STEAM Tales

Lesson plans

Elvira Fortunato

Co-funded by
the European Union

Elvira Fortunato's biography

Credits: Heinz Troll. Original source: https://images.impresa.pt/expresso/2020-09-23-European-Inventor-Award-2016-Elvira-Fortunato-Portugal-Photo-3.jpg/original

Elvira Fortunato, born in Almada, Portugal, in 1964, is a trailblazer in materials engineering and sustainable electronics. She holds a degree in Physics and Materials Engineering (1987) and a PhD in Microelectronics and Optoelectronics (1995) from NOVA University of Lisbon, where she became a Chair Professor, Vice-Dean, and Director of the Institute of Nanomaterials, Nanofabrication, and Nanomodelling.

Fortunato is renowned for her invention of the first paper transistor in 2008, launching the field of paper electronics. Her projects INVISIBLE and DIGISMART, supported by European Research Council grants, advanced eco-friendly electronics, and her e-GREEN project explored low-cost, sustainable materials. With over 800 scientific papers, she has received more than 50 awards, including the Blaise Pascal Medal, the Pessoa Prize, and the Horizon Impact Prize. In 2022, she was named one of 27 inspiring European women by the French Presidency of the European Union.

Beyond research, Fortunato promotes gender equality through the SPEAR project and contributes to science policy, having served on the European Commission's Scientific Advice Mechanism. Her groundbreaking work and advocacy make her a global leader in advancing greener, more inclusive technologies.

Co-funded by the European Union

Lesson plan 1

The fruit battery **Keywords: electricity, battery, chemical reaction**	
Duration: 65 min	**Age:** from 8 to 9 years old
Place: Classroom	**Related STEAM areas:** **S** (Science): generating electricity with natural materials through chemical reactions **E** (Engineering): building a battery to produce electricity
Description	This experiment demonstrates how to generate electricity using a lemon (or other fruits like oranges, potatoes or apples), copper and zinc strips and a simple LED light to teach children about the properties and interactions between different components in a fun manner. The acidic juice in the fruit acts as an electrolyte, creating a chemical reaction between the metals that produce electricity to power the LED.
Learning objectives	At the end of this experiment, children will be able to: • Explain, in their own words, what electricity is. • Explain, in their own words, what electrons are.

Connection to the female role model	This experiment is inspired by Elvira Fortunato's work on electricity and innovations of the materials used to develop eco-sustainable gadgets.
Individual or group	Group activity: 6 children or fewer in each group
Safety	This experiment is safe to perform, but it requires careful supervision and help during the implementation. As well as requiring a certain manual skill, it briefly involves using a knife.
Materials	☐ 5 lemons at least (alternatives: oranges, potatoes or apples) ☐ 1 copper strip (alternatives: a few clean, unoxidized copper coins) ☐ 1 zinc strip (alternatives: galvanised nail) ☐ 1 small LED light ☐ 2 simple wires (with stripped ends) ☐ 1 knife (ask an adult for help!)
Lesson plan	
Introduction (5 min)	Do you like to try new things and see things unbelievable happen before your eyes? You've probably heard of electricity and seen how it's used in everyday life. But what do you think electricity is? Where do you think it comes from? How do you think we can generate it? What if I told you we could use

	fruit juice? Imagine that: using a fruit and its juice to turn on a light! **If you read the story before the experiment:** Do you remember that Elvira developed new materials to electronics, gadgets and innovations and to generate electricity in an eco-sustainable way?
Research question/hypothesis (5 min)	Do you know what serious scientists do all the time? Curious as they are, they ask themselves a lot of questions and they search for answers. **So here is a research question for all of you**: Will we be able to turn on the LED light with a fruit battery? (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 (40 min)	**Step 1 – Prepare the Fruit:** • Select a fresh lemon (or another fruit like an orange, potato, or apple). • Gently roll the lemon on a table with your hand to make it softer and juicier.

	Step 2 – Cut slits in the fruit: • The teacher should help children make two small slits in the lemon using a knife. • The slits should be about 1-2 cm deep and just wide enough to fit the copper and zinc elements. **Step 3 – Insert the metal strips:** • Carefully insert the copper strip (or a coin) into one slit and the zinc strip (or nail) into the other slit. • Make sure they do not touch each other inside the lemon. **Step 4 – Connect the wires:** • Take one of your simple wires and tightly wrap one end around the copper strip. • Wrap the other wire around the zinc strip. Ensure the wires are connected securely to create a path so that electricity can flow through them. The tighter the connection, the better the electricity will flow.

