PLAYING WITH PROTONS GØES DIGITAL

HANDBOOK OF RESOURCES

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Abstract	This document represents a Handbook of Resources, comprising of a set of Playing with Protons Goes Digital activities, including activities with the use of basic AR/VR applications, a guide on how to design/adapt your own STEAM activities and extreme scenarios such as pandemics and associated school closures. The Playing with Protons Goes Digital kit of STEAM and digitally enhanced activities is a unique document addressing particular skills in science teaching, also aiming at clarity, with an emphasis on straightforward introduction and implementation by schools and teachers. This document highlights the significant role (here, in the form of concrete classroom activities) of all the chosen methodologies and ideas. The activities cover a wide range of subjects and areas connected to STEAM as thoroughly determined in O1. The Playing with Protons Goes Digital Handbook, is a kit of high-quality activities, covering both late primary and secondary education. The kit contains full expositions of each activity and tips for tools, settings, contexts and modifications (again, following the framework produced in O1). Moreover, instructions are offered to teachers to fully incorporate each activity in the science curriculum and in an interdisciplinary fashion. There is also a strong element on how to implement such activities remotely, again with an emphasis on practicality and safety.
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Reviewer(s)	
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EXECUTIVE SUMMARY

The "Playing with Protons Goes Digital" project proposes a science teaching approach built on authentic and engaging science learning experiences to late primary and early secondary students (aged 10 to 15 years). The "Playing with Protons Goes Digital" approach will be using such elements for the purpose of empowering teachers to be confident digital content designers and co-creators as well as science ambassadors that strive to excite the young minds about the world of science, how science works, and why it may be worthwhile for students to follow a career in science.

In addition, the project will offer structured support through a school roadmap to use a "Playing with Protons Goes Digital" science curriculum as a vehicle for community engagement and change. Along with it, it will also offer a set of policy recommendations to educational authorities focusing on schools as hubs of open innovation, involving knowledge flows across school boundaries, towards enhancing the image of science in the eyes of the local school community as a key pillar of education, in the context of an innovation economy. It will also promote inquiry, creativity and collaborative learning among students, as well as meaningful collaboration between schools through eTwinning projects.

This document (IO2) includes three main chapters and provides a Handbook of Resources, comprising of a set of Playing with Protons Goes Digital scenarios, including activities with the use of basic AR/VR applications and templates on how teachers can design/adapt their own STEAM activities. The activities will cover a wide range of subjects and areas connected to STEAM as thoroughly determined in O1.

This document (IO2) provides a Handbook of Resources, comprising of:

Chapter 1

This chapter serves as an introduction to the content of IO2 document.

Chapter 2

This chapter provides an AR Starter Pack, with quick AR projects to accompany STEAM activities and classroom explanations, and to be the practicing base for the Playing with Protons Goes Digital scenarios.

Chapter 3

Provides a set of Playing with Protons Goes Digital scenarios, covering a wide range of subjects and areas connected to STEAM as thoroughly determined in IO1 and including activities with the use of basic AR applications. There are given the templates and guides for teachers to adapt their own Playing with Protons Goes Digital activities. The reference document for IO2 is the O1, as in this are fully described the essential features of creative science education and the proposed conceptual and methodological framework which is based on the specific features. This chapter also describes the themes of the educational scenarios which were created and based on the new curriculum for primary and secondary education and moves towards the scenarios which has been created based on Primary and High school’s curriculum.

1

INTRODUCTION

1 PLAYING WITH PROTONS GOES DIGITAL AND THE DEEPER LEARNING PARADIGM

The Handbook of Resources is a kit of high-quality activities, covering both late primary and secondary education, according to the definitions offered by the Playing with Protons Goes Digital project.

The Handbook contains the AR Starter Pack, all the educational material produced, scenarios, markers and QR codes for each scenario, following the framework produced in O1.

The AR projects can be found and downloaded from the following link (https://playingwithprotons.infn.it/educational-scenarios/).

The educational scenarios were produced by using the methodology taken from the Inquiry based science learning approach and Arts-Based technologies.

In particular:

- The target user audience of this Handbook are teachers, scientists, and artists.
- The age range of the students it addresses is between 10-17 years old.
- The approximate time typically needed to address the scenarios are between 1-3 teaching hours.
- The technological tools required are basically the Playing with Protons AR authoring tool and MetAclass Studio app.
- The activities relate to primary and secondary education curriculum and the themes of scenarios connected with the science education, physics, astronomy, particle physics, microcosm, animals, teaching science with the Big Ideas, CERN-and-INFN-inspired research in science education, AR/VR, etc.

2

AR STARTER PACK

2 AR STARTER PACK

The AR Starter Pack is a set of basic AR projects developed in the AR Authoring Tool, covering a wide range of possibilities in terms of subjects (science, technology, biology, animals etc.) classified, when possible, according to the main Big Ideas in Science, and thought to be the base for the AR activities inside the Playing with Protons Goes Digital Scenarios.

Some of the projects in this pack, come from the necessities detected inside the consortium to better explain concepts such as the universe and planets, how gravity works in terms of physics but also in the artistic world, climate and climate change or molecule formation. Other projects are meant to be the first contact of teachers with AR and a simple way to better understand the capabilities the AR Authoring Tool offers (interaction between markers, marker and markerless projects etc.) and how AR can be used to show invisible concepts (e.g. atoms) or to mix technology and science.

Projects from this Starter Pack have been used in the first stages of the Playing with Protons Goes Digital project, in both internal and external workshops, to showcase the first set of AR-enhanced resources and explore further the possibilities of the AR Authoring Tool. They are a useful tool, along with the User Guides, to help teachers become familiar with AR technology, its possible uses, and how to use it within their educational projects.

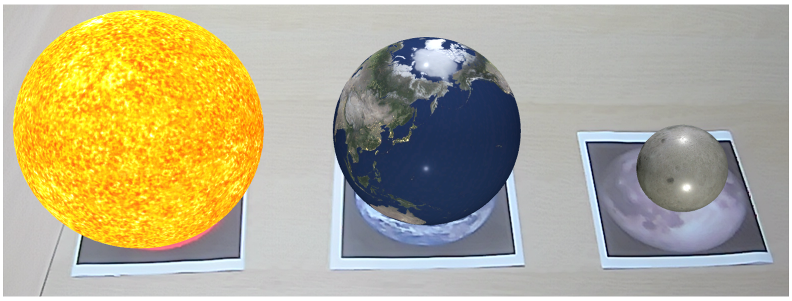
2.1 EARTH, MOON & SUN

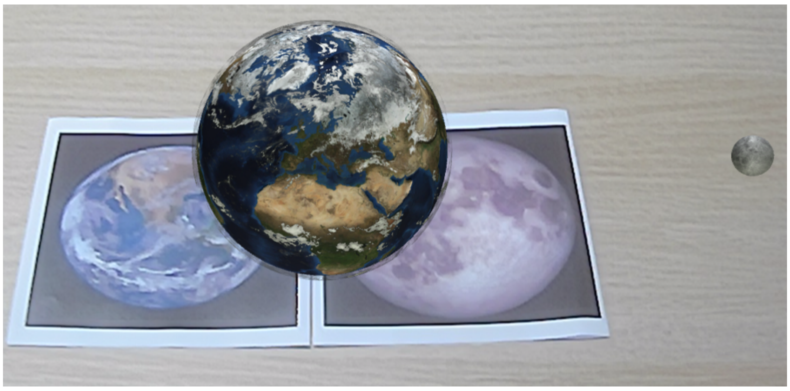
Keywords: science, space, planets, Universe, Earth, Moon, Sun
Link to Big Ideas of Science: Universe, Earth, and the Solar System
AR Project Type: 3 markers: 2 and 3 marker interaction

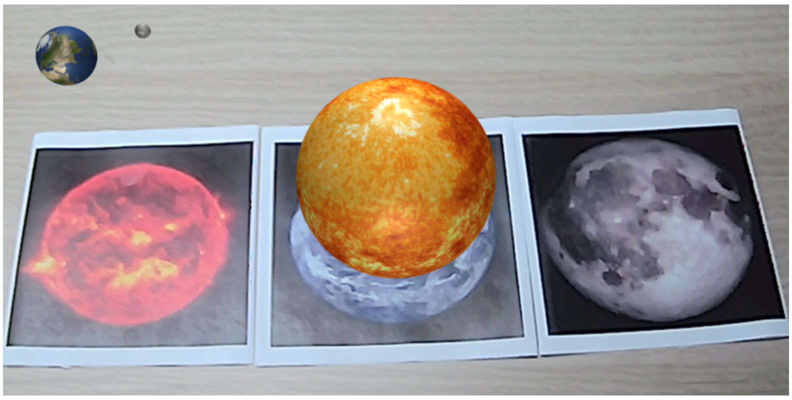
Inside the Project

This project shows the 3D models of the Sun, Earth, and Moon.

- When they are separated, the markers show each their own 3D models.
- When we put the Earth and Moon together, it changes to a 3D animation of the Moon revolving around the Earth.







In classroom

This project is used while explaining about the Universe and, more specifically, about the Sun, the Earth and Moon.

Students can visualize the 3D models separately and then mix them to understand the relationship between them.

It is also used to help them understand concepts such as gravity between bodies. This project can be used in combination with the following projects about the Solar System.

2.2 ECLIPSE

Keywords: science, space, planets, universe, Earth, Moon, Sun

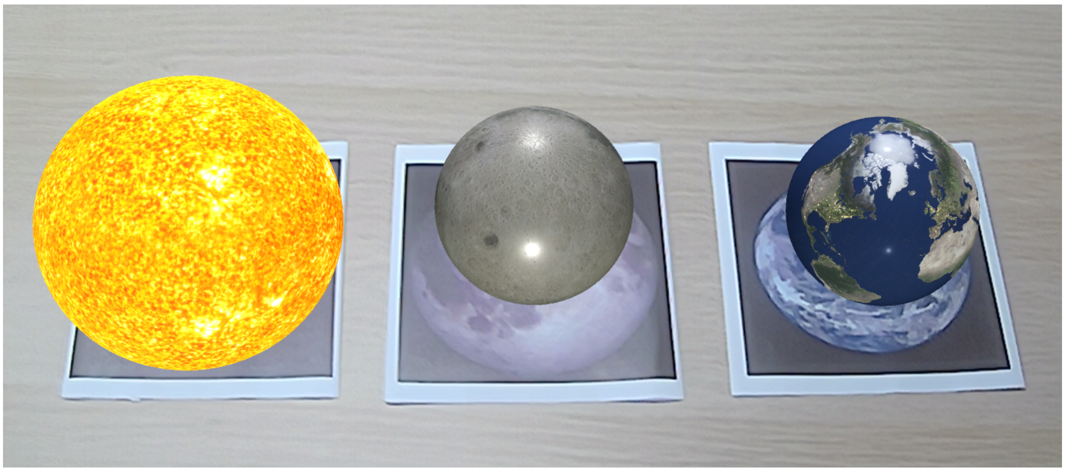
Link to Big Ideas of Science: Universe>Earth and the Solar System

AR Project Type: 3 markers: 3 marker interaction

Inside the Project

This project shows a video of an eclipse and the 3D model of the Sun, Earth, and Moon.

- Separated, the markers show the 3D models of the Sun, Earth, and Moon.
- Joined, they show a video of an eclipse and the 3D animation of the Moon revolving around the Earth and the Earth around the Sun.



[In classroom]

This project is usually used after the previous one, that explains about the Sun, Earth and Moon. When students have seen how they spin and revolve, they are more prepared to understand how an eclipse works.

Students can visualize the 3D models separately and, when together, they can see the animation to understand at what point an eclipse would occur as well as watch the video of the fenomena.

2.3 SOLAR SYSTEM

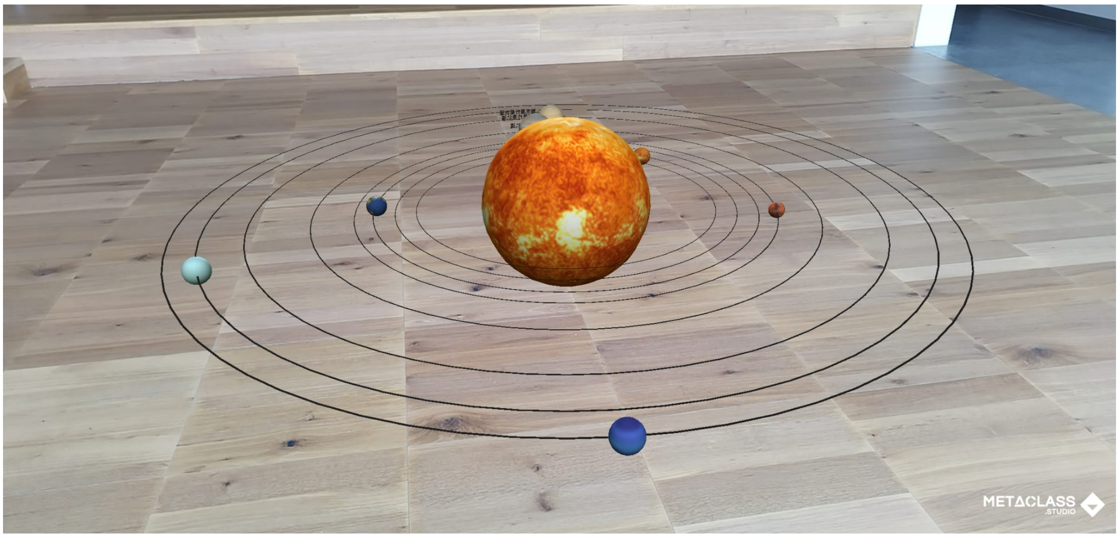
Keywords: science, space, Universe, Solar System, planets

Link to Big Ideas of Science: Universe, Earth and the Solar System; Universe, Earth's place in the Universe, Celestial objects; Universe, The history of Universe

AR Project Type: Markerless

Inside the Project

This project shows the animated 3D model of the Solar System over the real environment.



In classroom

This project is used as a first approach to the Solar System.
Placing this 3D model in the middle of the classroom, children can get near each planet, see how they move, where they are in relation to the Sun etc.

Explanations such as which is the hottest planet, the biggest one, the coldest one etc. are much easier understood if they can find them in the model visualizing around them.

2.4 SOLAR SYSTEM AND PLANETS

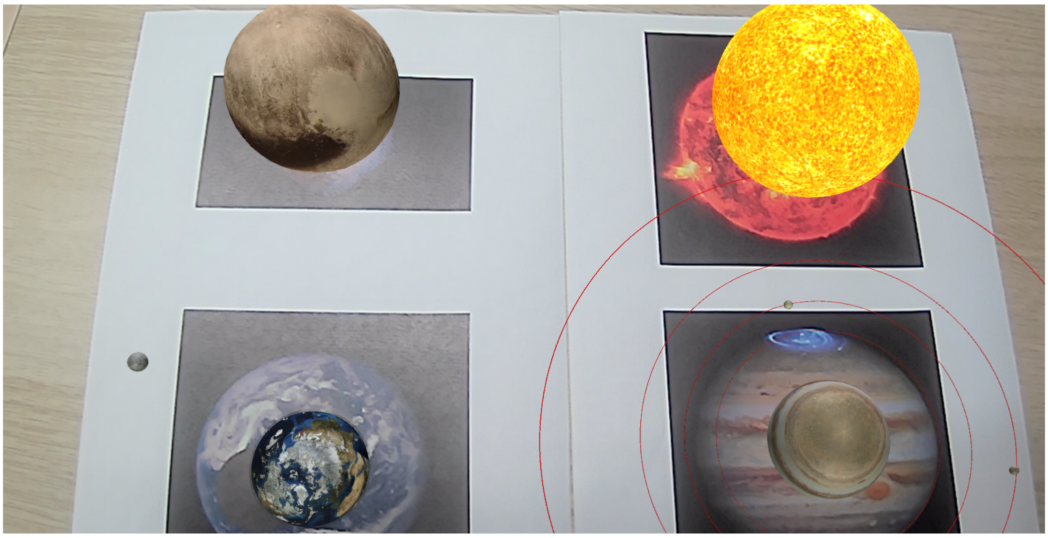
Keywords: science, space, planets, universe, Solar System

Link to Big Ideas of Science: Universe, Earth and the Solar System

AR Project Type: 6 markers: simple markers.

Inside the Project

This project shows the 3D models of different planets and the whole Solar System. Some of the planets such as the Earth are animated, with the Moon revolving around it. In the case of Jupiter, we can see also its moons revolving around it.



In classroom

This project is used as a first approach to the Solar System and the planets. In combination with the previous projects, it helps explaining the differences between the planets, their main characteristics etc.

The AR content can be further expanded to cover the 3D models of all the planets of the Solar System.

2.5 SCALE OF THE UNIVERSE

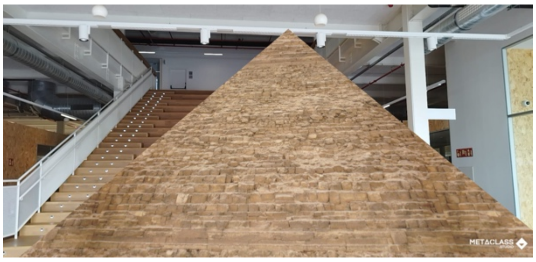
Keywords: science, universe

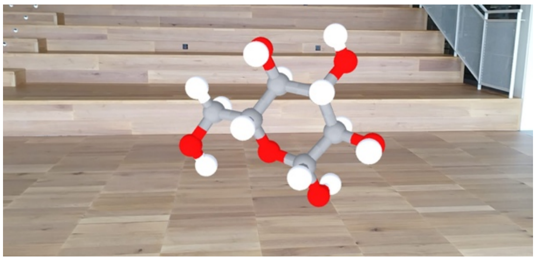
Link to Big Ideas of Science: Universe, The history of our universe, Scales of our Universe

AR Project Type: Markerless

Inside the Project

In this project, once the firs 3D model (the Sun) is fixed to the floor, every 3 seconds a new element (pyramid, whale, human, cat, mouse, molecules) is shown, from the biggest one to the smallest ones.





In classroom

This project is used to help students understand the scales of the universe (from huge bodies such as the Sun to the smallest known elements) along with other resources and materials.

Within the project, they must move across the room while some examples of different scales are shown, including a part of the explanation where molecules (invisible to the naked eye) are maximized thanks to the power of Augmented Reality.

2.6 CLIMATE

Keywords: science, Sun, Earth, climate

Link to Big Ideas of Science: Earth, Earth's Climate, Weather and climate; Earth, Earth's Climate, Earth and the Sun

AR Project Type: 3 markers: 2 marker interactions

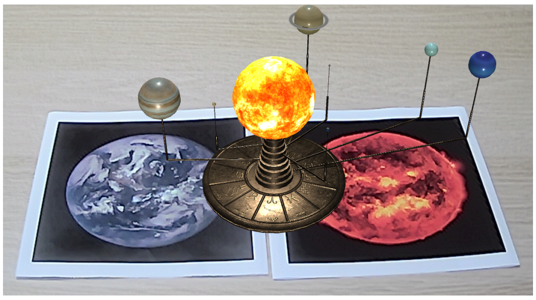
Inside the Project

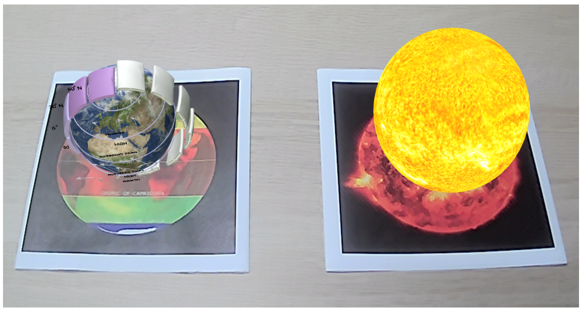
This project shows 3D models and explanations about the climate:

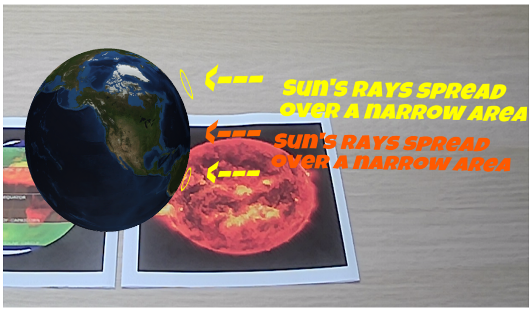
- When separated, the image of the Sun shows a 3D model of it, the marker of the Earth shows a representation of the layers composing the Earth and the image of the climate zones shows a 3D model of it.

