ACTIVITY TITLE: Invisible geometry

Activity code: ncACINV02

DURATION	90 min
AGE RANGE	11-12
TOPICS	3D CREATIVITY GEOMETRY DESIGN SCIENCE

Description of the project

In this activity, students will explore the invisible forces of nature by creating geometric shapes (figures of Plateau) using wire or pipe cleaners and dipping them into a soap solution. These figures reveal minimal surface structures due to surface tension, creating surprising and beautiful geometric forms.

This scientific phenomenon becomes the gateway to a broader reflection: just like these soap films, many important things in science and society are invisible at first sight—like the contributions of women and other underrepresented groups in STEAM.

By the end of the session, students will have built their own 3D structures, observed physical phenomena, and reflected on gender roles and the value of what is often unseen or silenced.

Objectives: What will I learn?

- Understand how surface tension works in soap films by observing the formation of minimal surfaces when dipping geometric structures into a soap solution to explain everyday physical phenomena and recognize their scientific and technological applications.
- Explore minimal surfaces and 3D geometry by building and analyzing 3D structures through hands-on experimentation with soap films to gain insight into geometric principles and their relevance in efficient structural design.
- Develop creativity by designing 3D structures by using straws and pipe cleaners to create custom geometric forms to encourage creative thinking and practical engagement with geometric and scientific concepts.
- Make connections between physical phenomena and social structures by reflecting on how invisible forces in nature can symbolize hidden dynamics in society to develop critical thinking about the parallels between science and social issues.
- Reflect on the visibility and recognition of women and minorities in science by learning about figures like Agnes Pockels and discussing their relevance to the activity to raise awareness of the value of often-overlooked contributions and to promote inclusivity in science.

Materials: What do I need?

Provided by the teacher/institution:

- Pipe cleaners
- Straws
- Scissors
- Tape
- Liquid soap
- Water + wide container
- Documenting and justifying results

Previous preparation

- Prepare the soap solution ahead of class. This may be done by mixing soap with water in a large and high container.
- Organize students in small groups (2-3 people).

RESEARCH

Have a look at these resources

Soap films naturally create the smallest possible surface between edges—making them perfect models for understanding **mathematics, physics, and art** all at once. But, how do we know this?

Before answering this last question, let's start with another one:

What shape do bubbles have? — Let's think about this for a moment.

Probably the main answer is a sphere, but, is it always like this? — What do you think?

Take some time to think about this , for example, 3-5 minutes

Some questions to help guide the discussion may be:

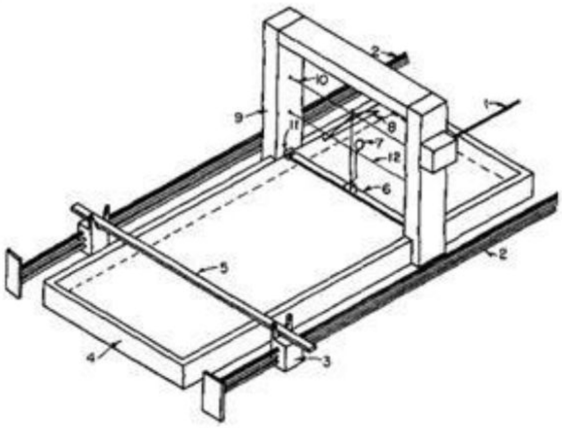
- What shape do bubbles usually have when we blow them?
- Have you ever seen a bubble that wasn't a sphere?
- Why do you think bubbles tend to be spherical?
- Do you think that the shape of the bubble maker affects the final shape of the bubble?
- Is a sphere always the most efficient shape? Why or why not?

Photo of Braedon McLeod in Unsplash

So, after discussing a bit, it might seem obvious that bubbles are always spheres — but have you ever wondered why?

It's because a sphere is the shape that has the **smallest possible surface area** for a given volume. Nature, as it turns out, is incredibly **efficient**. When a bubble forms, surface tension pulls the liquid into the most compact shape possible — and that's a sphere. This idea isn't just a fun fact; it's rooted in physics and was deeply explored by scientists like Agnes Pockels and Joseph Plateau, whom we'll talk about in the next few paragraphs. By studying bubbles, they helped us understand how invisible forces like surface tension shape the world around us.