	Step 5 – Light the LED: • Connect the free ends of the wires to the two legs of the LED light. • Observe if the LED lights up. If it doesn't, try switching the wires. If it still doesn't light up, consider using a different fruit or connecting multiple fruits in a series by linking the zinc strip of one fruit to the copper strip of another. **Step 6 – Experiment with other fruits:** • Repeat the experiment using different fruits like an orange, potato or apple, which can have different levels of acidity. • Follow the same steps: prepare the fruit, insert the strips, connect the wires, and light the LED. • Compare how bright the LED lights up with different fruits. You can even try connecting two or more fruits together to see if it makes the light brighter.
Source	Videos with steps: "Fruit-Power Battery" by Sick Science! "How to Make a Lemon Battery" by SciShow Additional resources:

	"Fruit battery" by Science Project "12 Hands-on Battery Experiments for Kids" by 123homeschool4me
Conclusion (5 min)	Check the research question/hypothesis. The answer to our research question is «Yes!». We were able to lit the LED light with a fruit battery! The light bulb is lit with the help of the juice of the acidic fruit. This happens because the lemon's acidic juice allows electrons to move between the ends of the wires (in other words, it acts as an *electrolyte*).
Explain the experiment (10 min)	The lemon juice **conducts electricity** (i.e., it is an **electrolyte**), making the fruit act like a **battery**. The **zinc and copper strips** serve as the **negative and positive terminals**, just like in a real battery. When the zinc strip is inserted into the fruit, it reacts with the acidic juice, releasing **zinc ions** and leaving behind **free electrons** in the metal. These electrons cannot travel through the juice itself but need a **path** to move. This is where the **wires**, which act as **electrical conductors**, come into play. When connected properly, they allow the electrons to flow from the zinc strip to the **copper strip**, creating an **electric current**. This movement of

	electrons through the wires generates enough electricity to turn on an **LED light**. Rolling the fruit before the experiment **breaks down its cells**, making it **juicier**, which improves the flow of ions in the juice, helping to complete the **circuit**. The **acidity of the fruit** is crucial, as it affects how well the reaction occurs—**more acidic fruits** tend to generate more electricity. The **tighter the connections** between the wires and the metal strips, the better the electricity flows, improving the brightness of the LED. If a single fruit does not generate enough voltage, multiple fruits can be **connected in series** to increase the power output. This experiment is a fun and simple way to understand how **chemical reactions** can produce electricity, just like in a real battery!
The science behind	**Electrons**: The electron is a subatomic particle with a negative electric charge. Electrons play an essential role in many physical phenomena, such as electricity, magnetism and thermal conductivity. **Electrons and electricity**: Electricity is the movement of electrons, sub-atomic particles with a negative electric charge (which play an essential role not only in electricity but in many other physical phenomena, such

	as magnetism and thermal conductivity). A concentration of electrons in one place makes an electric charge. You can measure how strong the electric charge is by measuring its voltage. Electrons will move through some materials easily; these are called conductors. In order to keep the electrons contained in a conductor, it is surrounded by an insulator. An electric wire, made from a conductive core (usually copper) and an insulating sheath (usually plastic), can move electric charge from one place to another. We can count the number of electrons moving past a point in the wire, and this is called current, which is measured in amps. The electric charge does not spontaneously gather itself in one place; in order to do this, we have to work to push the electrons together. This is what we do to produce electricity, usually, we use a magnet to push the electrons through a wire in a machine called a generator. **Fruit juice**: A reaction takes place between positively charged ions in the fruit and the zinc metal in the nail, liberating electrons (which are negatively charged). Electrons travel from the positive pole, or terminal, of the battery through a copper wire — each end of which

is connected to the nails with crocodile clips — to the negative pole. The movement of charge generates enough electricity to light the bulb.

Battery: A battery is an energy source consisting of one or more electrochemical cells and terminals on both ends, called an anode (–) and a cathode (+). Electrochemical cells transform chemical energy into electrical energy.

Conductive materials: Conductive materials are those that can conduct electricity to a greater or lesser extent. These types of materials allow electrons to flow freely and fluidly from one point to another if they are connected to a power source.

The history and the future of electricity generation:

Ancient Greeks discovered static electricity by rubbing amber. Much later, in 1600, English scientist William Gilbert coined the term *electricus* to refer to materials that could attract other objects after being rubbed.

