

Emmy Noether

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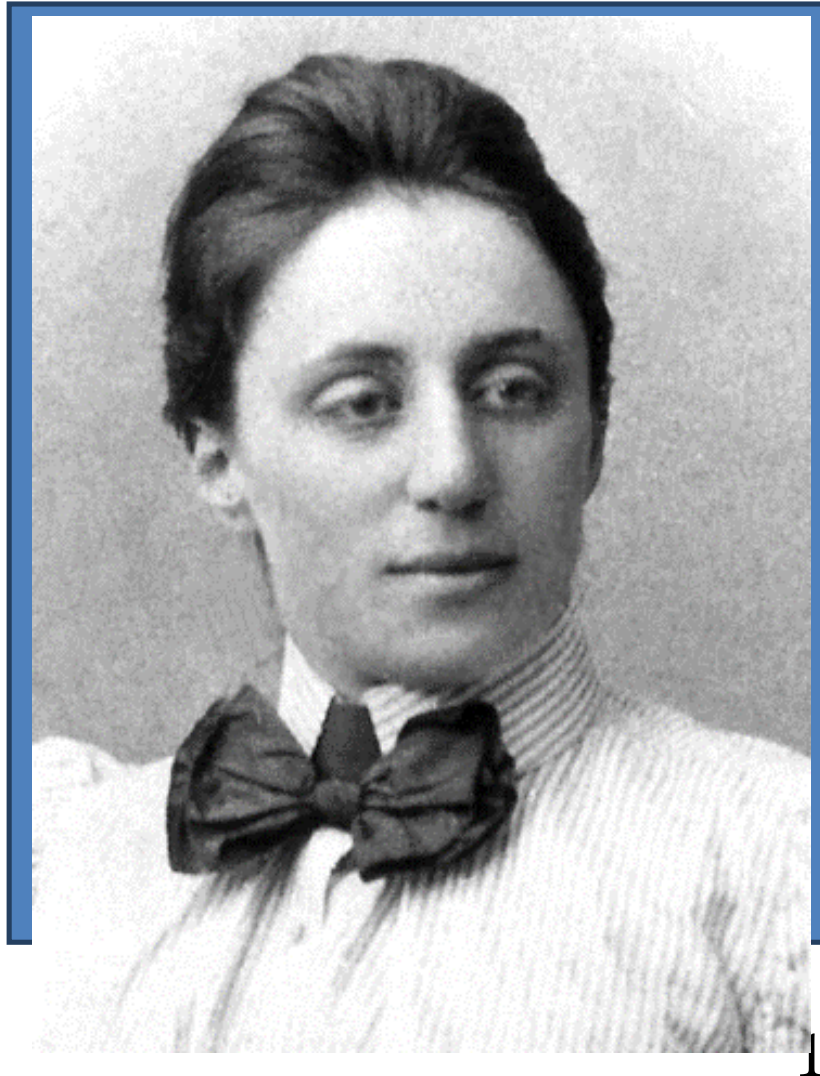


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Chapter 1 - Emmy's Childhood:

On March 23rd, 1882, in a town called Erlangen, a little girl named Emmy Noether was born. Probably at the time her parents and everyone around her assumed that she would grow up to be a mother and work in the home. Little did they know that Emmy would grow up to be one of the most important mathematicians of the early 20th century.



Erlangen University, where Emmy's Father worked

One day when Emmy was a child, she attended one of her friend's birthday parties where her father gave them logic puzzles to complete and Emmy got every one of them right. From a young age, everyone could see that Emmy was bright.

Chapter 2 - Emmy Goes to High School:

As a teenager, Emmy took classes in French and English (her native language was German) and prepared to be a teacher of young girls. She was really good at this and went as far as taking the tests to qualify to teach, getting a score of "very good". But she realized that was not really what she wanted to do.

What Emmy wanted to do was learn about algebra. This was a bit of a problem because Emmy was a girl, and this was the 1800s.

At this time, people didn't think that girls could do things like math or science. In early school they would be taught how to add, subtract, multiply and divide, but that was as much as they were expected to learn. While her brothers went to high school and were taught about the mathematical ideas that Emmy wanted to learn, Emmy wasn't allowed to attend.

Luckily, Emmy had a supportive family. Her father worked as a professor of mathematics at the local university. So Emmy began taking algebra lessons from her father who was an excellent teacher.

