NEUROMORPHIC CHIPS

NANOSCIENCE SCENIC ARTS MANUAL

TEACHER'S WORKBOOK

EUREKArt

Co-funded by
the European Union

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Neuromorphic Chips

IN THIS WORKBOOK:

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EUREKArt

EXPLORING NANOSCIENCE

EurekArt is an innovative Erasmus+ educational project developed to promote and increase societal **scientific knowledge** among students aged 12 through 16. It provides broad social value through an educational synergy between the **visual and performing arts** framed by cutting edge research in nanotechnology.

EurekArt aims to **generate connections** between different areas of education by means of the following actions:

- Encourage and develop **students' curiosity** about the process that leads from creativity to **culture creation.**
- Develop an interest in **scientific knowledge** with social value through an educational synergy between the **visual and performing arts** together with nanotechnology.
- Develop **innovative practices** in the field of education, by combining performing and plastic arts with nanotechnology.
- Provide young adults with the necessary **tools** and **skills** to find creative and innovative solutions that allow them to face unprecedented social risks and challenges.

Furthermore, it provides **useful tools for teachers who want to use the scenic and plastic arts in their school teaching curriculum.**

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ed objectives

CONNECTING TO SCHOOLS

This workbook contains a series of exercises to teach topics such as nanotechnology and nanoparticles to young students by using a scenic arts approach. Here we focus on **Neuromorphic Chips**. In order to make our approach more exciting and useful, we will also suggest some soft skills and story writing exercises. This way the students will access this material from a multidimensional approach for a well rounded experience. More specifically, we will explore:

Scientific content

The topics treated in this worksheet will link to a school science curriculum. More specifically, students will touch upon topics such as **Electricity**, **Robotics**, **Neurons** and **Artificial Intelligence**.

Creating connections

One of the most prominent uses of Neuromorphic Chips is in the development and fabrication of AI - Artificial Intelligence. **AI is part of our every day's life** starting with how we shop to how we find our way around cities and the music we listen to. Connecting to this topic is fundamental in order to understand the times we live in.

Soft Skills

Students will learn skills linked to **teamwork, public speaking** and **storytelling** during their work of co-creation of knowledge. Group activities will improve **critical thinking** and **negotiation** skills while enabling students to discover deeper meaning of the scientific topic.

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instructions

TEACHERS BECOME GUIDES

This activity has been created **for the teachers of every subject**, to allow them to introduce the topic of **Neuromorphic Chips** connecting this issue to the school curriculum and at the same time to society.

At the heart of our approach is the idea that the students should find **ways to connect their own universes to each topic with a creative attitude**, while getting a general understanding of the science behind it. We propose that the teachers guide the students through a series of exercises where the students become **explorers**, taking a **voyage of discovery**. Teachers will also explore the topics with the students and **gain a potentially new awareness** around how such topics impact society and they will also learn a **new teaching technique**.

The approach we have used is that of **informal learning** where students don't face a typical frontal lesson, but they access the topics through a **learn-by-doing** approach.

Although being a science teacher could be useful when giving students some basic information about nanoscience, **teachers don't need to be science experts**: EurekArt is an **interdisciplinary project**. Students will be doing their own research to find scientific information and when the moment to write their stories comes, humanities teachers could find themselves in the right place.

What teachers really **must have** is an **open mind**! In the **Soft Skills workbook** teachers will find tips and exercises to give students (and themselves) a set of tools to begin their nanoscientific journey with.

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If you haven't read it yet, **start with the Soft Skills** workbook and decide which of the proposed activities would benefit the most for you and your students. Then **come back to this workbook** to get your hands dirty with nanoparticles!

TIMELINE OF THE PROJECT

To explore nanoscience through the lens of scenic arts requires several meetings with the students because of all the different aspects involved in the project. Here we suggest a possible path, but **teachers can personalise EurekArt**: change the order of the meetings, choose only the ones they need, or share the load with colleagues who teach different subjects, to make sure interdisciplinarity is on the plate.

Suggested meetings (maximum 10 hours):

- Soft skills on scenic arts (1 to 3 h): especially needed if the students come from different classes and/or the teacher is not familiar with theatrical approaches or storytelling techniques;
- The hero's journey (1 h): brief frontal lesson or video resources;
- Introduction to nanoscience (1 hour): go through the proposed keywords, background and curiosities and make research on what you want to know better;
- Scenic arts and nanoscience (1 to 2 h): physical embodiment of the scientific concepts to better understand them and... have fun!
- Story writing (1 h): recap on storytelling, analysing a famous story and collectively improvising a new one, plus giving the assignment of writing a story;
- Story reading (1 to 2 h): students read their stories to teachers and peers and get feedback. This meeting can be repeated multiple times to read the stories improved by the feedback.

Please note that when **introducing Nanoscience** to your class, you will only use **background** and **curiosities** sections of this workbook.

