STEAM Tales

Lesson plans

Emmy Noether

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Emmy Noether's biography

Portrait of Emmy Noether

Unknown author. (ca. 1900). *Portrait of Emmy Noether, around 1900* [Photograph]. In Wikimedia Commons. Mathematical Association of America, Brooklyn Museum, Agnes Scott College. https://commons.wikimedia.org/wiki/File:Noether.jpg

Emmy Amalie Noether was born in 1882 in Erlangen, Germany. Her father, Max Noether, was a renowned mathematician, and two of her brothers pursued careers in science. As a child, Emmy used to watch her father work and was fascinated by patterns and symmetries, which sparked her love for mathematics. As an adult, she became a famous mathematician known for her work in abstract algebra and Noether's theorem, which linked symmetries to conservation laws in physics and helped advance Einstein's Theory of Relativity. She published over 40 papers and collaborated with renowned mathematicians like Felix Klein and David Hilbert. Despite facing gender discrimination, she gained worldwide recognition. Later, she emigrated to the U.S., where she continued her research and taught at Bryn Mawr College. Emmy Noether passed away in 1935 and left a legacy that continues to inspire mathematicians and scientists worldwide.

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Lesson plan 1

Exploring Noether's Angular Momentum Keywords: Angular momentum, gyroscope, rotational symmetry, conservation laws	
Duration: 50 min	**Age:** from 6 to 9 years old
Place: Classroom	**Related STEAM areas:** **S** (Science): The physics of how spinning objects move and change direction and the basics of forces and movement.
Description	In this experiment, children will learn about angular momentum and how spinning objects influence motion and direction. The experiment is divided into two parts: in the first part (step 1 and 2), weights are used; in the second part (step 3 and 4), a bicycle wheel is used.
Learning objectives	At the end of this experiment, children will be able to: • Describe angular momentum in their own words and give an example of gyroscopic motion observed during the experiment. • Explain how changing mass closer or farther

	from the center of rotation changes the object's spinning speed. • Show how repositioning weight on a rotating object alters its rotation speed, illustrating the principle of angular momentum conservation.
Connection to the female role model	Emmy Noether's work connected symmetries in nature to conservation laws, including the conservation of momentum, which changed the understanding of physics and led to other discoveries. During this experiment, children will follow Emmy's footsteps and will act as "little physicists" by exploring one of these conservation principles, the angular momentum.
Individual or group	Individual
Safety	This experiment is safe for children with supervision. An adult should assist with rotating the chair, the bicycle wheel, and ensure weights used are manageable for children.
Materials	☐ Bicycle wheel with handles (or a gyroscope) ☐ Rotating chair with wheels ☐ Small weights that can be held in hands (e.g. two 2KG dumbbells or two bottles of water)

Lesson plan	
Introduction (10 min)	Begin with a question: “Have you ever played with a wheel or watched one roll on the ground? When it’s moving fast, it seems to stay upright all by itself. But as soon as it starts to slow down, it gets wobbly and might tip over. Why do you think that happens?”. Tell them that with this experiment, they will see how objects that are spinning behave differently and how this relates to a principle called angular momentum. Introduce Emmy Noether by sharing how her studies on physics laws have helped scientists understand concepts like this.
Research question/hypothesis (5 min)	Ask: “Do you think that moving your arms in or out while spinning will change how fast you turn?” (Children should be encouraged to give their answers, even the wrong ones. All opinions should be included and not discarded right away even though the teacher knows they are not right. The experiment will answer the research question, mimicking the scientific method.)

Step-by-step instructions (35 min)	**Step 1 – Observing arm extension while rotating:** Ask for a volunteer and have the child sit on a rotating chair while holding a small weight in each hand. Gently spin the chair and ask the child to stretch their arms out. Ask all children to watch the speed at which the chair rotates. **Step 2 – Changing arm position to vary speed:** While still rotating, instruct the child on the chair to bring the weights closer to their body. The rotation speed of the chair will increase. If the child stretches their arms again, it will decrease, and vice versa. **Step 3 – Introducing the spinning bicycle wheel:** For the next part of the experiment, ask for another volunteer child to sit on the rotating chair while holding the bicycle wheel horizontally. This time, gently spin the bicycle wheel and have the children observe that the child on the chair starts to rotate. **Step 4 – Tilting the wheel to alter rotation:** • Ask the child on the chair to tilt the bicycle wheel vertically and have the children observe that the rotation will slow down or even stop