- When the Earth and the Sun are put together, they show an Orrery 3D model of the Solar System.

- Then the climate image on the Earth and the Sun are put together, the 3D model of the Earth appears with text on how Sun's rays strike its surface.







In classroom

This project accompanies explanations about the climate, naming, solar radiation and latitude, season and how the Sun is directly related to all of this. Along with the next project, it serves to raise awareness about phenomena such as climate change, the thinning of the ozone layer and more.

2.7 CLIMATE CHANGE

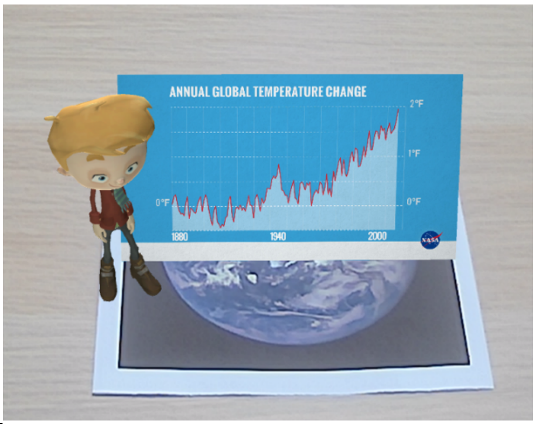
Keywords: science, Earth, climate, climate change

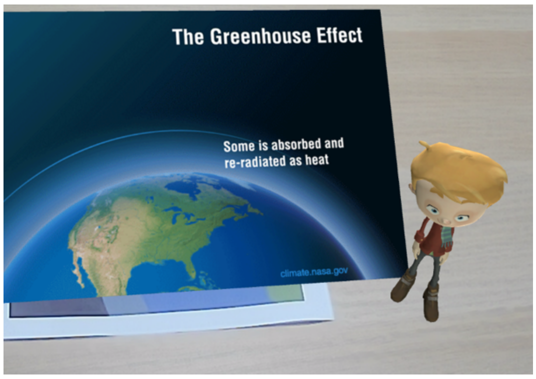
Link to Big Ideas of Science: Earth, Earth’s Climate, Global climate change; Earth, Earth's Climate, Human impact on Earth

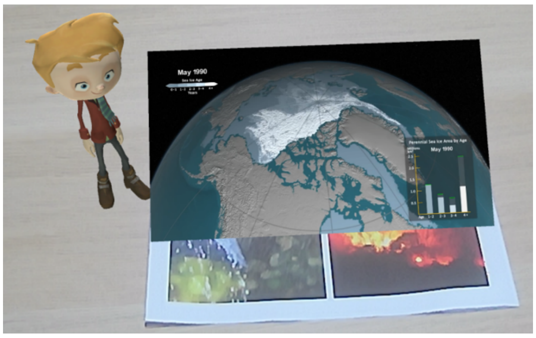
AR Project Type: 4 markers: simple markers

Inside the Project

This project narrates about the climate change, rising of Earth temperature and greenhouse effect in a sequence of four markers showing a talking avatar and a combination of images and gif images:







In classroom

Once students understand about the climate and the influence of the Sun over the Earth, they also study about Climate Change and the human influence on this subject.

This project, thought as a small storytelling on Climate Change, helps them explore on concepts such as temperature rise or greenhouse effect and accompanies activities where they must search for more information and propose measures to decrease the impact humans are having on our planet.

2.8 (ARTS) SAVANNAH, DINOSAURS AND VARIOUS ANIMALS

Keywords: science, biology, arts

Link to Big Ideas of Science: Evolution

AR Project Type: 23 markers: simple markers

Inside the Project

This project, divided into three parts, present 3D animated animals of different surroundings texturized like artworks.

In classroom

This collection of animated 3D animals, created by Miguelangelo Rosario, is preceded by explanations on evolution and evolutive traits.

In an exercise of imagination, students are presented with how animals would evolve if they were to live inside artworks and from there, they are presented with other possibilities to help them develop their imagination while understanding about scientific concepts.

2.9 ISS AND ASTRONAUT

Keywords: science, technology, space, universe, iss, astrounaut

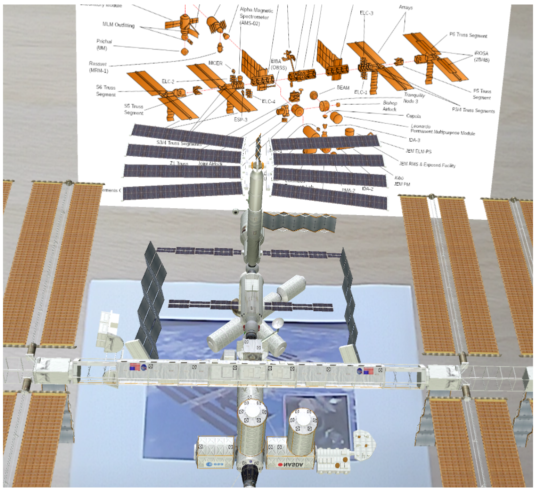
Link to Big Ideas of Science: Universe>Earth and the Solar System

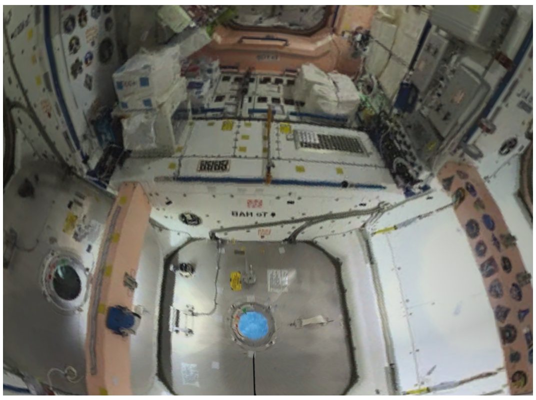
AR Project Type: 2 markers: simple + camera interaction

[Inside the Project](#)

This project displays an astronaut and the International Space Station:

- Over the imagen of the astronaut, the 3D model of an astronaut appears.
- Over the image of the ISS, from far away, we can see the 3D model of the space station as well as a plane with its structure. When we get close to the marker, a sphere showing the inside of the ISS appears.





In classroom

This project helps children understand more about the universe. According to students' age, it accompanies explanations about technology, first explorations of the space, spaceships, and space stations, how astronauts live and the requirements inside a spacecraft.

It can be used along with the AR projects of the Solar System to link concepts around space, as well as the next project about Rovers.

2.10ROVERS

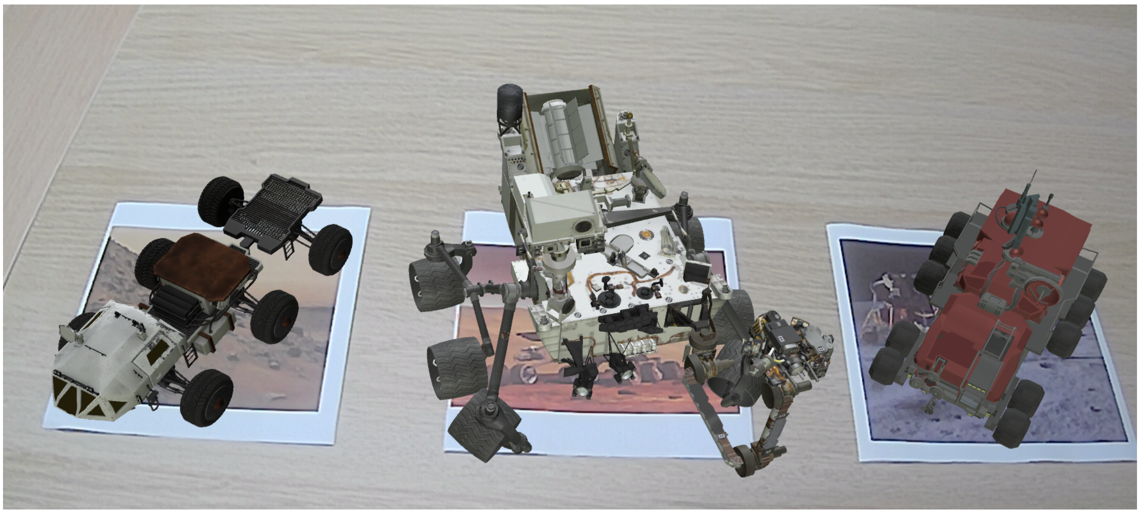
Keywords: science, technology, space, rovers

Link to Big Ideas of Science: Universe>Earth and the Solar System

AR Project Type: 3 markers: simple markers

Inside the Project

This project shows, upon 3 different images, the 3D models (one of them animated) of different rovers.



In classroom

This project accompanies the projects about space to help students understand the technology used in the space, how samples are taken from the Moon and planets such as Mars etc.

It has been used inside storytelling activities where children used the rovers to explain part of their living plan once they colonized Mars.

2.11 DINOSAURS

Keywords: science, biology, dinosaur, prehistoric, fossils

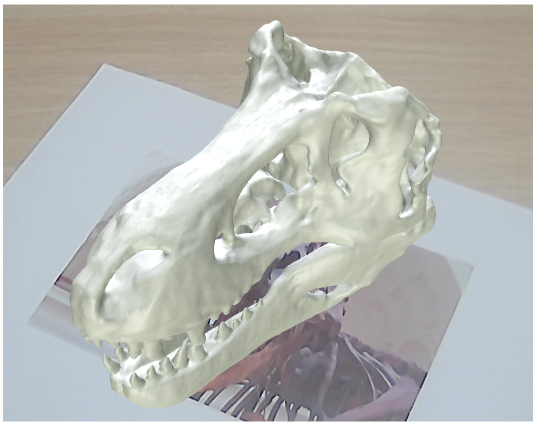
Link to Big Ideas of Science: Evolution>Natural Selection & Darwinian Theory; Evolution>Biodiversity

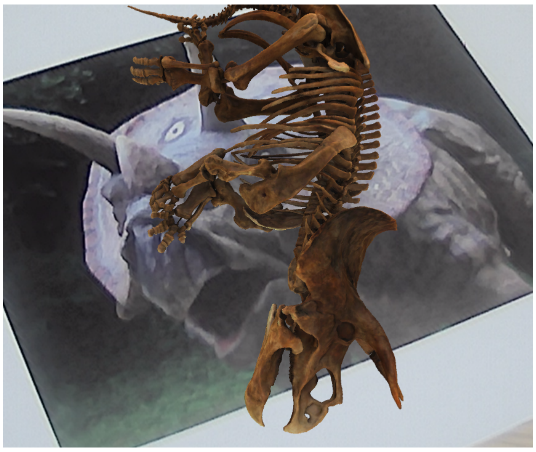
AR Project Type: 4 markers: simple + camera interaction + 2 marker interaction

[Inside the Project]

This project shows the 3D models of dinosaurs and skeletons:

- The T-Rex skull marker shows the 3D model of the skull.
- The Triceratops marker shows, from far away, the 3D animated model of the dinosaur and, from a close-up, its skeleton.
- The T-Rex markers show an animated T-rex. When we put two markers together the animation changes to a battle between them.





In classroom

This project is used to engage students when learning about dinosaurs, fossils, and evolution. It accompanies explanations on when dinosaurs inhabited the Earth, their life, habits, and extinction.

It can be combined with activities about paleontology, classification of dinosaur types etc.

The AR content can be further expanded with more models from Sketchfab, for example.

Note: 3D models of Dinosaurs are usually heavy and can take their time to load. We recommend using more than one project with dinosaurs to ensure a good experience.

2.12CORAL REEF

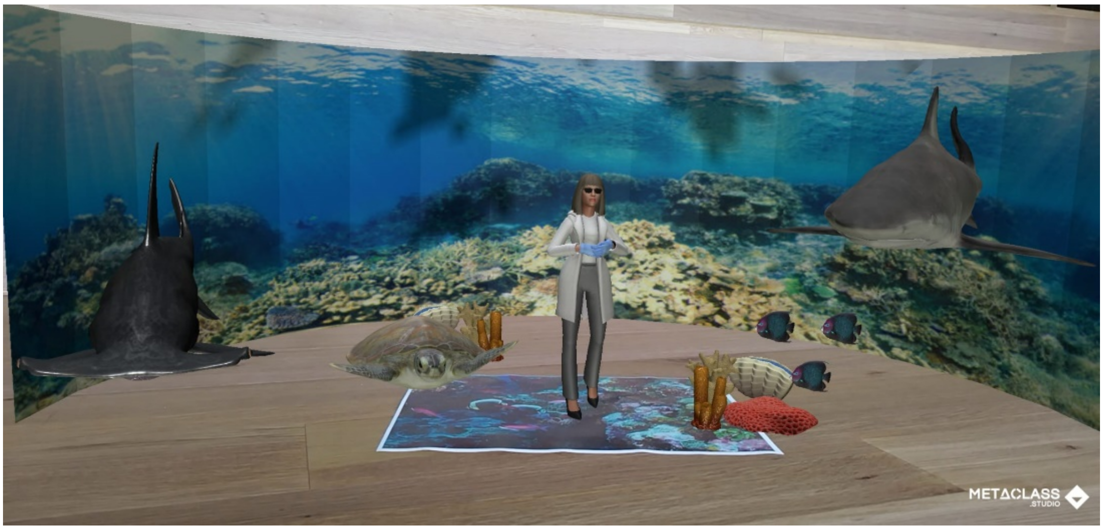
Keywords: science, biology, Earth, ocean, biodiversity, ecosystems

Link to Big Ideas of Science: Earth>Ecosystems

AR Project Type: 1 marker: simple marker

Inside the Project

This project shows, over an image of the bottom of the ocean the 3D models of different animals and plant in an oceanic environment along with an avatar of a scientist.



[In classroom]

This simple yet powerful project shows about ecosystems and the biodiversity of the sea life.

The animated 3D models of turtle, fish, and sharks, along with the avatar, help students work with concepts such as organism living in an ecosystem, social interaction or interdependent relationships in ecosystems.

The AR contents could be further developed to include audio explanations and other projects showing terrestrial ecosystems too.

2.13 AEROGENERATOR

Keywords: technology, engineering, energy, renewable energy, wind energy

Link to Big Ideas of Science: Energy>Forms, Conservation of energy and energy transfer>Energy sources

AR Project Type: 1 marker: simple marker

Inside the Project

This project shows the 3D model of an aerogenerator with the lid up.

In classroom

This simple project is used to explain the mechanisms of wind energy and the parts that form a wind turbine such as the engine, the rotor, the blades etc. Getting into the 3D model, students can observe its components and understand how wind energy is transformed into electricity.

2.14ATOMS & MOLECULES

Keywords: science, chemistry, physics, particles, atoms, molecules

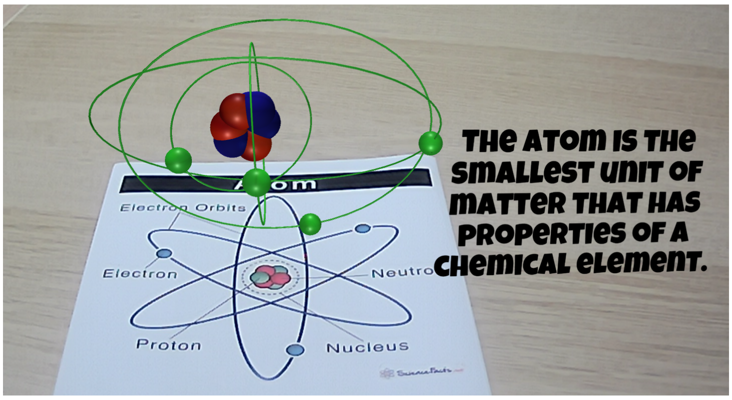
Link to Big Ideas of Science: Particles

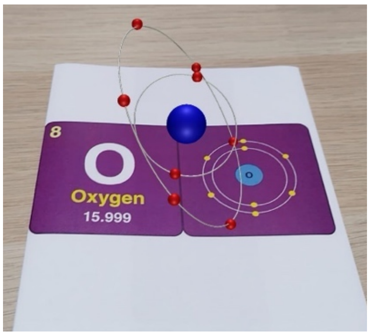
AR Project Type: 9 markers: simple + 3 marker interaction + 3 marker interaction + 2 marker interaction

Inside the Project

This project shows the 3D models of atoms and molecules:

- Over the image of the atom, it shows an atom with its protons, neutrons, and electrons as well as a small text about it.
- Over the elements: oxygen, carbon, hydrogen, sodium, and chlorine, it shows their respective 3D models.
- If we put together the atoms of H + O + H, an animation of water will appear.
- If we put together the atoms of C + O + O a visual explanation of carbon dioxide will appear.
- If we put together the atoms of Na + Cl a 3D model of a salt shaker will appear.




8
O
Oxygen
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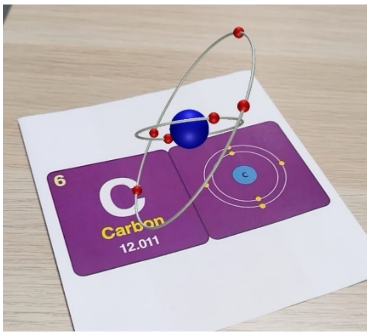
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C
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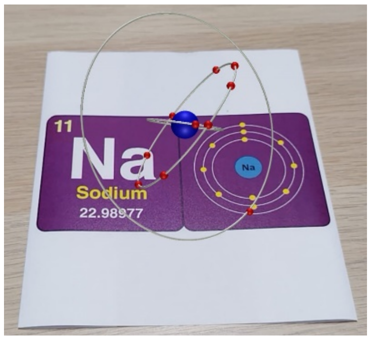
11
Na
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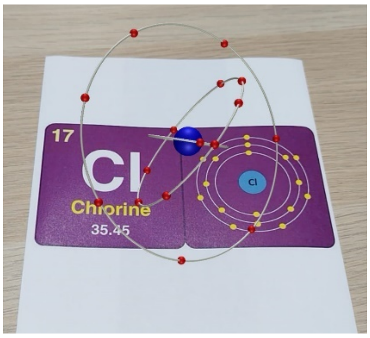
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Cl
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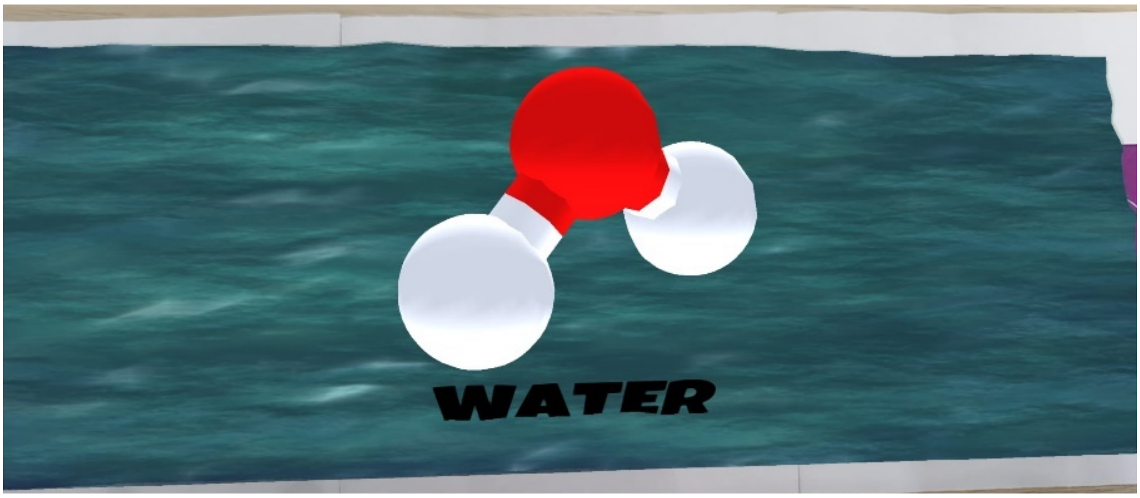
11
Na
Sodium
22.98977
SALT
Cl
35.45


WATER

[In classroom]

This project accompanies the explanation of matter, atoms, and molecules. Showing some of the common molecules, such as water, salt or carbon dioxide, students can understand how atoms join to form molecules, as well as watch all these elements with the naked eye thanks to the augmented reality.