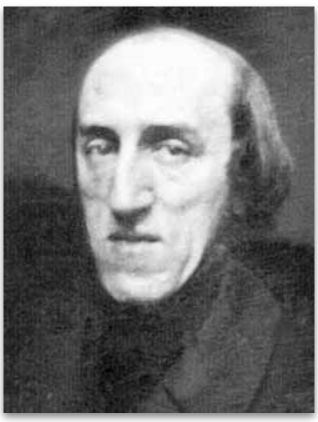
This knowledge comes from pioneering minds like **Agnes Pockels**, an Austrian scientist whose groundbreaking experiments at her kitchen sink laid the foundation for the study of surface tension—long before women were formally accepted in scientific institutions. With limited access to formal education or laboratories, she ingeniously designed her own equipment using household items to measure the effects of different substances on the surface of water. Her curiosity and determination led to the development of what would later be known as the **Pockels trough**, a device still used today in scientific research.



Agnes Pockels was born in Vicenza, then part of the Austro-Hungarian Empire. After her father's retirement from the army in 1871, the family moved to Brunswick, Germany. While her brother, Fritz, studied science at school, Agnes attended a girls' school where science wasn't taught. Curious and determined, she taught herself using her brother's textbooks.

While her brother Fritz pursued a career in physics—earning a PhD in Göttingen and discovering the Pockels electro-optic effect—Agnes stayed at home to care for their aging parents. Despite this, she kept learning through Fritz's textbooks and science magazines like *Naturwissenschaftliche Rundschau*.

Their kitchen became an informal lab where Agnes began investigating surface tension. She designed a simple but clever experiment using a water-filled tray, a wooden disk, and a tin strip to measure how substances like oil or alcohol affected the surface of water. By moving the tin divider across the surface, she observed how surface tension changed and could return to its original state. This was the first **prototype** of the Pockels trough—pioneering experiments that revealed complex molecular behavior at liquid interfaces, and laid the foundation for modern surface science.



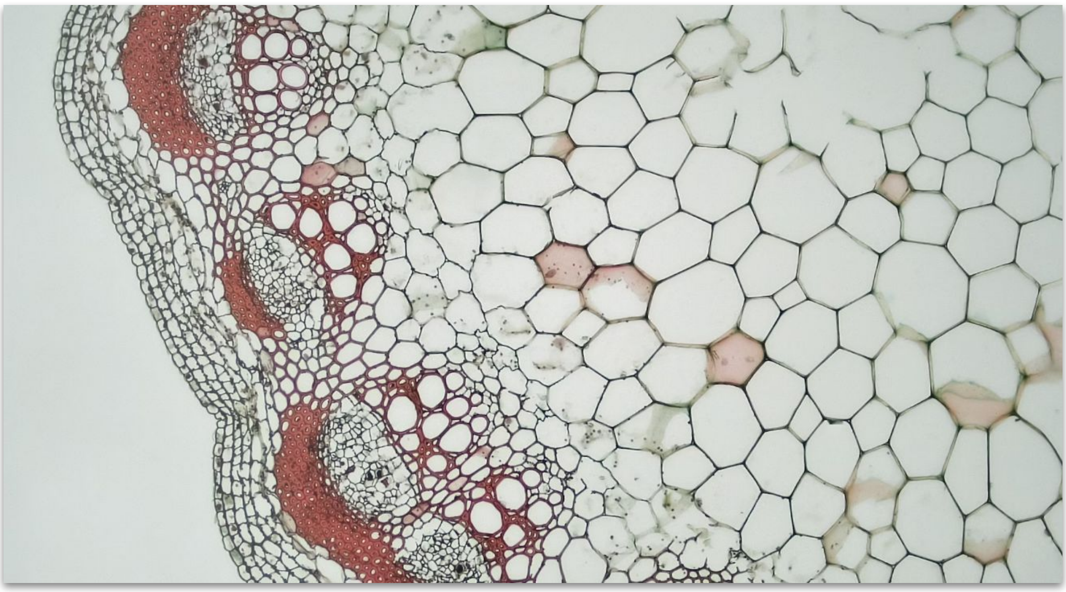
A few decades before Pockels began her experiments, Belgian physicist **Joseph Plateau** was exploring the shapes formed by soap films. In the 1840s, he discovered that these films naturally create **minimal surfaces**—the smallest possible area between boundaries—and described their behavior in what are now known as **Plateau's laws**. While Plateau revealed the **geometry** of soap films, Pockels later uncovered the **molecular forces**, like surface tension, that make these shapes possible. Together, their work helps us understand why bubbles take on such elegant forms—and sets the stage for exploring the science of shapes in motion.

