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Magnetic Liquids Technology – Ferrofluids

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Universitatea Valahia din Targoviste

Magnetic Liquids Technology - Ferrofluids

An educational module for phisics 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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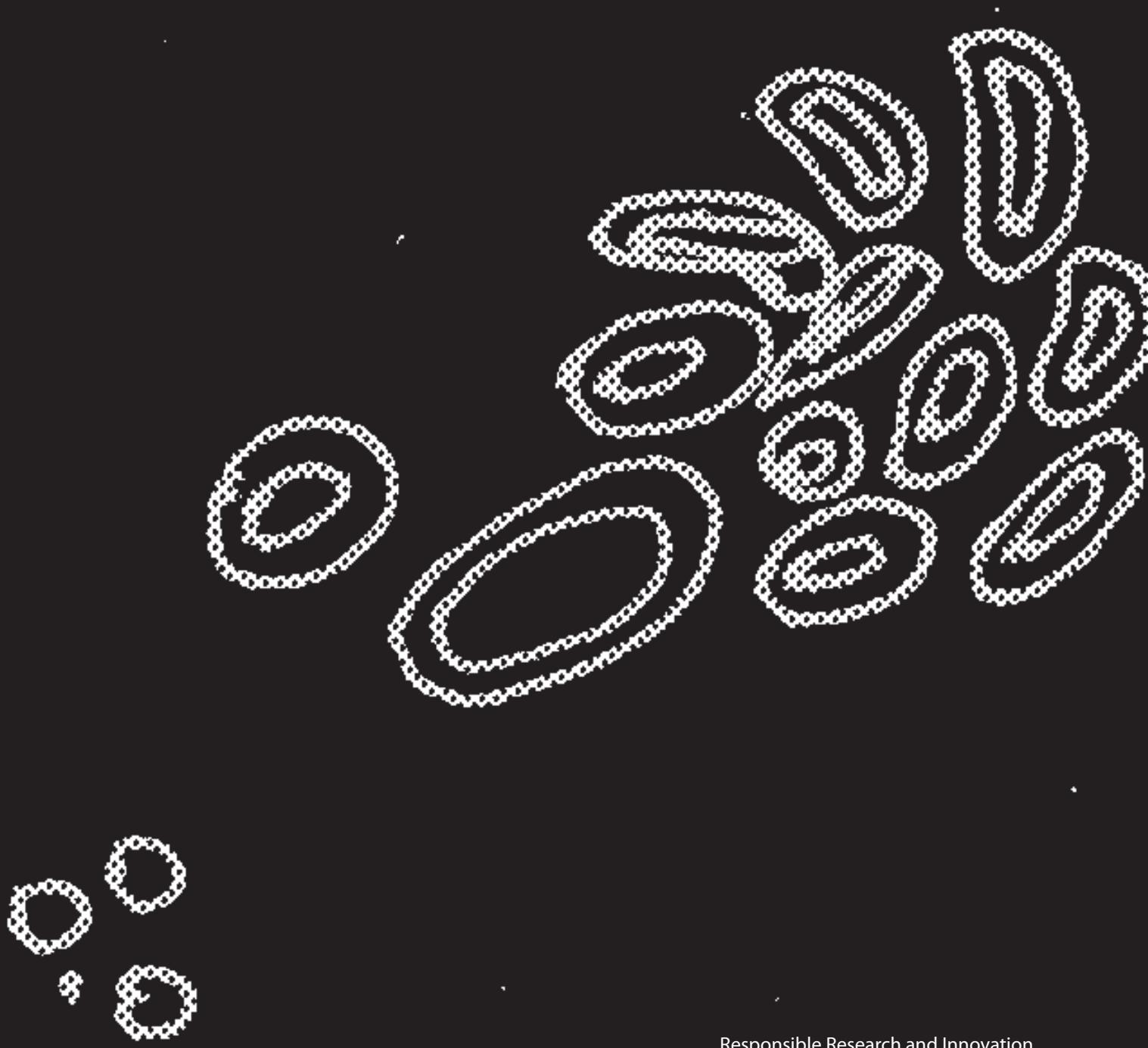


