology that will be groundbreaking for marine life experts is the Deep-sea Grabber. The new technology was invented by Robert Wood who is a roboticist at Harvard University. The Deep-sea Grabber has a five-fingered claw at the end of a robotic arm. Wood designed the claw using origami. The claw folds into a twelve-sided container. The walls are made up of a pattern of triangles and pentagons. The claw is connected to a robotic arm which is designed to be connected to a submarine. The amazing part about this technology is that the Deep-sea Grabber works off of one motor. Wood said that the most important thing about the Deep-sea Grabber was that it was simple because it would be used in severe environments. They will be using the Deep-sea Grabber to catch delicate marine life such as octopi and jellyfish without hurting them. The Deep-sea Grabber will make it possible for marine rehabilitation experts to rescue and nurse fragile sea creatures back to health and return them to their natural habitat. (Gent, 2018)

An engineering team at Brigham Young University have revolutionized bulletproof shields for cops and possible more. The leaders of the team, Dr. Larry Howell and Terri Bateman have used the Yoshimura folding pattern to create the shield using the same material that a bulletproof vest is made from. The Yoshimura pattern allows for a flat material to transform into a curved figure. Traditionally, bulletproof shields are over one hundred pounds, don't cover the whole body, take minutes to set up and only protect one person. The bulletproof shields design at Brigham Young University could increase the safety of first responders. This shield is twenty-four square feet. Since it is so large it can protect the whole body of two to three full grown adults. The shield is also half of the weight of traditional bulletproof shields, weighing in at about fifty-five pounds. Also, the origami inspired shield can be set up in under five seconds. In testing, this shield could withstand the pressure of the most powerful handguns and pistols. Unfortunately, the origami inspired shield cannot take the pressure of guns that have tinier and sharper bullets like assault rifles. Regardless, Howell and Bateman have big dreams for this shield. They are looking for a company to mass produce these shields so they can be placed in schools for teachers and students to use in the unlucky event of a school shooting and for cops. The origami inspired bulletproof shield coils help save the lives of students and teachers. (Schwab, 2017)

Both the Deep-sea Grabber and the redesigned bulletproof shields are perfect examples for how relevant using origami in technology and engineering is. Currently there is a big push to include more Science, Technology, Engineering, Art and Mathematics (STEAM) based activities in the kindergarten through eighth grade classroom. Origami inspired technology and engineer projects allow for a seamless integration of STEAM into the classroom. Engineering and technology should be fun, engaging, and exciting for students. Origami gives educators the opportunity to teach technology and engineering in a way that could inspire students. Teaching technology and engineering using origami has the potential to close achievement gaps and prevent them from forming. See an example activity in the supplemental activities. Teaching technology and engineering using origami allows for hands-on, engaging and fun projects that encompass the true meaning of STEAM and have the potential to inspire future technologists or engineers.

Origami and Medicine

Recently, origami has been used in medicine for groundbreaking research, creating new technologies and to visualize things that we otherwise wouldn't be able to see. Though many advancements are being made using origami, two are truly groundbreaking. The first, which was mentioned in the introduction, is ingestible robots that can perform surgeries (Gent, 2018). However, these robots have the potential to do much more. The second way origami has shaken up the medical field is through tissue paper and folding that promotes muscle, tissue and organ healing (Paul, 2017). Origami is making waves through the medical field in many ways beyond the two listed and described here. Origami engineers and bioengineers are working closely to create new equipment that is more precise and useful in surgeries (Reporter, 2019). Doctors have also been able to use origami to analyze how chromosome folds are linked to genetic mutation (Zheng et. al, 2017). Origami's applications in medicine have the potential to transform the medical field in unexpected ways.

A team of researchers and engineers out of Massachusetts Institute of Technology has developed a new robot using origami patterns. This robot is small enough that it fits inside a pill capsule. A person then can swallow this pill. Once in the stomach, the capsule breaks down and the robot comes to life. The robot can then perform simple surgeries. The robot operates with external magnetics. As of right now, the robot can remove batteries, stop internal bleeding in the stomach and other simple surgeries in the stomach. The robot does this all without an invasive surgery. The team's goal is to move on to other “in vivo" or in the body procedures. The team at MIT is predicting that testing for this technology will last until 2022 maybe longer. This ingestible robot has the potential to revolutionize simple surgeries to make this less invasive and cut down healing time. (Gent, 2018)

Another example of origami research in the medical field is tissue paper out of Northwestern University. Tissue paper was created by accident and it can change wound healing, life for cancer patients and women going through menopause and much more. Adam Jakus, a lead researcher on the team, was working with a three-dimensional printer to print models for organs. However, Jakus unintentionally knocked over the printer and before he could wipe up the solution it froze into a paper. (Paul, 2017) This paper was made out of animal organs such as a pig heart, pig liver and animal muscle that was cut into half millimeter cubes and washed for many days with a very powerful soap (Samuelson, 2017). This process is known as decellularization (Samuelson, 2017) Then Jakus and his team take the decellularized organ and grind it into a powder and then format the powder into paper. This paper is strong but thin enough to be folded into typical origami creatures such as a crane. This paper can be placed on the desired organ it's made from (kidney to kidney, ovary to ovary, liver to liver, etc.) to help that organ heal and by growing the cells which ultimately produce the needed hormones. The hope is that this paper can be made slightly damp and applied through a simple surgery to help people going through menopause, battling cancer or with internal wounds. This tissue paper also promotes the production of adult stem cells. This innovation in the world of medicine could improve the lives of many. (Paul, 2017)