In 1800, Italian chemist and physicist Alessandro Volta invented the first true battery by stacking alternating layers of zinc and copper discs separated by cloth or paper soaked in saltwater or an acidic solution. He

	discovered that this setup produced a continuous electric current, unlike static electricity. Thus, he created the first reliable source of continuous electrical energy, opening the door to practical applications of electricity. Later, in 1831, his British professional colleague Michael Faraday discovered electromagnetic induction, the principle that a changing magnetic field can generate an electric current. He demonstrated this by moving a magnet through a coil of wire, which induced an electric current in the circuit. He also built the first electromagnetic generator, proving that mechanical energy could be converted into electrical energy Volta and Faraday's discoveries laid the foundation for electric generators, transformers, and motors, which became the backbone of industrialization. Their works directly led to the development of power stations, long-distance electrical transmission, and widespread electrification. This fuelled industrial growth by providing efficient mechanical power, leading to advancements in manufacturing, transportation (electric trains, trams), and communication (telegraphs, telephones, radios).

	Much of the world's electricity is still generated with the aid of fossil fuels – coal, oil and natural gas. In thermal power plants, they are burned to produce heat, which converts water into steam, which then spins turbines connected to generators, thus producing electricity through electromagnetic induction. However, there is a problem: this process emits a large amount of carbon dioxide (CO_2), a greenhouse effect gas that is the main culprit for global warming. The possible depletion of fossil fuels, which are not renewable, leads to more risks. It is therefore important to find renewable sources for sustainable development.

Lesson plan 2

The power of chemicals Keywords: electricity, battery, chemical reaction	
Duration: 55 min	**Age:** from 8 to 9 years old
Place: Classroom	**Related STEAM areas:** **S (Science):** generating electricity with natural materials through chemical reactions. **E (Engineering):** building a battery to produce electricity.
Description	This experiment introduces children to electricity generation and energy transfer using simple materials like salt and vinegar, copper and zinc strips. It shows children how an electrolyte (vinegar) creates a chemical reaction between the metals to generate electricity and helps them visualise its path through the materials.
Learning objectives	At the end of this experiment, children will be able to: • Explain, in their own words, what electricity is. • Explain, in their own words, what electrolytes are.

Connection to the female role model	This experiment is inspired by Elvira Fortunato's work on the use of paper transistors that allow to make technology and circuits cheaper, easier to use and more eco-friendly (much like salt and vinegar in the experiment).
Individual or group	Individual or group activity: 4 children or fewer in each group
Safety	This experiment is safe to perform, but it requires careful supervision and help during the implementation. For instance, help might be required to ensure that the wires are correctly attached.
Materials	☐ White vinegar (as much as needed) ☐ Salt (as much as needed) ☐ 4 cardboard cups ☐ 4 zinc strips ☐ 4 copper strips ☐ Crocodile clips ☐ 1 beaker ☐ 1 small LED light
Lesson plan	
Introduction (5 min)	Do you like to try new things and see things unbelievable happen before your eyes? You've probably heard of electricity and seen how it's used in

	everyday life. But what do you think electricity is? Where do you think it comes from? How do you think we can generate it? What if I told you we can use everyday materials you can probably find in your kitchen to produce electricity? Imagine that: producing electricity with the help of vinegar and salt. **If you read the story before the experiment:** Do you remember that Elvira invented a groundbreaking technology that uses paper instead of metal to make gadgets? She is the inventor of the paper transistor, a much more sustainable and environmentally friendly material.
Research question/hypothesis (5 min)	Do you know what serious scientists do all the time? Curious as they are, they ask themselves a lot of questions and they search for answers. **So here is a research question for all of you**: What sort of materials might we use to produce electricity that are cheap, eco-friendly and easy to use? (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 (30 min)	**Step 1**: Measure approximately 120 ml of white vinegar in a beaker. **Step 2**: Add 1 spoon of salt and mix well. **Step 3**: Pour the mixture into a cup. **Step 4**: Dip the copper strip and the zinc strip into the cup, making sure they do not touch each other. **Step 5**: Connect the two strips to the LED with crocodile clips: the copper should be connected to the long leg of the LED and the zinc to the short leg. **Step 6**: If the LED does not light up, use more than one cup. • Repeat the aforementioned process with a new cup. • Assemble the cups in a serial electronic circuit, connecting the copper strip of one to the zinc strip of the other, making sure that the condition stipulated earlier is maintained: that the LED is connected to a zinc strip (through the first's short leg) and a copper strip (through the first's long leg).
Source	"How to make a Vinegar Battery" by Elearnin

