STEAM Tales

Lesson plans

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Andreja Gomboc's biography

Photo credit: Gregor Ravnik

Andreja Gomboc was born in 1969 in Slovenia, in Murska Sobota. She became interested in the Universe in Primary school. Due to a lack of role models and the fact that astrophysics was not as widely recognised in Slovenia at that time, she chose to study physics instead. During her studies, her fascination with astrophysics only grew and led to her future career in astronomy.

She is a professor and researcher of Astronomy at the University of Nova Gorica. She is a member of many international astrophysical collaborations like The Vera C. Rubin Observatory, Gaia, Theseus, and others. Her main areas of research are tidal disruptions of stars by massive black holes and gamma-ray bursts. She is also very active in promoting science and equal opportunities in science for everybody.

So far, Andreja has received many awards. To name a few: together with her coworkers, she received The Times Higher Award: Research Project of the Year in 2007, in 2015 she received the Zois award, a prestigious national recognition in Slovenia for outstanding achievements in scientific research and development, and she also received the Fulbright scholarship. Currently, she is in her 50s and lives in Slovenia.

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Lesson plan 1

Why do stars twinkle? Keywords: stars, atmosphere, light	
Duration: 50 min	**Age:** from 6 to 9 years old
Place: Classroom	**Related STEAM areas:** **S** (Science): Children will learn why stars appear to twinkle when we look at them.
Description	During this experiment, children will learn that stars do not actually twinkle but only appear so because of the distance light has to travel through the atmosphere. Children will use simple objects to mimic the night sky and observe how a simulated "atmosphere" causes stars to appear to twinkle.
Learning objectives	At the end of this experiment, children will be able: • Gain basic knowledge about the atmosphere • Be able to explain why stars appear to twinkle when viewed from Earth • Be able to identify at least one constellation • Practice fine motor skills and precision

Connection to the female role model	Andreja Gomboc is an astrophysicist and one of her main research areas is stars in the vicinity of black holes. She was fascinated with stars even before she became an astrophysicist.
Individual or group	Individual.
Safety	Some supervision is needed when cutting the foil.
Materials	☐ Printed constellations of stars (approx. 5 examples) ☐ Aluminium foil, approx. 40 cm for each child ☐ Pen ☐ Flashlight ☐ Glass bowl, medium size ☐ Water, approx. 1,5 l
Lesson plan	
Introduction (10 min)	Do you like staring at the clear night sky? What do you like the most about stargazing? When you look at stars, how do they appear to you (what colour are they, are some bigger or brighter than others, do they twinkle)? Well, actually, they only appear to twinkle. Today we will learn why this happens.

	Do you know the names of any of the stars or maybe of a star constellation? Have you ever heard of the Great Bear (also known as Ursa Major) or Orion? Before we move to the experiment, you can pick one of the constellations that appeals most to you. **If you read the story before the experiment:** Do you remember how fascinated Andreja was with stars and the fact that although they are really far away from Earth, we can still get to know them quite well? Today, we will get to know a little something about stars, we will find out why stars appear to twinkle.
Research question/hypothesis (5 min)	Before scientists start researching, they ask themselves a research question. And here is my research question for you: Why do you think stars twinkle? (Prepare for possible answers: because they are far away, because they turn on and go out, because there is something around them…)

	(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 serve to answer the research question, mimicking the scientific method.)
Step-by-step instructions (25 min)	Before the experiment: the teacher will have to print a few examples of constellations of stars (some examples of where to find material are listed after the steps, but you can find your own). **Step 1**: Each child will choose one of the offered constellations. **Step 2**: Each child will cut a piece of foil (a bit smaller than the A4 paper) **Step 3**: Each child will pierce the piece of foil mimicking the chosen constellation of the stars, by making small holes. (Explain to children as you go: “Little dots on the foil will represent stars”.) **Step 4**: Darken the classroom. (“We will now make night”)

	Step 5: Put a flashlight behind the pierced foil, making it look like a night sky (from the other side). ("Stars start to shine on the night sky") **Step 6**: Observe (ask children) if "stars" twinkle. **Step 7**: Turn the light back on. **Step 8**: Put water into a bowl (Explain to children that water represents the atmosphere, the thick coat around the Earth). **Step 9**: Put the pierced foil on one side of the bowl filled with water and put the flashlight behind it. Observe the twinkling of the "stars" from the other side. (Ask children why they think that dots- stars twinkle now.) **Step 10**: To make them twinkle more, you can carefully shake the bowl or move the bowl around. Printable star constellations: "Stars and constellation" (from page 24 on)
Source	"Why do stars twinkle" by Dr Michelle Dickinson
Conclusion (5 min)	Check the research question/hypothesis.

