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Nanoscience – A facilitator background for a united group

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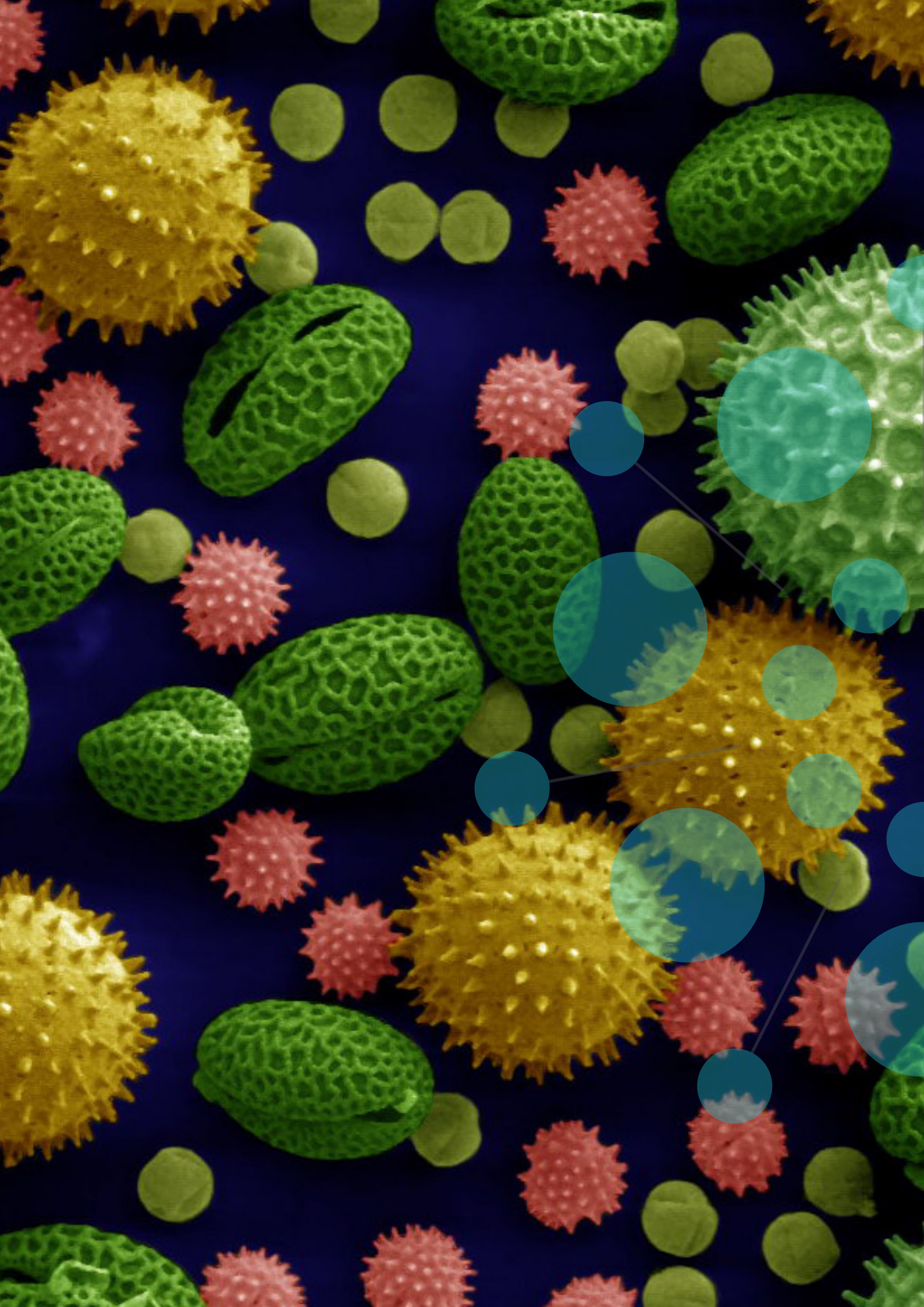

Nanoscience -

A facilitator background for a united group

An educational module for the chemistry, phisics and biology - lessons for lower and upper secondary school levels, developed by Romanian teachers from Târgovişte.

Developed within the framework of the European project -IRRESISTIBLE – Engaging the Young with Responsible -Research and Innovation – www.irresistible–project.eu

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Overview

Nanoscience -

A facilitator background for a united group

Ecological education in curricular and extra- curricular activities, train and develop environmental sensitivity, allows cross-skills development and eco-attitudes of employment and their ability to act, ethical responsibility and improve quality of the environment protection, rational use and the management of reusable resources, to develop in a healthy and sustainable environment.

Production of metallic nanoparticles can contribute to cleaning up and remediating the environment, thus solving the problem of environmental pollution by organic solvents, which is toxic to the environment.

In the last years, nanotechnology has become one of the most important and exciting close-ups of almost all fields of research, particularly in physics, chemistry, engineering and biology. Nanoparticles of Au and Ag have an important role, due to to their particularities.

The term "green nanotechnology (eco)" includes a long list of applications, from environmental protection processes, systems of reduction or minimization of waste, total or partial elimination of toxic materials, to processes that reduce pollution in the manufacture of filters for air and water.

At the nano scale, Ag presents remarkable physical, chemical and biological use of nanosilver becoming increasingly used in medicine, cosmetics, pharmaceuticals, biology, because of it's disinfectant and antimicrobial properties .

For centuries, Ag is used for its ability to destroy bacteria - from ancient

Romans who were treating water with silver coins to NASA using the metal to purify water aboard space shuttles. Ag nanoparticles are incorporated into medicated patches due to their ability to inhibit the transmission of viruses.

Nanomaterials can be integrated into a large number of products, from fertilizers or medicines to monitoring sensors.

The new technology will transform everyday products and how they are made by manipulating atoms so that materials can be reduced, improved and lighter at the same time. Although modest, the current nanotechnology products, such as stain-resistant fabrics and fresh food packaging, which have already entered the market, will play an important role in the future.

In the context of the proposed activities of this module, students will become familiar with nanometals, and they will obtain thru „green" methods, metallic nanoparticles of Ag and colloidal Au, using plant extracts obtained from them. Activities will be conducted in interdisciplinary research teams pointed to do applications of nanomaterials in medicine, environmental protection, industry, dental, thus acknowledging the importance of science education in everyday life.