Chapter 3 - Classes at University:

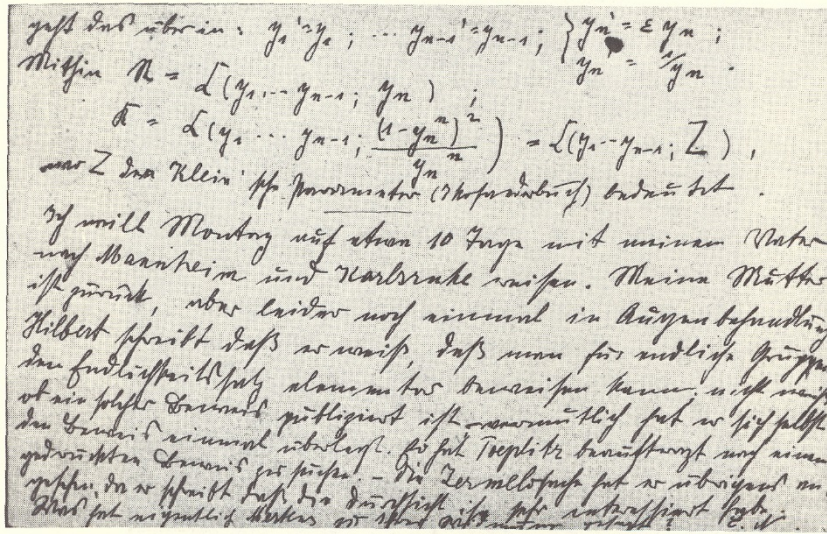
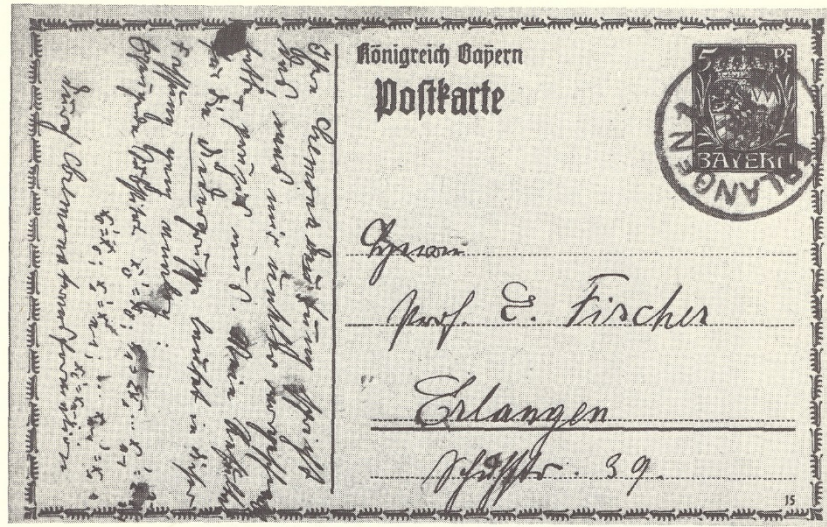
Once Emmy got a little older she wanted to continue her studies at the university her father worked at, Erlangen

University.

Remember how Emmy wasn't allowed to take high school math? Well a girl taking college courses in math was just as weird to the people of the time. There was one other woman attending at the same time as Emmy, and neither of them could officially take courses. They had to "audit" the classes instead, which means sitting in on the courses and learning everything, but not getting any credit for it. She had to also ask the permission of the professors whose courses she audited.

Even though she hadn't officially taken any of the classes she went to, she studied hard this way for two years and then took the final test at Erlangen and passed.

Chapter 4 – Becoming a Scholar



A postcard from Emmy at Göttingen to her family

After passing her test at Erlangen, Emmy applied to the university Göttingen to get her doctorate. This was one of the most famous mathematics-focused universities in Germany, with famous mathematicians like Felix Klein and David Hilbert teaching and studying there. These were big names in the math world.

Emmy studied at this famous place, impressing the famous mathematicians who worked there for one semester before the university tightened its rules on whether women were allowed to study there.

So Emmy returned to Erlangen to finish her PhD. Because of her and her father's reputation there she was allowed to be an actual student this time instead of just

auditing classes and she got her doctorate.

Chapter 5 – Emmy’s Adulthood

Armed with her new degree, Emmy was now equipped to teach math to college students, except she had one problem. She was still a woman, and despite the fact that mathematicians who read her work agreed it was brilliant, universities still would not hire her.

So she taught at Erlangen without pay for seven years. This might be enough to make a lot of people quit doing math and pick something else that they could get all the credit and payment they deserved for, but Emmy really loved math. There was really nothing else for her to do. She kept studying on her own while she was teaching, of course, and kept writing too.

She read the important work of the professors at Göttingen like Dr. Hilbert, and she wrote her own work in response. Her work was good, so the Göttingen professors took notice.

In 1915, Dr. Hilbert and Dr. Klein tried to get her a job at Göttingen. Unfortunately, it took a vote from all the professors at the school to hire a new professor. Some of the professors thought women should not teach at universities. World War One was happening at the time and one professor said, "What will our soldiers think when they return to the university and find that they are required to learn at the feet of a woman?" Hilbert and Klein argued against the other professors. If she knew what she was talking about, what did it matter if she was a woman? Nevertheless, the vote did not pass. Tragically, and suddenly, Emmy's mother

died shortly after she arrived at Göttingen. Emmy rushed back to Erlangen to be with her father and attend the funeral. She stayed with her father and helped him for a few weeks, and then went back to Göttingen.

Since she could not become an official member of the faculty, once again Emmy worked without pay. She and her mentors had to be clever to let her teach at all. She would schedule lectures under Dr. Hilbert's name and officially she would just be "helping out," but really she was the one teaching.