1 Overview

Magnetic Liquids Technology - Ferrofluids

Ferrofluids, known as magnetic fluids or magnetic nanofluids is a special class of nanomaterials that brings together both the properties of ordinary liquid and magnetic properties. These are fluids composed of ferromagnetic colloidal particles, ferrimagnetic or paramagnetic, dispersed in a liquid. In the last decade of this century ferrofluids have increasingly more applications.

The purpose of this activity we will continue to make it known teams of students following scientifically relevant: the concept of nanoparticle, the nanoparticle exceptional properties and areas of application. These properties can be used in medicine.

The organization of the work needs that students have knowledge about magnets, magnetic field and magnetic materials. The experimental activities will help them understand the unusual behavior of very fine particles dispersed in the liquid. To perform demonstrations ferrofluid used containers made in research laboratories. It asks the students assumptions about the unusual behavior of fluids that do not flow in a manner known magnetic field, on the contrary, wet vessel walls is located. In successive steps, discuss the properties of fluids which are dispersed particles of increasingly smaller. Students have the opportunity to discover which is when they fail to get ferrofluid. Further, students are asked to find applications and even to check the lab. Very important it is that activities are organized through guided discovery method for students to actively participate in the debate, arguing for or against their

claims. Student groups can receive or investigate a problem to be solved in the community (pollution, diseases, removal of impurities that can be solved using magnetic particles or ferrofluids). Problems are resolved by group discussion with proposals for alternative solutions and motivating the choice of the final solution.

The method used to obtain ferrofluids is simple and requires only a powder with different particle sizes, which can be obtained commercially or by successive grinding processes.

Overview

Grade/Educational level	VIII - lower secondary, upper secondary X-XII (some activities- dedicated exclusively to this level are marked with an asterisk*)
School subject	Physics
Learning unit	Magnetic phenomena
Module theme(s)	**Ferrofluids technology**
Specific competences	1. identifying the defining characteristics of natural systems found in nature; 2. description of magnetic phenomena; 3. identifying practical opportunities for the application of theoretical knowledge in the field of magnetism; 4. comparing phenomena and physical characteristics of the phenomena of magnetism; 5. analysis of causal relations existing in conducting physical phenomena in the magnetism; 6. application of knowledge acquired through the study of physics in the development and study of the ferrofluid properties; 7. presentation, written or oral form, the results of a scientific investigation approach, using the terminology of physics; 8. argumentation of advantages and disadvantages of current and future technologies for the environment.

Derived competences		1.1.finding specific information on the web sites proposed; 2.1. characterization of magnetic interactions and effects of the magnetic field; 3.1. analyzing pros and cons of using nanotechnology, namely those based ferrofluid; 4.1. classifying substances according to their magnetic properties 5.1 Selected analyze information in relation to the proposed questions; 5.2. the decision for or against (individual and group) on use of nanotechnologies; 6.1. obtaining, by experiment, a given amount of ferrofluid; 6.2. determine the physical properties of ferrofluid obtained experimentally (behavior in magnetic field); 7.1. an exchange of views about the right to work, the right to a healthy environment, the right to life and physical integrity, as well as the right to exercise an economic activity in a democratic society; 7.2. publishing a report showing individual decisions and arguments related; 7.3. presentation made to the collective decisions of students in class, 8.1. analyzing the consequences of the use of nanotechnology for society and environmental quality; 8.2 optimal decisions about the use of nanotechnologies.
Required preconditions		Knowledge, skills and abilities related to: magnets, magnetic field, materials with magnetic properties, magnetic fluids, nanoparticles and nanotechnologies
Procedural resources (teaching strategy)	Teaching-methods and procedures	SERC method (Structured Academic Controversy) deliberation, conversation, explanation, observation, exercise, case study
	Educational means	computer, projector, flipchart, text support
	Forms of activity organization	Frontal, in groups of 5 students, individual
Estimated time		4 lessons / extracurricular activities