As one can tell, the world of medicine is going through major innovations that will change medicine as we know it. That being said, learning about what's new in the world of medicine could spice up the traditional biology lessons in the kindergarten to eighth grade curriculum. Most schools don't go much beyond traits, Punnett squares, systems in the body, genetic diseases, cancers, muscles and bones. The ingestible robot and the tissue paper are revolutionizing medicine in these areas. Though both these examples are biology based, origami can be applied to all sciences and science related fields. Teach students about this would not only update the science curriculum (see activities for a biology-based activity), but also could interest them in a way that the typical curriculum wouldn't.

Origami and Math

Information for this section came from Hull, T. (2021). *Origametry*. Cambridge University Press.

People have been using origami for mathematical purposes for a long time. Origami as a medium allows for theorems and concepts to be differentiated to all learner levels. For example, Thomas Hull taught Maekawa's Theorem (to be discussed further later) using a hands-on activity that made the theorem easy to visualize and very accessible. Then he went on to explain the math at a more advanced level. Hull's, *Origametry*, is a collection of mathematical theorems, proofs and concepts around origami. In *Origametry,* he defines several terms that are useful for discussing origami in terms of mathematics, introduces the basic origami operations and discusses a theorem that kickstarted using origami for mathematical purposes.

There are eight basic origami operations, or legal origami folds, in mathematics. They are listed below.

Operation 1: Given two points $\square_1$ and $\square_2$, we can fold a crease line connecting them.

Operation 2: Given two lines, we can locate their points of intersection, if it exists.

Note: The point of intersection will not exist if the lines are parallel to each other.

Operation 3: Given two points $\square_1$ and $\square_2$, we can fold the point $\square_1$ onto $\square_2$ creating a perpendicular bisector.

Operation 4: Give two lines $\square_1$and $\square_2$we can fold line $\square_1$onto the line $\square_2$creating an angle bisector.

Operation 5: Given a point $\square$and a line $\square$, we can make a fold line perpendicular to $\square$passing through the point $\square$making the fold line perpendicular to the point.

Operation 6: Given two point $\square_1$and $\square_2$and a line $\square$, we can, whenever possible, make a fold that places $\square_1$onto line $\square$and passes through point $\square_2$.

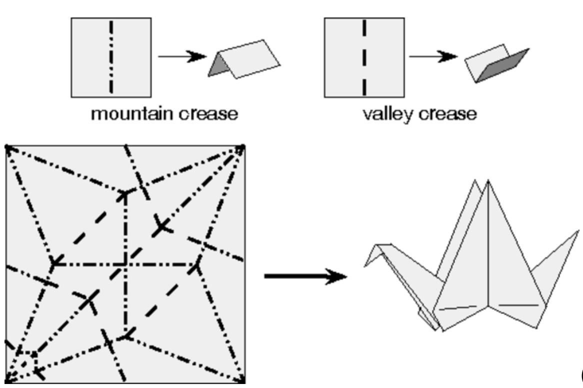
Note: This operation is not possible when $\square_1$and $\square_2$are close together.

Operation 7: Given two points $\square_1$ and $\square_2$and two lines $\square_1$and $\square_2$, we can, whenever possible, make a fold that places $\square_1$onto $\square_1$and also places $\square_2$onto $\square_2$.

Note: This operation is not possible when the distance between $\square_1$and $\square_2$is smaller than the distance between $\square_1$and $\square_2$.

Operation 8: Given a point $\square$and two nonparallel lines $\square_1$and $\square_2$, we can make a fold perpendicular to $\square_2$that places $\square$onto $\square_1$.

From these basic origami operations, we get the following theorem. If we only allow one-fold at a time and we are assuming all our creases are straight lines, then the only folding operations possible are operations one through eight. Robert Lang proved this theorem to be true in 2003. Using these eight operations, one can prove any origami mathematical theorems.



(Hull, 2015)

Maekawa pioneered two contributions in the world of origami and mathematics. The first was a crease pattern. Crease patterns are essentially blueprints for a specific pattern. See the figure below for an example. See the figure to the left for an example. As one can observe from the figure, this is a crease pattern for a traditional crane. One may notice that there are two different types of lines on the crease pattern. The key above tells us that the lines with more dots are mountain creases and lines with three dashes are valley creases. Mountain creases are when one folds the paper to create an inverted “v”. Valley creases are when one folds the paper to create a “v”. Maekawa’s Theorem, his second contribution to origami and mathematics, works with mountain and valley creases. Put simply, Maekawa’s Theorem states that when doing flat folds the total number of mountain creases (M) minus the total number of valley creases (V) equals plus or minus two. In math terms, it looks like the following $\square - \square = \pm 2$. See supplemental activities for an accessible activity to prove the theorem. Note, a flat fold is when a paper can be folded but reminds flat against a surface. A flat fold is important because by making flat folds, one can make a material with a large volume small. The flat fold is helpful when designing airbags and satellites. A flat fold essentially saves space. In math, we use them because they have predictable properties. Maekawa was among the first of many mathematicians who studied the intersection between origami and mathematics.