Teaching approach is based on prior learning of students: extraction, chemical reactions, pH, salts and metal properties. In conducting experiments are used plants that students find them everywhere in the garden, in the park on field. Students will be asked to learn about nanoparticles and identify applications of Au and Ag metallic nanoparticles. Capitalizing IBSE strategy, the activities with students will be organized and conducted so that by his own effort, they discover (rediscover)

scientific facts, solve problem situations in everyday life, using metallic nanoparticles of Au and Ag. There will be interactive debates arising from the peculiarities particulate matter involved in chemical reactions and their application areas.

"Green" methods for obtaining metal nanoparticles from Ag and Au, using plant extracts are easily achieved by students. The necessary materials and laboratory tools are found in school laboratories (production tubing / coffee maker, plants, AgNO3).

The activities are intended to trigger students' interest in the study of metal nanoparticles to study sciences and applied research responsible.

figure 1
Gold crystals
Source: https://en.wikipedia.org/wiki/Gold

Overview

Grade/Educational level	Lower secondary / upper secondary
School subject	Chemistry
Learning unit	Metals
Module theme(s)	**Nanoscience – A facilitator background for an united group**
Specific competences	1. Explaining phenomena, processes, procedures encountered in everyday life. 2.Investigation of the behavior of substances, chemical systems and biochemical systems. 3. Using theoretical aquisitions to solve problem situations, to formulate explanations for conducting investigations and reporting of results. 4. Assessing the consequences of the action of chemicals on their own person and the environment. 5. Applying gained knowledge by studying chemistry and biology in their related fields.
Derived competences	1.1 inferentially identifying uses of plants (calendula, fennel, mint, basil, geranium, spinach, garlic) and fruits (elderberry, buckthorn), based on their active principles. 2.1. analyzing and interpreting the observations / data obtained by investigative activity; 2.2. use of the laboratory equipment, information technologies for extractions study to obtain nanometals with Ag and colloidal Au. 3.1. written and oral communication of the results of scientific step investigations, using scientific terminology; 4.1.recognizing the benefits and the risks of using metallic nanoparticles of Ag and Au; 4.2. analyzing the benefits and risks of using nanobiotechnology; 5.1.identifying fields in which we can apply the knowledge of nanometals using Ag and colloidal Au 5.2. creating activities involving displaying a responsible attitude towards others and towards the environment and towards applied science research.

Required preconditions		Knowledge about: - Chemical reactions, pH, extraction method; - Chemical properties of the salt and metals; - ”Nanometer“, Habits and behaviors: - elological type in protecting the environment (waste management for the conservation of natural resources); - to execute chemical reactions; - making experimental observations, interpret them and draw conclusions; Attitudes : - respect for truth and rigor; - information desire and affirmation; - respect for the scientific arguments against science education; - interest in exploring different ways of communicating, including those provided by ICT; - critical appreciation of the relationship between benefits and undesirable effects of the application of technologies; - caring for oneself, for others and for the environment; - interest and curiosity; - creative expressions.
Procedural resources (teaching strategy)	Teaching-methods and procedures	Heuristic conversation, brainstorming, experiment, directed discovery, scientific inquiry, problem solving, case study, game - for acquaintances study, group interaction, expression through drawing and color, role - that help stimulate and develop positive thinking and community interest in terms of biodiversity protection, individual interest for oneself (of health), systematic observation technique 3-2-1, portfolio, Peer / self-evaluation
	Educational means	Chemical reagents, instrumentation and laboratory tools, worksheets, computer, flipchart, flipchart sheets, markers, video projector, flipchart with labor protection rules
	Forms of activity organization	Frontal, in groups, individual
Estimated time		4 lessons / extracurricular activities

Short Theoretical Background

• Nanotechnologies - modern technology which allows the manufacture of molecular sized devices capable of manipulating matter atom by atom. The term was introduced in 1959 by the English physicist Richard Feynman, considered the "art of manipulating tiny devices at nanoscale"
• nanoparticles - particle size between 1 and 100 nanometers (1 nm = 10-9 m);
• nanomaterials - those materials whose components have a size between 1 and 100 billionth of a meter
• pollution - a complex phenomena that have changed or tend to change the environment at the expense of natural ecological balance; it affects the atmosphere (particles, gases, etc.), surface water or groundwater, seas and oceans, soil, plants, animals and human communities
• Extraction - a method of separating, on the basis of a difference in solubility, a mixture of substances. The principle of the extraction of this activity is a solid material that will come in contact with a suitable solvent.
• Colloid - a substance that consists of ultra-fine particles which do not dissolve, but remain in suspension in a medium of a different material (particle size between 0.01 to 0.001 of a micron in diameter).
• Colloidal state - the state in which the component particles of a substance has at least one dimension ranging between 10-9 m and 10-6 m (1 nm = 10-9 m).
• Biogenic method- a method for producing metallic nanoparticles by applying green chemistry approaches to nanotechnology
• applied scientific research - a thought applied is the activity being investigated by the objective reality of the world
• responsible research / innovation - research and innovation are carried out responsibly.

For learning activities proposed, it is assumed that students know - separation methods (extraction), pH, general properties of metals, salts properties, chemical reactions, nanometr- as a unit.