Along with the next one, this project serves as an augmented microscope that helps understanding concepts too small to see in our daily lives.

2.15DAILY MOLECULES

Keywords: science, chemistry, physics, molecules

Link to Big Ideas of Science: Particles

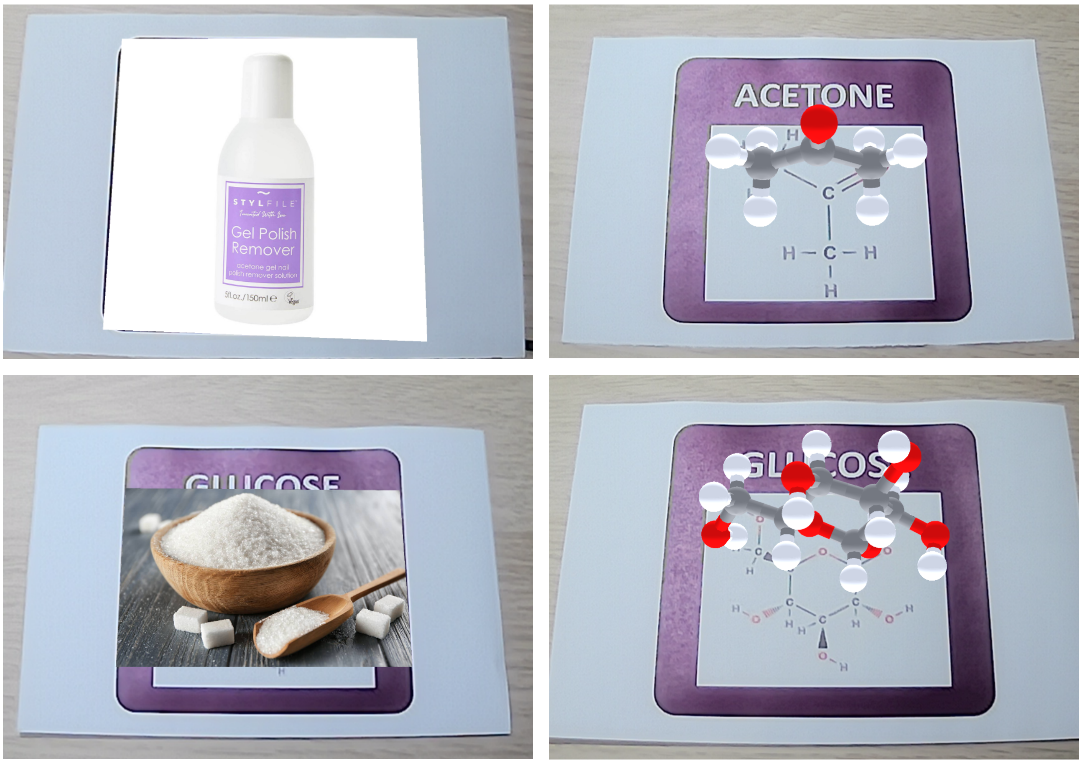
AR Project Type: 12 markers: camera interaction

Inside the Project

This project shows the use of components and, when the camera is close to the marker, their 3D molecular representation:

In classroom

This project, used to explain about molecules and how they are formed, help students link them with daily products such as sugar, coffee, or nail polish remover. The camera interaction of the markers, helps them "get into" these products and see the composition that lays behind them, helping them better understand and retain these concepts.



3

SCENARIOS BASED ON PRIMARY AND SECONDARY EDUCATION CURRICULUM

3 SCENARIOS BASED ON PRIMARY AND SECONDARY EDUCATION CURRICULUM

In this chapter are described AR-STEAM scenarios based on primary and secondary education curriculum. These scenarios cover a wide range of subjects such as exploration of the universe, Solar System and phenomena related to them, particle formation or women inventors throughout the history.

Each of these scenarios identifies first the main key points of the activity, including target audience, if the activity can be carried out outside a classroom (such as in a pandemic situation), the connection with the curriculum to allow teachers to easily identify the most suitable activities, and what kind of materials are required.

These activities also provide and augmented section so both teachers and students can experiment with the Augmented Reality both to visualize content related to the activity or to create some of the augmentations themselves.

3.1 SCENARIO 1 - DAY AND NIGHT ALTERATION

Background information

Title: "Day and Night alteration"

Brief Description: Through this scenario students will understand the phenomenon of the day and night alteration and how it is affected by the rotation of the Earth.

Keywords: Earth, Sun, shadow, rotation

Target audience: students of 6th grade of Primary school

Age range: 11-12 years old

Context(s): School

Time required: 60' – 90'

Technological tools required: MetAclass app, tablet/smartphone, markers

Authors background: General education Primary school Teacher

Connection with the curriculum: This scenario is aligned with "Unit A: The Earth as a celestial object" of the new Geography curriculum for 6th class of Primary School in Greece.

Learning objectives:

- Understanding the phenomenon of day and night alternation.
- Exploring the role of the Earth's rotation around its axis.

Materials:

- Three-dimensional (3D) models of the Earth and the Sun.
- Mobile phone or tablet with Augmented Reality (AR) application.
- Images and graphics depicting day and night alternation.
- Markers

Guidance for preparation: Upload scenario to student's devices using the QR code of the scenario, follow the steps of this guide.

EARTH: DAY AND NIGHT ALTERATION

1. Setting the scene

Start with a brief discussion about the phenomenon of day and night alternation and ask students about the differences in time in different places on the globe.

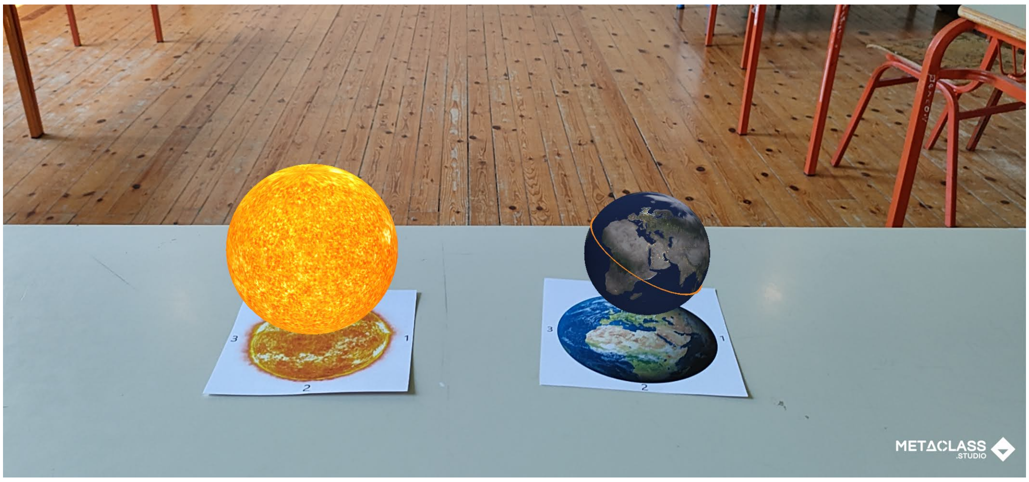
Display images that illustrate the Earth during daytime and nighttime. Ask students to express their thoughts about the phenomenon.

2. Look around

Play a video that shows Earth from space to ignite a discussion about the rotation of the Earth. Ask questions about how long does it take to a full rotate and what is the speed of rotation.

Provide students with the marker of digital Earth and the marker of the Sun. Ask them to align the 3D models to simulate how the Sun's light hits the Earth's surface.

Demonstrate how the phenomenon can be observed from different geographic locations, by changing the device camera angle.



3. Investigation – Part 1

Ask students to rotate the digital Earth so as the Sunlight hits Europe (number 1 on the Earth's marker faces the Sun) and ask them to answer the following questions in their notebook:

1. Observe the system and think what might the time be in central Europe right now?
2. Locate New Zealand and imagine what might the time be in that area right now?

3. Locate India and think about what might the time be in that country right now based on the light that hits the country.
4. Locate the USA and think about what might the time be in that area right now?

4. Investigation – Part 2

Encourage students to rotate the Earth until Europe is placed to the opposite side of the planet (number 3 on the Earth's marker faces the Sun). Repeat the above questions again.

Ask students to take pictures of every simulation and create an image canvas to explain the phenomenon of the alteration of day and night.

5. Communication and discussion

Attract the class's attention and discuss how the day and night alternation phenomenon works.

Groups share their canvas creations and explain how they used the models to simulate the phenomenon.

Conclude the lesson by highlighting the importance of experimental learning and exploration for understanding natural phenomena.

3.2 SCENARIO 2 - EARTH 4 SEASONS

Background information

Title: “Earth-4 seasons”

Brief Description: In this scenario students will understand the phenomenon of the season’s alteration and how this is affected by the equator and the Earth’s movement around the Sun.

Keywords: Earth, Sun, shadow, rotation, equator, solstices

Target audience: 6th grade Primary school students

Age range: 11-12 years old

Context(s): School

Time required: 45’-60’

Technological tools required: MetAclass app, tablet/smartphone, model markers

Authors background: General education Primary school Teacher

Connection with the curriculum: This scenario is aligned with “Unit A: The Earth as a celestial object” of the new Geography curriculum for 6th class of Primary School.

Learning objectives:

- Understanding the phenomenon of different seasons on our planet.
- Exploring the role of the Earth's rotation around the Sun.

Materials:

- Three-dimensional models of the Earth and the Sun.
- Mobile phone or tablet with augmented reality application.
- AR markers
- Small cards with seasons names and solstices
- Pictures of Christmas in Australia

Guidance for preparation: upload scenario to student's devices, follow the steps of this guide.

EARTH: 4 SEASONS

1. Setting the scene

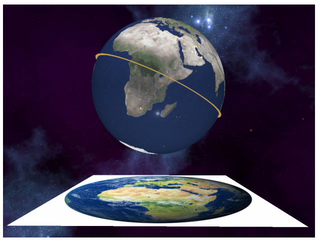
Start with a brief discussion about the phenomenon of 4 seasons alternation.

Ask students what the season in Europe is. Ask them if every country on the planet is on the same season. Ask what the season in Australia is.

Display images from Christmas in Australia (Christmas in summer)

Encourage students to explain the phenomenon of different seasons on the same planet.

2. Look around

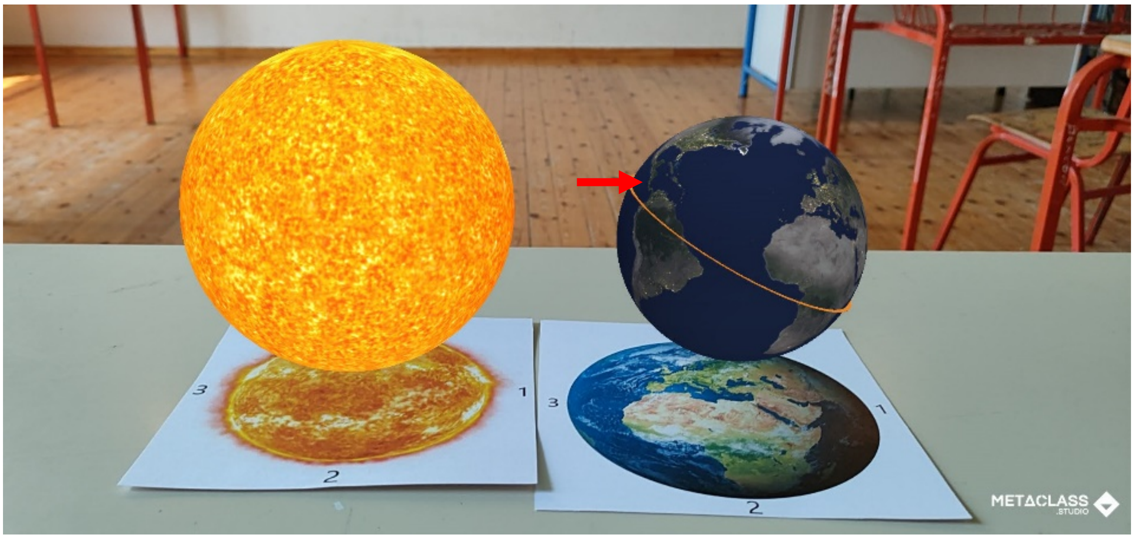


Provide student teams with the marker of the Earth and ask them to scan it. Ask students to observe the Earth's equator.Provide student teams with the marker of the model of Sun.Start a discussion about the Earth's movement around the Sun and simulate that movement.

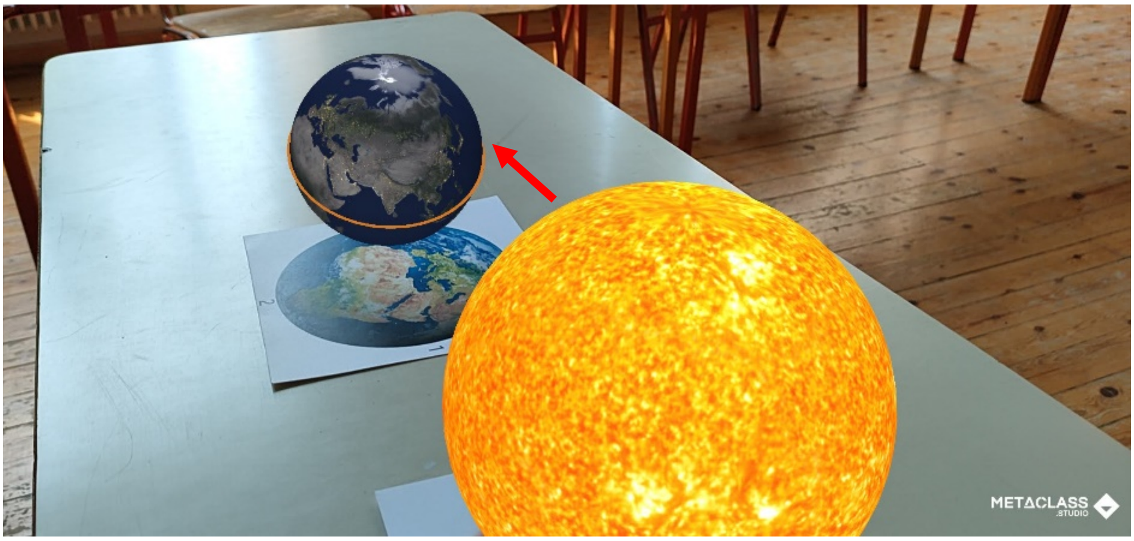
Introduce the concept of summer and winter solstices.

3. Investigation

Have students in groups use the augmented reality application to align the 3D models of the Earth and the Sun to simulate how the Sun's light hits the Earth's surface (Earth is placed in front of number 1 on the Sun's marker). Ask students to describe which hemisphere of the Earth receives the most energy from the Sun. Ask them to explain why. What is the season in that hemisphere? Encourage students to rotate the Earth and note in their notebook all the big countries that are on the same season.



Have students move the Earth in position number 3 of the Sun's marker. Ask students to describe which hemisphere of the Earth receives the most energy from the Sun and to note down the biggest countries that are in summer.



Ask students to move the Earth in position 2 and in position 4 according to the numbers on Sun's marker. Then explain what the season in Europe in each position is.

Assign students to place the season name cards on the correct positioning of the Earth, indicating which season corresponds to each position and to take pictures of every simulation (1 to 4) to create an image canvas that explains the phenomenon of the different seasons on the Earth.

4. Communication and discussion

Attract the class's attention and discuss the role of the Earth's axial tilt in the seasons and the effects of the amount of Sunlight reaching the Earth's surface. Have each group share their creations and explain how they used the models to replicate the phenomenon. Conclude the lesson by highlighting the importance of experimental learning and exploration for understanding natural phenomena.

3.3 SCENARIO 3 - INVESTIGATING OUR SOLAR SYSTEM

Title: "Investigating our Solar System"

Brief Description: Through this activity students will learn about the main characteristics of the planets of our Solar System and will make comparisons about distances and planet size.

Keywords: Planets, Solar System, the Sun

Target audience: 6th grade Primary school students

Age range: 11-12 years old

Context(s): School

Time required: 45'-60'

Technological tools required: MetAclass app, tablet/smartphone, model markers

Authors background: General education Primary school Teacher

Connection with the curriculum: This scenario is aligned with "Unit A: The Earth as a celestial object" of the new Geography curriculum for the 6th class of Primary School.

Learning objectives:

- To learn about the planets of the Solar System and estimate their characteristics.
- To align the planets based on their size
- To arrange the planets based on their distance from the Sun.

Material:

- Three-dimensional models of the planets of our Solar System
- Mobile phone or tablet with augmented reality application.
- AR Planet markers

Guidance for preparation: upload scenario to student's devices, follow the steps of this guide.

INVESTIGATING OUR SOLAR SYSTEM

1. Setting the scene

Begin the conversation by showing an image of the night sky and asking students what all the shining dots that they can see in the night sky are.

Ask students what the difference between stars and planets is and how many planets they can see in the night sky.

Spark their curiosity by providing them with the marker of a digital planet and a device to scan it and observe it, using the MetAclass app.

2. Look around

Engage students in a brainstorming session to elicit their prior knowledge about the planets of our Solar System, how they look like, how big they are, or about their distance from the Sun.

Write down their ideas on the whiteboard and define the main goals of the activity (what the planets of our Solar System are, how big they are, how far they are).

Start a conversation about the distances in the Solar System and what is an astronomical unit (AU).

Help students understand what Augmented Reality is and how to use MetAclass application to explore science.

