Mathemalchemy: Math+Art

Dr. Kim Roth and Kathryn Blake
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Kim Roth is Professor of Mathematics at Juniata College.
Kathryn Blake is the Director of the Juniata College Museum of Art.

Mathemalchemy is an interdisciplinary visual and online project initiated at Duke University that blends math and art. The art installation was exhibited at the Juniata College Museum of Art in 2022 as the second stop on its multi-city tour. The installation occupies a space of approximately 10' x 20' x 10' vertical; it fit diagonally in the East Gallery of the JCMA. This collaborative project was realized by a team of twenty-four mathematical artists and an artistic mathematician. It is a dense work with much to see, so we recommended first viewing the installation if possible and subsequently exploring the website (Figure 1).

In this article, Dr. Kim Roth provides a brief history of the project and its creation. Kathryn Blake focuses on how it came to the Juniata College Museum of Art, the details of the installation, and response to the exhibition. Kim concludes with expanded commentary on the aspect of the installation with which she is most familiar: Tess the Tortoise.

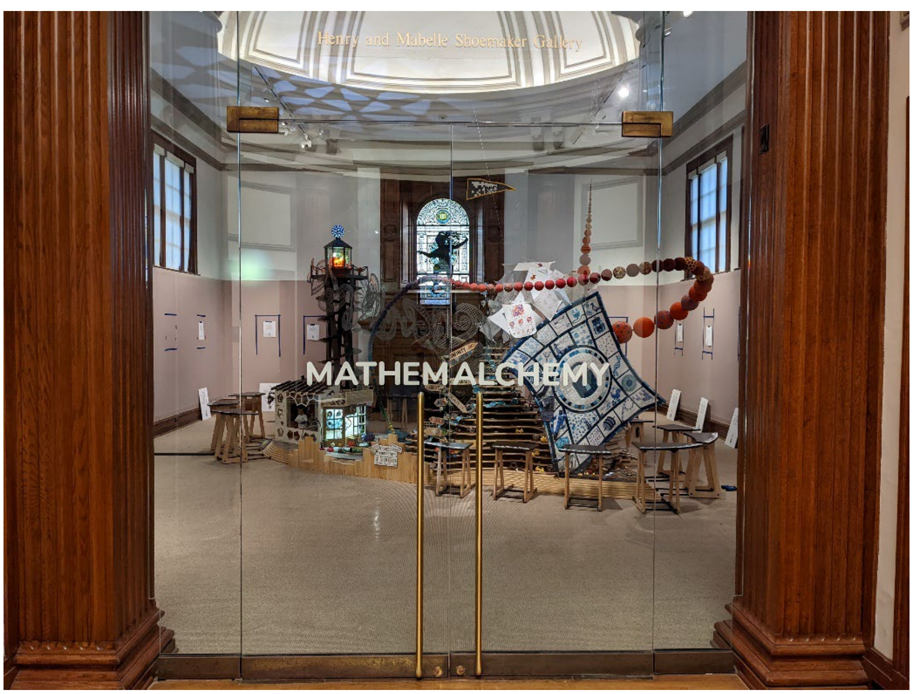

Figure 1. The Mathemalchemy installation in the Juniata College Museum of Art. Photo credit: Dominique Ehrmann. Used by permission.

THE INSPIRATION

Dr. Kim Roth: This all began with Dr. Ingrid Daubechies, the James B. Duke Distinguished Professor of Mathematics and Electrical and Computer Engineering at Duke University. She had been to Burning Man and she enjoyed the art there. It piqued her interest in doing an art project. Daubechies connected with fiber artist Dominique Ehrmann after seeing Ehrmann's piece, *Time to Break Free*, at Highfield Hall & Gardens on Cape Cod while she was at a conference. In that object, we do not just see a beautiful work of art; we also see a machine that transforms a 2D object into 3D. Mathematically this can be viewed as a function, something that takes in an input and gives a single output.