Origami could be a hands-on medium to engage students in mathematics lessons in a variety of ways. In the early childhood classrooms, origami can be used to teach shapes. In the upper elementary grades (third, fourth, and fifth), one can teach perimeter, area, surface area, volume and basic graphing with origami. In middle school mathematics education, the opportunities are endless. Origami constructions offer more variety than simple compass and straight-edge construction. Origami is also a cheaper option and often requires less supplies. As origami can act as a straightedge and a compass. Even though a straightedge and a compass sound old fashioned, origami makes it more interesting. Some examples of how origami can be used in mathematics education are the following; proof of the Pythagorean Theorem, to teach systems of linear equations, similar triangles, translations, rotations, reflections, lines of symmetry and so much more. Even though origami is a traditional art form, it provides opportunities to do fun, engaging and memorable math lessons that can boost students' confidence.

Conclusion

Not many people are aware of the research opportunities or scientific discoveries that origami has provided us. As one can tell from this paper, the research is new, relevant, exciting and potentially groundbreaking. Students either love or hate STEAM related subjects which directly correlates to how much they care. The systems we are using to teach science, technology, engineering, art, and mathematics is old. It may have worked once but it doesn’t do its job well enough now. The generation of students in kindergarten through eighth grade now and to come have grown up with technology. For some students, every answer is one click away. If we use origami, we can engage, entertain and teach students in a more meaningful fashion. We can all think back to a time when we were in a class and either you or someone else asked, why do we care or why do we need to know this? Could your teacher give you and your class a real answer? Mine couldn’t. If we, as educators, lead with a brief explanation of some of the cool and flashy origami research being done in the field then do an origami activity, we could change a student’s whole mindset about STEAM. We could close the achievement gaps and inspire the future of our nation. Origami provides endless opportunities to enrich students' learning and we should take advantage of it.

Supplementary Classroom Activities

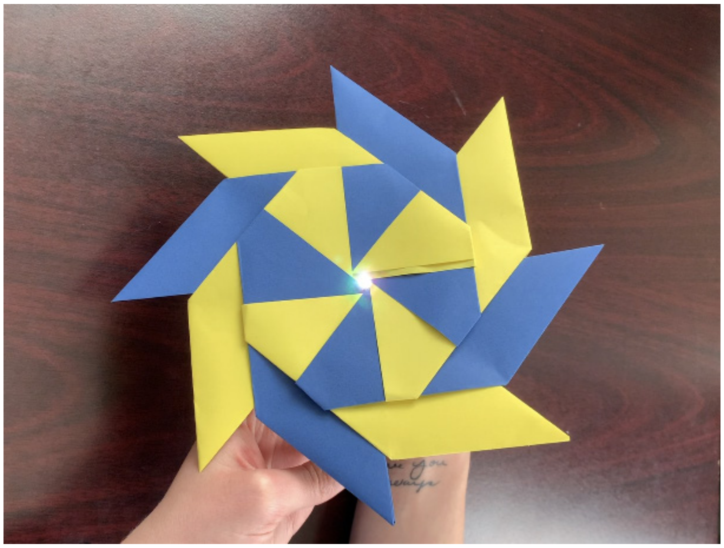
This section contains five classroom activities that are centered around using origami to teach STEAM. Each activity has a section for the teacher, students, instructions, takeaways and a reflection aspect. The teacher section includes relevant standards, materials, and other basic information. The materials are hyperlinked to a site where you can buy the product. This section is meant for teachers to be able to read quickly, get a rough idea of the idea and decide whether or not it's for your class. The student section is an introduction to the activity. It contains information about what materials a student will need and what they will learn. The introduction also contains a hook and is meant to engage the students in the activity. The instructions have a video hyperlinked in it with an example, pictures or both. The takeaways are written so students are either filling in the blank, answering short answer questions, or circling the answer. This will help get the students engaged in reading about it. Lastly, the reflection piece allows teachers to get a feel for what the students learned from the activity and what they thought of the lesson. The design is intended to be simple and easy for teachers to use in the classroom.

Throughout this whole paper, we have made the case that since origami research is new and relevant then origami should be used in kindergarten through eighth grade STEAM curriculum. Origami provides us the opportunity to foster an entertaining and interesting hands on learning activity. The following five activities are a few ways that origami can be used in the classroom. We intend to continue to develop more activities to share with educators. Origami is an old practice but mixed with the right level of enthusiasm from the teacher, fun gadgets (i.e lights, motors,...), and a willingness to be adventurous, it could greatly impact students STEAM mindset and STEAM education.

Light-up Pinwheel

Activity for third-fifth graders

Total cost of this activity for 20 students: $20.53 (including batteries, LED lights and origami paper) -- Note: There will be extra supplies.