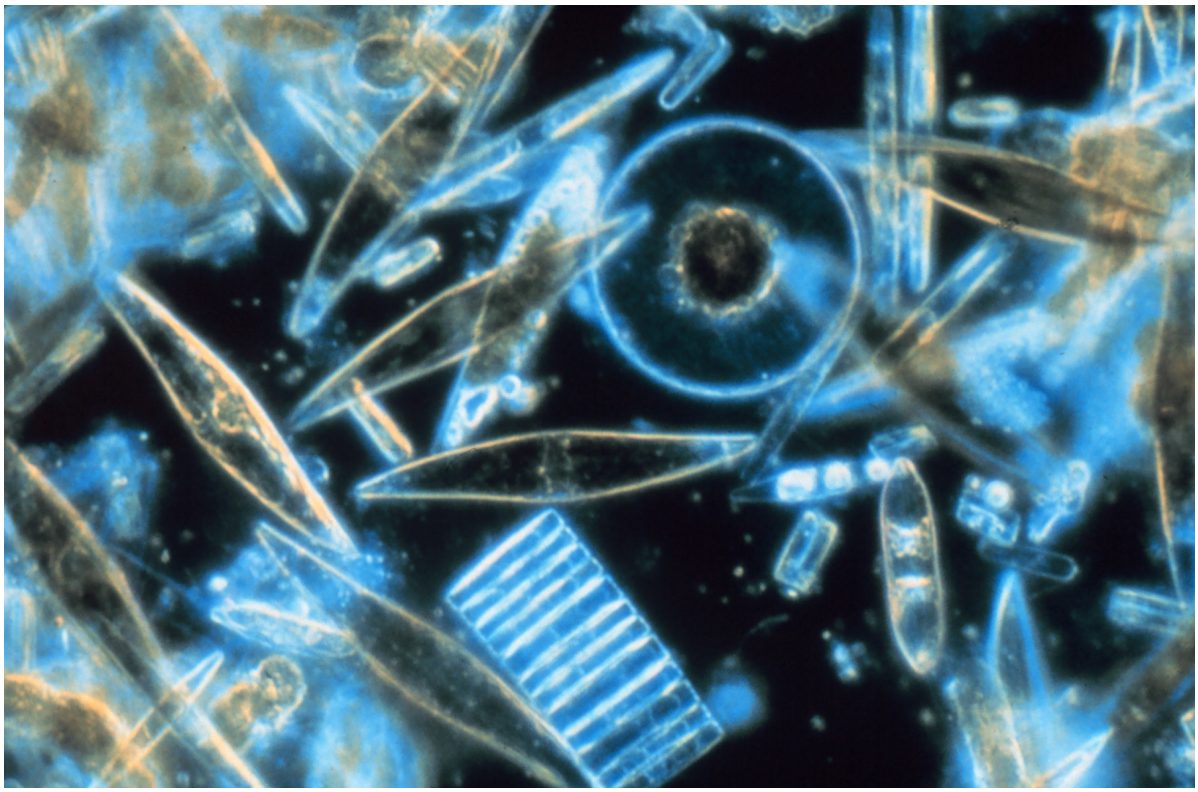


figure 2
Biogenic silica
Source: https://en.wikipedia.org/wiki/Biogenic_silica

Educational scenario

Steps of teaching approach/time management	Derived competences (codes)	Teacher activity	Learning activities**
1. Engage	5.1; 5.2	Presents information on nanomaterials and nanometals to students , starting from real-life solved problems using nanotechnology; - create research groups; - establish an investigation plan for each group consisting of: chemist, doctor, herbalist, sociologist, and government representative in the territory - indicate sites, links to documentation for students - creates a wiki site	- watching a movie describing the progress made on the scientific community regarding the nanometals use; - creates a spiderweb conceptual map on a flipchart, with the scientific progress from nanometals field; - Makes a creatively slogan of activity showing respect for colleagues and work opinion necessary for more efficient teamwork;
2. Explore	1.1., 2.1, 2.2.	- Present the real problem to be investigated; - establishes requirements for each activity; - inform students about registration information, organization and presentation at the end (after each activity will create a product) - provides the necessary materials for the proposed experiments; - process of the labor protection rules - supervises and directs the teams - structure the contents acquired by students	- carry out extraction from plants and fruits using expertise; - Performs reactions with AgNO3 and HAuCl4; - make experimental observations, record experimental data, draw conclusions - send out valuable hypotheses on the use of nanometals obtained; - completes assessment tools;
3. Explain	1.1; 2.1; 3.1; 5.2.	Students are told that they will learn about something "small", you still can not see easily, but that has begun to change our lives. It is a new technology that studies the impact of nanomaterials on human (clean water, so better hygiene, intelligent humans-nanorobots) and the effects of these small nanoparticles on humans and the environment;	Each student will demonstrate tolerance, sensitivity to the problems of those around him, he will avoid discrimination, prejudice, negative stereotypes, labeling and potential conflicts will respect the curing dignity those around will promote gender mainstreaming in investigative approach, so it will be a responsible researcher. Posting restructured information, photos during the activity, those with products made on the created site-wiki;

Learning activities**	Educational strategy			Evaluation
	Teaching methods and procedures	Means of education	Forms of organisation	
- new scientific - conceptual map with scientific advances in nanomaterials; - creation of a brochure with achieving slogans entitled "Ethics Charter Cantacuzin-carabelliene" - a code of ethics, to be known by that name. knowledge about nanomaterials; - slogan;	heuristic conversation explanation brainstorming problematization debate role play conceptual map	PC – PPT presentation, flipchart, sheets, markers, projector	frontal, research teams (5 members)	3-2-1 Technique, systematic observation of the activity and behaviour of the students.
- extracts from plants and fruits -metallic nanomaterials with Ag and colloidal Au; -Photographing with images from the activity; -Photographing the final products from the activity - Handling (skills for handling reagents and laboratory tools);	heuristic conversation, experiment, guided discovery, scientific investigation (ibse), problematization	- plants -Reagents -extraction column - worksheets, assessment tool sheet activities, verification tool skills in team assessment tool collaboration;	in groups of 5 members	practical test, evaluation instruments;
wiki site	brainstorming, heuristic conversation, explanation	Computers, Internet connection	frontal	systematic observation, practical test

4. Elaborate	2.1;2.2; 3.1	Create a stimulating learning environment focused on scientific investigation, research, experimentation, discovery, placing the student in the position of a responsible researcher.	Each team focuses on interdisciplinary research synthesized by the „green" method of nanoparticles by reducing HAuCl4 and AgNO3 with a reducing agent, which is an extract from plants or fruits obtained from them.
5. Disseminate / Share / Present / Expose	4.1; 4.2; 5.1; 5.2	It requires students to submit their completed portfolios, where they can find the products of each activity and their answers for the questions asked at their first activity	Shows to other colleagues from other groups applications of nanomaterials in medicine, cosmetics, environmental industry protection, which lists troubleshooting solutions for their team colleagues the answers to questions that were raised in the first activity
6. Evaluate	3.1. 4.2.3	Assessment portfolios in order to verify the understanding of new concepts, acquisitions that students creatively translated in the presented materials	Complete portfolio assessment tool presentation and feedback questionnaire

synthesized nanoparticles	explanation, conversion, scientific investigation, remark, guided discovery	chemical substances and laboratory tools	group work (interdisciplinary research teams)	systematic observation, practical test
Selected products for the realization of an exhibition	conversation, explanation, exposure	portfolios	portfolio method	oral assessment by arguing the selection criteria for choices
Portfolios, posting portfolios and photos from the activity on the wiki site	self evaluation/ peer evaluation	assessment tool to check portfolio presentation, feedback questionnaire	frontal	Self evaluation/ portfolio peer evaluation

3

Teacher guide

Teacher guide

This section gives suggestions on how teachers can be organized, coordinated, managed the teaching-learning activities. Teaching strategies are described,a number of recommendations and helpful suggestions are mentioned and also possible problems to avoid. Also, indicate the learning outcomes for each lesson / activity extracurricular basis.