Once Daubechies saw *Time to Break Free,* she recognized Ehrmann as an artist who is accustomed to large-scale projects, seems to have a mathematically focused mind, and might enjoy the idea of integrating math and art. Daubechies, who did not know Ehrmann personally, wrote Ehrmann on Facebook to talk about potentially starting a combined project. In January of 2020, Daubechies and Ehrmann gave a presentation at the Joint Mathematics Meetings at the Mathematics and Fiber Arts Session. At the presentation, Ehrmann showed a maquette of their project plan. They asked the audience to give their thoughts so as to include them in the creative process. At the time, I was in the audience because Daubechies gives good talks and I often go to sessions dealing with math or art. My original intention did not include becoming a collaborator. However, after the end of the presentation, I went up to Ehrmann to connect her to a great mathematical quilter, Professor of Mathematics Dr. Chawne Kimber, who at the time was at Lafayette College (Kimber is now the Dean of the College at Washington and Lee University). Ehrmann, grateful for the information, noticed that I had been knitting during the presentation. She asked, "Don't you want to be a part of this?" Since I was on sabbatical, the timing sounded good.

THE TEAM

The initial team of mathematicians and artists was recruited through this talk and word of mouth at the Joint Mathematics Meeting. There was an initial team meeting at the conference; I could not attend because I had another obligation. Other people were added into the Mathemalchemy project as expertise was needed or people had further connections concerning mathematical art to complete the team. This group became the core team. Altogether, twenty-four people collaborated.

Most of the team are primarily mathematicians who surround themselves with art, along with a group of people who are artists that understand mathematics. The original plan included holding a workshop at Duke University in March of 2020 and then wrapping up the project between August and

September. Then the Covid-19 Pandemic happened. In March of 2020, Duke was not allowing visitors on campus. It was closed, like everything else at the time. Instead, we did lots and lots of Zoom. We had a two-day workshop collaborating over Zoom to replace the in-person March plans. We held the Zoom workshop and we had weekly meetings for quite a number of months. Thank goodness I was on sabbatical! We subsidized the postal system because many sets of hands touched most of the things you will see in the exhibit. At one point, we sent someone to Lowe's and asked them to get a lot of paint samples. The paint samples were mailed to each collaborator so that we could all use the same color palette. Starting in July of 2021, we finally got to meet in person. Each team member had responsibility for components of the installation that were put together under the direction of Daubechies and Ehrmann.

THE FINAL EXHIBIT

I went to Duke University in July of 2021 for one week. Altogether, it took the team a total of three weeks to build the exhibit. The team disassembled the installation in December 2021 and shipped it to the National Academy of Science Gallery in Washington, DC. It was installed in January 2022. The project resided at the NAS until June 2022, when it traveled to the Juniata College Museum of Art. In December 2022 it went to Boston, where it was on view for a large national math conference, the Joint Mathematics Meetings. Boston University will have it for the Spring semester and then the University of British Columbia until October 2023. It will travel thereafter to the University of Northern Kentucky and then to Georgia Tech. Eventually, Mathemalchemy is going to end up back in Duke University’s Mathematics department.

THE DESIGN CONCEPT

Mathemalchemy consists of many scenes and vignettes; each scene had a collaborative team. Once the scenes were designed, it was time to put them together. Ehrmann, who has substantial experience with large-scale art projects, built a quarter-scale maquette, a smaller model of what the exhibit would look like if it were on a tabletop. The details of the maquette do not quite match the finished project, but it is close. Creating the quarter-scale maquette ensured that everything fit. Moving from 2D to 3D is quite challenging. You must think about scale and understand how it will be positioned. Plus, you must be aware of how you are going to transport the object, take it apart, put it back together, and then end up with a completed project (Figures 2 and 3).

Figure 2. The north side of the Mathemalchemy maquette. Photo: Dominique Ehrmann.

Figure 3. The south side of the Mathemalchemy maquette. Photo: Dominique Ehrmann.

DECISION-MAKING

Accepting the Project

Kathryn Blake: I am going to speak about the pragmatic aspects of obtaining an exhibition. There are many behind-the-scenes details that are not evident to most people. Dr. Roth approached me with this concept while she was still thinking about working on the project. This project is what we would call an installation because it contains multiple pieces of art work assembled into a singular experience that takes up a three-dimensional space. I didn't have a good visual when Dr. Roth and I talked about the proposed installation. As a museum person and an art historian, I want to know what something is going to look like. I do not like taking things I do not have a clear vision of.

I used the maquette to get a sense of what was going on. There was a lot of back and forth. We initially had a conversation about the project in January of 2021, before they had even installed it for the first time. At that time, they intended to send it on the road but were not sure where. Normally museums' loan contracts are completed a year or two in advance to allow for preparation. We did not have that luxury with this project. I do not think we actually signed the contract until January of 2022 and received the installation only a few short months later.