Short Theoretical Background

Nanoparticles and Nanotechnologies

The nanoparticles have a size between 0.1 and 100 nanometers. How small is a nanometer? Well is one meter divided by one billion. This dimension is hard to imagine. Nanometers But if we zoom in we make as a small pin, then a meter would become a thousand kilometers. For comparison, a DNA molecule having two nanometers in diameter, the atoms are between 0.1 and 0.2 nanometers, and a red blood cell has a diameter of 7,000 nanometers.

Nanotechnology is the science of working to achieve atomic objects. The raw material is made up of atoms and even, in certain ways, they are "forced" to form groups that give special properties of materials. Then, realizing mechanical structures of molecules can be obtained nanorobot created, capable of performing certain tasks on a schedule.

Nanotechnology, shortened to "nanotech", is the study of the control of matter on the molecular scale. In general, Nanotechnology is concerned with the size of the structures 100 nanometers or less, and involves equipment or devices in which size is under development. Nanotechnology is very diverse, from new extensions of physics - conventional device - to completely new approaches based on molecular self-assembly, to developing new materials with dimensions on the nanoscale, even to speculation - whether we can directly control matter at the scale Atomic.

Materials with magnetic properties. Magnetic fluids.

Ferromagnetic Nanoparticles are a colloidal fluid is a mixture consisting mainly of magnetite nanoparticles and a carrier solution. Interest on magnetically fluids first appeared in the years 1960 -1970 at NASA, about the necessity of handling liquid fuel missile under conditions of weightlessness.

Magnetic fluids called ferrofluid magnetic liquids or colloidal suspensions are defined as very stable ultra fine particles (<10 nm), and keep ferromagnetic materials in liquid media such as hydrocarbons, esters, etc.

Definition

Ferrofluids, known as magnetic fluids or magnetic nanofluids, is a special class of nanomaterials that brings together both the properties of liquid and magnetic properties as usual. These are fluids composed of ferromagnetic colloidal particles, ferrimagnetic or paramagnetic suspended in a carrier liquid. The number of particles is very large, about 1023 particles per cubic meter.

First ferrofluid

Ferrofluids were discovered in 1960 at the NASA Research Center, where researchers were interested in methods for controlling fluids in space, namely to achieve a fuel system controlled fluid flow in conditions of weightlessness. Ferrofluids was immediately evident advantage: they can be controlled by applying a varying magnetic field and this will force fluids to flow.

The researchers prepared ferrofluid particles containing small ferromagnetic metal (cobalt and iron) and magnetic compounds that $Zn_x\ Mn_{1-x}\ Fe_2O_4$ (0 <x <1). But most ferrofluids that they were used was tiny particles of magnetite in composition - Fe_3O_4 .

Features: Representation and types

Magnetic fluids are colloidal suspensions ultrastables, consisting of a base liquid and magnetic particles (nano-particles) ferro or ferrimagnetic. Due to the small size and high concentration of the order of 1018 -1023 particles/m3, the Brownian motion is very important and has a role in maintaining stability in colloidal suspension and transmission magnetic force inside the magnetic fluid when it is placed in an external magnetic field.

The advantages of magnetic fluid were seen immediately: the location of the liquid may be precisely controlled by applying a magnetic field and by varying the field intensity, forced fluids could flow. Researchers obtained the ferrofluid comprising small particles of ferromagnetic metals such as cobalt and iron, and magnetic compounds, such as manganese zinc ferrite. However, the best results were obtained Ferrofluids containing small particles of magnetite, Fe_3O_4.