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The purpose is to **engage the students** around the topic. Then you can ask them to **search online** for some **keywords**, and discuss with them the meaning of what they found, using the content of the **keywords** section of the workbook as a backup.

It is important for the students to **learn how to make a research online** on their own and to understand that some **sources** are reliable, while some others are not. Later on, when they'll be writing their stories, they will have to search for proper sources of scientific knowledge. You could even ask them to take notes of the sources they consulted. It's a good exercise of **scientific citizenship**!

The suggested meetings are very important to give the students a sense of direction towards a goal, but after they receive their assignment, is fundamental that they can **count on the teacher(s) to ask for any clarification**. Make sure they know you will guide them in their research of information or with developing a good story. Teachers should make themselves available at least once to check in with the students on the developing of their work.

Remember that, for a student, the **most difficult** part of scientific story writing is... **science**! They may write a beautiful story but forget to make science an important part of it, or the other way round: they might write a complete explanation of a phenomenon but little to no plot. Be patient. Give them feedback on how to make their story shine and **get ready to be amazed** by your students' creativity.

The workbooks and the video resources on the EurekArt website contain everything you need to follow this path, but it's important that teachers feel free to change, modify and hack the proposed exercises. Nothing is written in stone! Depending on the class size and disposition, teachers can choose whether to make students work independently or in groups, explore variations of the exercises or even **invent brand new ones**!

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our journey

WE ARE THE HEROES!

EurekArt is a **journey of discovery** that teachers and students undertake together.

As stated in the **Soft Skills Workbook**, our adventure needs some basic ingredients: the **HERO**, who is the main character, a **COMPLICATION** to overcome, the **TRIALS** needed to overcome it and the **SOLUTION** to the complication. At the end of the story the hero learns an important lesson about life that s/he is ready to share with the world. We call this the **ELIXIR**!

In EurekArt, **we are the heroes**!

We face the **complication** of having to deal with new knowledge: **keywords**, **background** and **curiosities** on nanoscience could easily scare us. That's some hot stuff!

Now we have to tackle the problem with some **trials**, so we take **action.** We embody the nanoparticles to better understand the processes of deterioration and protection of our tangible cultural items. Our last, but finally successful action is **story writing**, which leads us to the **elixir**: we learn that the new knowledge we were facing can be part of our lives and we are proud to tell the world our stories.

EurekArt involves **performing arts** to promote **knowledge** and skills in **scientific areas** by influencing domains of **cognition** and **motivation**.

Let the journey begin!

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background

UNDERSTANDING IS POWER

STORY BEHIND THIS TOPIC

When trying to develop a technology to emulate the human brain and despite the current progress in semiconductor integrated circuit technology, the extreme complexity of the human cerebral cortex, with its approximately 100.000.000.000.000 synapses, makes the hardware implementation of neuromorphic networks with a comparable number of devices exceptionally challenging.

To provide comparable complexity while operating much faster and with manageable power dissipation, networks based on circuits called **memristors** have been developed.

To date, the rapid growth of modern electronics has had unparalleled impact on the ways humans work, live, and socialise in the past few decades. This exponential growth has mostly been driven by device scaling, i.e., constant shrinking of the size of transistors that form the basic building block of integrated circuits. However, continued geometrical scaling will likely come to a halt within the next decade as the device size approaches fundamental physical limits at ≈5 nm.

It is here where new devices such as memristors that offer new functionalities and provide new state variables, which can be used for computing and data storage, are of great interest to maintain the growth of the semiconductor industry.

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Neuromorphic computing spans a broad range of scientific disciplines from materials science to devices, to computer science, to neuroscience, all of which are required to solve the neuromorphic computing grand challenge.

CONNECTION TO SOCIETY

Neuromorphic computing can emulate the human brain and thus be implemented in different technological (smart) devices that rely on Artificial Intelligence such as mobile phones, tablets, computers, smart watches and so on.

Maybe we don't realise it yet but we are surrounded by objects and devices that are "artificially intelligent". This is arguably one of the biggest achievements of this century and at the same time it represents one of the biggest causes of concern.

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curiosities

COOL THINGS TO KNOW

The world of Neuromorphic Chips and Artificial Intelligence has been populated by many really smart people: scientists, entrepreneurs, writers, visionaries... Here we mention a few of them but with a little bit of research many more can be found and identified, and lots of stories can be told.

ALAN TURING
He was a British mathematician that helped develop the field of theoretical computer science. He also invented the famous Turing test: *a computer could be said to "think" if a human interrogator could not tell it apart, through conversation, from a human being*. Turing was the subject of a very famous movie: **The Imitation Game** starring Benedict Cumberbatch and Keira Knightley.

ISAAC ASIMOV
A Russian born American professor, he is famous for being the big theoretician behind the idea of robotics. He wrote hundreds of science fiction stories and novels in which he explored the ideas of the interaction between humans and robots. He devised his three laws of robotics:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.