Questions Pre-Installation

Mere months away from installing the exhibit, I still had not seen the real thing. I at least had the images from the Washington, DC installation. Those were helpful. But there are many considerations in bringing an exhibition to a museum. What are the dimensions? Will it fit in the gallery? The measurements were not as simple as just length and width but there was also the dimension of height. We had to consider that. I will say even with the pictures and the maquette, I was still unsure about the project until we actually got it in the museum.

Transportation was another consideration. How is this packaged and delivered to us? How is that going to work? What do we need for labor to get it into the building? How does it get placed? What should the placement layout look like? What is the cost of that? Crates are used for elaborate projects, such as this one, and can be custom-built. The team tailored the crates to include various little boxes inside of them that contain elements of the installation. There are five of these crates. Four of them are six feet by three feet. One of them is about eight feet tall by three feet wide. What's the first question you need to know when you're looking at crates that are coming to your institution? Do they fit through the door? That is not something you can kid around about. Fortunately, we had a new back door to the museum that opens wide, and we could fit it through. However, it meant that we could not store these crates in the museum once they were empty, because we could not get them down to our lower-level storage space. They were transferred to the basement of the Halbritter Center for Performing Arts. That is the kind of stuff that you have to problem-solve. Museum work is problem-solving. That is how I sell my Museum Studies classes!

Other information that is good to know: What kind of interpretation comes with the project? What is there besides the object? What is there to help the audience understand what the subject is about? And to make sense of it? Is there nothing preexisting? Do we need to create it? How is it accessed? What does it cost to create this access? Then there is promotion. How are we going to promote it? To whom? How will we manage those things? These are all the considerations that, you know, I am ticking through in my brain quite quickly.

Cost and Funding

I came to the realization that we were going to need funding for this installation. It is beyond the budget that we usually have for exhibitions at the museum. We insure everything that we have at the museum, not only our own collection; anything that arrives to us on loan has an assigned value. We do not assign the value. The lender assigns the value and we purchase the additional insurance. Wall to wall is the term. In other words, from the point in time when the project leaves the previous exhibition location until it leaves our facility for the next location, insurance coverage is our responsibility.

What about the artist fees? Does the artist get paid? Are there any other costs such as the cost of interpretation? Insurance and artist fees are price factors, but transportation is often the highest one. Trucks cost money, particularly now. Transportation of art objects is a particular niche within the industry. It has specific fees and scheduling. That generally translates into higher costs. Then you also have the cases the installation comes in. Museum crates are gorgeous. They are masterpieces of workmanship because the intention of a crate is to protect everything placed inside. The last case that we had built for a painting coming to us cost us $4,000 just for the crate. That price does not include moving the crate or even getting it on the truck. Then we had to find the shipping money for that, right?

Putting the Pieces Together

There are many small elements in this installation. The team unpacked this project by color coding everything and labeling the boxes while they unpack so that they could easily repack it for the next shipment. It is all about efficiency. Dominique Ehrmann and her husband Stéphan Lacourse were in Washington, D.C. to deinstall the exhibit there. From that point, they drove up to Huntingdon, met the truck, and only took a week to install this exhibition at the museum here (Figures 4 and 5).

Figure 4: Stéphan Lacourse and JCMA Registrar Elizabeth Gordon work on the installation. Photo: Dominique Ehrmann.

Figure 5: Installation Process in the Juniata Museum of Art. Photo: Dominique Ehrmann.

CONNECTIONS

For this exhibition, the way the museum connects to its visitors has been pushed almost entirely to the internet. The mathemalchemy.org website is robust, with information about the team, details of the process, and insight into all of the mathematical concepts that are included. You should go visit that website. But if you are in the gallery, how do you get that content? There is a difference between learning online and learning on-site. Museums are informal learning environments. People hopefully do not think of museums like school. They want to look at things in a different way. They want to see the physical stuff.