Magnetic fluids are a unique class of liquids, which can be induced substantial magnetic forces that can lead to a radical change of behavior of liquid when a magnetic field acts on him. The measurement of the magnetization of the ferrofluids, combined with the knowledge of the particle size distribution obtained by electron microscopy, ferrofluids allow comparison of their magnetic behavior with the superparamagnetism theory.

Electron microscopy measurements made on different types of magnetic particles of colloidal suspensions indicates the physical diameter of 9 nm environment.

The main types of materials meet both the magnetic properties and the fluid - smart magnetizable nanofluids - is:

- Magnetic Liquids (ferrofluid magnetic fluids);
- Magnetically emulsions;
- Magnetic Liquids (ferrofluid) "reverse";
- Magnetic Fluids polymerized.

Magnetic fluids have the following components: magnetic particles (PM) feri- or ferromagnetic (Fe_3O_4 , γ-Fe_2O_3 , $CoFe_2O_4$, Co, Fe, etc.), base liquid (LB) and one or more stabilizers (S). In principle, the base fluid may be any fluid, including metal.

The magnetizable emulsions are made by ultrafine dispersing of a magnetic liquid in an immiscible non-magnetic fluid.

Reverse magnetic or magneto composites liquids are obtained by dispersing solid particles of micron-sized non-magnetic, insulating or electrically, in a magnetic liquid, which is considered as a base liquid quasi homogeneous magnetized.

Magnetic fluids a based on organic substance, initially as liquid (monomer). By polymerization are obtained magnetizable monopolymers. If the liquid phase is added and dispersed non-magnetic inclusions - microspheres or microfibres – it obtained magnetizable nano/micro composites.

Methods used in the preparation of magnetic fluids

Usual, the methods for the preparation of magnetic fluids are related to methods for the preparation of very small ferromagnetic particles to be dispersed in a base liquid, and at the same time stabilized. There are physical, chemical and magnetically fluid preparation methods.

Schematic representation of a magnetic fluid on the three scales specific size

a) On a macroscopic scale, magnetic fluid is like a liquid used to.

b) On the size scale colloidal magnetic fluid consists of small solid particles dispersed in a solvent.

c) Each particle is formed of a core of a material with magnetic properties, the molecular chains having the surface coated with the stabilizer.

Given the basic component of magnetic fluids, magnetic nanoparticles, they fall into a broad category of smart nanoparticles, respectively peak in nanoscience, nanotechnology. A schematic representation of a ferrofluid three specific length scales is given in figure 1.

Application areas of nanotechnology-based ferrofluid

Magnetic fluids have found applications in many areas; they are an essential component of many modern industrial devices and technologies being used in electrical, geophysical, technical space, nuclear energy, mineral processing, medicine and biology.

Magnetic fluids are used: biology, primarily in human and veterinary medicine in biotechnology (gene transfer) and vegetable in the determination of changes in the organelles, chromosomes and the growth rate of plants.

Some applications biocompatible magnetic liquids, which have attracted particular attention include:

• Bioseparation techniques for the purification of biological materials;

• Identification techniques of organisms or cells; a new method based on magnetic field concentration was develop to identify TB bacteria, using magnetic fluids. This method proved more sensitivity than other methods previously used. This is explained by the existence inside Koch bacillus of magnetical particles which make magnetic nanoparticles to adhere on its surface;

• Regeneration techniques of tissues;

• Using magnetic liquids as prepared or X-ray contrast agent;

• Directing by the magnetic field to a target of medications using as courier substances with reduced toxicity;

• Growth antitumor effect of hyperthermia and tumor delimitation, based on contrast property of X-rays;

• Applications in the plant (researches on magnetic fluids in this area were initiated for the first time worldwide at the Technical University of Timisoara, in cooperation with the Banat University of Agricultural Sciences);

• Research in tumor therapy (chemotherapy and radiotherapy locoregional hyperthermia intratumoral embolization of blood vessels);

• Magnetic bioseparation in liquid medium;

• Detection of rare cells, subcellular components, biologically active compounds, pathogens, xenobiotics carcinogenic etc. ;

• Contrast agents in magnetic resonance imaging;

• Embolization of blood vessels in therapy.