To facilitate the work of the teacher, will present essential information, references to various materials, experimental details, worksheet proposals, references ect.

There is relevant information specified (including formulas, reactions, ect.) that students require to solve workloads. Obviously, the basics are identified in the textbook, but is recommended to incude it's extra/ complementary elements.

This educational activity allows students to acquire/to form new knowlendge, skills, attitudes, regarding :
a) Nanoparticles, nanotechnologies, colloids;
b) Obtaining metallic colloidal nanoparticles from Ag and Au using plant or fruit extracts;
c) The importance and use of natural nanomaterials in industry, medicine, environmental protection and other areas;
d) Forming a responsible attitude towards the environment by using metal nanoparticles Au and Ag.
e) The formation of responsible attitude to scientific research.
f) Growing respect for responsible scientific research work.
g) Respect for the principles of ethics in scientific investigation process.

Assumptions

At the counseling and guidance class, students have discussed about equality of opportunity and tackling discrimination because there are students in class from several ethnic groups, and students with health problems that are not always accepted.
Each time, at the gym class it can sense unpleasant feet smell of some colleagues.
A collegue feels marginalized due to a skin disease that has been fighting with for a while..
Following the referral of these problems, we decided to bring the nanoscience in the classroom to solve it, watching the scenario presented above.

Learning results

At the end of the **first lesson**, the students will be capable to:
- acquire new scientific knowledge about nanotechnologies, nanomaterials, nanoparticles;
- realizinga slogan of an activity of showing respect towards work and oppinion of others, necessary for a more efficient teamwork;
- create a conceptual map with the scientific progress in the field of nanomaterials;
- develop a brochure of slogans, entitled "Ethics Charter Cantacuzin / carabelliene".

At the end of the **second lesson**, the students will be capable to:
- split the active componets of plant, using the extraction method
- to properly execute the separation extraction method, following the procedure indicated in the No.1 worcksheet ;
- respect the ethical principles in the effort of making a scientific research.
It will take pictures that capture the carried out activity .

At the end of the **third lesson**, the students will be capable to:
- conduct experiments (as described in the 2nd worcksheet) to obtain metallic nanoparticles of Au and Ag, using plant extracts;
- to form / develop correct habits laboratory work using tools and reagents;

- to observe and interpret experimental observations and conclusion;
- respect the ethical principles in the effort of making a scientific research.

It will take pictures of obtained reaction products.

At the end of the **fourth lesson**, the students will be capable to:

- acquire information about nanomaterial applications;
- understanding the importance of using metallic nanoparticles from Ag and colloidal Au, in various fields of activity(medicine, environmental protection, industry, cosmetics, pharmaceuticals);
- analyze the benefits and risks of using nanobiotechnology;
- judgemental appreciation of the ratio between benefits and the undesirable effects of applying nanotechnology.

Recommended training modalities

By implementig this teaching modality, we propose: the development of students motivation for learning through applied scentific research, based on previous knowledge acquired in chemistry, biology, technonogy, ect. Using these teaching strategies, students will acquire exploration and investigation skills, communication and networking skills, developing the capacity of critical analysis of the relationship between the benefits and undesirable effects of applying nanotechnology. Students will understand that they have to respect the ethical principles in researching approach of innovation/reaserch.

3.1. Lesson 1

In the first lesson, students will be introduced to a real-life problem situation. It will formulate questions that students will have to find answers in the coming lessons. It will present information for students (PPT) related to nanomaterials and their applications. It shows a video of the history / progress of nanomaterials.
It will form research groups made up of 5 members: chemist, physician, herbalist, sociologist, territorial government representative and establishes a research plan.
The students will seek answes for this questions:
1. Do nanotechnologies represent something new?
2. Small, small...but how small?
3. How colud nanotechnologies/nanomaterials will change our lives in the next 20 years?
4. Nanotechnologies/nanomaterials are curretly used in products?
5. What negative aspects might nanotechnologies/nanomaterials have on our societys?
6. Will nanotechnologies/nanomaterials affect the environment?
7. Are there any risks in which nanotechnologies/nanimaterials will affect our health
8. What is special about things that are created at nanoscale?

Students will become familiar with new concepts - Nanomaterials, Nanotechnology, nanoparticles, colloids, nanomaterials applications.
Educational methods: : heuristic conversation, exposure, brainstorming, game, problematization.
Students are told that they will build a portfolio with materials that shows their acquisitions acquired during the three hour activity and responses to questions/ problem situations, presented in the first hour and they will present in the fourth hour .
Assesment methods: 3-2-1 technique, systematic observation of the activity and behavior of the students.

Assignments

1. Make a conceptual spiderweb map that illustrates the progress of nanotechnlogy

2. Create an activity slogan showing the need to respect work and the oppinion of the colleagues towards a teamwork activity more efficient.

3. Create a brochure "Ethics Charter Cantacuzin / carabelliene"

4. Create a wiki site

3.2. Lesson 2

The second lesson, the students under the guidance of the teacher, will perform extractions from various plants, following the steps shown in the worksheet No.1.
This is a biogenetic method used to obtain metallic nanoparticles and this is a result of tendency to apply green Chemistry approaches in nanotechnology. It is the first step in finding a solution to integrate students, colleagues without feeling discriminated, because creams that are used to cure skind diseases are made of active components from plants and fruit then used to obtaining Ag and colloidal Au nanoparticles.
Educational methods: the experiment, problem solving, guided discovery, systematic observation and heuristic conversation.
Assessment methods: systematic observation, practical test

Worksheet no. 1

Solid-liquid extraction is performed continuously in Soxhlet device. The product to be extracted (dried plant, crushing) is inserted in the filter cartridge (extraction). Insert the cartridge with extracted product in the second extractor, without exceeding the height draintrap.The third refrigerant is set up, and then the cooling water and the solvent (water) are introduced through a tun dish from the top of the refrigerator until the level of the liquid from the second extractor will slightly exceeds the height of the tun dish. The cartridge and the product will be imbued with solvent. Prime the tun dish so the solvent will reach the no.1 distillation flask. By heating the flask 1, the solvent distills, the vapors pass into the side tube of the second extractor and is condensed in the third refrigerant. The condensation will then be dripping from the cartridge extractor over the product and extract the soluble component. When the liquid will reach the level of the tun dish, it will prime again passing the liquid into the distillation flask.

Method to perform an infusion / extraction

1. The plant is shredded.
2. The shredded plant is placed into a Berzelius beaker.
3. The plant is moisten (only slightly moisten on the surface) with three parts of water.
4. Allow 5 minutes to moisturize.
5. Over the shredded and moistened plant, pour over boiled water.
6. Cover the bowl with a watch glass and let it infuse for about 30 minutes, stirring contents occasionally with a glass wand.