The Mathemalchemy team has made extensive use of QR codes. There is a resurgence in the museum world of using QR codes. They were popular at their inception, but then everybody hated the clunkiness of them (special app to scan them, special landing pages to create, etc.). We got rid of them. Now they have come back because of the way technology has made them easier to access. We must think about what the visitor wants when they are in the exhibition. Do they want to look at their phone or do they want to look at the object? How do we have that interaction? How do you navigate this exhibition? If I have a tour of twenty-four students in the museum all trying to access QR codes but the Wi-Fi signals are weak, they will not be happy. It just does not work well for us. Exhibition designers in general need to know that kind of thing to plan for it.

We solved this dilemma using a couple of different methods. There were only four labels in the exhibition when it came to us. That is all they sent us. One was a huge panel for all the QR codes. That did not make much sense to me. I wanted to be able to break it up. Thus, we created separate labels for each QR code. We spread them around the gallery near where you might see that part of the installation. The other thing that was not sent to us was an introduction to the gallery. I wrote an introduction and provided the QR code to the overall website so that people could access it (Figure 6). I also tried to tailor it to what I thought was relevant here, at Juniata College, a liberal arts college that gives to students the advantage of combining the humanities and sciences.

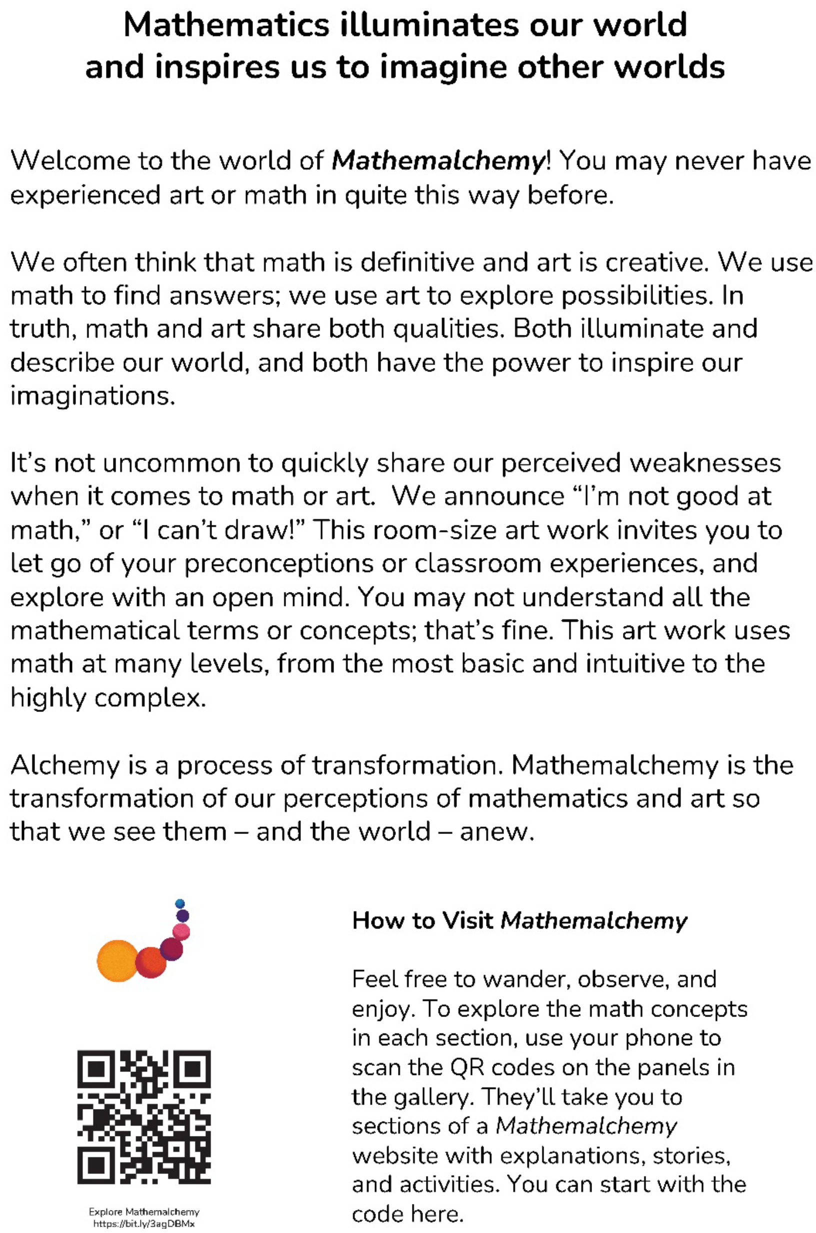

Figure 6: Introductory Panel. Photo:Kathryn Blake.

