MAGNETIC NANOPARTICLES FOR BIOMEDICAL APPLICATIONS

NANOSCIENCE SCENIC ARTS MANUAL

TEACHER'S WORKBOOK

EUREKArt

Co-funded by
the European Union

EUREKArt
Magnetic Nanoparticles

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 **Magnetic Nanoparticles**. 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 the topic of **magnetism**, **heat**, **cancer**, **medical issues** and **body physiology**.

Creating connections

Magnetic Nanoparticles are mainly used in medical treatments of several types of cancer (brain cancer, for example). They are also used in anemia treatment (for iron deficiency) and as contrast agents in MRI - Magnetic Resonance Imaging.

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 **Magnetic Nanoparticles** 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

Magnets have been known to humanity for thousands of years. Uses of magnetic lodestone were reported in ancient history. In fact, before even knowing the details of magnetism, we were able to guide ourselves with magnets in compasses, a tool that has allowed the exploration of the world.
During the 19th century the relationship between electricity and magnetism started to be understood, giving rise to developments such as the first electromagnet by Christian Oersted.
Later, in the twentieth century the miniaturization of magnets led to the study of **magnetic nanoparticles** and then this type of particles were used in our daily life as part of recording media.
Very recently, these tiny magnets have been proposed for their use in humans. Once injected in the body, we can use them for diagnosis and treatment of diseases.

CONNECTION TO SOCIETY

Magnetic nanoparticles are like tiny magnets. For biomedical applications, these particles are usually made of iron oxides, similar to some of the red soils we see in the fields or the pigments used in the prehistoric paintings. These particles can be used to **deliver drugs** to specific sites, using an external magnet to guide them. We can also use them to **heat tumors** and kill their cells, applying an external alternating magnetic field. They have a huge potential in medicine as a result of their interesting physical properties and their low toxicity.

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Drug Delivery

Imagine you take a drug, like paracetamol, because you have a headache. The drug does not know that you have a headache and will be distributed along your whole body. Therefore, the dose you need has to be enough for a small part of the drug to reach your head. This is not a problem for paracetamol which is pretty much harmless, but it is a big issue for chemotherapeutic agents that are quite toxic. If we manage to tell the drugs where they have to go (the tumor) less amount of drug is needed and less side effects. Researchers do this with the magnetic particles.

Magnetic Hyperthermia

Imagine you have a compass needle and a magnet, if you move the magnet around, the needle will follow it. We do something similar with the particles. We apply a magnetic field that changes the direction very fast. Each particle's magnetic field has a direction (scientists call them the "magnetic moment"). This magnetic moment wants to align with the alternating external field, so the particles rotate, and because of that heat is generated. Scientists can use the heat to “burn” cancer cells.

curiosities

COOL THINGS TO KNOW

Magnetic nanoparticles are non-toxic: there is more iron in your morning cereals than what is used in biomedical applications. They can be moved remotely using magnets. They can also be heated and they can carry drugs!
They are smaller than cells, with a size similar to some proteins, so they can interact with them at the same size level.

Magnetotactic Bacteria

These bacteria are able to generate a chain of magnetic nanoparticles inside their bodies. They use these particles as the needle of a magnet to orientate their bodies in the Earth's Magnetic Field. In addition to their interesting magnetic properties, these bacteria form part of a curious hypothesis related to an observation found in a meteorite. Scientists found chains of magnetite crystals in a meteorite called ALH84001 and hypothesized about the biological origin of these particles inspired by the chains of magnetotactic bacteria form.

Iron

The iron in our bodies was formed in the stars millions of years ago. It is quite interesting for students to discover how the different elements were created and that life would not be possible without iron (as a matter of fact almost all living forms depend on it).

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Magnetic nanoparticles to reduce CO_2 in the atmosphere?

Several years ago, a project was focused on the fertilisation of areas of the Ocean that have low nutrients, so the algae and plankton could grow and that way we would generate "forests in the ocean to capture CO_2 and transform it into O_2". Several types of iron compounds were tested as potential nutrients, some of them similar to the composition we use for our magnetic nanoparticles.

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keywords

LET'S TEACH SOME TERMINOLOGY

Iron oxides

These are chemical compounds composed of iron and oxygen.

Magnets, Magnetism and Magnetic fields

Magnets are materials (pieces of metal or rock) that are able to attract some types of metals. Magnetism is the force that makes them stick together. Some iron oxides behave like magnets, creating a magnetic field around them. We can also generate magnetic fields with moving electric charges.

Alternating magnetic field

Magnetic fields pass through space, attracting or repelling other magnetic objects. When we think of a magnetic field, we generally have in our mind the image of lines connecting two opposite magnetic poles. These lines indicate the direction of the magnetic field. You can see these lines in the alignment of iron filings sprinkled on a paper placed over a magnet. These are static magnetic fields.