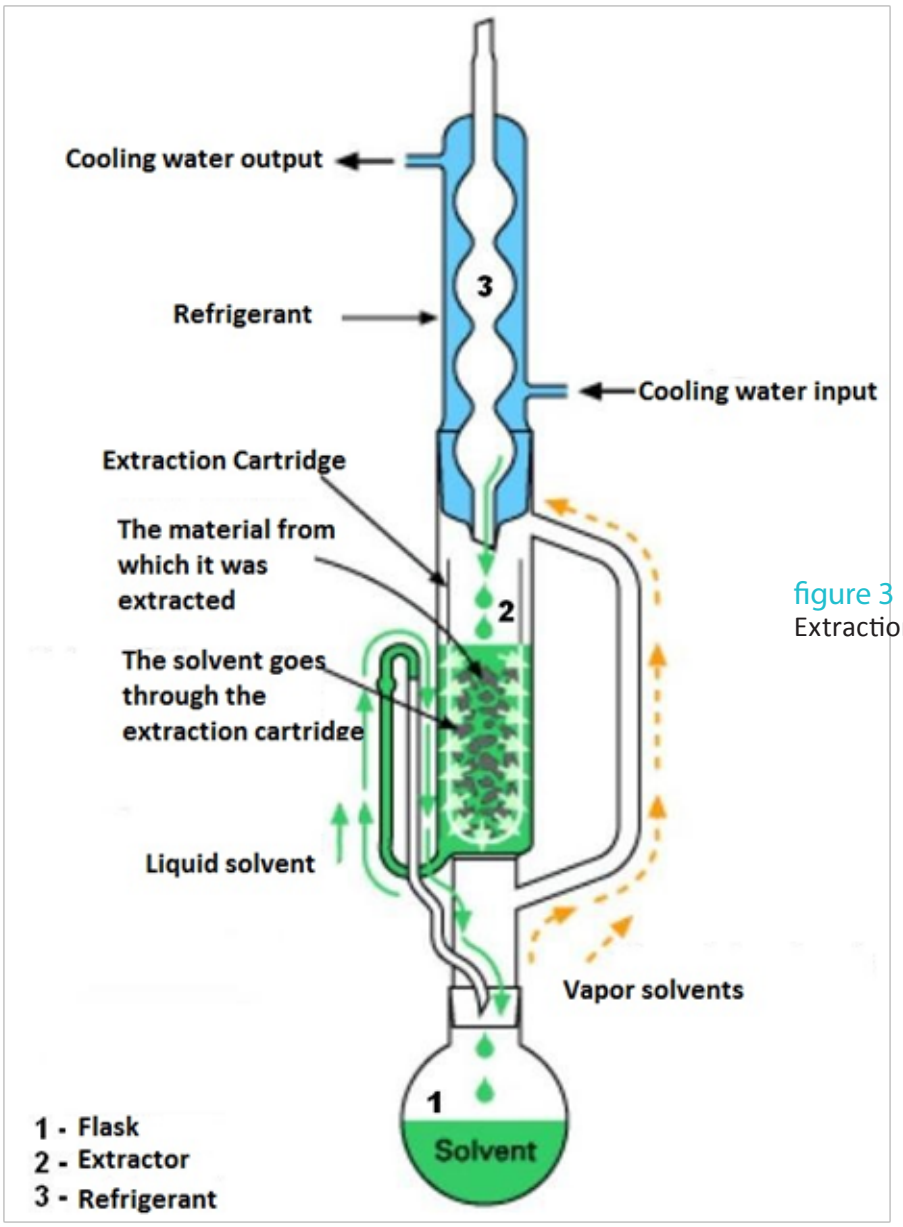


figure 3
Extraction

After that time has elapsed, the infusion is filtered through filter paper (cloth, gauze or cotton - which is the most recommended since cotton has the highest retention capacity of the various plant parts used in infusion).

Garlic extract is obtained by boiling 20 g minced garlic clove in 150 ml. distilled water, all in a 250 ml Erlenmeyer flask. After 5 minutes of boiling, the mixture is decanted and the supernatant (which floats on water surface), is filtered off and after is used as a reducing agent, to obtain the nanoparticles.

3.3. Lesson 3

In the third lesson, students create experiments to obtain nano-colloidal Au and Ag metals, using extracts from plants or fruits obtained in the previous hour. Following the procedure indicated in Worksheet No. 2, students:
- will carry out a scientific investigation rediscovering the scientific truths.
- make experimental observations, interpretations
- draw conclusions.

Educational methods and procedures: scientific investigation, guided uncovering, heuristic conversation, questioning, debating
Assessment methods: systematic observation, practical test

Worksheet no. 2

Experiment 1

In a 50 ml. tube, add the aqueous extract, obtained from the plant material, over which add 10 ml. of AgNO3 10-3 M solution.
Observe what happens.
Write down observations made. Keep the mixtures.

Experiment 2

In a 5 ml. tube add the aqueous extract obtained from the plant material, over which pour 10 ml of HAuCl4 10-3 M solution.
Observe what happens.
Write down observations made. Keep the mixtures.

NANO – ROLE PLAY
It is normal to sell antibacterial socks containing Ag nanoparticles, as long as it is not known yet if they are completely safe for the environment?
Roles:
• PRODUCING COMPANY Representative
• CONSUMER
• ENVIRONMENT AGENCY Representative
• SCIENTIST (It represents the community of scientists and researchers in nanoscience and nanotechnology.)
• GOVERNMENT Representative
The teacher will list at the end: PRO-TRADING antibacterial SOCKS NANOMOTVATIONS.

3.4. Lesson 4

In **the fourth lesson**, students:

- will present the results of the documentation and scientific research on applications for nano-materials with colloidal Au and Ag metals.
- they answered questions submitted in the first activity.

Suggested teaching methods: lecture, heuristic conversation.