Ferrofluids are very important in organic systems with magnetic properties.

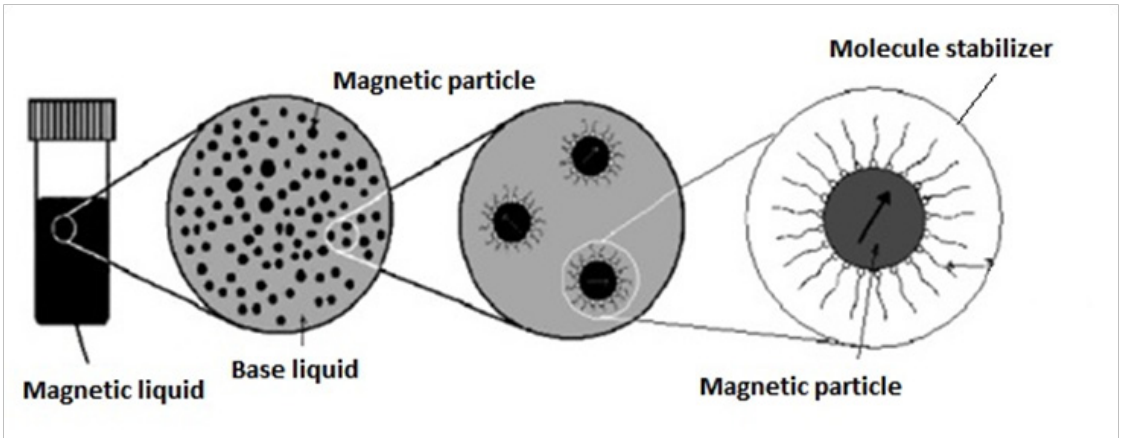


figure 1

A schematic representation of a ferrofluid three specific length scales

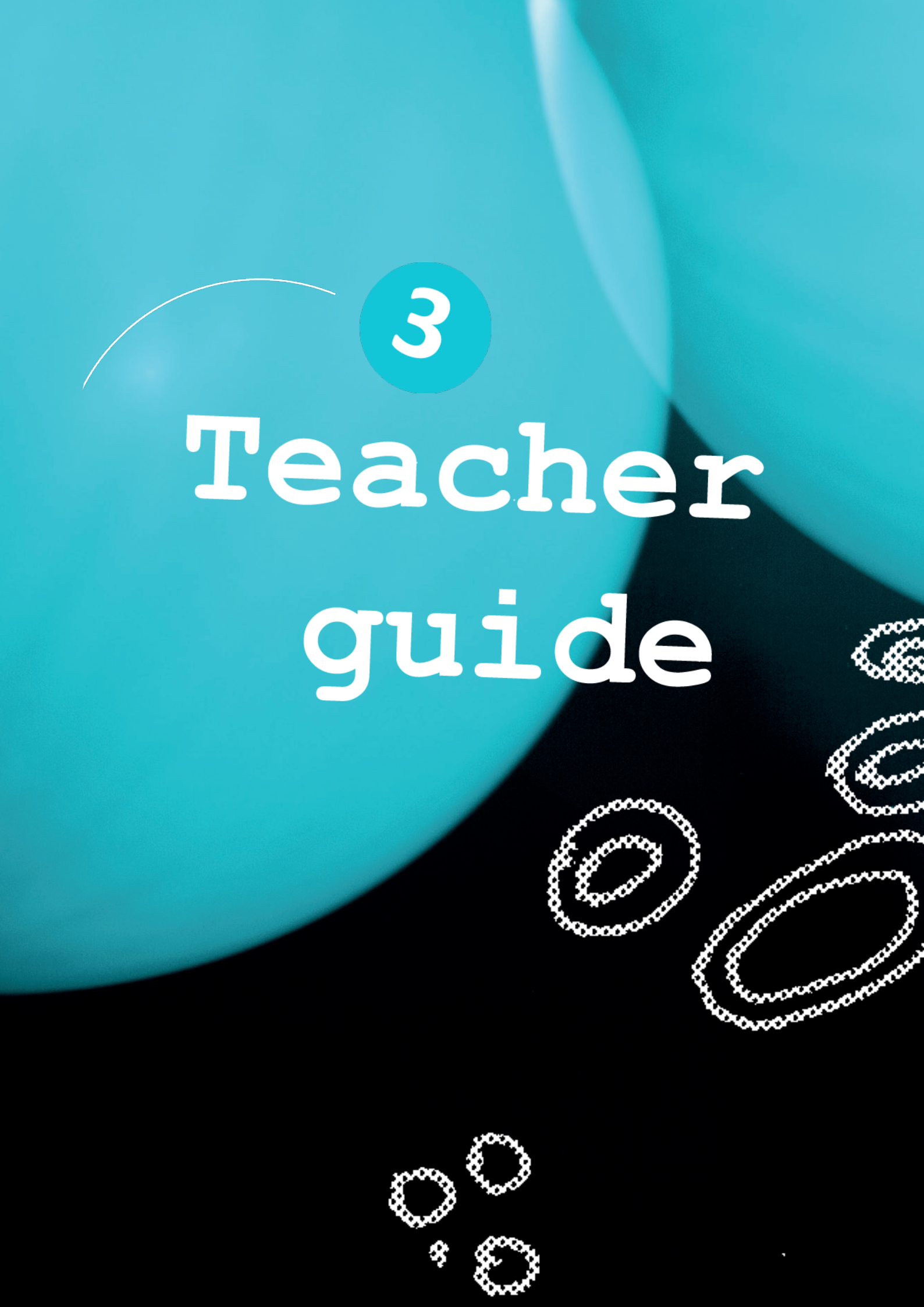
Educational scenario

Steps of teaching approach/time management	Derived competences (codes)	Teacher activity	Learning activities**
1. Engage	1.1., 3.1., 5.1.	- Keep the investigation of a situation in real life; - Formulation of hypothesis, planning investigations; - creating teams; - Specifying websites for research: a. collecting and organizing information; b. interpretation of final results * Creating a blog of each Expert Committees	- Generate a list of such rapid technological progress and record them on the board; -Talk about how new technologies affect individual personality, moving to our privacy; - Mentioning both positive and negative consequences of technology and record them on the board.
2. Explore	1.1., 3.1., 7.1.	- Presentation of deliberation question - Presentation of text support with information about nanoparticles, nanotechnology and ferrofluid	- Thinking to Problems arising from the point of view of the expert group it represents. - Plenary reflections on: a. defining the problem to be investigated b. the definition of an action plan -Students Identify stakeholders, establish relevant facts, identify unanswered questions, determine the values of each stakeholder, and consider possible solutions, - Defining the concept of "ethics for students", emphasizing the idea of morality.5 -to short of those fundamental rights provided in the Constitution can be violated or compliance with which may conflict with others
3. Explain	1.1., 3.1., 5.1., 7.2., 8.1.	Drafting Individual Report	Each member of the group - by role assumed - will draw up a report (maximum one A4 page) in summarizing their opinions (expert) as regards the suitability of nanotechnologies

Learning activities**	Educational strategy			Evaluation
	Teaching methods and procedures	Means of education	Forms of organisation	
- Increase student interest to real life problems;	Conversation	marker, board, computer	frontal, in groups of 5 members	oral assessment
- Stimulate students' desire to deepen understanding of the current problems of society; - student answers regarding the stages covered	Conversation	marker, board	frontal, in groups of 5 members	oral assessment
- Increasing student interest regarding principles of democracy; - Expressing their opinion by each student	Conversation	marker, board	frontal, in groups of 5 members	oral assessment