	completely. Tilting it back horizontally will make the chair rotate faster again.
Source	"Conservation of Angular Momentum" by Springfield College "Spinning Wheel on Spinning Chair" by utexascnsquest
Conclusion (5 min)	The experiment confirmed that moving weights closer to or further from the centre of rotation changes the spinning speed. By pulling the weights in, the speed increased, whereas moving them farther away slowed it down. Similarly, with the bicycle wheel, we saw that changing the wheel's direction affected the child's spinning on the chair, demonstrating how spinning objects can influence each other's motion. This is due to the angular momentum.
Explain the experiment (5 min)	When something spins, it generates angular momentum. By bringing the weight closer to the centre of a rotating object, that object will start spinning faster due to the conservation of angular momentum. On the other hand, when the object's mass is distributed across a wider area (i.e., when the arms are stretched), the rotating speed slows down.

	To help children visualise this and relate what they observed in the experiment to things they see every day, the teacher can explain what a gyroscope is (a spinning device that helps keep objects steady by resisting changes in direction). When something spins, like a gyroscope, it has angular momentum, which makes it harder to tip over or change its motion suddenly. There are many cases that we can see daily that use this concept: • When a bicycle's wheels are spinning, the bike stays balanced and is easier to ride, thanks to the angular momentum. • In smartphones, tiny gyroscopes detect if you turn or tilt the device, helping it adjust the screen orientation. • Angular momentum is also crucial in keeping trains and cars stable when they navigate curves. These examples show how spinning and balance are connected, helping children relate what they observed in the experiment to things they see every day.
The science behind	Angular momentum is a core principle in physics which describes the rotational inertia of a spinning object. As we have seen before, when something spins, it generates angular momentum.

Hence, angular momentum of a spinning object depends on the mass distribution of the object and speed of the spinning object. Mathematically, it is represented by the following formula:

$$\mathbf{L} = \mathbf{I} \cdot \boldsymbol{\omega}$$

Where:

- $\mathbf{L}$ is the angular momentum,
- $\mathbf{I}$ is the moment of inertia (or how the mass is distributed relative to the centre of rotation), and
- $\boldsymbol{\omega}$ is the angular velocity (or the rate of spin).

When an object starts spinning, a value for $\mathbf{L}$ is generated. Since $\mathbf{L}$ is constant as the object starts spinning, it means that if the moment of inertia $\mathbf{I}$ decreases (e.g. weights are brought closer to the axis of rotation), $\boldsymbol{\omega}$ must increase, so the object starts spinning faster. Conversely, if $\mathbf{I}$ increases (by moving the weights away from the axis of rotation), $\boldsymbol{\omega}$ decreases, so the spin slows down.

The same concept is applied on the spinning wheel part of the experiment. When the child held the

	spinning wheel horizontally, its force tried to "push" against the chair, causing both the chair and child to spin. This happened because the angular momentum (i.e. the wheel's spinning force), was aligned with the chair's rotation. But when the wheel was tilted vertically, its force pointed straight up or down instead of sideways, so there was no longer anything "pushing" the chair to keep spinning. Thus, the chair stopped rotating because the wheel's spin was now in a direction that did not affect the chair's movement. Emmy Noether's research helped to demonstrate that conservation laws, like angular momentum, are connected to symmetries in nature. That is, angular momentum is conserved in rotationally symmetric systems, meaning its total amount remains constant in the absence of external forces. This conservation principle explains why objects with angular momentum, like spinning tops or bicycle wheels, maintain their rotational state.

Lesson plan 2

<table>
<tr><th colspan="2">Exploring Noether's conservation principles with the Bernoulli principle