For the teacher:

During this activity students will create a pinwheel with a light up center. Students can move the pinwheel from the pinwheel shape to more circular/octagonal shape. Students will also learn and understand batteries, LED lights, basic circuits, and geometry. This activity can be used as part of the following standards; CCSS.MATH.3.G.B.A1, CCSS.MATH.5.G.B3, and Next Generation Science Standard 4-PS3-4 for third through fifth graders. To complete this activity, students will need one battery, an LED light (color or white), and two different colored-pieces of origami paper (4 of each color per student). At most this activity will cost $20.53. This activity is a fun and engaging way for students to learn basic circuits, and geometry. Enjoy this origami activity with your students!

For students:

Get pumped for an adventure creating a movable and light-upable origami figure. You will use the materials supplied for you to create a pinwheel. In front of you, you should have a small LED light, a battery, and a total of eight pieces of paper (four of each color). To begin this activity, you will follow all of the instructions below. See the photos and video clips supplied for reference. The written instructions from folding the origami pinwheel are from *The Book of Fabulous Origami* (pgs. 84-87). After creating the origami figure, please complete the takeaways and reflection pieces. Have fun!

Instructions

1. Take one piece of paper and fold by bringing the bottom edge of the paper to the top. Crease well and unfold. Then take the right most corners and fold them to the center line. Crease well and unfold. Fold in half again (the same way you did earlier).

2. Take the top left corner of the figure and fold it to meet the bottom right corner. Crease well and unfold. Then fold the same top left corner to meet the bottom left corner. Crease well and unfold.
3. Tuck the left side in on itself (see the video)
4. Repeat steps 1-3 seven more times.
5. Next take two of the quadrilateral shapes you created (for best visual effect, use one of each color), See video for instructions for how to put the shapes together.
6. Keep going until you create the octagonal figure. See video for how to transform it into a pinwheel.
7. To make the figure light up, stick the LED light through the center of the pinwheel. Next take the battery, and use it to light the battery up. The flat side, or positive side, should touch the long prong. The shorter prong should touch the rough side, or negative side, of the battery.

Takeaways

Word bank: traditional, battery, modernizes, LED light, positive, negative,

During this activity, you worked with a __________, and a ______________ to make your pinwheel light up. This activity ____________ origami which is a very _________ practice. We know that the flat side of the battery is the ____________ side. The rough side is the___side. The long prong of the LED light is the positive. The shorter prong is the negative. So, it should be positive to positive and negative to negative. Now please answer the following short answer questions and answer the reflection piece.

- The word "quadrilateral" was used to describe the shape of a figure in the instructions. What is a quadrilateral? What are the characteristics of a quadrilateral?

- What happens when you match the positive prong to the negative side and the negative prong to the positive side?

- What happens if you only match the positive prong to the positive side of the battery and don't attach the other prong and side of the battery together?

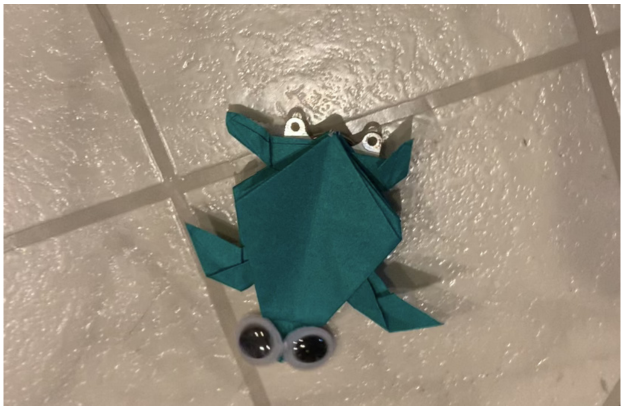
Reflection

List three things you learned from this activity.

1.
2.
3.

Moving Turtle

Activity for k-8 students (Scaffolding would be required when working with k-4 students)
Total cost of the activity for 25 students: $280.00 (a kit with all the needed supplies)
Note: There will be extra supplies. We will continue to search for similar supplies with a better price.



For the teacher:

During this activity, students will create a moving turtle by building a simple circuit. Students will learn the basics of energy transfer, conductive v. nonconductive tapes, simple circuits, and connect it to mathematics. This activity follows the following standards; Next Generation Science Standards: K-2-ETS1-2, 4-PS3-4, and MS-ETS1-4. As for the Common Core State Standards it works with the mathematical practices and standards relating to mathematics in the real world. To complete this activity, you will need to purchase the activating origami kit from Tekiniko, scotch (or some other type of clear) tape, and googly eyes (optional). Unfortunately, this is a very expensive activity but it is very fun for students. The tape will do the job but is by no means a perfect solution to hold everything in place. Feel free to take the opportunity with your class to brainstorm, discuss and try different ideas. This is a fun activity that blends modern technology with an art artform. Have fun learning and experimenting with your students!