Conclusion (5 min)	Check the research question/hypothesis. Explain to the children what role each ingredient plays in the experiment. By joining vinegar and salt, a substance is created that conducts electricity (an electrolyte) while copper and zinc generate a flow of electrons.
Explain the experiment (10 min)	This experiment mimics a battery by using an electrochemical reaction to generate electricity. **Vinegar (acetic acid)** and **salt (sodium chloride)** create an **electrolyte**, a substance that conducts electricity through the movement of charged particles (ions). **Copper** and **zinc** serve as the **electrodes** in this battery. Since zinc is more reactive than copper, it loses electrons more readily in the electrolyte, setting up an electric potential difference (voltage) between the two metals. Putting it simply, the zinc loses electrons and the copper gains them. This movement of ions enables the completion of the electrical circuit, allowing electrons to move through the external wires and power the LED.

	Adding more cups of the vinegar and salt mixture with copper and zinc strips increases the voltage. This is because each additional cup functions as another small battery, and when stacked in series, their voltages add up. In this experiment, we are using cheap, eco-friendly materials such as salt and vinegar. What we are doing here might be important for the future because extracting and refining the materials generally used for batteries requires huge amounts of energy, and their mining pollutes the soil and water. Scientists are working on more ecological ways of generating electricity and building batteries.
The science behind	**Electricity**: Electricity is the movement of sub-atomic particles called electrons. A concentration of electrons in one place makes an electric charge. You can measure how strong the electric charge is by measuring its voltage. Electrons will move through some materials easily; these are called conductors. In order to keep the electrons contained in a conductor, it is surrounded by an insulator. An electric wire, made from a conductive core (usually copper) and an insulating sheath (usually plastic) can move electric

	charge from one place to another. We can count the number of electrons moving past a point in the wire, and this is called current, which is measured in amps. Electric charge does not spontaneously gather itself in one place; in order to do this, we have to work to push the electrons together. This is what we do to produce electricity, usually, we use a magnet to push the electrons through a wire in a machine called a generator. **Environmental pollution associated to the technology**: The tech industry accounts for 7% of global emissions and is expected to rise rapidly with the growth of data centres, cloud computing, and the widespread use of electronic devices. The energy consumption of the IT sector is significant, with data centres alone using 70 billion kWh of electricity. Moreover, extracting and refining critical materials, such as those used in smartphones, requires significant energy. Mining these materials often results in land and water degradation due to the intensive and polluting processes involved. For instance, producing a single smartphone requires around 12,760 litres of

	water, considering all the steps from mining to manufacturing. Big Tech companies significantly contribute to greenhouse gas emissions, accounting for approximately 4% of global emissions in 2023. These numbers paint a complex picture. E-waste, the rapidly growing mountain of discarded electronics, is a significant concern, with an estimated 57.4 million metric tonnes. **Sustainability**: Power generation from renewable sources is important for sustainable development due to the depletion of traditional fossil fuels and related environmental pollution. Paper is used to generate electricity under moisture ingress. As a result, a piece of untreated print paper (1.5 cm2 in area) can induce a voltage of 0.25 V and a current of 15 nA. The power output can be conveniently tuned by changing the humidity, temperature and number of devices by simple series/parallel connections. Such paper-based moist-electric generators (PMEGs) are expected to find their applications in the daily ambient environment owing to the wide availability and low cost of paper.

	Electrolytes: An electrolyte is a substance that conducts electricity through the movement of ions, but not through the movement of electrons. This includes most soluble salts, acids, and bases, dissolved in a polar solvent like water. **Electrochemical reactions:** Under ordinary conditions, the occurrence of a chemical reaction is accompanied by the liberation or absorption of heat and not of any other form of energy; but there are many chemical reactions that—when allowed to proceed in contact with two electronic conductors, separated by conducting wires—liberate what is called electrical energy, and an electric current is generated. Conversely, the energy of an electric current can be used to bring about many chemical reactions that do not occur spontaneously. A process involving the direct conversion of chemical energy when suitably organised constitutes an electrical cell. A process whereby electrical energy is converted directly into chemical energy is one of electrolysis, i.e., an electrolytic process.

#steamtales–project

www.steamtales.eu

Co-funded by the European Union

All content is under CC BY-NC-SA 4.0

STEAM Tales (KA220-HE-23-24-161399) is funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the Nationalen Agentur im Pädagogischen Austauschdienst. Neither the European Union nor the granting authority can be held responsible for this.

MIND gGmbH Mittelhessisches Institut für Nachhaltigkeit und Diversität

GoINNO

U.PORTO

cesie the world is only one creature

LogoPsyCom