Assessment methods: portfolio, self-evaluation / Peer evaluation.

figure 4
Colloidal solutions of Ag, Au and Ag-Au bimetallic nanoparticles
Image credit: Jim Yang LEE's Group, http://cheed.nus.edu.sg/stf/cheleejy/Gallery-research.html

Target competences

Derived competence	Learning activities
1.1 inferentially identifying uses of the plants (calendula, fennel, mint, basil, geranium, spinach, garlic) and fruit (elderberry, calin) based on their active principles	- accumulation of new scientific knowledge about nanotechnologies, nanomaterials, nanoparticles; - conducting scientific investigations will rediscover the scientific truths; - recording and interpretation of their experimental observations; - creating conceptual maps with scientific advances in nanomaterials; - creating a slogan that shows the need to respect work and colleagues opinion for an effective teamwork activity; - developing a brochure with slogans named "Ethics Charter Cantacuzin / carabelliene"; - creating a wiki site that will publicize all obtained products.
2.1 analyzing and interpreting the observations / data obtained by investigative activity	- the performance of the experiments to obtain the metallic nanoparticles of Au and Ag, by using extracts from plants or flowers; - understanding the importance of using metallic nanoparticles of colloidal Au and Ag in various fields (medicine, environmental protection, industry, cosmetics, pharmaceuticals); - observation and interpretation of experimental observations, drawing conclusions; - respecting the ethical principles in approaching the scientific research conducted;

2.2 use devices and laboratory equipment, information technologies for extraction study and to obtain nanometals with Ag and colloidal Au;	- separation of the active components of the plant using extraction method; - correct execution of separation extraction method, following the procedure indicated in the given worksheet; - forming and developing the right skills to work in laboratory using tools and reagents.
3.1. written and oral communication as of the results of scientific investigation approach, using scientific terminology;	- representing the results of documenting and scientific investigations research on metallic nanomaterials with colloidal Au and Ag as a portfolio; - wiki website presentation;
4.1 recognizing the benefits and risks of using metal nanoparticles of Au and Ag;	- stimulate strengthening of the interdisciplinary research teams that will ensure human resource development for performance scientific research - exploring different ways of communication ; - root scientific knowledge; - presenting the benefits through scientific argumentation.
4.2. analyze the benefits and risks of using nanobiotechnology	- cooperating promotion - concepts and solutions to improve development policies, the processes of evolution - new or improved models and methods for studying processes and phenomena - techniques, methods, models and unconventional equipment for medicine, industry, pharmacy, dentistry and biotechnology;
5.1. identify areas where knowledge can be applied about Ag and colloidal Au nanometals; 5.2. displaying a responsible attitude towards other people, towards nature and towards applied research.	- creating the portfolio - scientific research activities

3.5. Evaluation

This section gives suggestions on formative assessment or methods, techniques and tools in this capitalized endeavor.
Evaluation strategy can be projected on lessons / extracurricular activities subsumed teaching module being adapted to the specific activities carried out.
We recommend using assessment scales - tables which include items evaluation criteria and associated performance indicators, as well as those of self evaluation/ peerevaluation.
Formative assessment of students' concerns (mentioned objectives of this approach): Developing students' motivation to learn through applied scientific research.

- Training skills for exploration and scientific investigation.
- Develop personal skills of communication and networking
- Developing the capacity for critical analysis of the undesirable benefit-effects of applying nanotechnology.
- Acquiring knowledge about nanomaterials in general and metallic nanomaterials, especially.
- Practical training skill to use laboratory tools/devices, chemical substances
- Responsible attitude for training and applied scientific research.

Assessment strategy

1. **Formative evaluation**

- **individual and group assessment;**
- **evaluating each activity;**

Formative assessment is conducted throughout activities by:

- **systematic observation of the activity and behavior of the students (manipulation tools, laboratory equipment, chemicals, compliance with the procedure as outlined in the worksheet; the correct execution of laboratory operations; etc.)**
- **3-2-1 tehnique**
- **Practical test**
- **Self evaluation/peer evaluation**

3. **Summative assessment**

- assessment of behavior / attitude and competențeler acquired in these activities (personal, social);
- assessment of practical skills to use laboratory tools / equipment, chemicals;
- evaluating the ability to observe, to interpret experimental observations and interpret them;
- Portfolio-based assessment.
- self evaluation/ peer evaluation.

Assessment tools

Examples: worksheet assessment activity instrument, verification team skills instrument, collaboration assessment tool, evaluation tool to check presentation portfolio.

Assessment Tool activity sheet

Criteria	4	**3**	**2**	**1**
Content	I've completed correctly all the tasks I personaly performed	I've completed all tasks correctly, but I did not give a personal interpretation	I completed all the tasks, but most are wrong	I filled in some of the tasks and the majority are wrong
Language	I used a specific sciences language and know the meaning of used terms	Used a specific chemical language but did not know the meaning of all terms	I used plain language, nonspecific	The language used by me is poor
Results interpretation	We compared the results with reality and wrote the correct conclusions	We compared the results with reality	I tried to interpret the results	I did not give any interpretation

Team skills verification tool

	YES	**With help every time**	**Occasionally with help**	**NO**	**Comments**
Can fulfill most of tasks within the team					
Complete all the tasks I have in the group					
Accept others team mate ideas					
Ask questions to clarify arising issues					

Collaboration Assessment Tool

Instructions: Use this grid to assess the way you collaborate with members of the group to which you belong.

Evaluation type : Formative

Collaboration Assessment Tool

4	3	2	1
Contribution			
I always actively participate in the discussions of the group to which I belong. I always fulfill my tasks. I help setting goals and direct the group towards their achievement.	Actively participate in discussions of the group I belong to. I fulfill the assigned tasks.I help setting goals and achieving them.	Sometimes I need encouragement to perform my assigned duties. I need help for setting and reaching goals	I choose to not participate. I do not fulfill the assigned tasks. I disturb my group to achieve objectives.
Cooperation			
I share many ideas and I contribute with relevant information to the subject; I encourage the other members to express their ideas	I share ideas when requested and allow others to do so.	Cooperation I occasionally share ideas when requested, and also allow most members to do so	I don't like sharing ideas. I don't participate in group disscutions. I often interrupt the discussions.
Active listening			
Alternate hearing speech. I am always concerned about the ideas and feelings of others.	I can listen to others I look receptivity to the ideas and feelings of others.	Sometimes I listen to others. Sometimes take into account the ideas and feelings of others.	I don't listen to others I don't consider the ideas and feelings of others.
Problems solving			
I am actively involved in groups to solve problems Help the group to take wise decisions.	I offer suggestions for problems solving. Help the group to make decisions.	I offer suggestions for problems solving. Help the group to make decisions.	I choose to not participate in solving problems and making decisions

Assessment tool to check presentation portfolio

Yes/No	DESIGN
	Is the information from the presentation easy to understand?
	Is the sequencing information and section from the presentation clear and logic?

Yes/No	CONTENT
	The concept/ followed process is approaced/explained scientifically correct?
	Are the results explained using appropriate terminology?