She flourished while she taught at Göttingen, having around her some of the greatest mathematicians in the world to learn from.

Emmy went on to be one of the most important figures in a field of math called Abstract Algebra. She helped change the role of women in math and science. Before her time it was easy for people to say that women had to be bad at math. After all, when had a woman ever proven anything important? But she showed that even when all the schools were trying to keep her from studying math, she could still accomplish great things and make it impossible for the people around her to deny her skill. If this is what a woman could do when the world took every effort to keep her from doing it, what could the women of tomorrow do with nobody in their way?

Thanks to Emmy it is no longer unusual to have a female math teacher or professor. You have probably had one. You will probably have more in the future. And every day female mathematicians discover new things and teach young mathematicians.



An inscription placed at Emmy's childhood home. It reads "Birthplace of the Mathematician".

Chapter 6 – Emmy’s Work:

Let’s talk a bit about the math Emmy was working with.

Emmy worked in a subject called Abstract Algebra. You may have taken an algebra class already. Abstract Algebra is basically what happens when you do algebra on things that are not necessarily numbers.

The basic idea behind algebra is that you can talk about things even if you do not know exactly what the thing you are talking about is.

Let’s say we have a number, and we do not know what it is yet, but we know that if we add 7 to it and then subtract 3, then we get 12. If we give our mystery number a name, then we can write an equation

involving it. Let's call the number "n".

$$(n + 7) - 3 = 12$$

Now, to find out what n is, all we have to do is notice that if we subtract something and then add the same thing, or add something and then subtract the same thing, then we end up adding 0, which is the same as doing nothing. So we can add 3 to both $(n + 7) - 3$ and to 12 and get a new equation.

$$n + 7 - 3 + 3 = 12 + 3$$

And since subtracting and then adding the same number is the same as adding 0, we have...

$$n + 7 = 0 = 12 + 3$$

Or just...

$$n + 7 = 12 + 3$$

Then we can subtract 7 from both of them and get

$$n = (12 + 3) - 7$$

When we evaluate what this is, we find that $n = 8$.

So what was the feature of numbers that we used to do that algebra? There are two things:

1. We have what is called an identity. An identity is something that leaves things the way they were. In this case our identity was 0.

2. We have things that “undo” each other and leave the identity behind. If we subtract 3 and then add 3 then we end up adding 0, which does nothing. These objects are called “inverses”.

Now the fun part comes in when we realize that we do not have to be using numbers to do this.

Let’s say you have five cups in front of you labeled 1, 2, 3, 4, and 5. You start out with them in a row starting with cup 1 and ending with cup 5. But then you start rearranging them. Let’s say you arrange them into the order 2, 4, 5, 3, 1. You can rearrange them back into the beginning order by putting cup 2 back in the second position, 4 back in the fourth position, etc. So we have an inverse to this rearrangement.

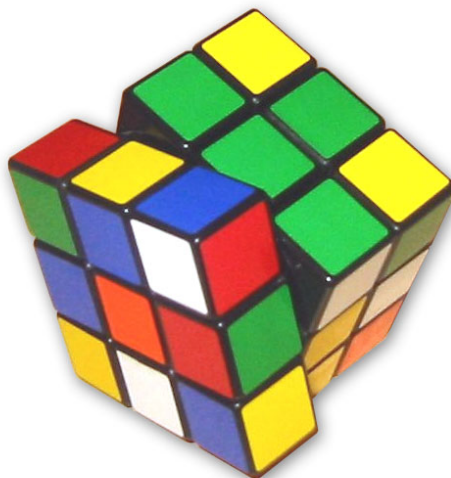
We also have an identity, because you could choose not to move any of the cups.

Things that we can do algebra on like this are called “Groups”. The cups are an example of an important group called a Permutation Group with five elements.

On the next page there are pictures of a few more examples of groups.



The rotations and reflections of a snowflake make a group.



The moves that we can make on a Rubik's cube form another group.

If you pay attention, you can find examples of groups all over in the world. Groups are one of the simplest examples of algebraic structures. The work Emmy did was mostly on more complicated structures with more operations (like multiplication). But Emmy spent her life proving things about structures like Rubik's cubes and snowflakes.

Glossary

Algebra: The field in math where one learns how to apply operations, such as addition and multiplication, to numbers and other objects without necessarily knowing what the objects are. We use a variable like the letter “x” to refer to an object we do not know about, or something that could represent any object.

Equation: A statement about mathematic objects involving an equals sign. For instance, $5 = 4 + 1$ or $8 - 4 = 2 \times 2$. For an equation to be true, the things on both sides of the equal sign have to be the same thing, even if they are written in a different way.

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Common Core State Standards

CCSS.ELA-Literacy.RI.6.10

By the end of the year, read and comprehend literary nonfiction in the grades 6-8 text complexity band proficiently, with scaffolding as needed at the high end of the range.

CCSS.Math.Content.HSA.REI.A.1

Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.

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