Despite the limitations she faced, Agnes Pockels's dedication eventually gained the recognition it deserved. In 1891, she sent a letter detailing her findings to the renowned physicist Lord Rayleigh, who was so impressed by her work that he helped publish it in the journal *Nature*. This marked her first scientific publication and a turning point in her journey—from self-taught researcher to respected contributor to the field of surface science. Her work not only laid the foundation for future discoveries, but also opened the door for women in science at a time when their voices were rarely heard.

The discoveries made by Agnes Pockels and Joseph Plateau continue to shape the world we live in today. From the way soap and cleaning products are designed, to how engineers and architects use principles of minimal surfaces to create lightweight yet strong structures, the science behind bubbles and surface tension has countless modern applications. We even see it in technology—like in the development of liquid coatings, sensors, or materials that mimic the behavior of water at the molecular level. What began with simple curiosity at a kitchen sink or a soap film on a wire frame has grown into knowledge that touches fields as diverse as medicine, design, and environmental science—proving that even the simplest experiments can lead to discoveries that last for generations.

Picture of Simone Hutsch in Unsplash

Beyond their scientific discoveries, Pockels and Plateau's work serves as a powerful reminder that **not everything important is immediately visible**. Just like the forces behind soap bubbles and minimal surfaces, many of the most influential ideas in science operate behind the scenes, quietly shaping the world around us. Their work reveals that sometimes, the most profound impacts come from forces that are unseen, but essential—whether in nature, architecture, or the everyday tools we use.



Picture of Bioscience Image Library by Fayette Reynolds in Unsplash

CREATE

Some things you need before beginning

Surface tension and minimal surfaces aren't just fascinating physical concepts—they explain **how many thing around us work**, often in surprising ways:

For example, in nature, insects like **water striders** can *walk across ponds* thanks to surface tension at the top of the water body.

Photo by viswaprem anbarasapandian in Unsplash

In the world of **architecture**, designers and engineers have drawn inspiration from these same principles to create elegant, lightweight structures that are both strong and efficient—mimicking the way soap films naturally form the most stable shapes. For example the work of **Zaha Hadid** was deeply inspired by minimal surfaces.

Photo by Teymur Mammadov in Unsplash

Even **honeybees** make use of minimal surface geometry in the construction of their hives: the hexagonal cells of a honeycomb are the most efficient way to divide space using the least amount of material. These real-world examples show how understanding simple concepts like surface tension and geometric efficiency can reveal deep connections between science, design, and the natural world.

Photo by Jordan Ryskamp in Unsplash

Note for teachers and educators:

As you guide students through this activity, encourage them to embrace their curiosity and experiment with different approaches to solve challenges as they arise. Foster an environment where all students, feel empowered to ask questions, explore new ideas, and think critically. By supporting their efforts to explore different solutions and think creatively, you'll help them develop a deeper understanding of the scientific process while also highlighting the value of diverse perspectives in tackling scientific problems.

You can encourage this by asking questions (such as those posed throughout this document) and prompting students to consider different ways of approaching the activity.

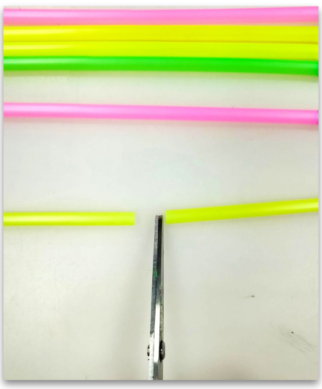
Now, follow these steps

Step 1: Preparing the materials and the soap solution:

First, students will prepare in a large and wide container a soap solution mixing dish soap with water. Also, they will prepare the materials needed: various straws, scissors and pipe cleaners.

Step 2: Cutting the straws:

Now, they will cut the straws into pieces that fit through the open part or the jar/container that has the soap solution. Each of this pieces will be a "side" of the geometrical shapes that will be created.



Make sure that all the pieces are the same length. We recommend that students put each cutted straw next to the one they are going to cut in order to make them the same length.