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3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Asimov has inspired countless movie makers. His story **The Bicentennial Man** has been turned into a movie starring Robin Williams.

INTERNET GENIUSES and VISIONARIES
These past 25 years have seen the rise of entrepreneurs that, with their vision and energy, have shaped the way we look at the world: Elon Musk (Tesla, SpaceX), Jeff Bezos (Amazon), Larry Page and Sergey Brin (Google), Mark Zuckerberg (Meta) and many more. Their successes rely on how they have been able to use new technologies and the internet but most importantly the tools provided by Artificial Intelligence like **machine learning, deep learning, data mining** and such. Lots can be said about them, but certainly they have impacted in a huge way on our way of life and even on how we interpret our social and professional existences.

FUTURE OF HUMANITY INSTITUTE and **FUTURE of LIFE INSTITUTE**
These U.K. and U.S. based outreach and research centres conduct research on the existential threats posed by new technologies, with special focus on Artificial Intelligence. More specifically, they "work on reducing global catastrophic and existential risk from powerful technologies" by connecting scientists, philosophers, entrepreneurs and other professionals from all disciplines, opening up useful and meaningful conversations. **Future of Life Institute**: https://futureoflife.org

Future of Humanity Institute: https://www.fhi.ox.ac.uk/

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keywords

LET'S TEACH SOME TERMINOLOGY

Electrical resistance

The electrical resistance of an object is a measure of its opposition to the flow of electric current. Its reciprocal quantity is electrical conductance, measuring the ease with which an electric current passes through the material. Resistance is measured in ohms, symbolised by the Greek letter omega (Ω).

Memristor (memory + resistor)

Device that has a variable electrical resistance depending on how much electric flux had gone through it in the past. In other words, it has "memory". It was described and named in 1971 by Leon Chua, completing a theoretical quartet of fundamental electrical components which also comprises the resistor, capacitor and inductor.

Neuronal synapses

A synapse, also called neuronal junction, is the site of transmission of electric nerve impulses between two nerve cells (neurons) or between a neuron and a gland or muscle cell (effector). This is a process in which an electrical or a chemical signal is passed from a neuron's axon to a target cell. A synaptic connection between a neuron and a muscle cell is called a neuromuscular junction.

Neurotransmitters

These are chemical substances made by the neuron specifically to transmit a message.

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Resistive-switching

Resistive Switching refers to the creation of conduction channels in an insulator material, that is, a material that should not conduct electricity, but may do it when subjected to an electric field or current. This means a change in the value of the material's resistance. An interesting application of resistive switching is the fabrication of novel “resistive random-access memories” (RRAM) for electrical devices. This effect is also at the base of the behavior of the so-called memristor devices and neuromorphic memories.

Artificial intelligence

The theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages. Artificial intelligence is the simulation of human intelligence processes by machines, especially computer systems as opposed to the natural intelligence displayed by animals including humans.

Neuromorphic chips

Electronic devices capable of emulating volatile and non-volatile neuronal synapses. They have the potential to create an artificial brain, thus artificial intelligence. The devices used for this purpose are mainly memristors, which are devices which can change between its insulating and conductive state having a “memory” (non-volatile) or losing its track (volatile) from one state to the other.

Neuromorphic computing

Implementation of aspects of biological neural networks as analogue or digital copies on electronic circuits.

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actions

LEARNING BY DOING

Basic philosophy of these exercises

Through movements, actions and **personification of scientific ideas** and pretend-embodiment, the students will get a sense for nanoscience. They will also experience the power of **metaphors** making it easier to use them in their storytelling exercise. Moreover, this is a powerful **team building** activity, especially with students from different classes. Here we will work on **Neuromorphic Chips**!

Exercise 1 - Memristors

location: empty room/ free space

The basic idea behind memristors is that they keep a memory of what happened before: in this case, the amount of electrical flux that has gone through the device.

Let's try to emulate this: the students are placed in a circle, everyone is facing the centre. Let's assign them tags: student A, student B, C, and so on. Student A says a number. Now student B says a different number. Then she/he repeats the number of student A and that of student B. Now student C says a number and then she/he repeats the numbers of A, B and C... and so on until the first mistake is made and the game is restored to its initial state.

Now try this with words and not numbers. How about combining words with movements? Try the student's names too! This is a great way to get the group to know each other's names. The combinations are infinite!

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Exercise 2 - Neurotransmitters
location: empty room/ free space

This is a rather loud exercise but it is also a lot of fun. The students create a human wall that separates two students: one on one side (student A) and the other on the other side (student B) of the wall. Student A has the task of passing on a message to student B (for example a short sentence that was previously written on a piece of paper, or a sequence of numbers, or a description of a picture...).