Yes/No	SCIENTIFIC METHOD
	Did it was established the experimental procedure to be followed?
	Did it was identified: the equipment, toos and necessary materials?
	Did the experimental work was conducted?
	Did it represent the data?
	Did the data was interpreted and did it established the conclusions ?

Yes/No	COMMUNICATION
	Are the ideas effectively communicated?
	Are the results discussed?
	Is the text creative and engaging
	Is the bibliography properly quoted?

Feed-back questionnaire

Dear students!

Thank you for your participation, we invite you to answer a few questions about the impact this had on your activity.

1. Do you consider that the steps to specific research and responsible innovation should be included explicitly in the lessons context of Science(Chemistry, Physics, Biology)?

Very much	Largely	In moderately	To a small extent	In a very small extent

2. Appreciate the activity that you attended today was interesting for you?

Very much	Largely	In moderately	To a small extent	In a very small extent

3. Do you consider that the experiments were interesting for you

Very much	Largely	In moderately	To a small extent	In a very small extent

4. Do you wish to attend to this kind of activities again?

Very much	Largely	In moderately	To a small extent	In a very small extent

5. Today we learned about.....

.....

6. I like it more when .....

.....

7. I would like to know more about .....

.....

.....

8. In today's activities were discussed related items:

RRI principles	Da	Nu
Involvement - highlighting the role of all social actors (researchers, teachers, students etc.) in research and responsible innovation process		
Gender equality – ensure optimal representativeness of women (students, researchers and teachers) in research and innovation.		
Science education – handling students with a set of knowledge and skills necessary for responsible participation in the research and innovation.		
Accessibility - ensuring transparency and open access to research results and innovation in order to boost their capitalization and adequate social level.		
Ethics - respecting and valuing ethical principles in research and innovation process.		
Governance - students must realise the role that policymakers have in terms of prevention / combating of research and innovation efforts that disregard ethical principles and bring social harm.		

RRI Principles

Any steps of research and innovation must be done in the context of ownership by the researcher of social and individual responsibilities.

This means that research and innovation must comply a number of principles of social ethics, be beneficial to society as a whole and for every individual, to consider the benefit versus risk ratio, contribute to human progress, to subordinate the positive goals ect .

The RRI specific principles aim:

1. *Involvement* - highlighting the role of all social actors (researchers, business people, the concept of social policy, civil society, etc.) in the responsible process of research and innovation

Man was and always will be interested and curious to discover and understand better the environment in which it operates. Through this curiosity and openness to the research and development, the student is constantly adding new facets of what he creates to better cover the priority needs.

2. *Gender equality* – ensure optimal representativeness of women in research and innovation activities.

In our teaching way we must treat correctly/ fair the colleagues around us (employees, partners, colleagues, clients, etc.) to prove tolerance, sensitivity to the problems of those around us (especially for girls) and admit when we are the problem and not others, to avoid negative discrimination, prejudice, negative stereotypes, labelling and even potential conflicts, through a process of awareness of these issues that might arise, to respect and strengthen the dignity of those around us, increasing feminine participation in research, gender balance in decision-making, gender mainstreaming in research and innovation

3. *Science education* - handling students with a set of knowledge and skills necessary for responsible participation in the research and innovation process.

The conduct of thorough scientific investigation related to planning strategies and work stages, which requires knowledge of techniques and working methods; determine research objectives; identify problems and research trends; research group dynamics and flexibility; the behaviour of the students involved in research. The created product is the result of creative activity; the creative person being the subject he creates and investigates new; the creative process is a process of cognitive science research that meets the requirements and standards for education.

4. *Accessibility* - ensuring transparency and open access to research results and innovation in order to boost their capitalization and adequate social level.

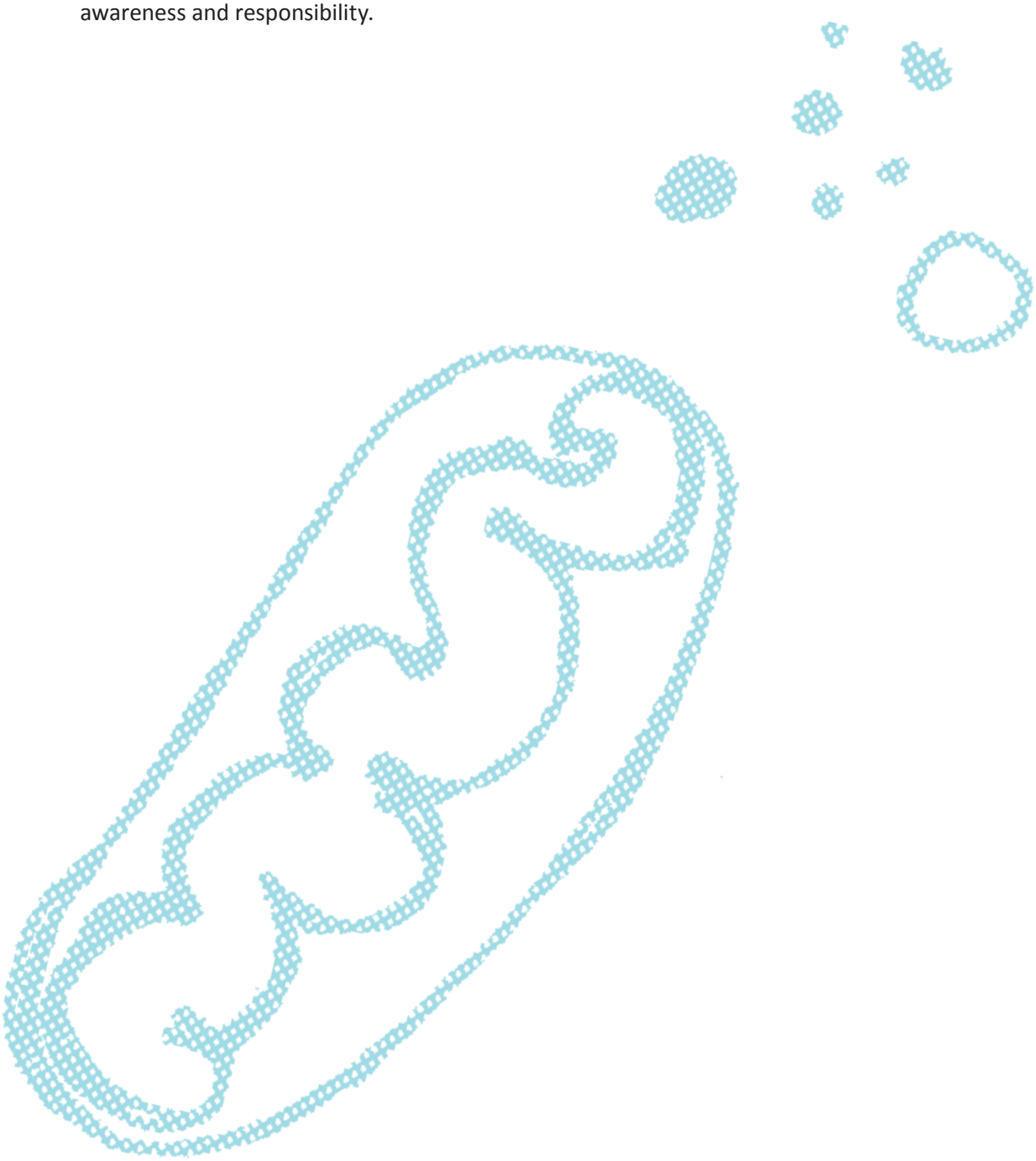
It cannot start an innovative process ignoring the fact that the result should be perceived and understood easily by those who are interested and must lead to something better than what exists now and that should be easy to apply.