TESS THE TORTOISE

Roth: Tess the Tortoise is my main artistic contribution to Mathemalchemy. Tess the Tortoise is a character in a story about infinity. Jessica Sklar, who currently works at Pacific Lutheran University, came up with story. Tess helps bring to life ideas of infinity.

Various elements of Tess were made by different people. I made the body of Tess and the ceramic artist, Elizabeth Paley, made the shell. Tess the Tortoise's body is knit. I knitted and designed Tess's body from scratch. She is stuffed with polyfill and armature wire to hold her up. Her eyes are made from plastic. She is my first adventure in knitting design. I, like most knitters, fiddle with my patterns, but I do not usually design them. I made two models for Tess, the test model and the final piece. Tess walks along Zeno's path carrying her list of tasks and holding the string of her kite dangling a bag containing her lunch. The frame for the kite was made by the artist Bronna Butler. The fabric was put onto the kite by a very scared team of mathematicians, including me, who were afraid we would put things on wrong. Most things in the installation had the input of multiple people. The kite shape is a fractal. It is called a Sierpinski Tetrahedron. The word "tetrahedron" is a formal way of describing a pyramid made of triangles. The fractal part comes from removing the center of the tetrahedron and then from the remaining tetrahedrons (Figure 7).

Figure 7: Tess the Turtle. Photo: Dominique Ehrmann.

The Story of Tess

Here is the story that Sklar wrote about Tess.

Tortoise's Story

This is a story about Tortoise, who goes on an adventure and learns about limits/infinite processes.

One fine day, Tortoise wakes up in her room at Hilbert's Hotel and decides that she will climb to Koch's Peak, the summit of Riemann Hill. She sets off.

As she strolls along Zeno's Path, a straight path from her home to the hill a mile away, she ponders: to get to Riemann Hill, she must get halfway there; then half the remaining distance; etc. She must, therefore, travel along an infinite number of line segments. How will she ever get there?? She passes markers letting her know she has traveled 0 mi, ½ mi, ¾ mi, ⅞ mi, along the path. She passes some fractal trees and maybe some other things.

She arrives at Riemann Hill. While climbing the hill, Tortoise wonders: what is the above-ground volume of the hill? She realizes that she can estimate this using cuboids.

Tortoise reaches Koch's Peak, takes off her backpack, and looks up at the sky, where Koch Snowflakes are falling!

Hilbert's Hotel

Hilbert's Hotel is a math joke. Hilbert's Hotel has an infinite number of rooms; thus, the hotel is never full. Even if all the rooms are full, since there are an infinite number of rooms, if everyone moves to the room one number up from their current room, then room 1 is now open. That is why the hotel sign always advertises that rooms are available.

Mandelbrot Bakery

The Mandelbrot Bakery is named after a mathematician named Benoit Mandelbrot. He coined the term "fractal" to describe a pattern repeat at different scales. The Mandelbrot set is a particular kind of fractal. Mandelbrot sets can be seen throughout the installation. However, the name Mandelbrot is also the name of an almond cookie or means almond bread. The team thought it would be humorous to have the Mandelbrot Bakery (Figure 8).

Figure 8: Mandelbrot Bakery. Photo: Dominique Ehrmann.

Zeno's Path

Next, Tess walks Zeno's path to the lab terraces of the integral hill attempting to reach Koch's peak. Who is Zeno? Why is Zeno included? Zeno of Elea was a Greek philosopher. None of his work survived. We know of Zeno because Plato, an ancient Greek philosopher, wrote about him. Around 450 BCE, Plato claims to have met him. He detailed that Zeno was interested in the paradoxes of time and movement.

This is called Zeno's Dichotomy Paradox. To get somewhere, you must go halfway first. You still have halfway left. You are going to go half of that halfway, and then half of that halfway, and half of that halfway until you are going to get there. This is called Zeno's key idea and it is a well-known paradox in mathematics, philosophy, and physics. If you can only go halfway at a time, you are never going to really get there, though for practical purposes you do. Theoretically, this is what is it like to experience infinity, and Zeno's Path is set up to show that. Tess being a slow-moving tortoise is the perfect protagonist to convey this idea. She travels slowly, she goes halfway, but halfway into the remaining half she still has halfway to go. The real question is will she ever arrive? Zeno's Dichotomy Paradox is easily illustrated in Tess's story where the path is one pattern for the first half, then another for the next quarter of the path, and then another pattern for the next eighth and so on. Tess walking Zeno's path is another way of thinking about infinity (Figure 9).