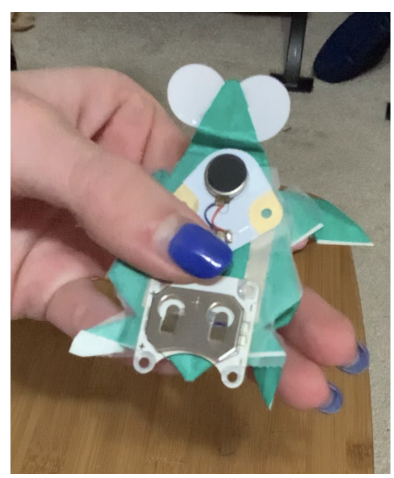
For the students:

Are you excited to create a moving origami figurine? This will be a fun adventure! First, you will be folding an origami turtle. Then you will build a small circuit. Don't panic!! It's not too scary! I promise! In front of you, you should have a piece of origami paper, a motor board, a battery board, a battery, two pieces of conductive tape about an inch long. To begin this activity you will follow all of the instructions below. See the photos and video clips supplied for you as reference. The written instructions from folding the origami turtle are from *The Book of Fabulous Origami* (pgs. 36-40). After creating the origami figure and completing the circuit, please complete the takeaways and reflection pieces. Happy folding!!

Instructions

1. Fold your paper in half horizontally. Crease well and unfold. Turn the paper over. Now fold the bottom right corner to the top left corner. Crease well and unfold. Fold the bottom left corner to the top right corner. Crease well and unfold.

2. Fold along the horizontal and push in the corners so you end up with a triangle (see video).
3. Fold the top flap right corner up to the center line. Crease well. Repeat with the other side. Fold the left corner point of the triangle to the center line. Crease well. Repeat the other side. Unfold both sides.
4. Grab the left corner and fold along the creases you made in the opposite way (see video). The point of the leg should meet the tip of the figure. Grab the right corner and fold along the creases you made in the opposite way (see video). After folding it, fold it back on itself so the leg points down.
5. Repeat steps 2 and 3 on the other side. Then fold one of the legs that meet at the top of the figure at an angle. Turn the figure around and match the angle for the other leg. These will be the turtle's front legs.
6. Hold the figure with the front legs on the right and the back legs pointing towards you. Now fold the top leg pointing towards you to the right and crease well. Then unfold. Using the fold, you just made, fold the leg in on itself. Turn the figure over and repeat the steps so it matches the other back leg.
7. Take the left flap on the figure and fold it over. Then turn the figure over and repeat. Fold the front legs back and crease well. Now unfold and fold it on itself. Then fold the back legs back and crease well. Now unfold and fold it on itself.
8. Turn the figure over. Fold the head back and then fold it back towards the front of the turtle.
9. To make the circuit…
    - Using a pencil to mark the places for the battery pack and the motion pack, place the battery pack so that the battery is facing the back legs and mark the spot. Place the motion pack with the wires facing the battery pack and mark.
    - After marking it, using the two 1-inch conductive tape sections that you have, place the tape sections so that it touches where the battery pack and goes to where the motion pack will be. It is important that the sections of tape do not cross, break or rip.
    - Then tape the motion pack and battery pack in place. Once it's secure, place the battery in it with the positive, or smooth side up. Now your origami should be moving.



Takeaways
Please answer the following questions.

- What would happen if you put the battery in with the negative side up? Why does this occur?

- Why shouldn't you cross, rip or break the pieces of conductive tape?

- In what ways did you use mathematics to do this project? (yes, mathematics does exist in the everyday world and you used it this activity)

- Using your answer from the previous question, write a problem or situation in which you could use this origami project in math class?

- Draw a diagram of the circuit you made. Include a brief explanation on why we need each piece in the circuit. What would happen if we took any one piece of the circuit away?

Reflection

1. What did you learn from this activity?

2. What did you enjoy about this activity?

Origami Hand Activity

Activity for K-8 grade students.

Total cost of the activity: $10.43 (including origami and yarn)

Note: There will be extra supplies.

For the teacher:

During this activity, students will be using origami and some other materials to create a hand. Students will learn about joints, bones, tendons, and muscles while using geometry and doing a hands-on project. This activity could be scaffolded and used in grades ranging from kindergarten through eighth grade. To complete this activity students will need origami paper, scissors, glue sticks, yarn, an empty toilet paper roll or a small box, hot glue, and a cake tester (optional). This works with the standards relating to the human body in the kindergarten through eighth grade Next Generation Science curriculum. Feel free to come up with a better way to put them together. This is an exciting hands-on project for students to do and will promote learning through curiosity! Have fun with the students!

For the students:

This origami activity idea inspired by Mystery 1 from Mystery Science. During this activity, you will create an origami hand. To complete this activity, you will need the following materials: three sheets of origami paper, scissors, a glue stick, five pieces of yarn, empty toilet paper roll or a small box, hot glue, plastic straws, and cake tester (Optional). In this activity, you will use geometry while doing a hands-on science activity. After finishing the activity, you will complete the paragraph by filling in the blanks. Happy origaming!

Instructions

Click here to see a video.

1. Take one piece of origami paper and fold it in half. Cut along the line.
2. Take one of the pieces and fold it in half. Fold it in half again and then unfold just the second fold.
    a. Optional: Cut up to an inch off the top to vary the lengths of the fingers.
3. Carefully, cut three triangles with roughly even spaces in between.