3. Investigation – Part 1

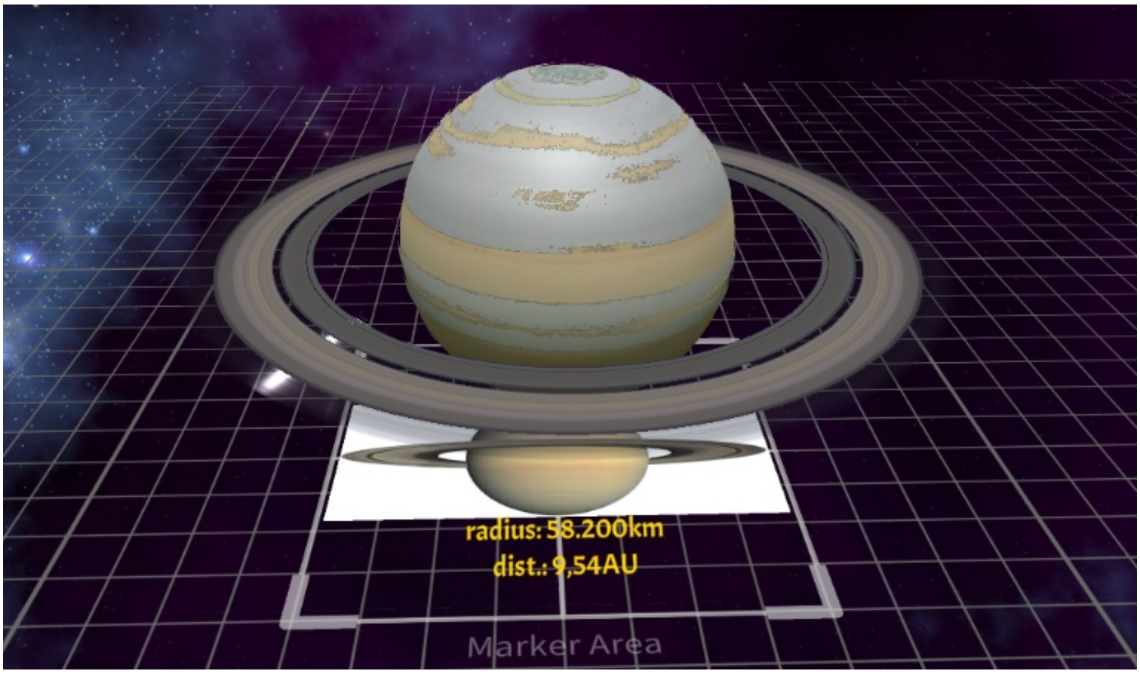
Encourage students to start their investigation by scanning the provided marker and explore their digital model from different angles.

Then answer the following questions in their notebook:

- How does your planet look like?
- How big is your planet?
- How far is your planet from the Sun?
- Start your research and try to identify the name of your planet.

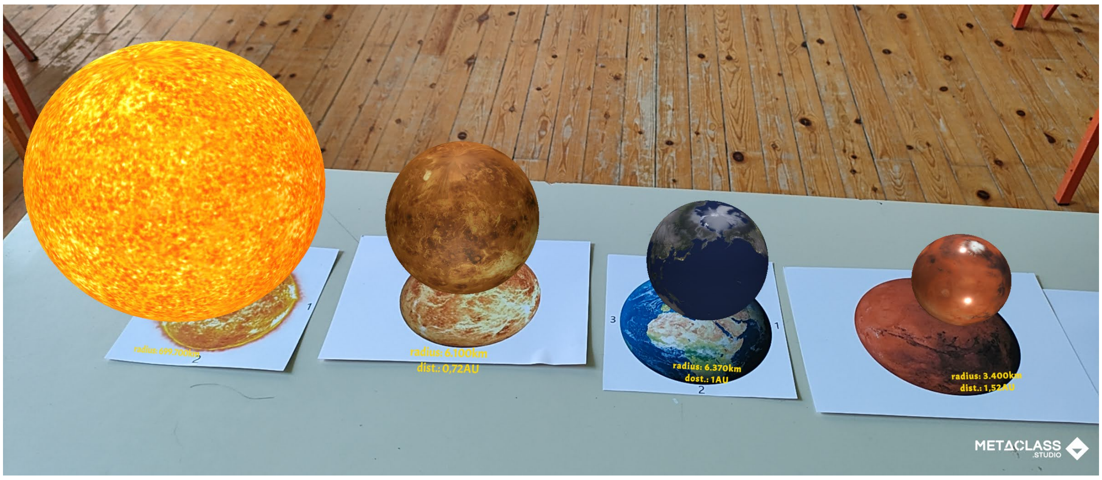
4. Investigation – Part 2

Student teams scan all markers of the class to search for information **about the size** of every planet and arrange them in order starting from the largest, using their notebook.



5. Investigation – Part 3

Student teams exchange information with each other and cooperate to arrange markers/digital planets in order, based on their records about the planets' distance from the Sun.



6. Investigation – Part 4

Teams create an artwork showing our Solar System and planets, according to the information they acquired during their research.

7. Communication and discussion

Focus the class on discussing the differences among the planets of our Solar System that the groups discovered. Highlight the key features of each planet. Ask students to present their artworks about the Solar System and the main information they have acquired.

3.4 SCENARIO 4 - THE MOON PHASES

Background information

Title: "The Moon phases"

Brief Description: Through this inquiry-based activity students will understand the Moon phases and how this phenomenon is affected by the position of the Earth and the Sun.

Keywords: Moon phases, Earth, Sun, shadow, rotation

Target audience: 6th grade Primary school students

Age range: 11-12 years old

Context(s): School

Time required: 45'-60'

Technological tools required: MetAclass app, tablet/smartphone, model markers

Authors background: General education Primary school Teacher

Connection with the curriculum: This scenario is aligned with "Unit A: The Earth as a celestial object" of the new curriculum for 6th class of Primary School.

Learning objectives:

- Understanding the phases of the Moon and the reasons behind them.
- Exploring the orbit of the Moon

Materials:

- Three-dimensional models of the Earth, the Sun and the Moon

- Mobile phone or tablet with augmented reality application.
- AR markers
- Pictures the Moon in different phases

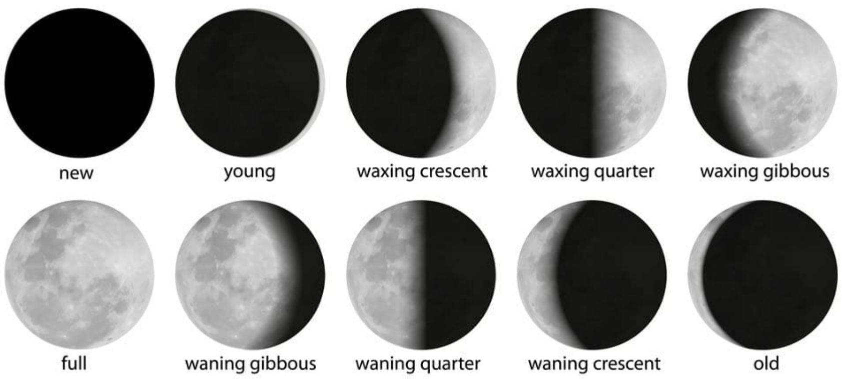
Guidance for preparation: upload scenario to student's devices, follow the steps of this guide.

THE MOON PHASES

1. Setting the scene

Begin with a brief discussion about the phases of the Moon and how the appearance of the Moon changes during the month. (Sample Questions: How many times have you seen a full Moon? How often you can observe a full Moon? What does the night/Moon look like when a full Moon occurs?)

Display images that illustrate the various phases of the Moon.

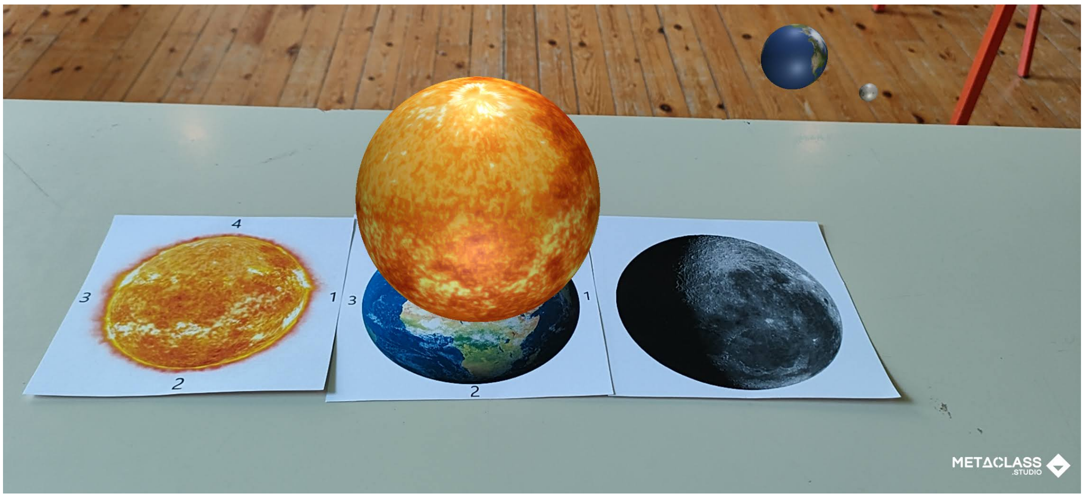


Spark student's curiosity by providing teams with the Moon's marker to explore using the AR application.

2. Look around

Provide student teams with the marker of the Earth and the Sun.

Start a discussion about the Moon’s movement around the Earth and ask students to simulate that movement by combining markers of the Earth and the Moon. Ask teams to combine the three markers and observe the new system of the Sun-Earth-Moon model, with a focus on the Moon. Discuss how our perspective changes as the Moon orbits the Earth.

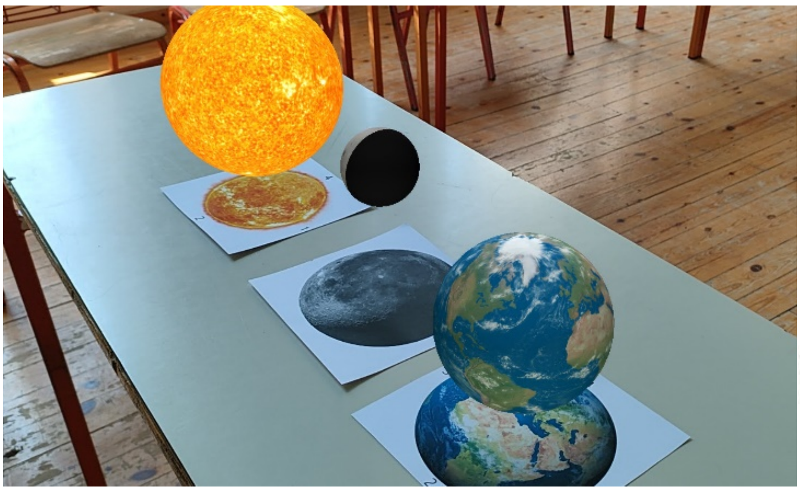


3. Investigation - Part 1

Have students in groups use the augmented reality application to align the 3D models of the Earth and the Sun (Earth’s number 3 on marker faces Sun’s marker). Place the Moon’s marker (use half-Moon model) in position number 1 on the Earth’s marker aligning the Sun with the bright side of the Moon. Ask students to change their view and observe the Moon from the Sun. Ask them to observe how the Moon looks from the Sun (bright, dark, half-bright). Continue by asking them to change their view again and observe the Moon from the Earth. How does the Moon look from the Earth? Choose the right image from the Moon's phases collection images.

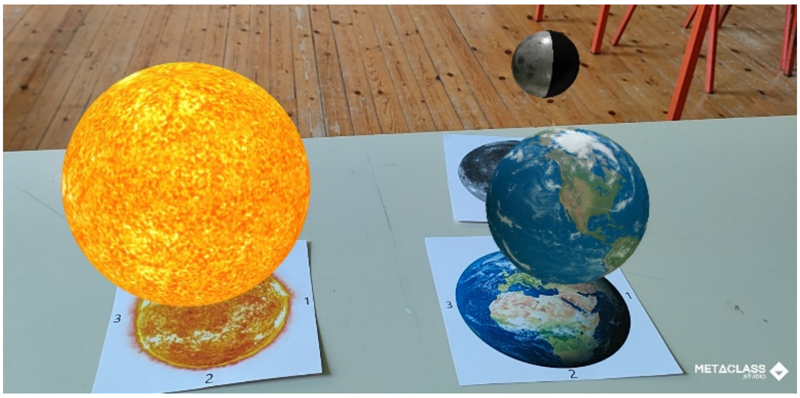
4. Investigation - Part 2

Ask students to rotate the Moon around the Earth and place the marker between the Sun and the Earth (position number 3 on Earth's marker). Encourage them to observe the Moon from the Sun and describe how the Moon looks like. Ask them to observe the Moon from the Earth and select the correct image from the Moon's phases collection images.



5. Investigation - Part 3

Have students rotate the Moon around the Earth and place the digital model in position number 2 and in position number 4 on the Earth's marker and note how the Moon looks like when observed from the Earth.



Ask students to gather evidence about different views of the Moon while rotating the Earth, by capturing images of the digital models and demonstrate them in an image canvas.

6. Communication and discussion

Start a discussion about the different views and how our perspective changes as the Moon orbits the Earth.

Discuss how the phases of the Moon are affected by its position in relation to the Sun and the Earth, along with the role of shadows in the Moon phases.

Have each group share their creations and explain how they used the models to replicate the phenomenon.

Conclude the lesson by highlighting the importance of experimental learning and exploration for understanding natural phenomena.

3.5 SCENARIO 5- THE STRUCTURE OF HYDROGEN ATOM

Background information

Title: Let's become "Atomic Architects"

Brief Description: Through this Inquiry-based activity students will understand the basic structure of an atom. They will be introduced to the basic elements of matter 'protons, neutrons and electrons which form an atom. Moreover, they will represent the atomic structure of hydrogen through an AR/VR activity.

Keywords: structure, atom, electrons, neutrons, protons, AR/VR, hydrogen

Target audience: teacher with students

Age range: 10-12 years old

Context(s): school

Time required: 90 minutes.

Technological tools required:

- Playing with Protons Goes Digital Authoring Tool
- MetAclass App for Android

Author(s)'s background: science teacher

Connection with the curriculum: Physics, 5th grade in primary school, structure of matter.

Learning objectives:

- Understanding of the basic structure of an atom: Students will understand that an atom consists of a nucleus (composed of protons and

neutrons) surrounded by energy levels or electron shells (rotating electrons)
- Engaging in scientific inquiry: Students will actively participate in the inquiry process by generating questions, making observations, constructing models and reflecting on their findings.
- Encouraging collaboration and communication

Guidance for preparation:

Gather all the materials you will need: Smarties, Candies, Playdough, small balls, toothpicks

LET'S BECOME "ATOMIC ARCHITECTS"

1. Setting the scene

- Begin by asking students if they know what makes up everything around us.
- Spark their curiosity by explaining that they will become "Atomic Architects" and explore how atoms are structured!

Introduce the atomic theory (planetary model) through the video:

https://www.youtube.com/watch?v=pNroKeV2fgk

2. Look around

- Engage the students in a Brainstorming session to elicit their prior knowledge about atoms and atomic structure.
- Encourage them to generate questions they have about atoms and their structure.
- Write down their questions on a shared chart or whiteboard.
- Set up inquiry stations around the classroom, each focusing on a different aspect of atomic structure.
- At each station provide materials and instructions for students to explore and construct atomic models

At this scenario we will introduce the atomic structure of Hydrogen, but with the same way, this scenario could be made for other atoms.

3. Investigation – Part 1

Make a maquette model showing the structure of an atom (in general)

They will need:

- Playdough, pom-poms, ping pong balls, marbles, or candies in different colors
- Toothpicks, wires, or string

What they do:

1. Core and nucleus

Students use Playdough or candies in different colors to create the core or nucleus of an atom using a different color from the rest of the atom.

2. Energy levels

Students use small balls, pom pom or marbles to represent electrons and toothpicks to construct energy levels around the nucleus.

3. Elements and symbols

Students write the symbol of different elements on index cards or small pieces of paper and attach them to their constructed atomic models

For the atom of Hydrogen:

1. Provide students the basic atomic structure of the atom of Hydrogen

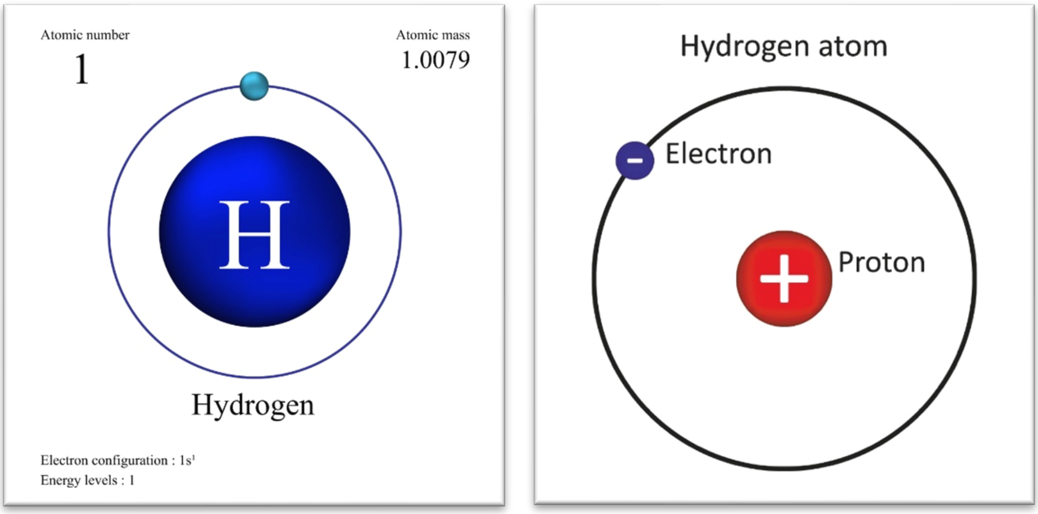


Figure 1: Models of atomic structure of Hydrogen

2. Set them free to make the representation of the atomic model own their own, with whichever materials they prefer. Here are some examples of the crafting:

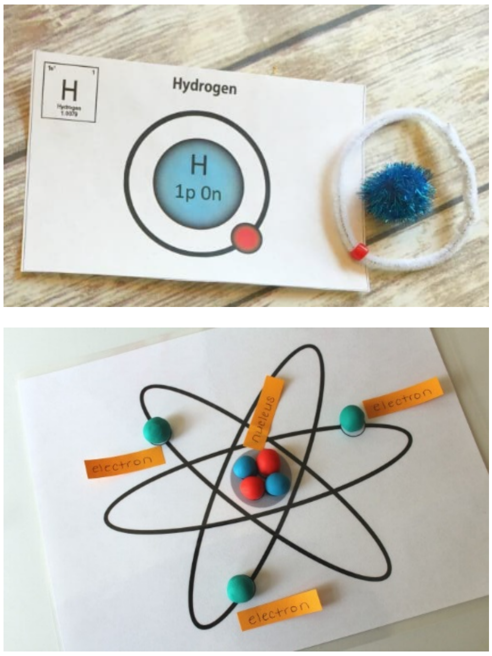


Figure 2: Examples of craft activities of atomic structure of Hydrogen

4. Investigation – Part 2

- Allow students to rotate through the inquiry stations in small groups, encouraging them to explore, construct and record their observations.
- Provide guiding questions at each station to stimulate their thinking and guide their investigations.
- Summarize the collective findings and explanations generated by students.
- Use the constructed atomic models to illustrate the basic structure of atoms, emphasizing the nucleus, energy levels and electrons. They may use a worksheet like this:

Name of atom	**Symbol**	**Number of protons (Atomic number,Z)**	**Number of neutrons**	**Number of electrons**	**Number of neutrons & protons (Mass number,A)**
Hydrogen	H	1	0	1	1

Make general conclusions about the atomic number and mass number of an atom and their connection.

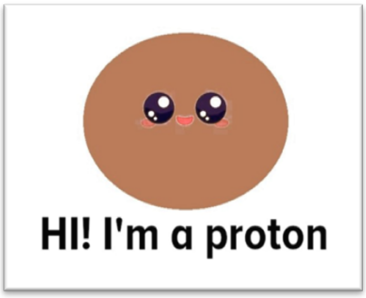
Reminder:

1. The atomic number (symbol Z) of a chemical element is the charge number of an atomic nucleus. For ordinary nuclei, this is equal to the proton number, or the number of protons found in the nucleus of every atom of that element.
2. The mass number (symbol A) is the total number of protons and neutrons in an atomic nucleus.