Figure 9: Zeno's Path. Photo: Dominique Ehrmann.

Koch's Peak

The Koch's Peak is named after the Koch's Snowflake. It is a type of fractal that looks like a snowflake. They appear in a mobile at the top of the hill. One of the artists, Tasha Pruitt, took the s-laser-cut plastic Koch snowflakes and colored and painted all of them. One way to look at this mathematically is to inquire how it came to be, what steps were involved, and how many times the process repeats so that an edge is formed. These fractal snowflakes show it is possible to have figures that are infinite in perimeter but have finite area.

But wait, there is more! There is always more. This is a very dense exhibit. Even as a mathematics professor, I do not completely understand every detail of this exhibit. There is a lot of math terminology and ideas included. You will not fully comprehend every single aspect of it. However, the end goal is for the audience to grasp the parts of Mathemalchemy that most interest them.

Other Scenes

There are many other scenes in Mathemalchemy. There is a playground where the squirrels are finding primes with the Sieve of Eratosthenes and chipmunks are figuring out factoring with acorns. There is a giant quilt with the front side of cryptography puzzles and the reverse involves pictures from famous women in mathematics. The stack of books includes topics on or related to math. There is even a book on weaving included. Knotical Bay is also a significant part of this installation. Knot theory is a field of mathematics. It has to do with the shape of how loops of knots cross and can be distinguished from one another. For example, it is used in protein folding. That is why the nautical scene is spelled with a K. In addition, there is the lighthouse standing tall with the curio shop and the bakery on the side. All these scenes have stories conveyed through art elements, all of which are documented on the Mathemalchemy website.[1]

Infinity

There are other notions of infinity in this exhibit. The various signposts ping in multiple directions to infinity. This is the idea that infinity can go in any direction. These signs show that infinity is everywhere. You can go infinitely this way or infinitely this way. The beautiful tamari ball arches represent this idea of infinity. Ingrid Daubechies, Kathy Peterson, and Carolyn Yackel put together hours of hard work to construct this scene. One strand of balls arches up and stops. The other one just keeps on going until it dives down into the bay. The balls get smaller, and smaller, and smaller. Eventually, they become imperceptible. Nonetheless, the length of the arch continues to grow (Figure 10).

Figure 10. Ball Arches. Photo: Dominique Ehrmann.

A couple of other infinity notions include the idea of approximating area or volume by breaking it up into pieces, such as the Reimann wall, the Lebesgue Terraces, and the Reimann cliffs. You will notice that repetition is part of the theme about infinity in Mathemalchemy. The cliffs here are meant to look like the Giant's Causeway. They are meant to look like the basalt cliffs with the intention of approximating the volume under a particular surface. On the hill itself, the Lebesgue terraces are meant to be a different way of approximating area indulging in a fancier method of measuring volume. All of these scenes represent infinity in some way because they represent a step on the way of approximating something by dividing it into infinitely small parts.

CONCLUSION

Mathemalchemy, as a project, had multiple parts, pieces, and ideas. It is multidisciplinary. There are many kinds of art techniques used in Mathemalchemy – around 20 in total. When it came to building this installation, everybody contributed to different aspects of the construction. For example, I spent a lot of time taping paper flowers to wire because my dad is a florist and I had floral-taped flowers when working at his shop. If you are a painter, there are paintings. If you are a knitter, there is knitting. If you are a quilter, the quilt in this exhibit is both elaborate and beautiful.

Blake: There are different ways of describing the world. There are different ways to describe the world whether you are an artist or a mathematician. Both are creative, both are descriptive. Both require problem-solving. There is a lot of coordination between the disciplines. One of the goals of this exhibition is to show that integration, like many things, is intuitive, whether it's in math or in art. Various features of math and the arts are complex. While we may not understand all of them, we can understand parts of them. Ultimately, that is the benefit of Mathemalchemy being here.

NOTES

1. The web site for the project is https://mathemalchemy.org/.