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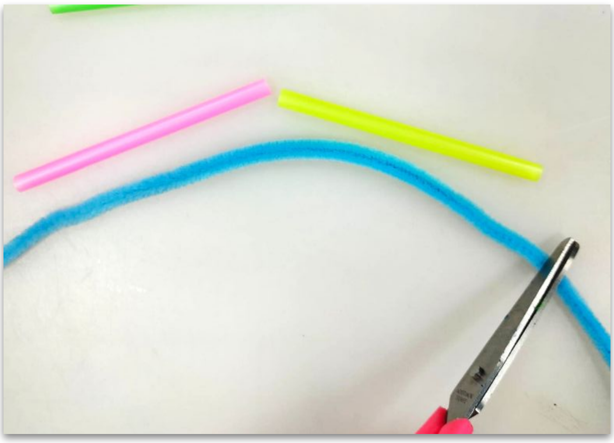
Repeat this last step 4 more times, and you should end up with 6 cutted pieces of straw like this:

Step 3: Measure and cut pipe cleaners:

The pipe cleaners are going to be used as unions between each piece of straw. For the firsts unions we are going to measure approximately the length of 2 pieces of straw next to each other and cut that length of pipe cleaner, approximately.



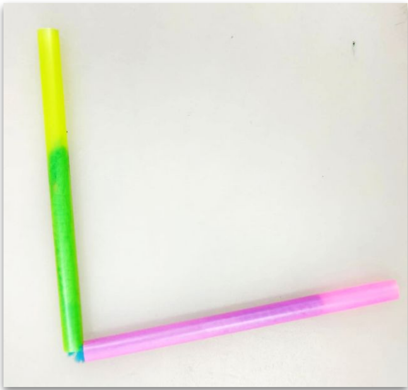
Step 4: Preparing the union:

Take the pipe cleaner that you've cutted in the previous step and twist both ends of it as shown in the images below:

Step 5: Making the union:

In order to make the union, you must insert one of the twisted ends of the pipe cleaner into one of the straws like the following image shows and then push it until the middle of the length of the pipe cleaner and the straw approximately:


Then you have to insert the remaining part of the pipe cleaner in the second straw:



And in this way you have your first union and what is going to be a vertex of the final 3D geometrical shape.

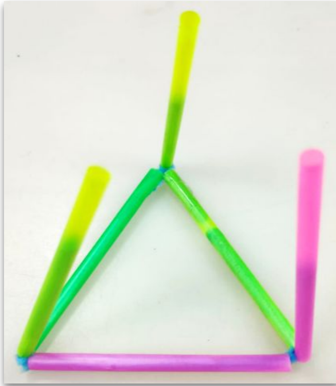
Step 6: Making the shape:

In this example, we are going to make a **tetrahedron**.

So we will repeat all of the previous steps in each of the vertex until the reach the desired structure. The pictures that follow show how to make this shape repeating the steps mentioned before.

It is important to note that the straws may break is too much pressure is done inside them with the pipe cleaners. If a little bit of the straw “cracks” you may use common tape to seal it.





Step 7: Final touches to the structure:

To give the final touch to the structure, we are going to add a pipe cleaner on top of it to use as “hanger” and make the process of dipping it in the soap solution easier.

Step 8: Making minimal surfaces:

Before making the minimal surface to this tetrahedron we are going to ask ourselves. How do we think the soap films will arrange themselves in this structure?

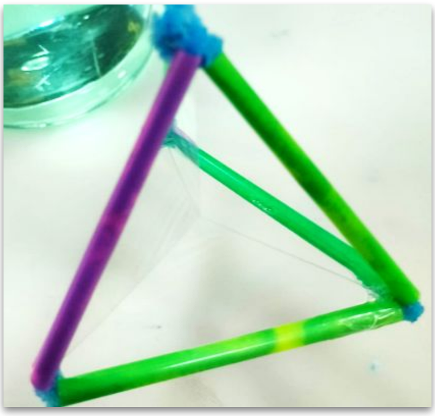
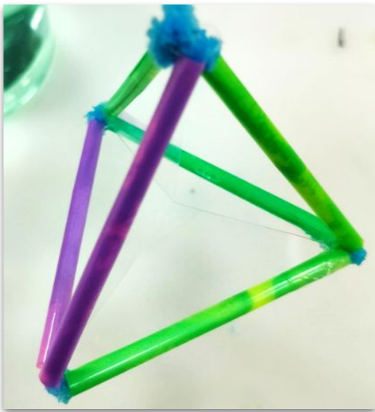
After discussing for a while, let’s try out our invention and see if our approximations and ideas no how the surfaces were going to display themselves is the reality or not:



Step 9: Analyzing results:

How did the soap films tuned out? How was the minimal surface displayed? Was it like you predicted?

