SPIN CURRENTS

NANOSCIENCE SCENIC ARTS MANUAL

TEACHER'S WORKBOOK

Co-funded by
the European Union

EUREKArt
Spin Currents

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 **Spin Currents**. 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 **electrons, voltages, spins and spin currents**.

Creating connections

Spin Currents are at the basis of the so called "spintronics" similar to electronics where the currents are not made by electrons that move, but by the spins of electrons that change with time. Spintronics is bound to revolutionize our digital and electronic lives, **bringing profound changes** to our lives.

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 **Spin Currents** 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

Electrical current is based on the movement of electrons and this dissipates energy in the form of heat. But electrons also carry another property called "spin" and scientists have been able to create a movement of spins, like a current, without the concomitant motion of electric charges. Therefore there is no real energy dissipation, no heat generated and electronic devices can be made much smaller than their classical electronic versions (that otherwise would melt!).

CONNECTION TO SOCIETY

Spin currents are extremely useful. They are currently used in devices for information storage in computers. But they are also used in the creation of Quantum computers that could solve complex problems that today's most powerful supercomputers cannot solve. They do this by using less space, less energy and doing it faster than the standard computing devices we are used to. Furthermore, Spin Currents and spintronics can also be used to construct futuristic energy harvesting devices that use residual energy that otherwise would go to waste, like that emitted by heat in a mobile phone that, thanks to spintronics, could be transformed back in power supply which could charge actively the battery of the phone itself.
The applications to society are vast and numerous.

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curiosities

COOL THINGS TO KNOW

A Spin current could use the wasted thermal energy from your mobile to charge it. In such a way that the mobile could not ever need to be charged. The more you use it, the more it is charged.

A Spin current can have the shape of a "sea wave" and they are called spin waves.

The spin of the electron gives an extra degree of freedom for technology since an electron can have a spin "up" or a spin "down".

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keywords

LET'S TEACH SOME TERMINOLOGY

Spintronics

Spintronics, also known as spin electronics, is the study of the intrinsic spin of the electron and its associated magnetic moment, in addition to its fundamental electronic charge, in solid-state devices.

Electric current

An electric current is a stream of charged particles, such as electrons or ions, moving through an electrical conductor or space. It is measured as the net rate of flow of electric charge through a surface or into a control volume.

Conductive material

In physics and electrical engineering, a conductor is an object or type of material that allows the flow of charge in one or more directions. Materials made of metal are common electrical conductors.

Insulating material

Any material in which electric current does not flow freely. Wood, plastic, rubber, and glass are good electrical insulators.

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Quantum computing

Quantum computing is a type of computation that harnesses the collective properties of quantum states, such as superposition, interference, and entanglement, to perform calculations. The devices that perform quantum computations are known as quantum computers.

Energy harvesting

Energy harvesting is the process by which energy is derived from external sources (e.g., solar power, thermal energy...) or obtained from residual energy normally wasted in electronic devices and stored or directly used. Energy harvesters store this residual energy and transform it into energy to be used as power for low energy electronics.

Thermoelectric effect

Phenomena by which either a temperature difference creates an electric potential or an electric potential creates a temperature difference. Thermoelectric materials show the thermoelectric effect in a strong or convenient form.

Spin Currents

These are electronic currents based not in the charge movement of the electrons but in the spin movement.

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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 **Spin Currents**!

Exercise 1 - Electrons and currents

location: empty room/ free space

Electrons are fundamental particles with negative charge. They can be moved by a voltage difference like that provided by a battery, moving away from the negative pole and towards the positive one.

For this game you will need a basket full of tennis balls. The tennis balls are the electrons. Two students make up the battery. When the battery is fully charged... the negative pole will keep all the balls while the positive pole will have none. The other students make up the wire, a line connecting the two poles of the battery.

Now let's switch on the electrical connection: which direction will the balls flow? What happens if we reverse the polarity of the battery? What happens when the battery is fully discharged? How could you charge the battery?

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You may want to create a game where the students need to charge a battery: can you identify limits why a battery cannot be charged at "infinite velocity"? And the faster you charge the battery the more it tends to warm up?

Exercise 2 - Insulators and conductors
location: empty room/ free space

Now the students are themselves the electrons. One side of the room is the positive pole while the other side is the negative one. Which direction will they move? How close can they get to one another? Can they touch?

Let's imagine now that their feet are really heavy... they have a real hard time walking. They have entered into an insulator! What if their feet are glued to the floor? Can there be an electrical current now?

Exercise 3 - Spins in insulators
location: empty room/ free space

One of the characteristics of an electron is its spin, a quantum mechanical property that can be "up" or "down". Now the students will impersonate the electrons, some with the spin "up" (the arms go up) and the others with the spin "down".

Now the students make a nice line, but again their feet are glued to the floor! They are inside an insulator but... can they make a spin current?

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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 **Spin Currents**. 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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Quantum Supremacy

Spintronics, based on spin currents, is the backbone of Quantum Computers. These computers exist already but are still in their infancy. In a not so far future it will be possible to buy these computers in regular stores and they will be used to make very complex and long calculations that today's computers cannot make in reasonable time.

So, why not ask the students to reflect upon these issues and **write a story** that inspires them to use this technology? 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 scientist has a very complicated problem to solve (e.g. predicting the Earth's climate in 10 years time, or discovering the meaning of life...) and s/he needs to find a very powerful computer to make the calculations. The regular super computers are not up to the task since they can take years for these complicated calculations. So s/he joins forces with researchers who are working on spin currents being used in a super quantum computer..." **Will the new computer work?** What are the parameters that will be needed to make these calculations? And what climate predictions will s/he make?

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 Spin Currents 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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