Keywords: Bernoulli Principle, airflow, aerodynamics, conservation laws</th></tr>
<tr><td>Duration:
60 min</td><td>Age: from 6 to 9 years old</td></tr>
<tr><td>Place:
Classroom</td><td>Related STEAM areas:
S (Science): The physics of how air moves and affects objects.
E (Engineering): How this principle helps design things like airplanes.</td></tr>
<tr><td>Description</td><td>Children will explore the Bernoulli principle and learn how differences in airflow and pressure can cause objects to lift. The experiment of divided in two parts: in the first part (step 1 and 2), children will use a polybag; in the second part (step 3, 4 and 5), children will use sheets of paper.</td></tr>
<tr><td>Learning objectives</td><td>At the end of this experiment, children will be able to:
Explain how moving air (airflow) creates pressure differences, causing objects like paper to lift or remain flat;</td></tr>
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	• Describe at least two observable changes in an object's behaviour (e.g., lifting, bending) when air flows underneath or over it; • Record and compare their observations (e.g., how many breaths needed to inflate a bag, how the paper moves) and discuss how airflow affects each outcome.
Connection to the female role model	This experiment connects to Emmy Noether's contributions to physics, especially her work on conservation laws. Emmy's insights laid the foundation for understanding how forces like airflow affect objects, a principle that allows modern technology, such as airplanes, to defy gravity.
Individual or group	Individual or in groups (of 3-4).
Safety	The materials used are safe for children with supervision from the teacher when (if) using a hair dryer.
Materials	☐ 5 poly tubing bags ☐ 1 hair dryer (optional) ☐ 1 roll of tape ❑ Sheets of paper A4 (one per child)

Lesson plan	
Introduction (10 min)	Start with a question: "Have you ever wondered how an airplane stays in the sky even though it's so heavy? How do you think it flies?" Explain that the children will be making an experiment with airflow and pressure, concepts that scientists and engineers take advantage of to prevent an airplane from falling from the sky.
Research question/hypothesis (5 min)	Ask: "Do you think the way we blow air into a bag or across a piece of paper can make things lift or move?" Encourage children to share their predictions. The experiment will reveal the answer!
Step-by-step instructions (30 min)	**Step 1 – Direct bag inflation** Ask for 4 volunteers or make groups of 3-4 children. Ask one of them to blow directly into a poly bag to fill it while other children count how many breaths were needed to fill it. **Step 2 – Efficient bag inflation** Demonstrate how it is possible to fill the bag quickly by holding it slightly away from the mouth and blowing into it.

	Step 3 – Preparing the paper edge setup: Next, give a paper of sheet to each child and help them tape a sheet of paper to the edge of a table in a way in which most of the paper hangs over the edge. **Step 4 – Blowing air underneath:** Ask the children to blow air underneath the hanging part of the paper. The same can be reproduced with a hair dryer to help children understand that no matter how strong the blows are the result will be very similar: the paper will barely lift or move. **Step 5 – Blowing air over the top:** Ask the children blow across the top of the paper or use a hair dryer to see the paper lift.
Source	Filling a poly bag: “Bernoulli’s Principle” by Wolf_Science Blowing the paper: “Bernoulli's Principle Demo: Paper on Table” by Physics Demos
Conclusion (5 min)	Review the initial hypothesis and ask the children to share their observations. Blowing air into the bag in a certain way caused it to be filled quicker.

	Similarly, blowing air across the top of the paper made the paper move noticeably and even lift, whereas blowing underneath it barely moved it.
Explain the experiment (5 min)	When blowing air directly into the bag from close up, only the air from the breath goes into the bag, so it takes more blows of air to fill it. But if the bag is held just a little away from the mouth and then you blow, the fast-moving air that will be created will actually pull more air from the room along with it. This extra air will go inside the bag too, and it will make the bag fill more quickly. When we blow under the paper, the paper barely moves. This is because the air pressure stays about the same on both sides, so there's no big difference in pressure to lift the paper. But when we blow over the top, it creates a lower pressure above the paper. This pressure difference causes the paper to lift, similar to what happens to airplanes (although, in airplanes, other factors like the shape of the wings also play a role).
The science behind	The Bernoulli principle was discovered by Swiss scientist Daniel Bernoulli in the 18th century. This principle describes how the speed and pressure of a

	fluid (like air or water) are related: as the speed of a fluid increases, the pressure it exerts decreases. This principle has important applications in the world around us, especially in aerodynamics, where it helps us understand how objects like airplane wings create lift. In an airplane wing, for example, the top surface is curved, so air has to travel faster over the top than it does below. This air that moves faster on top reduces the pressure on top part of the wing, while the air moving slower underneath it maintains higher pressure. The difference in pressure creates an upward force, called lift, which helps the plane stay in the air. The Bernoulli effect is essential not just for flight but for many forms of engineering and design. Emmy Noether’s work in the 20th century on conservation laws (i.e. principles that explain how certain quantities stay constant in nature) connected concepts like Bernoulli’s to deeper physical laws. By linking symmetries in nature to these conservation principles, her work helped scientists better understand motion, energy, and forces, which directly influence modern engineering and innovation, from designing safer cars to advancing space exploration.

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