	When we looked at our stars without the water between us and stars, they were still and were not twinkling. But when we put a bowl of water between us and the stars, they began to twinkle. Stars only appear to twinkle because we look at them through all the air above us, which is called the atmosphere. The atmosphere is a very thick and layered jacket that surrounds the Earth. When starlight enters our atmosphere, it is affected by what is happening in those layers; they can be hot or cold, and they move around at different speeds and this causes light that is traveling from the stars to our eyes, to twinkle.
Explain the experiment (5 min)	Starlight is affected by winds, different temperatures, and densities in Earth's atmosphere. When we look at stars, we look at them through Earth's atmosphere. In our experiment, stars were small dots in the foil and Earth's atmosphere was a bowl filled with water. When we moved the bowl, the movement of the water caused even more twinkling in our dots (stars). A similar thing happens when we look at stars from the Earth: all of the different happenings in layers of air that we call the atmosphere affect the beam of starlight that

	travels through it. It moves, bounces, and bumps through layers of air and we see this movement as twinkling. A similar thing happens when we look at objects through the hot air over a fire or if we stare at a road on a really hot summer day; objects near the heat source appear to be a bit blurry and wobbly.
The science behind	Stars appear to twinkle because of the effects of Earth's **atmosphere**. The atmosphere stretches approx. 10.000 km above the Earth's surface and is a mixture of gases. When we look at stars, light that passes through the atmosphere is refracted (bent) and distorted because of different temperatures and densities of air. The scientific term for stars twinkling is atmospheric or stellar scintillation. Air travels at different speeds, depending on its temperature; when the air is hot, it has loads of energy and moves around quickly. But when the air is cold, it does not move as much.

Hot air is also lighter than cold air, so it rises past and mixes with the cold air around it. This mixing creates swirls in the atmosphere known as "turbulence".

Why do only some stars twinkle?

»Stars« that are not twinkling are satellites, such as the International Space Station, or planets in our solar system. They are much closer to us than stars and, therefore, have a thicker beam of light that is not so easily affected by Earth's atmosphere. They can, however, also twinkle, just not as much as stars.

How much stars twinkle also depends on where on Earth we look at them. Stars near the horizon appear to twinkle more because the light from them has to travel through more atmosphere to get to the observer's eye. Another thing that plays an important role is the weather. Humidity, for instance, affects twinkling very much. These are also the reasons why all the biggest telescopes and observatories are placed in high and dry places. Some of these places are the Atacama Desert in Chile, the Spanish Canary Islands, and volcanic peaks of Hawaii.

	Some indigenous cultures (Indigenous Australians and Torres Strait Islanders, for instance) have been observing the twinkling of stars for thousands of years. “Reading of stars” or knowledge of how scintillation correlates with atmospheric conditions helped them predict wind movements, storms, hot weather, and the arrival of the wet season.

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Lesson plan 2

Visible light **Keywords: rainbow, Newton's disc, white light, visible light waves**	
Duration: 60 min	**Age:** from 6 to 9 years old
Place: Classroom	**Related STEAM areas:** **S** (Science): Children will learn that there are different kinds of lights, and that the one human eye is able to detect is called white light. They will learn the science behind the rainbow. **E** (Engineering): They will learn about different wavelengths of light. **A** (Art): Children will use colour to colour the disc.
Description	Children will make their own Newton's disc and try to create conditions to see the rainbow. This activity will allow them to understand the basic science behind the rainbow phenomenon and the basic principles of white light.
Learning objectives	At the end of this experiment, children will: • Explain, in their own words, how a rainbow is formed

	• Show a rainbow using a prism • List the colours of the rainbow • Practice (fine) motor skills and precision
Connection to the female role model	Andreja Gomboc is an astrophysicist. One of her main fields of research is gamma-ray bursts (GRB). These events that are the most energetic and luminous events ever known (apart from the Big Bang) are occurring in distant galaxies and are not easily detected. When they occur, different kinds of wavelengths are detected: firstly, gamma rays, and then in the afterglow X-ray, ultraviolet, optical, infrared (IR) and radio wavelenghts. During this experiment, children will gain basic knowledge of white light, a wavelength that a human eye can perceive.
Individual or group	In pairs or in group.
Safety	The knife should only be used by adults.
Materials	**Rainbow with a prism**: ☐ Prism ☐ Sunlight ☐ Flashlight (in case of non-sunny weather) **Reversed rainbow**: ☐ A4 paper sheet

	☐ Piece of cardboard (must be bigger than the CD) ☐ CD ☐ Wooden skewer ☐ Glue ☐ Scissors ☐ Ruler ☐ Pencil ☐ Colouring source (crayons, markers, …) ☐ 90cm string
Lesson plan	
Introduction (10 min)	Have you ever seen a rainbow? Do you remember what kind of weather was it when you saw it? It was probably after the rain when rays of sunshine started to shine through the clouds. But having luck with the right weather is not the only way you can see the rainbow. Today we will try to bring a rainbow into our classroom! And after that, we will make the colours of the rainbow disappear! It might seem like we will be doing some kind of magic, but there is a scientific explanation behind it!