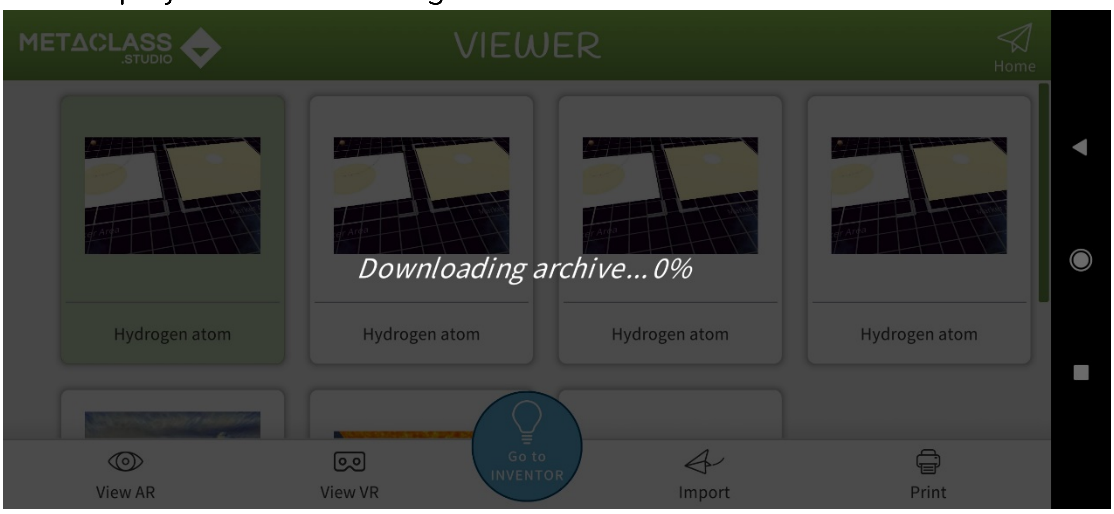
Creation of AR project

1. Print the QR code of the AR project:

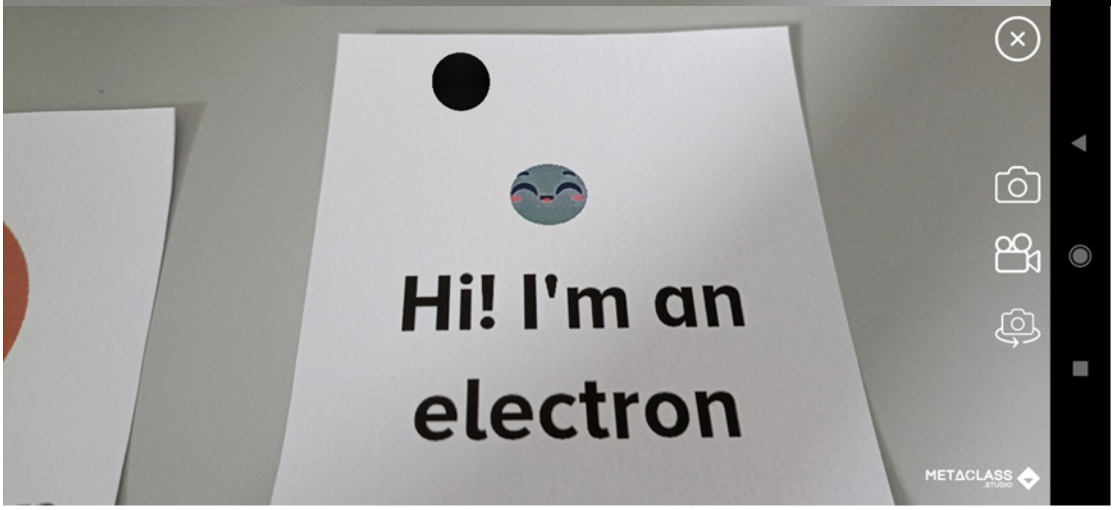
2. Print the markers of the Hydrogen



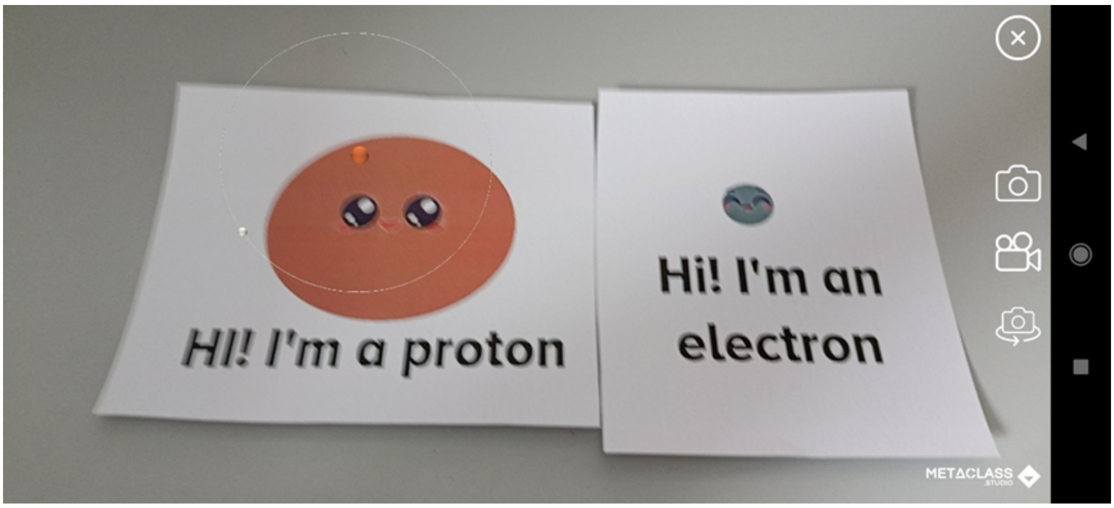
3. Open metAclass app and scan the QR code
4. The AR project is downloading.



5. Scan the markers of electron and proton.



6. Scan the Hydrogen atom.
   Put together the two markers and the animation of the rotating electron around the proton, it will appear:



5.Communication and discussion

1. **Recap of Key Concepts:**

Summarize the key concepts discussed during the activity, such as the structure of atoms, the role of the nucleus and the arrangement of energy levels

2. **Shared Reflections:**

Allow students to share their reflections on what they learned about atomic structure.

Encourage them to discuss the similarities and differences they observed in their constructed atomic models and how they relate to the real-world behavior of atoms.

3. **Answering Key Questions:**

Revisit the questions generated at the beginning of the activity and encourage students to provide answers or explanations based on their observations and understanding.

Discuss how their perspectives may have changed or expanded as a result of the inquiry process.

4. **Connecting to Everyday Life:**

Facilitate a discussion on the relevance of atomic structure to our everyday lives.

Help students recognize how the behavior of atoms and their interactions contribute to various phenomena, such as the properties of materials, chemical reactions, or the functioning of electronic devices.

Help students recognize the similarity between the bohr model of atoms and the planetary model.

5. **Expressing Understanding:**

Give students an opportunity to showcase their understanding of atomic structure through a brief written reflection, a diagram, or a presentation.

Encourage them to explain the key components of an atom, their relationships, and the significance of electron arrangement.

6. **Next Steps:**

Discuss possibilities for further exploration or extension activities related to atomic structure, such as investigating the periodic table, exploring different elements, or learning about the contributions of scientists in understanding atomic structure.

A good idea could be students to add the QR code and markers in their craft, so they have an AR perception in their craft models!

7. **Closing Remarks:**

Conclude the activity by highlighting the importance of atomic structure as a fundamental concept in understanding the world around us.

Encourage students to continue their scientific inquiry and exploration, fostering their curiosity and interest in the field of chemistry.

The conclusion of the activity should reinforce the main ideas, provide students with a sense of accomplishment, and inspire them to continue their scientific exploration beyond the activity itself.

3.6 SCENARIO 6 – EARTH'S ROTATIONS

Background information

Title: Let's explore Earth's rotations!

Brief Description: At this Playing with Protons AR/VR project, students are being challenged to explore by the Playing with Protons digital platform' real-world AR/VR modeling. Through the Inquiry based learning approach students will make an AR/VR visualization of the rotation of Earth on its axis and the revolving of Earth around the Sun.

Keywords: Earth, Sun, Moon, AR/VR project, rotation, revolve, axis

Target audience: Teacher with students

Age range: 11-12 years old

Context(s): The places that the Art-based STEAM activity involves: school, house, science centre, independently on the web, independently using the mobile phone, combination of the above

Time required: The approximate time typically needed to realize this Art-based STEAM activity is distinguished into the amount of time required for School-based work and out-of-school based work.

School-based work: 45 (or 90 minutes, if students will create the AR/VR visualization at their own). The extracurricular activity has duration of approximately 45 minutes.

Out-of-school based work: 45 minutes in total

Technological tools required: Playing with Protons Authoring tool platform and Android mobile phone or any Android device. Optionally, for the realization of the VR part of this activity are needed special technologies like a VR headset.

Author(s)'s background: school teacher, science educator, science communicator, scientist, combination of the above

Connection with the curriculum: Geography, Chapter A, Grade 6 of primary school

Learning objectives:

Students will understand the concept of Earth's rotation on its axis

Students will comprehend Earth's revolution: By using the AR authoring tool, they will understand and visualize the Earth's orbit' Moving around the Sun while rotating on its axis

Guidance for preparation:

For this activity is needed to have been installed:

- The Playing with Protons Authoring tool platform on the PC
- The MetAclass App on the android devices that will be used.

Moreover, is needed to have been printed:

- The QR code of the AR project
- The Markers of Earth, Moon, and Sun

EARTH: EARTH'S ROTATIONS

1. Setting the scene

This scenario aims to introduce the concepts of Earth rotation around its axis, its revolution around the Sun, and the Moon's revolution around Earth through an AR/VR visualization.

Show students the introduction video below:

https://www.youtube.com/watch?v=riMAITbLqZI

You may ask some inquiry questions:

- What do you know about our Solar System and the movements of the planets in it?
- What do you know about Sun-Earth and Earth-Moon rotations?

2. Investigation Part-1

This step included to the investigation part of scenario.

1. Spark interest and curiosity in Earth's rotation by observing and tracking shadows created by the Sun.
2. Spark interest and curiosity about the Moon's rotation around Earth

What will you need:

- Sticks
- Masking tape
- Timer

Gather the students in an outdoor area with ample Sunlight.

Prompt a question such as:

- Have you ever notice how your shadows change throughout the day?

Encourage them to share their observations and thoughts.

Explain that shadows are created when an object blocks the light from the Sun.

Engage them in an activity to observe and track how shadows change over time:

- Divide the students into small groups and distribute the materials.

- Instruct each group to place a stick or pole vertically in the ground, ensuring it remains stable.
- Using chalk or masking tape, have the students mark the base of the stick's shadow.
- Set a timer or stopwatch to record time intervals (e.g., every 30 minutes).

Provide each student with a journal to record their observations and reflections.

- Encourage students to observe and discuss the changes in the length and position of the shadow at each interval.
- Ask them to predict how the shadow will move and change over time.
- After each interval, have the students mark the new position of the shadow's tip.
- Repeat the process for several intervals, capturing a range of shadow positions throughout the day.

3. Investigation – Part 2

This activity can be done at home. You may trigger their interest in classroom. Begin by asking them what they know about the Moon and its relationship with Earth.

Spark their curiosity by posing questions such as:

- Have you ever wondered how the Moon moves in the sky?
- What do you think makes the Moon appear to change its shape?

Provide each student with a journal to record their observations and reflections they made at home.

Instruct the students to sketch or describe the different phases of the Moon they created and their understanding of the Moon's rotation.

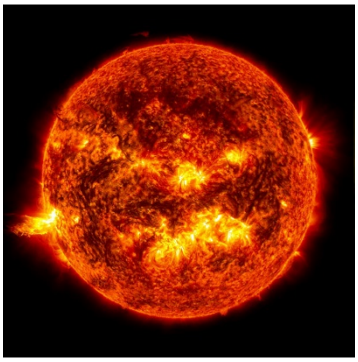
Encourage the students to write down any questions they have about the Moon's rotation or any new discoveries they made during the activity.

This activity aims to ignite students' interest in the Moon's rotation around Earth by allowing them to interact with physical models and explore the concept of lunar phases.

3. Investigation – Part 3

At this step, use the Playing with Protons Authoring tool and MetAclass app to visualize a 3D AR/VR model of Solar System. By bringing the images of the Sun, the Earth and the Moon, students can visualize the relative motions of these bodies.

1. Divide the students into groups of three and print the markers needed for each group. For the Solar System you will need 3 markers' Sun, Earth and Moon.



2. Then, print the QR code of the AR project

3. Go to metAclass app and scan the QR code. Then, from the option Viewer, scan the markers and see the visualization:

As a whole group, gather the students and their recorded observations.

For the first investigation part, ask them to compare and discuss the patterns they observed in the shadows.

Prompt questions such as:

- Did the shadow move in a specific direction?
- Did the shadow change length?
- What do these changes tell us about the Sun's movement?

Engage in a class discussion about how these observations relate to Earth's rotation. Explain that the changing positions and lengths of shadows are a result of the Earth rotating on its axis.

Encourage the students to share their thoughts and questions about Earth's rotation and the impact it has on daily life.

4. Communication and discussion

For the second investigation part, bring the students together for a group discussion about their Moon models and observations.

Ask the students to share their questions.

Facilitate a discussion about the Moon's rotation and its relationship with Earth.

Address any misconceptions, provide clarifications, and encourage further exploration and curiosity about the Moon and its rotation.

Extracurricular activity

Connection with the microcosm- Atomic model

Materials you will need:

1. Construction paper or poster board
2. Printed images of celestial bodies and atoms
3. Scissors
4. Glue
5. Markers or colored pencils

Instructions:

1. Divide the students into pairs or small groups and distribute the materials.
2. Instruct the students to create a collage that visually represents the similarities between the Solar System and the atomic model.
3. Ask the students to find images of Sun, Moon and Earth from the printed images. They should choose images that resemble each other in terms of structure or arrangement.
4. Have the students cut out the selected images and arrange them on their construction paper or poster board. They can use markers or colored pencils to draw connections or add labels if desired.

5. Encourage the students to discuss their choices and explain why they see similarities between the celestial bodies and atoms they selected.
6. Once the collages are complete, provide time for each group to present their collage to the class. Ask them to explain the similarities they found and the reasoning behind their choices.
7. Facilitate a class discussion to allow students to compare and contrast different collages. Encourage them to share their observations, ask questions, and engage in a conversation about the similarities and differences they noticed.
8. Display the collages around the classroom or in a designated area to showcase the students' work and foster further discussion.

3.7 SCENARIO 7 - RUTHERFORD'S EXPERIMENT

Background information

Title: Discovering the Nucleus (Rutherford's Gold Foil Experiment)

Brief Description: At this STEAM-AR project students get introduced to Rutherford's investigation about the structure of the atom.

Keywords: Rutherford, atomic model, nucleus, proton, electron, gold foil, science, physics

Target audience: Students of high school

Age range: 13-14 years old

Context: The places that this AR STEAM activity involves are: school, science museum, independently on the web, combination of the above, etc.

Time required: 2 teaching hours (approximately 90 minutes)

Technological tools required: Android device with AR MetAclass app downloaded and Playing with Protons authoring tool downloaded to a PC.

Connection with the curriculum: Physics grade 8 of High school

Learning objectives:

1. Understanding Rutherford's Experiment: Students should grasp the purpose, methodology, and significance of Rutherford's gold foil experiment in challenging the existing atomic model and revealing the structure of the atom.
2. Make observations: Through the simulation activity, students should learn to make observations, and draw conclusions.
3. Critical Thinking and Hypothesis Formation: Encourage students to think critically about why certain alpha particles were deflected and others

passed through, leading them to formulate hypotheses about the atom's structure.

4. Conceptualizing the Atomic Nucleus: Students should understand the concept of the atomic nucleus as a dense, positively charged center of an atom, which was a groundbreaking discovery from Rutherford's experiment.
5. Stimulating Interest in Science: Engage students' curiosity and interest in the field of physics by showcasing the exciting and transformative nature of scientific exploration and discovery.

These objectives aim to provide students with a comprehensive understanding of Rutherford's investigation and its significance in shaping our understanding of the atom's structure and the subsequent development of atomic theory.

EARTH: DISCOVERING THE NUCLEUS

1. Setting the scene

Objective: To understand Rutherford's model of the atom and the discovery of the atomic nucleus through a simple game.

As trigger, let students for 20 minutes to play the game:

https://phet.colorado.edu/sims/html/rutherford-scattering/latest/rutherford-scattering_en.html

2. Look around

Ask students for their observations.

Engage the students in critical thinking by asking questions like:

- Why did most alpha particles pass through the gold foil without any deflection?

- Why did a few alpha particles experience significant deflection or even bounce back?
- What does this tell us about the structure of the atom?
- ✓ As the "alpha particles" are flicked towards the foil, students should observe how they interact with the nucleus of gold atoms.
- ✓ Most of the alpha particles should pass through the foil with little or no deflection, but some may be deflected at different angles, and a few may bounce back.
- ✓ Discuss the observations and ask the students why they think this is happening.

Explanation:

- In Rutherford's original experiment, alpha particles had been used to probe the structure of the atom. Most of the alpha particles passed through the foil undeflected because the atom is mostly empty space. The few deflections and backward scattering occurred because the alpha particles were encountering the small, dense, positively charged nucleus at the center of the atom.
- This experiment helps students understand that the atom is not a solid structure as was previously believed. Instead, it is mostly empty space, with a tiny, positively charged nucleus at its center. This model revolutionized our understanding of the atomic structure and paved the way for modern atomic theory.

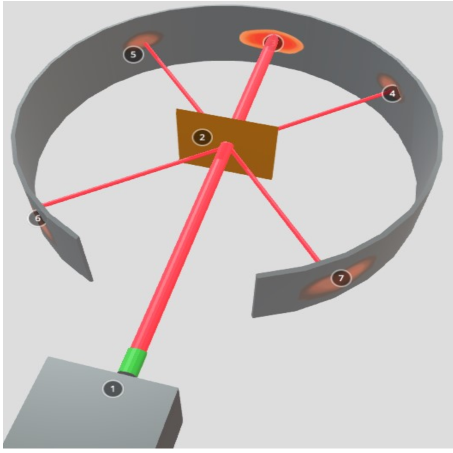
3. Investigation – Part 1

Creation of AR project - Part 1

To create your AR project, at first download:

- An image of Rutherford's experiment, and
- A 3D model of the experiment

Find them above:

1. 