4. Next put glue on an edge piece. Spread the glue evenly among the fourth of the paper. Then stick the top part of your yarn inside the fold and stick each end piece together so they overlap. It should resemble a triangle and have the yarn coming out of the opposite end.
5. Now you should be able to test it. If you pull on the end of the yarn, it should bend like a finger does.
6. Repeat steps 2-5 for the other half of the origami paper.
7. Repeat steps 1-6 to create the rest of the fingers. Note: If you would like to make the fingers different sizes complete step 2a.
8. After all five fingers are made, you can create a wrist for the fingers. Start by hot gluing the straws in the empty toilet paper or small box next to each other. Then feed the yarn through the straws. You can use the cake tester to help if needed.

Takeaways

Instructions: Using the word bank fill in the banks in the paragraph. Words may be used more than once. Word bank: ten, metacarpals, fingers, ligament, phalanges, 56, toes, carpals

During this activity, you can compare parts of your origami hand to parts of a human hand. The strings act as a ____________. A ______________is a short band of tough, flexible fibrous connective tissue which connects two bones or cartilages or holds together a joint. The bones in the bottom ⅓ of the finger is called ________________. Each human hand has five ________. Therefore, a human being has a total of ____________metacarpals. The second and third bones represented by the second and third sections of the fingers are called the _______________. There's a total of __________phalanges in the human body. The last bone at the base of your hand are called _____________.

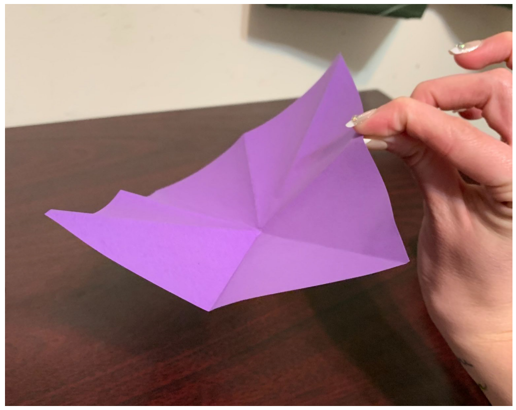
Reflection

List three things you learned from this activity.

-
-
-

Did you or did you not enjoy this activity, why or why not?

Proof of Maekawa's Theorem
Activity for k-8 graders
Total cost of this activity; $16.95 (markers and ream of paper)
Note: There will be extras.



For the teacher:

The idea for this activity came from Thomas Hull's virtual presentation through the New Port Art Museum on February 20, 2021. During this activity, students will not only do a hands-on basic origami activity, but they will also learn the basics of proofs. To complete this activity, students will need a marker and one piece of 8.5' by 11' computer paper. This activity serves as an exciting introduction to proofs. This activity is a fun, hands on activity that requires students to notice patterns, learn the basics of proofs and do subtraction (maybe even negative numbers). Happy origaming proofing with the students!

For the student:

Proofs are very important in mathematics. Some proofs are very short. They are almost little and cute. Others are long and beastly. The longest proof that I know of was a 129-page proof. Don't worry, we aren't to do anything too crazy like that! The purpose of this activity is to get us into the mindset of proving things. Maekawa's theorem was named after Jun Maekawa who is a Japanese software engineer and mathematician who developed a theorem. This activity will introduce you to his theorem and help you complete a basic proof of the theorem. Talk to your peers about this! Talking to others about mathematics can be very valuable! Today, it will be very helpful!! Have fun! Work hard and don't give up!

Instructions

1. Find the center point of the 8.5' by 11" paper. You can do this by gently folding (without creasing) both the hot dog and hamburger styles (click the link to see Katie W make a hot-dog and hamburger bun fold). Use the marker to the center point.
2. Make as many folds as you would like that include the point. These are flat folds.
3. Once you are satisfied by the number of folds, you can unfold the paper.
4. Count the number of mountain and valley creases.
5. Now find the number of mountain creases - valley creases. What does it equal?
6. Go talk to five other people in this class. Write their names out and a star next to their name if they got ± 2 in step 5.
    -

-
-
-
-

Takeaways

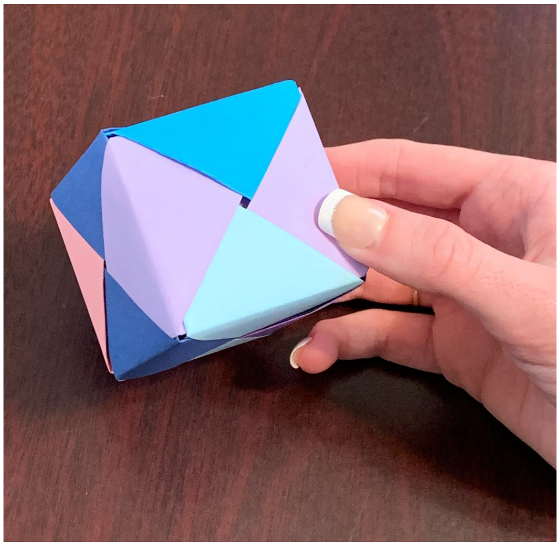
Instructions- Fill in the blanks.