Sometimes, minimal surfaces take on shapes that may surprise us, as they are probably not what we originally expected. They appear in various strange arrangements that catch our eye.

This is exactly what happens with soap bubbles, as we mentioned at the beginning of this session. No matter what bubble wand is used, they will always form a spherical shape, because the soap solution naturally tends to minimize surface area.

Step 10: Documenting and Justifying Results: Try out minimal surfaces with other geometrical bodies:

Now, as a final step in this practice, once that you have tested your tetrahedron, it's time to apply scientific reasoning to your observations. You will extend the experiment by trying at least one additional geometric frame (such as a cube, octahedron, or custom design).

Then:

1. Compare Geometries: test at least two different frames:
- One should be the tetrahedron.
- The second should be any other geometric shape your team chooses (cube, octahedron, pyramid, custom...).

2. Collect Data: Use the worksheet **"Documenting and justifying results"** to record your findings for each geometry, visualize results and justify them.

Step 11: Invisible Geometry and Invisible Voices
Just like minimal surfaces reveal invisible forces, many contributions to science and society remain invisible. Think of women scientists, indigenous knowledge keepers, or minority inventors whose work has shaped STEAM but is often unrecognized and:
- As a team, create an **art piece** (poster, collage, illustration, or digital image) that honors one person or cultural group whose contribution to science or geometry connects to the themes of this activity.
- You may choose to feature Agnes Pockels or explore someone from your own cultural background.
- Include a short text (2-3 sentences) explaining why you chose this person/group and what "invisible geometry" means in their story.

Regarding cultures, across them, traditional crafts and designs have often used geometry and minimal surface principles—long before modern science explained them. Therefore,
- Research one example of a traditional object, pattern, or structure that uses geometry to achieve efficiency, beauty, or function.
  - Examples: woven baskets, domed roofs, textiles, honeycombs, Islamic tiling, indigenous architecture.
- Create a visual representation (drawing, diagram, or mixed media) of this object and write a short paragraph explaining how its design reflects principles of minimal surfaces or efficient geometry.

COMMUNICATE

Firstly, teams will present their Invisible Voices art piece and their Traditional Knowledge visual, explaining how both connect to the science they explored in this activity.
Later, the process and debate about the creation of minimal surfaces must be explained:

- What was the hardest part of making the design? How did you solve it?
- Did anything surprising or interesting happen?
- Do you know anything that looks like what you made? (like buildings, toys, structures)
- If you could try a new shape, which one would you choose and why?

It is time to share!

In this section different social media will be presented in order to upload their activity result.

#invisiblegeometry

- LinkedIn: https://www.linkedin.com/company/steambrace-project/posts/?feedView=all
- Instagram: https://www.instagram.com/steambrace_eu/
- X: https://www.instagram.com/steambrace_eu/

KEEP ON LEARNING

How can I make a similar project by myself?

Below we provide a few examples of questions that may help students to further explore the topic beyond the activity done.

Reflection Questions:

- What was the most surprising part of the experiment?
- What does your structure say about the invisible parts of life or society?
- Can you think of another group whose work is often invisible?
- How could you make a more complex or expressive version of this sculpture?
- Once the activity has finished, consider how can we dispose of the straws safely.
  You can find different ways and tips in this guide:
  https://www.wikihow.com/Dispose-of-Plastic-Straws

Which are other connected projects?

If you enjoyed this activity, here are some fun and creative ways to keep learning and experimenting:

More ways to expand this experiment:

- Try using different shapes as bubble frames — do they still make minimal surfaces?
- What happens if you use different soap mixtures? Do the bubbles change
- Build a different 3D shape using straws from the ones presented, then dip it in soap solution and see what forms!

Research the relationship between minimal surfaces and real life applications:

- Research how architects use minimal surfaces in building designs. Can you find a building that is a good example of this?
- Look into how soap films help scientists study forces and structures — even in space!

LINKS FOR FURTHER INFORMATION

Here are some links to relevant website that you may find interesting related to this topic:

Soap Films, Minimal Surfaces and Beyond – HK Laureate Forum:
https://hklaureateforum.org/en/soap-films-minimal-surfaces-and-beyond