5. *Ethics* - respecting and valuing ethical principles in the research and innovation.

Honesty of the student researcher for oneself and for others colleagues is a basic ethical principle, for a good conduct in the scientific research. Dishonesty can lead to a wrong image and mutual trust can alter students. Cooperation and collegiality in interdisciplinary scientific research groups represents protection against fraud and errors, ensuring transparency of the

results.

6. *Governance* - awareness of the role that policymakers have regarding prevention / combating of research and innovation efforts that disregard ethical principles and bring social harm. The government can fund research into the benefits and risks of using nanoparticles, protect citizens from the risks that they might have on their health, promote any innovation that can provide progress of the nation, to effectively facilitate cooperation between scientists and society to attract and select new scientific talent and harmonize scientific excellence with social awareness and responsibility.



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4 Sources

Sources

- Image1 (pag. 2) - Image source: https://en.wikipedia.org/wiki/Nanoart
- Image 2 (pag. 37) - Image credit: Horia Varlan, https://www.flickr.com/photos/horiavarlan/4273225057
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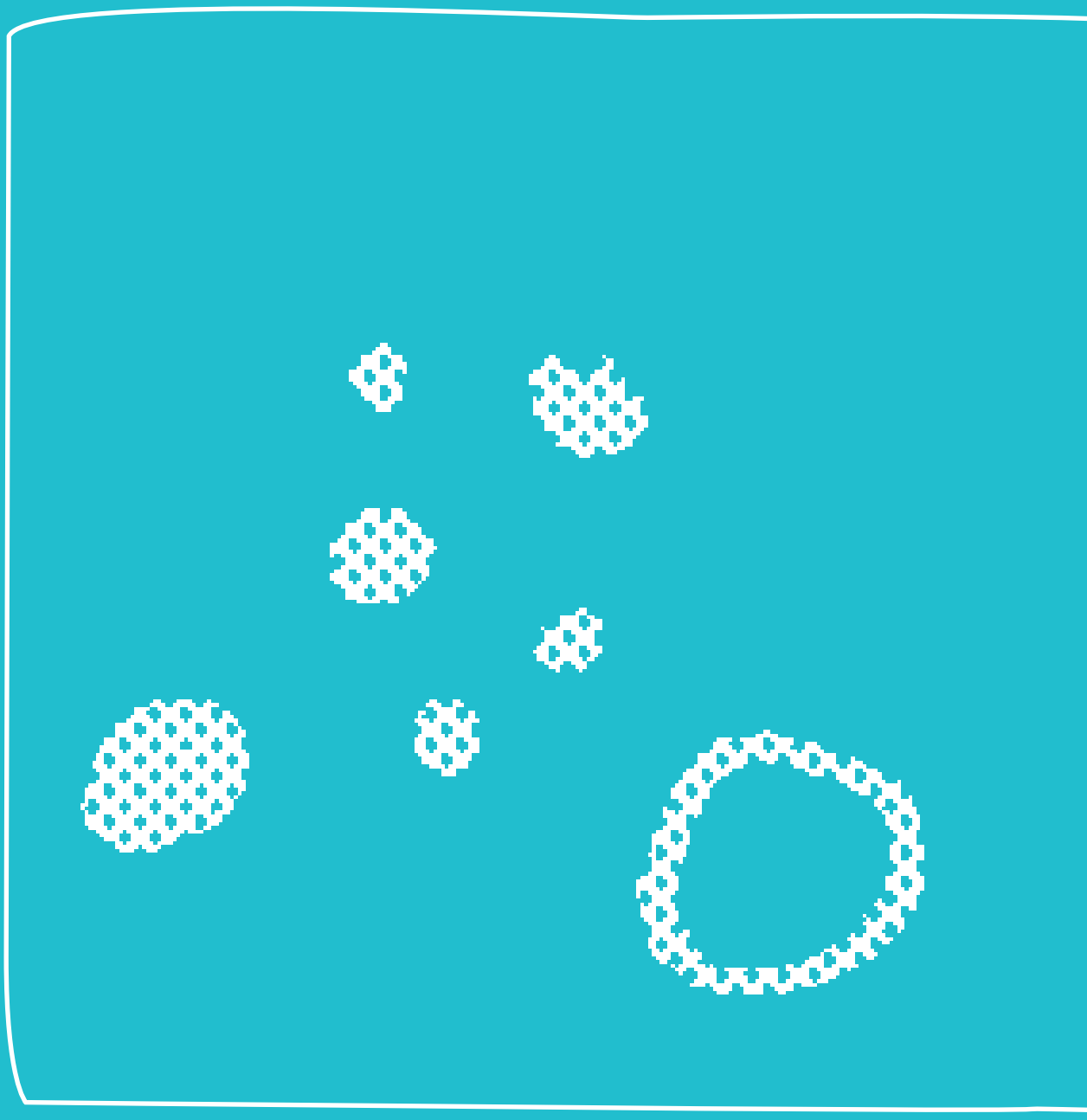
5 Colophon

Colophon

IRRESISTIBLE is a project on teacher training, combining formal and informal learning focused on Responsible Research and Innovation. It is a coordination and support action under FP7-SCIENCE-IN-SOCIETY-2013-1, ACTIVITY 5.2.2 Young people and science: Topic SiS.2013.2.2.1-1 Raising youth awareness to Responsible Research and Innovation through Inquiry Based Science Education. The project IRRESISTIBLE is funded by the EU as FP-7 project number 612367

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