In our design, we used mountain and valley folds. A mountain fold creates an upside-down or inverted "V". While valley folds create a normal "V". We created these folds by creating flat folds. A flat fold is an origami model that is flat. If we unfold our creases, we can see the crease pattern. Now looking at your crease pattern, how many mountain (M) folds does this your crease pattern have? Have many valley (V) folds are in your crease pattern? Fill these numbers in according to the following equation. M-V=______-______=________. Notice that the M-V=± 2. This is true for everyone in the class. Everytime someone does this, they will always get ± 2. Then we can call it a theorem. Hence, its name, Maekawa's Theorem. As mentioned above. Maekawa is a mathematician, a software engineer and an origami artist. He was born in 1958. He has written many books on the intersection of mathematics and origami. He is famous for helping to make crease patterns popular and for his theorem.

Create 3D shapes to practice volume and area

Activity for 3rd, 5th and 7th graders

Total cost of the activity for 20 students: $30.92 (includes origami paper, 8.5 by 11’ paper, and 11’ by 17’ paper) -- Note: There will be extra supplies. We will continue to look for cheaper supplies.



For the teacher:

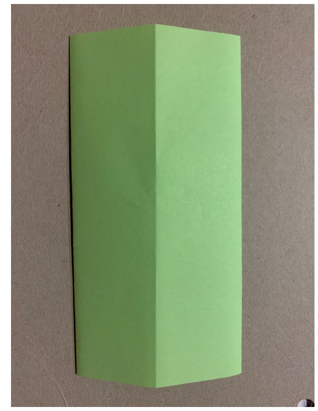
During this multi-day mathematics activity, students will create multiple origami boxes, find the area and volume of shapes. To complete this activity students will need; origami paper (6), 8.5’ by 8.5’ paper (6) (created folding on the diagonal and cutting off the extra), large paper (6) (created folding on the diagonal and cutting off the extra), ruler, pencil, and scrap paper. This activity can be used for the following standards; CCSS.MATH.CONTENT.3.MD.C.5, CCSS.MATH.CONTENT.5.MD.C.3, and CCSS.MATH.CONTENT.7.G.B.6. This is a fun and engaging math activity that is hands-on while also has students practicing finding areas and volume. Students will also compare and contrast the areas and volumes. Have fun with the students!

For the student:

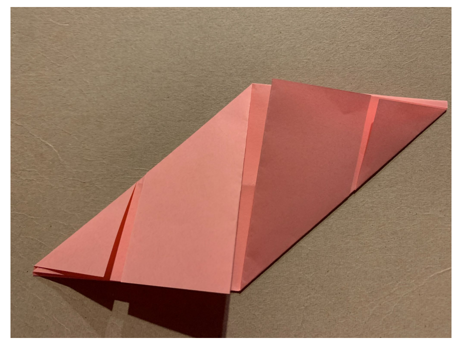
Are you pumped to make some boxes? I know, it doesn’t sound super exciting but the boxes aren't going to be like typical boxes, they are going to be made using an origami pattern! During this awesome activity, you will use three different sized paper, a writing utensil and a ruler. You will begin with using the origami paper and complete all the instructions using that paper. Next you will use the 8.5 by 11 paper (which you will need to make into a square before you can work with it, see the note at the beginning of the instructions) and follow all the instructions with that. The repeat one last time with the largest paper (which again you will need to make into a box). The instructions for this activity came from *The Book of Fabulous Origami* (pgs. 88 - 89). After you are all done folding, complete the takeaways and the reflection portions. Happy origaming!

Instructions

Note: To make the 8.5 by 11 and 11 by 17 papers a square, fold the top corner down so it creates a diagonal from the other top corner. Then cut the reminder off.

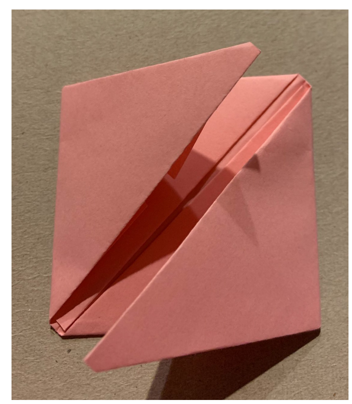


1. Grab one piece of paper and fold it in half. Crease well and then unfold. Then fold the top and bottom to the center line. Crease well and turn the figure over. Using the ruler to measure the side lengths (in cm), find the area. (Hint: Don't forget your units)
   Area=



2. Fold the top left corner down to meet the center of the bottom edge. Make sure that the folded edge of the underside of the figure also gets folded. Fold the bottom right corner up to meet the center of the top edge in same way. Using the ruler to measure the side lengths (in cm), find the perimeter. (Hint: Don't forget your units)
   Perimeter=

3. Fold the lower left point up to meet the figures top point. Fold the upper right point to meet the figures bottom point. Crease well and unfold. Turn over the figure.



4. Repeat steps 1-3 five more times with the same size paper.
5. After completing 6 papers so that they are in parallelograms. Make sure all of the figure's have their slit side facing up. Combining three of the figures by placing the points of 2 figures inside the opening on the face of the third figure. Click here to see a video.
6. Keep adding the figures, bending as needed, to tuck in the loose points and creating your cube. Using the ruler to measure the side lengths (in cm), find the volume. (Hint: Don't forget your units)
   Volume=

Takeaways

Directions: Circle the answer as needed

Before completing this section, go back and create the cubes out of the other pieces of paper. During this activity, you created three cubes. Throughout the origaming, you found the area, perimeter and volume. To find the (area/perimeter/volume) you multiplied the length times the length. You found the perimeter when you (added up all the sides/Length *Width/Length*Width*Height). Lastly, to find the (area/perimeter/volume), you multiplied the length times width times height. I found this activity to be (okay/kind of fun/fun).