Picture 1: Picture which will be used as a marker to the AR project

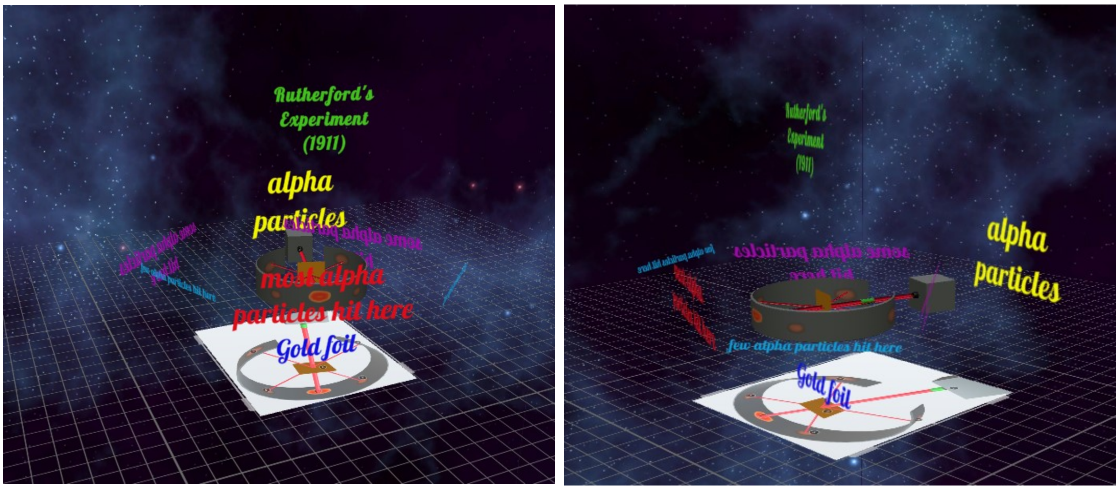
2. https://sketchfab.com/3d-models/rutherfords-scattering-experiment-1d83e005cc974ef9a6a3b88029611abe

Creation of AR project - Part 2

1. Open the “Playing with Protons AR” platform.
2. Load a marker for your project.
3. Load the 3D model.

For each spot that alpha particles may hit write a text as above:

1. Alpha particles
2. Gold foil
3. Most alpha particles hit here.
4. Some alpha particles hit here.
5. Some alpha particles hit here.
6. Few alpha particles hit here.
7. Few alpha particles hit here.
8. Picture 2: A perspective of the AR project



Pictures 3-4: Image of the AR project with the texts

Then, save the AR project and import it to your files.

3. Investigation – Part 2

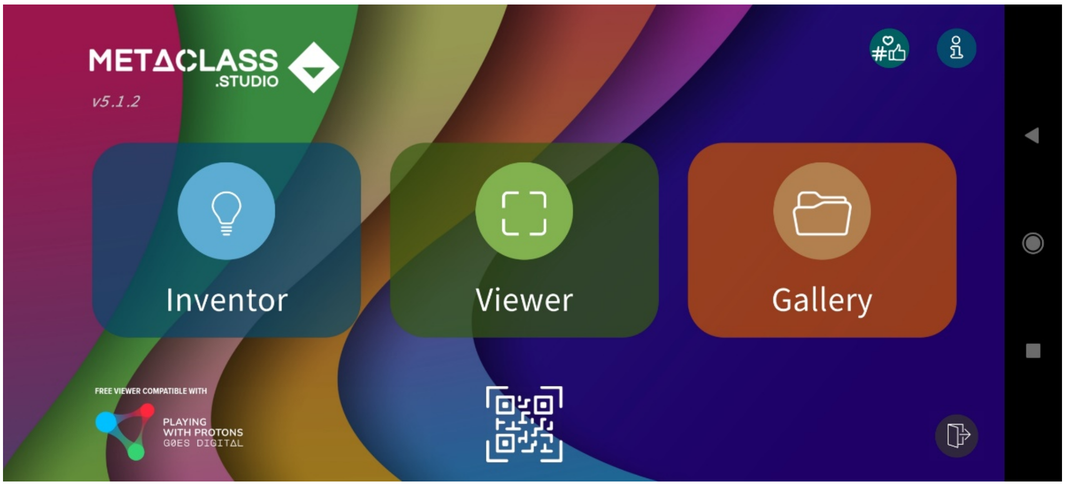
After you complete your AR project, download it as a QR code. The proceeding is the following:

1. At first, upload your project on a Drive with public access.
2. Then, copy the link.
3. Go to the https://www.qr-code-generator.com/
4. Paste the link and make the QR code.

PICTURE 3: QR CODE OF THE AR PROJECT

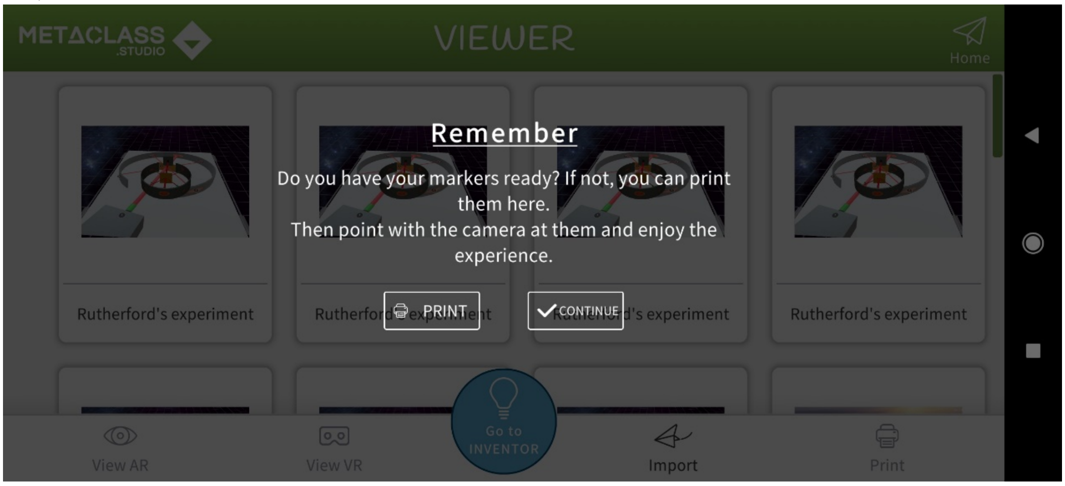
Scan your project

1. Go to metAclass app

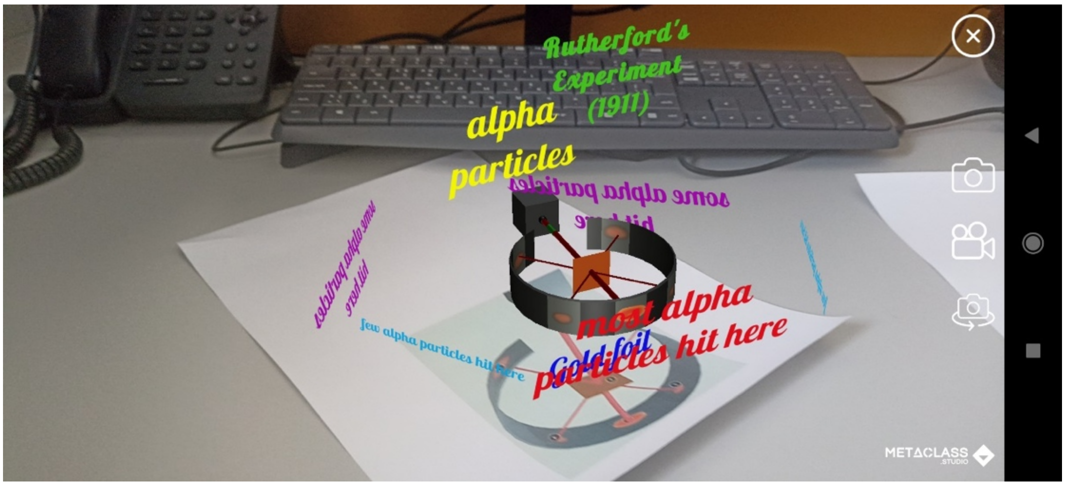


2. Scan the project

3. Import



4. View the AR project of the experiment.



5. Communication and discussion

Emphasize the importance of experimentation and observation in science.

Discuss how Rutherford's experiment led to the development of the nuclear model of the atom.

Mention the contributions of other scientists, such as Thomson and Bohr, to our understanding of atomic structure.

3.8 SCENARIO 8 – THE HISTORY OF UNIVERSE

Background information

Title: The history of Universe an art-based STEAM activity at school

Take your students on a journey to the history of the Universe; Photos, videos, goose game and AR-tool will bring us from the big bang to the present system.

Student Learning Objectives:

- Learn about the history of the Universe.
- Reflect on how the need to solve new problems leads to technological advancement.
- Improve propensity for observing celestial phenomena.
- Deepen some notions about planets, stars, and galaxies.
- Understand the concept of space and time.

Keywords: Universe, planets, stars, galaxies, time, space, Art, Exhibition, Creativity

Target audience: Teachers and students

Age range: 8-13

Setting: School, museum, and laboratory (onsite or virtually)

Duration: 5-6 hours in school/laboratory, 1.5 hours in the museum

Technical requirements: PC, large monitor/TV, WEB connection, cellular (for AR tool)

Author(s)'s background: scientist and science communicator.

Connection with the curriculum: This is a multidisciplinary learning tool, the use of which can include elements from several subjects. It represents multidisciplinary elements for STEAM pedagogy. In relation to the Italian school curriculum:

Primary school (8–10-year-old students): This pathway is suitable for the last two grades of primary school as a complement to the subjects of Science and History.

Middle school (11–13-year-old students): In middle school, this pathway is related to the subjects of Science, History, and Art.

Teacher Support Materials: Useful resources, suitable for the age group of your students, are available at the "Teacher Support Materials" tab.

Pre-activity materials

- Il rompi atomi (seminar)

Activity materials

- The History of the Universe (slide)
- The elements of the Universe (AR project)

Post-activity materials

- Spazio Tempo e Universo (seminar)
- La Materia nell'Universo (seminar)
- Big Bang and History of Universe (seminar)
- La gravità (cartoon)
- La Materia (cartoon)
- La spazio (cartoon)

Structure

This educational pathway follows an inquiry-based pedagogical approach, organized into 3 logical stages:

1. Pre-activity
2. Activity:
3. Post-activity

Guidance for preparation: Interested teacher, before launching the activities described in the following sections, must study the material provided (storytelling, slides, and cartoon) in order to have a clear understanding of the time needed and the strategy to follow during the narration.

1. Setting the scene

Phase 1: Provoke curiosity.

You can start with an open discussion with students about their concept of the Universe and how do they imagine it.

You can then use the following questions to initiate discussion, placing students in a familiar context suitable for engaging their personal interests and passions, and helping them observe the sky with a critical eye:

- Has the Universe always existed?
- How large is the Universe?
- Where is the Earth in the Universe?

Students should be then left free to respond and share their experiences and opinions. At this stage, your role is that of a facilitator, helping your students reflect on the basic knowledge of the Universe.

At the end of the pre-activity phase, you can also share with your students' useful materials to help them prepare the in person or virtual activity.

2. Look around

Phase 2: Front lesson

Activities, normally held in presence at the school/museum, can also be conducted online based on the circumstances.

You can use the Power-Point presentation (available at "Tracher Support Materials" tab) that includes many photos, videos, and cartoons, as main narrative of the activity - The History of the Universe

The first two questions to be addressed to your students are:

- What are the main objects of the Universe? (Galaxies, stars, and planets)
- What are the constituents of the matter? (Molecules, atoms, nucleus, quarks and electron)

The first topic of the lesson is to define, with the students, the main visible constituents of the Universe, considering that most of them are well known to the students. This is very well described in this set of slides (link).

The second topic is to reflect about how many kinds of "matter" eventually there are in the Universe (for example gas, liquid and solid or which?) and if we they know/imagine how matter is made of. The main aim is to understand that ALL the kind of "matter" are made by smaller and smaller components in a way like the matryoshka.

Let's the students make examples about what can be considered big or huge and what small or very small in the Universe and how matter is made of.

From the infinitely large, like a star, to the infinitely small, like to electron and quark, will be the main narrative of the lesson.

You can then proceed with a second group of questions that are very difficult to be answered but help students in imagining about the Universe.

- How much a star or a galaxy are large?
- How many galaxies and stars are there in the Universe?

Here it is important to introduce how we can measure quantities that are not usual to us. Dimension of a galaxy or of an atom, speed of speed and Light-year. Some very useful examples like why thunder and lightning do not come together, or why the light of a star that we see now is indeed left millions of years before.

3. Investigation – Part 2

Phase 3: The elements of the Universe (AR project)

Augmented Reality (AR) has revolutionized the way we learn and understand science. It allows learners to experience and interact with virtual objects in a real-world environment, bringing abstract concepts to life. AR provides a highly engaging and interactive learning experience that can captivate learners' attention and inspire curiosity. By enhancing visualization, AR enables learners to grasp complex ideas more quickly, and it can provide a safe and cost-effective alternative to traditional laboratory experiments.

The AR project "The Universe (link)" will let the students explore the Universe and learn about the main elements like galaxies, planets, stars, and black hole.

For each of the three scenarios we have a QR code, to upload it with the AR platform, and the tow markers to run it.

Using an Android cellular or tablet the students will have the possibility to explore the Universe and interact with some of the main elements and learn about their dimension, distance, and compositions.

First Scenario

It will describe the Earth and the Moon. When the markers are separated, they show their own 3D models. When we put the Earth and Moon markers together, it changes to a 3D animation of the Moon revolving around the Earth. Text and audio will help the students in understanding the relative dimension and the distance between the two (fig. 2)

Second Scenario

Three different planets will be described and compared: Mars, Venus, and Earth. When we put the three markers together the planets will be compared for what concern the relative dimension and distance from the Sun (fig. 3)

Third Scenario

In this scenario we will study the main characteristics of the Sun and other stars in the universe. Binary star and the Sun are the markers and when put together they will be compared (fig. 4)

Figure 2: first scenario markers and QR code

Figure 3: second scenario markers and QR code

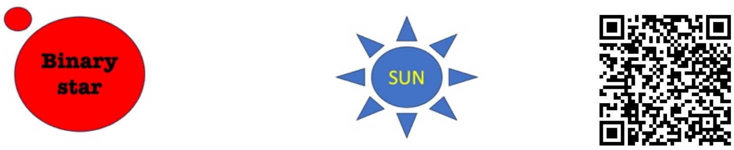


Figure 4: third scenario markers and QR code

This project is used while explaining about the universe and, more specifically, about the Earth and Moon, the planet, and the stars.

Children can visualize the 3D models separately and then mix them to understand the relationship between them.

It is also used to help them understand concepts such as gravity between bodies. This project can be used in combination with other activities described in the following section.

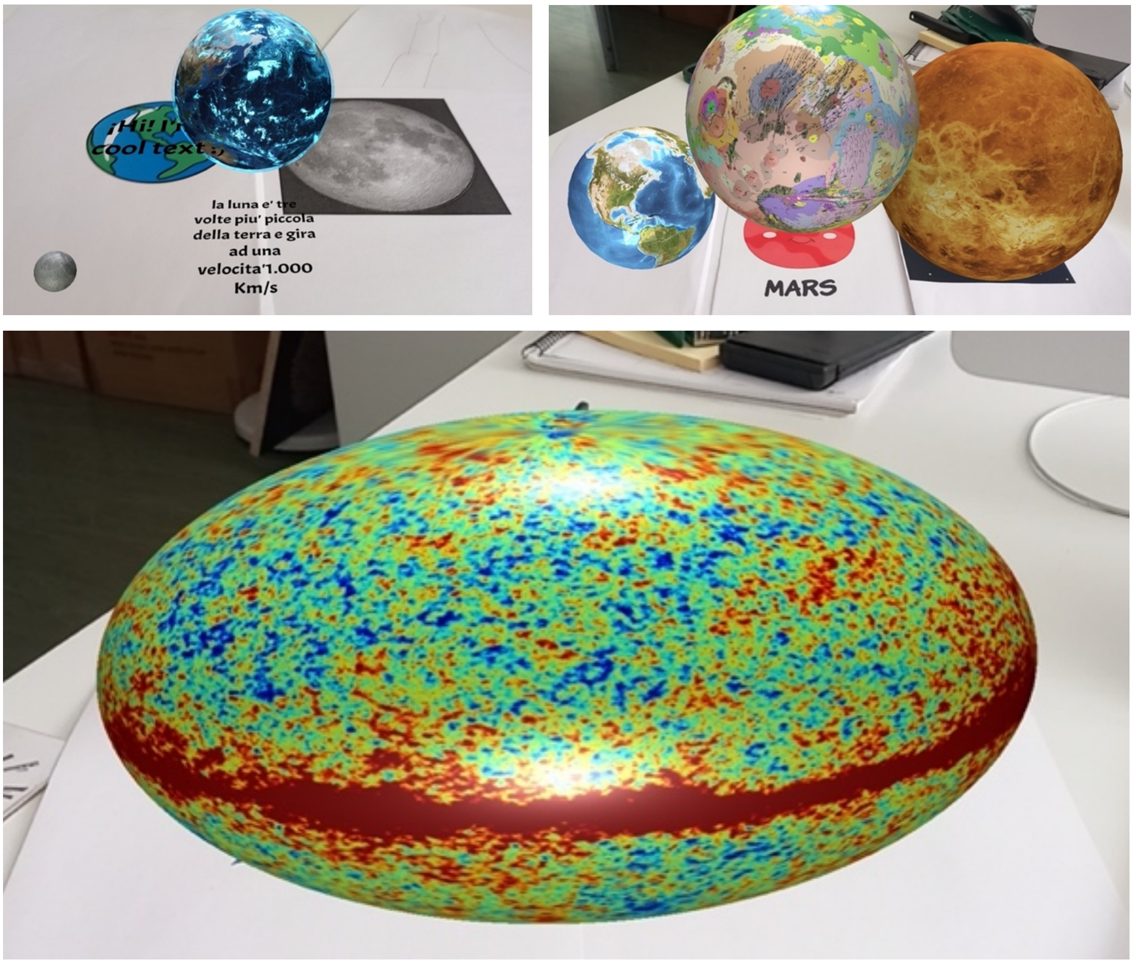


Figure 5: The example of what students will see in the three scenarios (from top to bottom; Earth-Moon, Earth-Mars-Venus and The Universe)

4. Investigation – Part 2

Phase 4: Goose game "The History of the Universe"

After having discussed the Universe and Matter it is time to play a game all together.

This activity is aimed at helping children discover the history of the universe by playing with the different physical objects present in it during the timeline: particles, atoms, stars, galaxies, black holes, etc.

Background: tell them about the history of the Universe

You can use the slides and the video about the History of the Universe available at “Teacher Support Materials” section.

Before starting the game, you can group all the students around you and tell them a history, the history of the Universe. The full text is available at “Teacher Support Materials” according to the age of your students.

Here the History of the Universe (to be moved in the Teacher support Materials)

Before the birth of the Universe (about 14 billion years ago), everything was clustered together in a very little space, imagining it as an orange in which everything was concentrated. Everything was very hot, still, and motionless. Neither space nor time existed. Quite unexpectedly, for no apparent reason, there was an incredible event that started the Universe. Do you know how it is called? With the Big Bang everything that was previously clustered together in a space like an orange begins to recede and cool down. Let's try to draw dots all close together on a deflated balloon: if we start to inflate the balloon, those dots that used to be close together will get farther and farther apart. And that's more or less what has happened in the Universe since the Big Bang. And the Universe continues to expand and cool today.

In the beginning, even less than a second after the Big Bang, there was a phase where the Universe expanded very fast, in a moment it became 60 times bigger than it was! This phase in the history of the Universe is called inflation. As the Universe got bigger and bigger and a little less hot, what we call particles began to form, which are the smallest bricks in everything we know, a bit like Lego. And some particles join with others and form protons and neutrons, which, after about 1 minute, join to form nuclei. And this is a good thing because nuclei are a fundamental part of atoms, the smallest parts of matter. But at this point, the electrons are still unable to bond to the nuclei, to form atoms.

To get to the formation of atoms and thus of matter, we have to time jump: the first atoms are formed 370 thousand years after the Big Bang! And about 10 thousand years later, 380 thousand years after the birth of the Universe, something extraordinary happens. You must know that, until that moment, there was no light in the Universe! Everything was completely dark! And just 380 thousand years after the Big Bang, light is released. And that light still reaches us, so much so that we can reconstruct the first photograph of the Universe!

Not much happens from here for a long time, until the first stars begin to form, and then galaxies, some 700 million years after the Big Bang. And then the first planets, and some 9 billion years after the Big Bang, the Earth, and the Solar System.