The human wall must prevent the passage of this information by shouting, making as much noise as possible and making sure that student A does not connect with student B even visually.

The more noise the more difficult it will be to pass the message! The transmission of information must be done in a given time (60 seconds?). Will student A be able to pass the message to student B?

What about making the message more complex by adding special gestures so that student B must also repeat movements and not just words?

Exercise 3 - Are we humans or are we robots
location: empty room/ free space

Each student decides if she/he wants to be human or robot. The teacher plays music and everybody dances as human/robot depending on their choice. How does a human dance? What about a robot? When the teacher says "dance with your kind" the humans will seek another human to dance with and the robots will do the same.

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At a certain point the teacher will say "dance with the other kind" and the couples will split, looking for their new counterpart.

When the teacher says "humans are robots and robots are humans" everybody changes again, becoming of the other type. The game continues as above until the music ends.

At the end, the teacher asks the students how difficult it was to become a robot or a human, if they were stereotyping, and if it is possible that humans and robots can learn to mix.

The teacher can pursue further the human/robot relationship: Can humans become friends with robots? What does it take to do it? Can a human even fall in love with a robot or an operating system? (check out the movie **Her**!)

Now, as a special treat, the teacher can show this video (and it is all real, no science fiction!): https://www.youtube.com/watch?v=fn3KWM1kuAw

And what about trying to reproduce this one? https://www.youtube.com/watch?v=XnZH4izf_rI

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story writing

SCIENCE IN STORY

Finding the Hero

Now it's time for the students to **write their own story**, exploring the scientific topic of **Neuromorphic Chips**. Going from physical embodiment of nanoparticles to story writing seems like a big jump, but it's easier than you could think!.

At first you can **analyse together a story everybody knows** and look for the elements of the **hero's journey**: status quo, complication, trials, solution and elixir. A good **example**, containing unexpectedly accurate science, is *Finding Nemo*. Let the students help you **go through the plot**, step by step, and guess what's true or fiction. Then check the answers online: do turtles migrate? Do clown fishes live in anemones? And so on. Of course you can use other examples. Point out the difference between a fiction based on actual science, like *Gattaca* or *Interstellar*, and a pure science-fiction, like *Transformers*.

The next step is more creative: **inventing a collective improvised story**. One after the other, in a circle, each student will tell a bit of a story, starting with the status quo and getting to the elixir. It's an **experiment**, so you will have to **guide** them through each step, giving them **hints** like "who is the hero?", "now we need a complication" and so forth, until the story ends. Was it too easy? Let's take the game to the next level: **a story about science**!

Students will have to work autonomously: choose a hero, invent a plot and find online reliable sources of contents about nanoscience. Teachers can guide them, but students have to do the job!

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Talking with a robot

Very often we happen to interact with machines even when we are not aware of it. For example, often when we connect with **call centres we end up in phone calls with robots**. They have a great voice, they sound human but... they are just robots.

So, why not ask the students to reflect upon these issues and **write a story** that inspires them to interact with artificial intelligence? They will work in **small groups** and could even use **different artistic expressions**, if they feel more inclined to **music**, for example, or **painting**, or making a **graphic novel** or an entire story with **memes**. As long as their creation contains all the basic steps of the hero's journey, it's a story!

If the students are stuck, here's a possible start: "a person wants to get information regarding a problem with their cellular phone that does not connect to the internet anymore. So s/he calls the internet service provider to find out where the problem is". **But is s/he talking to a robot or to a person?**

Let's instruct the students to play with how this conversation could go. What can we do to identify whether the "person" we are talking with is a robot or a human being? How does a robot think compared to a human? Also: **is talking to a robot all that bad?** What are the pros and cons of having to do with a machine?

Once the students have finished creating the story, why not **share** it with the class? Instruct the students to read it aloud if they wrote it, or present their artistic creation to the rest of the group. If they feel very adventurous, why not **try to act it out**?

With the **feedback** from their peers they'll see if what they wanted to say actually went through. If it did, they found the **elixir**!

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the elixir

YOU ARE THE HERO

What did I learn from this experience?

Teachers and students should dedicate some time to understand what lesson they are taking home from this experience. Just like the protagonist of any story at the end goes back to their world with an "elixir", so should the **teachers** and the **students**. After all, they **are the protagonists of their own stories**!

Let's ask the students these questions: ***if you were to explain to a friend what Neuromorphic Chips are, why are they important and what they are useful for, how would you do it? What would you say?***

Also, let's think about our journey, and ask the students: ***Did you find that telling a story about nanoscience could be easier than explaining in scientific terms what nanoscience is? Did you find it engaging? Did you like to use storytelling to explain science?***

Now, **let's ask ourselves the same questions**!

Note: if you have any comments or suggestions regarding this workbook and the exercises and tasks included in it, please don't hesitate to contact us at *direzione@arditodesio.org*

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