	If you read the story before the experiment: One of the main fields of Andreja's research is gamma rays. This is a type of light that a human eye cannot detect and it mostly happens far away in space. Because gamma rays are not visible, scientists like Andreja have to search for other clues to know when gamma rays are happening. We cannot go to space to search for gamma rays, but we can search for all the colours of the rainbow and see what kind of tricks visible light can do on Earth.
Research question/hypothesis (5 min)	Here is our research question: Do you think we will be able to see all the colours of the rainbow inside our classroom? What do you think will happen when we spin the disc with all the colours of the rainbow (Newton's disc) really fast? What will we see? 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 serve to

	answer the research question, mimicking the scientific method.
Step-by-step instructions (35 min)	**Rainbow with a prism:** **Step 1**: Take a prism to the sunlight. **Step 2**: Turn the prism around until you see the rainbow. **Step 3**: Observe colours that come through. **Step 4**: Identify the colours of the rainbow. In case of non-sunny weather, follow alternative steps: **Step 1**: Darken the room a little bit. **Step 2**: Place a prism on a table. **Step 3**: Turn on the flashlight behind the prism. **The last two steps are the same** **Newton's disc:** **Step 1**: Use a CD to draw 2 circles on the paper sheet and 1 on the cardboard. **Step 2**: Divide both circles on the paper into 6 equal sections and colour each section with rainbow colours:

	red, orange, yellow, green, blue, and violet. For best results, use bright colours. Mark the centre. You can use crayons for one circle and markers for the other and compare the results at the end. **Step 3**: Make the disc by cutting all three circles and glue the paper circles to the cardboard circle. **Step 4**: Make two parallel holes, approx.1 cm apart, in the centre of the disk with the skewer. **Step 5**: Take a 90 cm long string and pull it through the holes of the disk. Hold the ends, and when they are even, tie them in a knot. **Step 6**: Hold the ends of the string. Spin the disk around with one hand and then pull in and out, so the disk moves quickly.
Source	The whole process with pictures for every step: "Disappering Colour Disc" by STEAM Builders project. Video showing the whole process: "Newton's disc – Reverse RAINBOW (blending colours to be white)" by Kids Fun Science The electromagnetic spectrum explained: "The Electromagnetic Spectrum" by NASA Imagine.

Conclusion (5 min)	We can now answer our research question: The answer to our first question is yes, we were able to see all the colours of the rainbow! All we needed was sunny weather and a prism. The answer to our second question is: if you spin Newton's disc fast enough, all the colours of the rainbow blend into one – white or greyish.
Explain the experiment (5 min)	**Rainbow with prism**: White light that our eyes detect is a combination of all the colours of the rainbow, or, with more scientific words of all the colours in the electromagnetic spectrum. When white light enters a particular transparent object (a glass, a droplet, a prism), the light bends (refracts) and separates into all the colours of the rainbow (colours of the visible spectrum). When we see a rainbow after the rain, we see it because there are many water droplets in the air after rain, and they act like a prism in the classroom experiment we did; they bend the light from the Sun and separate the colours into a rainbow arc.

	Newton's disc: When we spun the disc coloured in the colours of the rainbow, we ended with a reverse result from the prism. All the colours of the rainbow blended into a white or greyish colour. The disc we created in the experiment is called Newton's disc (also reverse rainbow disc), and it proves that light is not colourless but a combination of colours of the rainbow. When the disc spins rapidly, all the colours blend into one because the human eye cannot detect individual colours anymore, because they change too quickly. This is called an optical illusion, more precisely persistence of vision.
The science behind	**Rainbow**: There are three scientific phenomena at work in the events called a rainbow: **reflection** (abrupt change in direction of light when hitting a surface), **refraction** or separation of colours (the change in direction of, in our case, the light wave) and **dispersion of light** (the wavelength of the wave influences its velocity). As the full spectrum of visible light travels through a prism, the wavelengths separate into the colours of the

	rainbow because each colour has a different wavelength. For instance, violet has the shortest wavelength, at around 380 nanometers, and red has the longest wavelength, at around 700 nanometers. Colours of the rainbow or colours of the electromagnetic spectrum that the human eye can detect are: red, orange, yellow, green, blue, indigo and violet. (We used 6 colours in the experiment because nowadays indigo is usually not included as one of the colours of the rainbow). In physics, "light" refers to any electromagnetic radiation of any wavelength, not just visible light that a human eye can perceive. Here are some other types of light apart from white light: X-rays, microwaves, radiowaves, infrared, ultraviolet, and gamma rays. **Newton's disc**: This physical experiment shows the link between colour, light and human perception while also illustrating the Newton's findings on the splitting and assembly of light. Persistence of vison: The human eye and brain cannot detect individual colours in isolation if they change very quickly. This

	phenomenon is also used in films and animations, where rapid sequences of images create a sense of continuous motion. Both experiments show us that white light is actually made from 7 colours that we call the visible spectrum.

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