Preparation of the game

After setting up the board, the teacher tells the story of the universe by following the boxes on the board and, when encountering special boxes, explains what they represent and what the effect will be on the game. During the story, students are encouraged to ask questions or make observations on the story: discussion among students must be fostered as much as possible.

The class must be split up into 4 or 6 groups. Each group, in turn, walks around the board to understand what the route looks like.

Rules of the game

The game follows the rules of the traditional goose game, but it traces the history of the Universe from the Big Bang to the present day, and the special squares have an effect related to some element in the history of the Universe (wormhole, inflation, dark Universe, black hole, galaxies, big crunch, etc.).

The children play in groups and take turns rolling the dice and walking on the board. Children are encouraged to organize their team turns by themselves.

When the children land on a special square, helped by the teacher, they have to try to remember what it represents and when the square causes them to lose a turn they can try small tests and games to get free.

5.Communication and discussion

After the match, teachers can stimulate a discussion among the students and recall some of the concepts discussed during the game to introduce specific topics, for example, the structure of the atom or black holes. Teachers can even assign students the task of drawing how they imagine those elements of the Universe we cannot see, such as particles or black holes, or the task of inventing a short story set in a particular moment of the history of the Universe.

6. Post activity

The aim here is to help your students reflect on the knowledge they acquired in the previous phases and develop their critical thinking.

In the “Teacher Support Material” section you find all you need to complete this phase. The materials are organized according to the age of your students and include:

- Quizzes
- Suggestions for group activities
- Videos

3.9 SCENARIO 9 - PARTICLE GO

Background information

Title: Particle GO

Brief Description: This activity consists in “building” a particle accelerator by collecting its main components: an RF-cavity to accelerate the particles, a bending magnet to deviate their trajectory, and two quadrupole magnets for focusing. It is possible to change the aim of the activity by replacing the components of the accelerator with the components of another device (e.g., a microscope, a molecule, a machine, etc.)

Keywords: building an object composed of parts, particle accelerators.

Target audience: Students, public

Age range: 11-99

Context(s): This activity can be done at school, or during public engagement events.

Time required: In school-based work, the activity can be done in 45 minutes. More time can be assigned to out-of-school activities. For example, one can use the scenario to realise a treasure hunt: in this case more time can be appropriate.

Technological tools required: AR device (currently only Android phones are supported).

Author(s)’s background: scientist.

Connection with the curriculum: The activity is suitable for every subject in which the description of something in terms of components is introduced. In this implementation, we focus on the construction of a particle accelerator, but teachers can use the same template to build an application for collecting the pieces of, e.g., a microscope, or the components of a molecule, a Solar System, a motor, etc.

In this example, the tool can be used to introduce electromagnetic interactions: electrostatic acceleration, Lorentz Force, and magnetic fields.

Learning objectives: Learn about anything composed by sub-component. In this particular application particles accelerators are considered.

In the particular example, the aim is to reinforce the conceptual understanding of electromagnetic interactions.

Guidance for preparation: The AR tool must be previously installed in participants' devices. If the activity is part of a game, the game setup must be prepared. Markers can be found in the attached file.

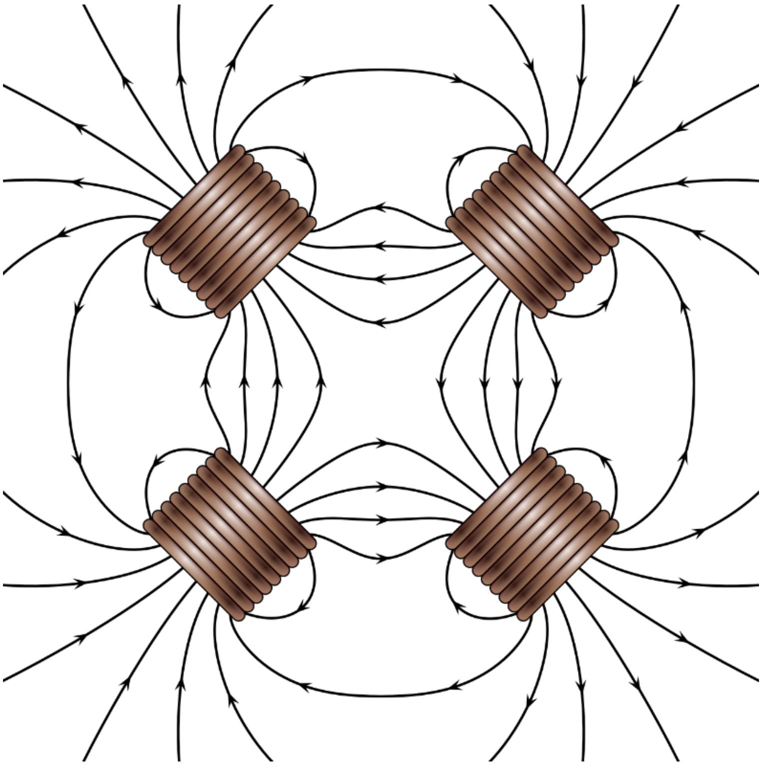
A particle accelerator needs at least four components: a source of energy (an RF-cavity), a bending magnet and two quadrupole magnets.

The RF-cavity is designed such that an electric field oscillates inside it in phase with the passage of the particles, such that the latter gain energy at each stage of the cavity. In the RF-cavity the electric field is always oriented along the cavity axis, such that particles are accelerated in the wanted direction. Leaving the cavity, particles have a given energy, and move straight according to Newton's first Law, at high speed.

In order to guide the trajectory of the particles along curved sections, a bending magnet is needed. A banding magnet is made of two coils that produce a uniform magnetic field. If oriented perpendicularly to the particles' trajectory, the magnetic field causes them to travel through an arc of circumference by means of the Lorentz Force.

When the particles exit the bending magnet, their momentum in the transverse plane may not be zero, and the beam tends to widen in both the horizontal and vertical directions. To squeeze the beam, two quadrupoles arranged to appear rotated 90 degrees relative to each other, are used.

A magnetic quadrupole provides the following magnetic field configuration:



Particles that are exactly in the center of the magnet are not affected. Positively charged particles exiting the page are then pushed toward the center of the magnetic system, in the vertical direction, but are pulled away from it in the horizontal one.

Using a second quadrupole rotated of 90 degrees, makes the beam to be squeezed in the horizontal direction and widen in the vertical one.

The combination of the two magnets causes an overall compression of the beam toward the center (focusing).

Look around

Look for markers: each marker corresponds to one of the elements needed to build the accelerator. Here we provide the following markers:

ALICE	ATLAS EXPERIMENT
CMS	LHCb

When you look at one of the markers through the smartphone display, a 3D model of one of the four components appears. Collect the corresponding marker or take a screenshot.

Arranging the markers in the proper order (RF-cavity, dipole, horizontal quadrupole, vertical quadrupole) it is possible to watch a movie that explain how the LHC accelerator works, using the AR device.

Investigation

Using the Inventor section of the App, or the desktop application, you can easily customize the game by using your own markers and your own 3D models. Possible ideas are, for example,

Build a microscope: you will need the 3D models for a light source, a transparent sample to be observed, and two convex lenses. Combining the four markers in a line may lead to the playback of a video showing the sample as observed through the microscope.

Build a molecule: in this case you need as many markers as the constituents atoms. For water, e.g., you need an Oxygen and two Hydrogen atoms, i.e., two types of markers. Combining together three markers (one oxygen and two hydrogens) leads to the appearance of a 3D model of the water molecule.

Communication and discussion

Discuss how Maxwell equations help physicists in building particle accelerators.

The RF-cavity can be thought of as a capacitor that applies a uniform electric field to the accelerating particle.

Dipoles can be exploited to introduce the Lorentz' Force, as well as quadrupoles that, in addition, challenge students in finding the right orientation to focus the beam in one direction.

You can use this game to introduce students to technical aspects of building an accelerator, special relativity, and the standard model.

This activity can be installed via the following QR-code:

3.10 SCENARIO 10 - ALL TOGETHER! THE WORLD OF ANTS AT CITTÀ DELLA SCIENZA MUSEUM

Background information

Title: All together! The world of ants at Città della Scienza Museum

Brief Description: The activity is meant for primary and middle school pupils visiting the exhibition about ants as social insects with their teachers. The experience is divided into two stages: the first involves a training meeting for teachers so that they are better informed of the experience that their pupils are going to carry out; the second is the actual activity that involves the pupils. For 75-90 minutes, pupils listen to the guide, observe and sometimes even touch the insects, observe models and watch videos. They also need to answer the questions and complete tasks in a special notebook. At the end of the activity, they talk about their experience with insects and what they have learned. Learning about the behaviour of social insects, pupils get introduced to topics from biology, zoology, ethology and ecology. Tasks and questions in the notebook are specially designed for the age range of the participants with some reference to the curriculum in natural science in school. This way the activity connects learning in formal and informal settings.

This activity mainly contributes to sparkle students' interest to science and developing their understanding of social animals, with a bit less contribution to developing scientific reasoning and reflection. This fits IDIS profile as a science museum with their priorities in terms of contribution to science proficiency being developing interest to science, engaging in scientific reasoning and understanding scientific content.

This is the true activity where the pupils will carry out a guided exploration in an exhibition showing real anthills of different species of ants.

This activity consists of spur students towards an interdisciplinary scientific vision inserting also social aspects of an organised community, capable of dealing with the complexity of the natural world, explaining how science can be connected to a model of daily lives. This activity can be insert also into activities model of Open schooling approach foresees an active meeting between students and explainers in the field of natural science and in an informal location off the school.

Based on the need to make young people, particularly girls aware on what science and technology professions are, activity was aimed at: connecting the schools with the world of the research and of the science centres; for building a direct contact between experts and students; give new opportunities for students to understand scientific data processing and analyzation in the research world.

The key element of the activity is the contact between the young people and the world of research that changes the idea on how to work in the scientific field.

Perception of science at school is very different from the one of in the "real world". It is well known that whereas science at school is seen as boring and "far away", other science communication forms can be more stimulants and appealing.

In the "outer world" outer of the schoolwork in science sector, however, still is a quite unknown and usually regarded unattainable, far removed from reality, difficult and, still today, considered not suitable for women.

Therefore, for students to overcome these stereotypes, it is necessary to integrate more and more extracurricular activities in scientific contexts, where there are more women than men, preferably young female researchers.

Keywords: Biology, museum, guide tour, biology, science life, communication science

Target audience: Primary and secondary school pupils, teachers, parents, public.

Age range: 6-13

Context(s): science centre/museum

Time required: 2 hours for visit the exhibition on the museum and 1 hour for answer to the questions and discuss together with teachers.

Technological tools required: No items needed

Author(s)'s background: responsible of exhibition area of the museum, naturalist expert on ants and expert in educational activities.

Connection with the curriculum: Life sciences (biology, zoology, ethology, ecology, evolution)

Learning objectives: subjects of natural sciences, botany, biology and sociology will be studied. For the art we will work on the structures present in nature that animals build for their survival. Pupils will carry out a guided exploration in a garden to find real anthills to observe. After this they will organize their knowledge answering some questions.

Guidance for preparation: to prepare the students involved in the study topics of the activity both through online research and in school textbooks related to some of the topics described below.

Social organization

Ants live in groups that can be made up of a few tens or millions of specimens. Inside the anthill, each ant has its own task and role.

- The queen lays the eggs: her job is to give life to other ants and she is also able to decide the sex of the unborn, usually female workers but, once a year, she brings new young winged queens into the world and winged males, ensuring the continuity of the species.
- The backbone of the company is made up of workers who take care of the eggs and raise the larvae, look for and store the food, build the anthill and keep it clean and tidy.
- The soldiers, always female ants, are in charge of defending the nest.
- The task of the males is to become adults in order to take flight, participating in the nuptial flight swarm, and then die after mating with the queen.

Ecological role

Ants play a vital ecological role. They are the most important soil mixing agent: they bring nutrients to the surface, useful for other living organisms, thus keeping the soil fertile. They are also the main predators of other insects and spiders, especially those harmful to plants.

A training aimed to let the teachers would be aware about the proposal their pupils will attend. During and immediately after the visit the pupils will answer the questions. To make this task more enjoyable for them, the questions should be proposed in the most playful way possible, for example, a specially written booklet, printed or in digital format on tables provided to pupils by the organizers. The pre-test would be submitted to the pupils by their teachers some time before the visit to the exhibition, as well as the post test would be proposed to them sometime later once they return to school. This is to avoid overloading the children with too many tests in a short time since they will already have to answer the questionnaire during the visit to the exhibition.

ALL TOGETHER! THE WORLD OF ANTS AT CITTÀ DELLA SCIENZA MUSEUM

1. Setting the scene

Screenplay (this visit includes a section inside the exhibition of Insects and another part in the garden. If for the latter the weather conditions do not allow it – or if the period in which it takes place does not allow the observation of ants in nature, it is replaced with a short laboratory activity at the end of the cards.)

The activity consists of 3 moments:

1. Previous knowledge about ants
2. Observation and discussion in front of the showcases
3. Field observation and/or laboratory activity

Previous knowledge about ants

The visit begins with a short chat with students about their knowledge of ants. The guide will write down or keep in mind the most interesting things (true or false) heard by the students' voice. He will ask if they have seen documentaries about ants on TV and what they remember about those documentaries. Sometimes ants are also topic of the news. The guide will take notes of those news that will then allow him to build (or destroy) on those statements his own speech at the appropriate time. For example, if the children say:

Student affirmation	→	Topic to be explored
Ants are annoying	→	Argentine ants, polygynous colonies, man-made problems
Ants can lift objects 100 times their weight	→	Anatomical structure of the ant, special examples
Ants have a hierarchical structure	→	Structure of the ant colony and their respective roles
Ants sting	→	Evolution of ants from wasps
I really like ants	→	The inclusion of all elements of the colony and the distribution of tasks

It is important that we can capture those beliefs and / or information, true or false that allow us to deepen the themes of the evolution of ant societies, the differences with other insects, the communication between the individuals of a colony and the advantages of group work. If these questions are not asked by the children, it will be up to the guide to introduce them starting from simple questions. I find it very useful to compare human societies with those of ants because even with the obvious differences due to our reasoning, the evolution of societies has many similarities, to which we will return later.

2. Investigation – Part 1

Observation and discussion in front of the showcases

In this section we want to address the issue of communication and collective behaviour, especially in those categories of insects defined as social. It will be shown how the development of sociability has allowed to greatly increase the potential of ants, wasps, bees.

Ants represent a group of insects that appeared for a long time on Earth's history, about 90 or 100 million years ago, but the peculiar characteristic of this group, eusociality, is much more recent, it is thought to be about 20 million years ago. Eusociality has allowed ants to dominate the world of terrestrial invertebrates, so much so that both in numerical size and biomass, ants surpass any other group of invertebrates. Even the biomass of ants is higher than that obtained by weighing all humans.

What is eusociality? It is the highest level of social organization that is realized by some animal species, and that meets the following conditions: cooperative care of the offspring, overlapping of adult generations and division of labour between the fertile queen and sterile workers (known as workers) This type of intraspecific interaction can give rise to real "cities" of insects, all linked by a family bond, with a remarkably complex social structure and an extraordinary diversification and specialization of tasks.

Such a complex social structure is regulated and kept under control by the queen thanks to pheromones, which also have the function of inducing sterility in the workers (in Hymenoptera all sterile individuals are females). The other great achievement of ants is their self-organization: in an anthill there is no ant that commands, but the actions that the colony performs are the result of the interactions of many individual behaviours that are regulated by positive feedback mechanisms; that is the ants recruit their mates whenever there is a task to be carried out (search for food, construction and maintenance of nest, defence of the colony) .

The first stop of the visit is at the anthill of Formica rufa. The thing to point out immediately to the students is the architecture of the acervo. Given that the ants made it and that our colony is about 4 years old, the next questions for the students will be: "how was it built, in your opinion? What materials and instructions are needed to make such a structure?"

The second stop is the Camponotus fulvopilosus anthill of South Africa. The fake skull and the desert rose in the arenaci help to predict the type of environment in which they live. Once we have established that they are desert ants, we make students think about the adaptations of ants to life in torrid environments. The morphology and behaviour of these ants are direct derivation of the environment in which they live. We note that like most ants, we are faced with hunter-gatherer societies. In this location it is also possible to illustrate (and observe live) the life cycle of ants.

The next installation is that of harvester ants, Messor capitatus. Contrary to the previous, the Messor collect seeds of cereals and other plants, and once collected they bring them to the nest, where they will be opened, crushed, and reduced to flour, The flour then mixed with water, allows the ants to knead the so-called "ant bread", food for the larvae, which can also be observed in the lower part of the nest. We are faced with a kind of ant with a more complex organization as they transform a natural element to obtain another with different characteristics. Even here you can show the similarity with the first human societies when the hunting and harvesting of fruits were flanked by the cultivation and processing of cereals.

The other two anthills, that of Camponotus vagus and that of Liometopum microcephalum allow us to talk about communication between ants. In fact, both species mark with pheromones the path for food so as to leave an olfactory trace that subsequent ants can follow. The first ones have a long acrylic tube that they can travel, the latter, smaller, make up beautiful black lines from the nest to the food, which intensify with the passage of time.

3. Investigation – Part 2

Field observation and/or laboratory activity

Weather permitting, the guide accompanies the students to the garden where in two specific locations it is possible to observe two wild colonies, the Messor minor and the Tapinoma magnum. These ants are excellent species to study because they have high numbers and very different behaviours. The Messor have a very orderly course, collect seeds and have a marked intra-colony dimorphism. While Tapinoma are fond of sugars, they move chaotically and are very fast.

The students, divided into small groups of 4 will first observe their behaviour in the absence of external stimuli, then give different foods (seeds, cooked chicken, dead insects and water with sugar) and observe the different reactions to the respective foods given.

They will then individually fill in a field form as per the attached model.

If the weather conditions or the season do not allow to observe the colonies in nature, we end the path with the compilation of a small notebook in the laboratory space, which serves to fix the ideas on what has been observed and discussed.

Possible Questions

The ants I observed are called TAPINOMA / MESSOR

Their colour is:...

They move in a manner...

Workers are of different sizes (Yes/No)

As food they accepted:

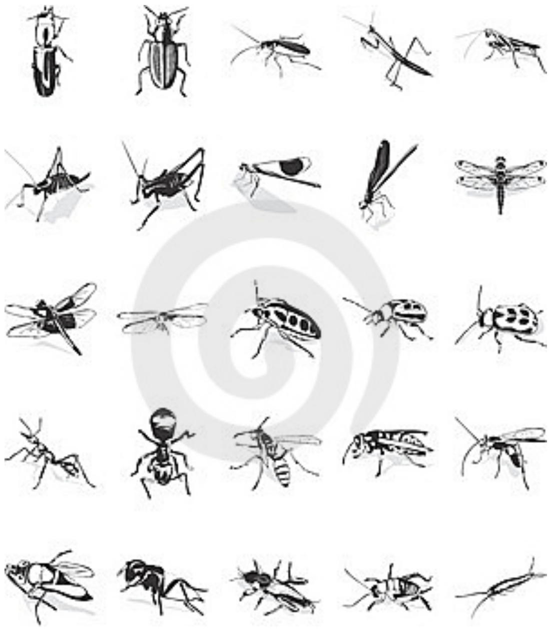
Sugar (Yes/No)

Seeds (Yes/No)

Chicken (Yes/No)

What else have you noticed about these ants?