Reflection

List 3 things you observed/liked/learned from this lesson:

-
-
-

References

Abel, Z., Demaine, E., Demaine, M., Eisentat, S., Lubiw, A., & Schultz, A. et al. (1998). *Algorithms for Designing Pop-Up Cards* [Ebook]. Retrieved 20 April 2021, from http://zacharyabel.com/papers/Pop-Ups_ADD+13_STACS.pdf.

About Jun Maekawa: Origami artist (1958-) | Biography, Facts, Career, Wiki, Life. peoplepill.com. (2021). Retrieved 21 April 2021, from https://peoplepill.com/people/jun-maekawa.

BETWEEN THE FOLDS | History of Origami | Independent Lens | PBS. Pbs.org. (2020). Retrieved 1 December 2020, from https://www.pbs.org/independentlens/between-the-folds/history.html.

Gent, E. (2018). *6 ways the centuries-old art of origami is bringing us the future*. NBC News. Retrieved 18 January 2021, from https://www.nbcnews.com/mach/science/6-ways-ancient-art-origami-bringing-us-future-ncna898731.

Hinders, D. (2019). *Express Your Creativity and Develop Math Skills By Learning Origami*. The Spruce Crafts. Retrieved 20 April 2021, from https://www.thesprucecrafts.com/brief-history-of-origami-2540653.

Hull, T. (2015). *Reading Between the Creases* [Image]. Retrieved 14 March 2021, from https://portside.org/node/7819/printable/print.

Hull, T. (2021). *Origametry*. Cambridge University Press.

Jobson, C. (2014). *Artist Sipho Mabona Successfully Folds Life-sized Origami Elephant from Single Sheet of Paper* [Image]. Retrieved 20 April 2021, from https://www.thisiscolossal.com/2014/03/white-elephant-sipho-mabona-2/.

Merriam-webster.com. 2021. *Definition of ART*. [online] Available at: <https://www.merriam-webster.com/dictionary/art> [Accessed 15 February 2021].

Newton, C., 2015. *Mega Menger: Building a Menger Sponge at MIT | Open Learning*. [online] Openlearning.mit.edu. Available at: <https://openlearning.mit.edu/news/mega-menger-building-menger-sponge-mit> [Accessed 15 February 2021].

Paul, M., 2017. *'Origami organs' can potentially regenerate tissues*. [online] News.northwestern.edu. Available at: <https://news.northwestern.edu/stories/2017/august/origami-organs-can-potentially-regenerate-tissues/> [Accessed 8 February 2021].

Reporter, S., 2019. *The Art of Origami is Now A Key Tool That Helps Doctors Save Lives*. [online] Nature World News. Available at: <https://www.natureworldnews.com/articles/43018/20191223/the-art-of-origami-is-now-a-key-tool-that-helps-doctors-save-lives.htm> [Accessed 8 February 2021].

Rick, F. (2005). *Dr. Jeannine Mosely and her Menger sponge* [Image]. Retrieved 20April 2021, from https://www.bookofjoe.com/2005/07/dr_jeannine_mos.html.

Robinson, N. (2021). *Origami - History of origami*. Encyclopedia Britannica. Retrieved 20 April 2021, from https://www.britannica.com/art/origami/History-of-origami.

Samuelson, K. (2017). *'Origami Organs' can potentially regenerate tissues* [Video]. Youtube; NorthwesternU, from https://www.youtube.com/watch?v=9a_vCOYR_q8

Schwab, K., 2017. *The Secret Behind This New Bulletproof Shield? Origami*. [online] Fast Company. Available at: <https://www.fastcompany.com/3068493/the-secret-behind-a-new-bulletproof-shield-origami> [Accessed 28 February 2021].

Stewart, J., 2017. *11 Cutting-Edge Origami Artists Who Are Masters of Paper Folding*. [online] My Modern Met. Available at: <https://mymodernmet.com/contemporary-origami-artists/> [Accessed 15 February 2021].

Video: Lillian Oppenheimer "My Life" Part I. Origami USA: We are the American national society devoted to origami, the art of paperfolding. (2021). Retrieved 20 April 2021, from https://origamiusa.org/video_lillian_my_life_1.

W, K. (2019). *Hamburger vs. Hotdog Paper Fold* [Video]. Retrieved 21 April 2021, from https://www.youtube.com/watch?v=bmmaA8o4fxQ.

Yoo, A. (2012). *Swarm of Locusts Made of Money* [Image]. Retrieved 20 April 2021, from https://mymodernmet.com/sipho-mabona-locusts-origami/.

Zhang, H., Chao, J., Pan, D. *et al.* DNA origami-based shape IDs for single-molecule nanomechanical genotyping. *Nat Commun* 8, 14738 (2017). https://doi.org/10.1038/ncomms14738