Another possibility is having alternating magnetic fields, in which the direction of the magnetic field lines changes with time at a given frequency. A compass near an alternating magnetic field will be moving continuously.

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Superparamagnetism

This is a form of magnetic behavior that appears in small magnetic nanoparticles. In nanoparticles that are small enough, when the temperature is high enough, including room temperature, magnetization can randomly flip direction. This does not usually happen in more regular magnets!

Cancer

Cancer is a group of diseases involving abnormal cell growth with the potential to invade or spread to other parts of the body.

Magnetic Hyperthermia

It's a cancer treatment in which magnetic nanoparticles are injected into the tumour and exposed to an alternating magnetic field, which increases the temperature, generating hot spots and killing cancer cells.

Drug delivery systems

These are the approaches, formulations, manufacturing techniques and technologies involved in transporting a pharmaceutical compound to its target site to achieve a desired therapeutic effect.

Nanocarrier

A nanocarrier is a nanomaterial being used as a transport module for another substance, such as a drug. Commonly used nanocarriers include micelles, polymers, carbon-based materials, liposomes, nanoparticles and other substances.

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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 **Magnetic Nanoparticles**!

Exercise 1 - Magnetic Nanoparticles

location: empty room/ free space

Magnetic nanoparticles are quite special because they are really small and yet they possess magnetic properties. Each particle has a North (N) and a South (S) side that can interact with the N and S sides of the other particles. This exercise will play with these properties. Each student will be a magnetic nanoparticle that moves around in space. Their back is the N while their front is the S side. Can they keep distant from each other? What happens when they hook up?

What if you play a music now and the music generates magnetic waves in the class... how will the student-particles move?

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Exercise 2 - Moving in the body
location: empty room/ free space

Magnetic nanoparticles are injected in the body and then they are controlled and moved in the body by means of external magnetic fields.

In this exercise the students create a maze in the room, by placing chairs and desks so that one has to navigate through them. This will be the body. The students work in couples: one is the magnetic nanoparticle, while the other is the magnet. The magnetic nanoparticle starts on one side of the room and has the task to cross the room with the eyes closed (a scarf on the eyes here would help). The other student (the magnet) helps the navigation by giving vocal orders: "left, right, forward, back" etc. If the student being guided hits any object the couple is eliminated and another couple has a try at it. Then the body is changed, things made more complicated and the game starts again with the couples that passed the previous selection. The game ends when only one couple remains.

You may want to make things more complicated by asking the student guide (the magnetic field) to use only nonverbal sounds (like ah - ah - ah -eh - eh - eh...) or even just by clapping the hands in order to guide the other student. Experiment with the possible ways the two students could communicate!

Note: this exercise is done a few students at a time

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Exercise 3 - The school is a body / subjective mapping exercise

location: the whole school

In this exercise we ask the students to map the whole school and identify places, corners and locations that they like and feel comfortable in and places that they don't like, those that bring up good memories but also those that bring up not so good memories or whatever they like. The idea now is to dispatch the whole class around the school so that they move around the school going from one location to the other in a well defined path focusing on places that "attract" and others that "reject" them. All of the sudden they become magnetic nanoparticles moving through the body under the influence of their feelings and memories (their own personal magnet). When they do it, they are not supposed to talk with anybody, but only to explore and experience the feelings they have.

When they comeback in class they are asked to explain where they went and what has been their experience around this big school body.

Why not getting out of the school? Explore other places, live other experiences.

Note: the whole school will be explored here. The students must be responsible enough not to take advantage of the freedom provided.

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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 **Magnetic Nanoparticles**. 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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Fantastic Magnetic Nanoparticles

In the 1966 movie **Fantastic Voyage**, directed by Richard Fleischer, the brilliant scientist Jan Benes develops a blood clot in his brain. However, using the technology developed by him that can miniaturize matter, a team of experts enters his body to help him. Sounds familiar? The problems they found are very similar to the ones our magnetic nanoparticles encounter when they are administered to the patients.

What if you had to do the same? Ask the students to **write a story** about it. 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: "you and your friends can shrink yourselves to the size of a nanoparticle and all of your physical abilities are unchanged (you can breathe, reason, move...). Your goal is **to delivery of a drug to the brain of a patient**, so you get injected in the body (where?) and then you make your way up to the brain, thanks to powerful magnetic forces (how?)..." **Try to describe this voyage**, and also, once you have delivered the drug, try to see how you can get out of this situation so that you can be brought back to your regular dimensions, go home and call it a day!

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 Magnetic Nanoparticles 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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