In our visit today we saw how ants are made. What are ants in the image below? Try to remember them by drawing a circle around the insects seen



Now try to answer these short questions:

1. What are the parts that make up the body of an ant?
   - ☐ 3
   - ☐ 4
   - ☐ 5
2. What does it mean when we say that an ant does metamorphosis?
   - ☐ That the ant divides into two halves
   - ☐ That the ant dies
   - ☐ That the ant changes shape and way of life
3. What are social insects?
   - ☐ They are very nice insects
   - ☐ They are insects that live in organized societies
   - ☐ They are parasitic insects
4. Chi "commands" in an anthill?
   - ☐ The Queen
   - ☐ Males
   - ☐ The workers
5. What do Messor ants eat?
   - ☐ The leaves
   - ☐ Seeds
   - ☐ Bread

6. What are "castes"?
   - ☐ The different types of ants
   - ☐ The nests of ants
   - ☐ Waste left by ants
7. How many different types of ants have you seen in the anthill of Città della Scienza?
   - ☐ 2
   - ☐ 5
   - ☐ 10

4. Conclusion

The choice of this activity of natural sciences, biology and sociology on ants and their articulated social organization as an example in nature of interdependence between living beings (anthills),

was suggested by the fact that in the Science Center of Città della Scienza there is an exhibition dedicated to insects from all over the world and in particular there is an exhib (the anthill) which develops slowly with the activity of the ants that they build. An exhibit with which a large number of visitors interact, especially groups of students from schools of all levels. Ants are particularly representative of that heterogeneous group defined as "social insects" and are characterized by the peculiarity of articulated individual behaviors such as to allow their own colony to achieve extremely sophisticated "social" objectives. Through this experience, it was therefore intended to convey to the students the importance of interdependence as a fundamental social value also in human communities.

With this intervention, the intention was to propose to the classes involved a topic that touched across various curricular disciplines, in particular the natural sciences and history, but which was characterized by clear references to ethical, social and, more generally, cultural issues. In particular, the interventions related the ethology of slave ants to the history of slavery in human societies, and that of raiding ants to the barbarian invasions, respectively.

5. Look around

Turning an anthill into a work of art. The anonymous US artist, after having melted the metal, pours it into the anthills which he uses as a mould. Once the aluminium solidifies, the works take shape.

Anthill Art, the pseudonym of an American artist who creates very special aluminium sculptures, is causing a lot of talk. He creates works using an original but much-discussed technique: as the video shows, the artist first melts the metal and then pours it directly into the anthills he uses as a mould. After pouring the red-hot liquid, the sculptor waits for it to solidify and then extrapolates the entire clod of Earth (cleaning it first with a jet of water).

However, the artist has ensured that the molten aluminium was only poured into the burrows of the red ants, which are harmful to the environment. Their nests are exterminated by the millions in the United States using poisons, gasoline and fire, boiling water, and very rarely molten aluminium.

Conclusions

This model of activity can be applied to different topics of other scientific disciplines.

3.11 SCENARIO 11 - WOMEN INVENTORS

Background information

Title: "Women Inventors"

Brief Description: This activity introduces children to different women inventors in fields such as science, technology, or health through an augmented reality experience.

Keywords: women, stem, steam, women inventors, augmented reality, creativity

Target audience: teachers with students (ages 6-12), students with parents (ages 6-12), students by themselves (ages 9-12)

Age range: 6-12

Context(s): This activity can be carried out anywhere, included but not limited to a classroom, museum/centre and at home.

Time required: Because of its nature, this activity can take from 1h (e.g. at home as homework or educational reinforcement) up to a 4/5 hour session.

Technological tools required:

- Mobile device/s with MetaClass AR app installed.
- Marker sheet (attached) printed to visualize the AR.
- (Optional) Computer/s with Playing with Protons Authoring Tool to create AR Experiences

Author(s)'s background: Expert teachers on STEAM education.

Connection with the curriculum: This activity connects to the different STEM fields covered in primary education, mainly science, technology, and mathematics, adding the artistic view from the exercises proposed. No prior knowledge is required.

Learning objectives:

- To understand the contributions of women inventors in various fields.
- To encourage critical thinking and discussion on gender roles in innovation.
- To promote research skills and historical analysis.

Guidance for preparation: For the AR-enhanced activity, the adult (teacher or parent) should have the cards attached in Annex printed and cut (one pack per group), so they can be distributed among children. If the activity is carried out inside the classroom, we recommend creating groups or 5/6 students so they can work together linking the different inventors-inventions. At home, students can work by themselves with the guidance of the parent if necessary.

WOMEN INVENTORS

1. Setting the scene

Elicit students' curiosity and existing knowledge about inventors, focusing on whether they can name any women inventors.

Introduce the topic through a short video series highlighting key women inventors throughout history.

* Here you can find a list of interesting videos (in Spanish) used in this activity. With this reference a teacher/parent can easily find similar resources in Youtube in their own language.

https://drive.google.com/drive/folders/1SVcxhhHdq8XWnO_SEwIWclpOQp3dPeAQ?usp=sharing

2. Look around

Students are divided into small groups and given a set of cards (Annex).

First, they try to match the inventor with the invention putting the images together without any help.

Example of the cards pairing Ada Lovelace with a Computer (programming).

Then, using MetAClass app, they discover if they were right. If pairs match, the portrait of the inventor and image of the invention will appear. Otherwise, nothing will happen.

Once matched, the images appear.

3. Investigation – Part 1

Once finished the initial discovery, each group is assigned a woman inventor (from the pull above) to research.

Groups present their findings, focusing on the inventor's contributions, challenges faced, and impact on society.

4. Investigation – Part 2

Now, based on their previous research, encourage students to develop their own invention crafting & AR project construction:

- Students use craft materials to create a simple prototype of an invention by their woman inventor.
- Then, they collaboratively create an AR project using Protons Authoring Tool about their woman inventor, based on the prototype crafted.
- Each project can contain different markers showing pictures, short videos, 3D models etc.
- They then present their prototype and explain its significance. For this, they can previously record a video using the AR, or make a demo in real time.

5. Communication and discussion

Attract the class's attention and discuss the importance of recognizing contributions from diverse groups, including women, in the field of invention.

Reflect collectively on how the activity changed or reinforced their views on gender roles in innovation.

Conclude the session with a recap of the key concepts and historical figures discussed.

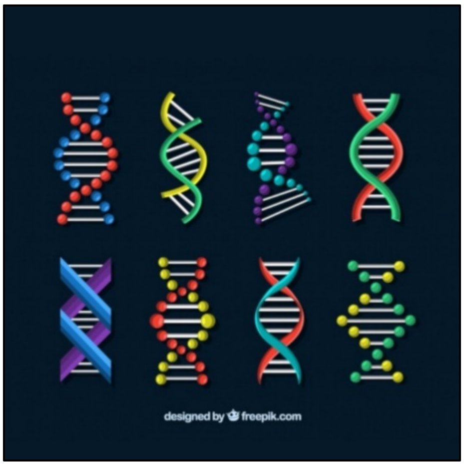
Annex: AR Initial project and markers

To load this Project:

1. Open MetAClass app
2. Go to Viewer
3. Tap on “Import”
4. Tap on “Scan”
5. Point at this QR code

Markers to print and cut:


ROSALIND FRANKLIN


designed by freepik.com


VIRGINIA APGAR


designed by freepik.com


CO2
KATSUKO SARUHASHI


CO2
UNDER THE SEA
designed by freepik.com


STEPHANIE KWOLEK


POLICE
POLICE
POLICE
POLICE
designed by freepik


MARIE VAN BRITTAN


HOME SECURITY
designed by freepik.com

3.12 SCENARIO 12 - BUILD THE BARYONS

Background information

Title: Build the Baryons

Brief Description: This activity consists in combining three quarks to build baryons, whose characteristics (charge and strangeness) can be inferred from their shape. It can be conducted in several ways, depending on the age of the participants, and on the context. For example, we used it as a challenge for pupils to build a given baryon using its constituent quarks within the framework of an escape room based on particle physics.

Keywords: Particles, matter, quarks, baryons.

Target audience: Students, public

Age range: 11-99

Context(s): This activity can be done at school, or during public engagement events.

Time required: In school-based work, the activity can be done in 45 minutes. More time can be assigned to out-of-school activities. For example, one can use the scenario to realise a sort of escape room or a treasure hunt: in this case more time can be appropriate.

Technological tools required: AR device (currently only Android phones are supported). Depending on the implementation, other tools may be needed.

Author(s)'s background: scientist.

Connection with the curriculum: The activity is suitable for introducing modern physics to students: in particular, the standard model and the quarks. It can, however, used to informally introduce the constituents of matter to younger students.

Learning objectives: Learn about the constituents of matter.

Guidance for preparation: The activity does not require preparation, per se, but for the printing of the markers of the AR tools. The AR tool must be previously installed in participants' devices. If the activity is part of a game, the game setup must be prepared. Markers can be found in the attached file.

1. Setting the scene

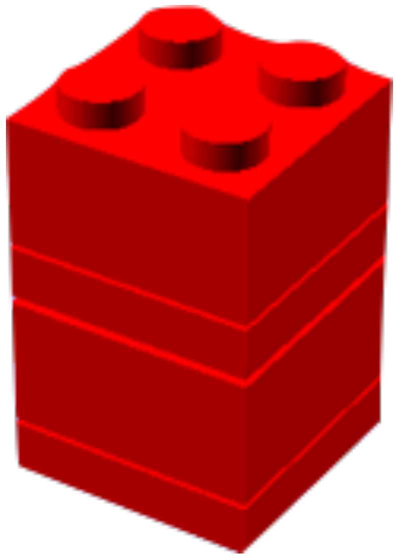
Explain how baryons are made as below.

Baryons are particles made of three quarks. Quarks carry electric charge (either 1/3 or 2/3 that of the proton), and strangeness: a quantum number that determines how the particle decays.

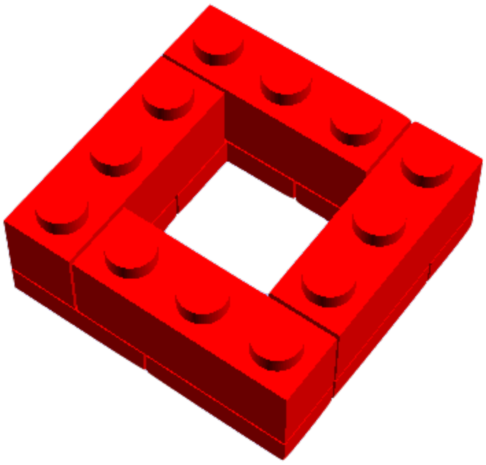
Baryons must have integer electric charge and strangeness, but, because of the Pauli's exclusion Principle, they cannot be made of three quarks of the same type.

There exist three quarks: the up quark, with charge +2/3, and the down quark, with charge –1/3, have no strangeness (actually, there are six quarks, each with a different quantum number, but all of them have either charge +2/3 or –1/3). The strange quark has strangeness equal to –1 and the same electric charge of the down quark.

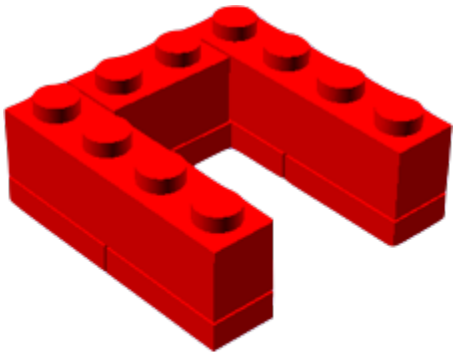
In the scenario, a quark is represented by an assembly of LEGO bricks. The charge of the corresponding quark is given by the height of the corresponding set of bricks, measured in units of number of bricks. Negative charges are represented as the depths of a hole at the center of the set of bricks, whose depth is proportional to the charge. So, the up quark, whose charge is +2/3, is represented as follow:



In fact, each protruding LEGO brick accounts for a charge +1/3. Contrastingly, a down quark is represented as

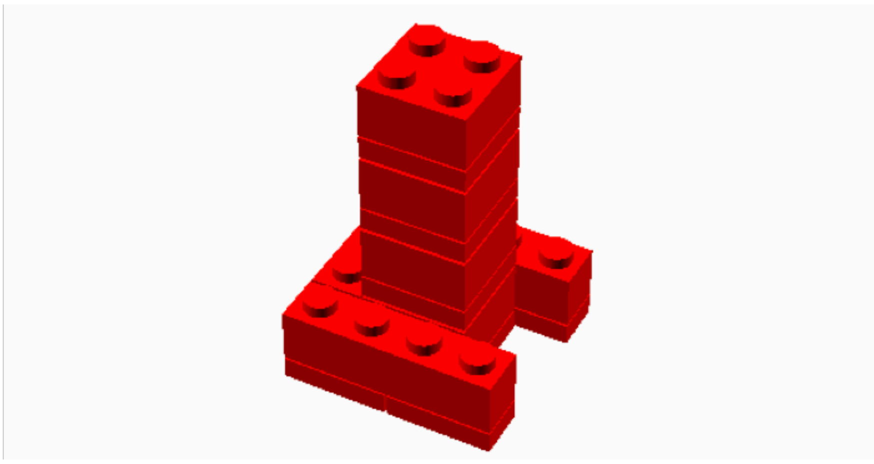


Which has a one brick deep hole at the center. The strange quark is like a down quark, but, being *strange*, has a modified side:



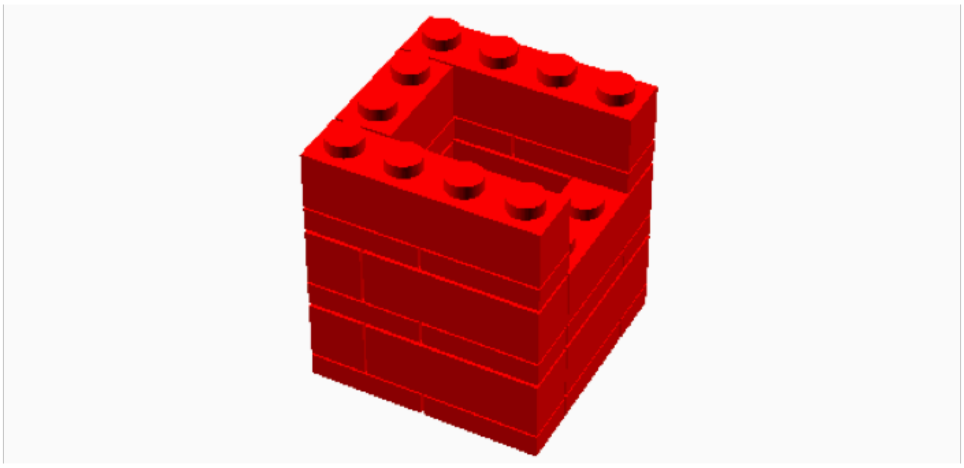
The game consists of combining three quarks and guessing the charge and the strangeness of the generated particle, then looking for its name by means of a search in textbooks or on the Internet.

As a result, a combination like uus, appears as follows:



The combination is made of two up-quarks and one strange-quark, and presents a central protrusion made of three bricks, corresponding to an electric charge of +1/3×3=+1. The s-quark has a missing side, and a hole at the center. The hole is filled by one of the bricks of the u-quarks tower. The presence of a missing side tells us that the corresponding particle has strangeness -1.

Neutral particles have a flat surface on top, while negatively charged particles exhibit a hole at the center, whose depth represents its charge in units of –1/3 per missing brick. The following image represents a Σ^- (pronounced sigmaminus): a particle whose strangeness is –1 with an electric charge opposite to that of the proton



The hole at the center has a depth of 3, such that the electric charge is $-1/3 \times 3 = -1$.

Distribute various markers around.

2. Look around

Look for the markers with the images of the quarks. Looking at them through the AR device will show their 3D model. Study them and get accustomed with their shape, from which you can infer their characteristics.

Select three markers and look at the particle they build, when markers are put side by side, close to each other.

A possible way of using the tool is to ask students to predict the characteristics of a given combination of quarks, then try to collect them and check if the combination is valid, and which particle they give.

Another possibility is to look for the name of the particles that have the observed characteristics, learn their properties, and the history of their discovery.

The scenario can be loaded using this QR-code:

3. Investigation/creation

Try to make all the possible combinations of u, d and s quarks. Compute their number, and look to what happens if you build the combinations. The uuu, ddd and sss combinations do not work and do not show any result. The reason being that the Pauli's exclusion principle forbids two or more particles to be in the same state, and this combination is forbidden. Combinations like uud are permitted because the two u quarks can exist in two spin states.

In fact, eventually people discovered particles that could be interpreted as uuu, ddd and sss combinations, which were expected to be forbidden for the reason given above. This observation gave rise to Quantum Chromodynamics: a possible explanation of the existence of these combinations is that quarks carry a further quantum number that was called "colour" (which, of course, has nothing to do with ordinary colours). It is said that quarks exist in three colours (imagine them as three sort of charges): red, green and blue. Only colourless particles can be observed. Colourless particles are formed by quarks of different colours. So, e.g., uuu does not violate the Pauli's Principle because the three u quarks are in different colour state.

4. Communication and discussion/presentation

The observation is an opportunity to talk about the scientific method. The colour hypothesis cannot be taken as a scientific theory, unless it is verified by some experiment. It is not possible to observe colours directly, because, by definition, only colourless particles can be observed. However, physicists eventually found methods to prove that, indeed, colour exist as a sort of charge: it can be interpreted as the charge that originates the strong force.

One of the methods consists in computing the probability of producing certain combinations of quarks in reactions occurring at accelerators, where particles are smashed against others. It turns out that the probability of observing certain final states after collision is three times larger than expected, when colour is not considered.

The factor three is consistent with the colour hypothesis, because each quark comes in three species, enhancing the probability of observing the final states.

In fact, the latter is not the only proof of the correctness of the colour hypothesis. There are tens of experiments that can be explained only by assuming that each quark has three replicas with different colour.

4

CONCLUSIONS

4 CONCLUSIONS

O2 is the “heart” of the Playing with Protons Goes Digital project, as it provides a set of concrete innovative STEAM/AR activities.

This “Handbook of Resources” includes activities that are suitable for schools in rural and remote settings and involve the engagement of distant stakeholders (research institutes, science centers and museums). Through this document is also given a concrete guide to how science teachers can build their own structured Playing with Protons Goes Digital activities by using elements taken form the methodologies/approaches.

All these activities will be applied in classroom activities of primary, secondary and informal education like museums, science centers and will also engage the local community and support a school opening-up strategy. This aspect of O2 will be in direct “dialogue” with O5, in which a full Playing with Protons Goes Digital policy recommendations for schools and educational authorities on how to open schools to the wider community will be elaborated.

5

TABLE OF SCENARIOS

5 TABLE OF SCENARIOS

	Title	Theme	Grade of school
1	3.1 Scenario 1 - Day and night alteration	Solar System - Universe	Grade 6 Primary school
2	3.2 Scenario 2 - Earth 4 seasons		Grade 6 Primary school
3	3.3 Scenario 3 - Investigating our Solar System		Grade 6 Primary school
4	3.4 Scenario 4 - The Moon phases		Grade 6 Primary school
5	3.6 Scenario 6 – Earth's rotations		Grade 6 Primary school
6	3.8 Scenario 8 – The History of Universe		Grade 4-7 Primary- Middle school
7	3.7 Scenario 7 – Rutherford's experiment	Particle physics	Grade 8 Middle school
8	3.9 Scenario 9 – Particle Go		Grade 6 Primary school-all ages

9	3.12 Scenario 12 – Build the baryons		Grade 6 Primary school-all ages
10	3.5 Scenario 5- The structure of Hydrogen atom		Grade 6-7 Primary school
11	3.10 Scenario 10 – All together! The world of ants at Città della Scienza Museum	Animals	Grade 1-7 Primary school
12	3.11 Scenario 11 – Women Inventors	STEAM careers	Grade 1-6 Primary school

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