4. Elaborate	2.1., 3.1., 4.1., 6.1., 6.2., 8.2	- students will prepare a given amount of ferrofluid; - students will sharing individual findings and arguments; - students will make a report on that group presents the arguments related decisions	- Physicist and chemist teams made a specified ferrofluid quantity; - Presenting arguments of each student from the group; -Each Committee investigating the implications of magnetic applications of ferrofluids; -Students deliberate by SERC method.
5. Disseminate / Share / Present / Expose	2.1., 4.1., 5.2., 7.1., 7.3., 8.1., 8.2.	- students present their final decision on the proposed question; - students present the final product - film, poster, PowerPoint presentation, collage, drawing (homework)	- Expert Comities state the final position of the group, supported by the strongest argument FOR/AGAINST -Students working on the final product and a collective report, which reflects the position of the expert group -Each Committee present to their colleagues through a chosen student the final decision, which will be in the final product.
6. Evaluate	3.1., 7.1., 8.1.	- students answering questions expressing personal opinions; - students fill the questionnaires	- Students answer the teacher's questions; - Students fill the questionnaire (Appendix 2)

Individual report which give the idea about the acquisition by students of skills and abilities needed to act as citizens; - Expressing their opinion by each student; by enunciating each student's own argument.	- Structured Academic Controversy (SERC) - conversation	post-it, flipchart, marker	frontal, in groups of 5 members	oral assessment, evaluation of practical activity
-The final product of the group and the group's argument position; - presentation of these views to representatives of public institutions;	conversation, explanation, exposure	flipchart, markers, laptop &projector	frontal, in groups of 5 members	oral assessment, products assessment
- Training young people in order to express their views on civic issues; - Participation in debriefing of most of the students; - SWOT analysis.	conversation, explanation, demonstration	flipchart, markers	- frontal	- Oral and written assessment; - evaluation of reflection form given as homework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Teacher guide

Teacher guide

Note: The teacher will distribute students contents of the 4 scenarios (Nano Labels, Nano Health, Nano Environment and Nano Journey) before the start of the lesson one.

Learning results

The aim is to achieve such objectives, which although not specific sciences, contributing to the training of young people as unique personalities, able to discern and make informed choices.

- To increase student interest to civic problems and principles of democracy;
- List of technological advances;
- Training young people in order to express their views on civic issues;
- Participation in debriefing most students;
- SWOT analysis business;
- The end product of the group and the group's argument position;
- Presenting these views to representatives of public institutions;
- The acquisition by students of skills and abilities needed to act as citizens;
- Expressing their opinion by each student;
- Assertion by each student's own argument;
- Stimulate students' desire to deepen understanding of the current problems of society;
- Student responses about the stages
- Increased self confidence of students and willingness to engage in discussion of civic issues.

Learning activities

1. It will make groups of 5 students (Comities);
2. Accessing websites dedicated to collecting information.
3. Each member of the group – depending on its assumed role - will draw up a report (maximum 3 A4 pages) that abstracts own opinion (the expert) in terms of opportunity to use nanotechnologies;
4. After discussing the arguments presented by members of the group, it:

a) publish a joint report justifying the final decision regarding the suitability of nanotechnologies;
b) choose the optimal mode of presentation of justification (film, poster, PowerPoint presentation, collage, drawing, etc.).

5. Conclusions made by different groups of students will be presented and discussed with the entire class.

Learning tasks

In order to evaluate the impact of various nanotechnologies on society itself, constitute committees on areas consisting of five experts: 1) scientists; 2) doctors; 3) biologists; 4) The humanists; 5) businessman; 6) Government representatives. These Committees shall decide on the appropriateness and effectiveness of the use of nanotechnologies.

Each Committee will issue a collective report on how nanotechnologies affect society, about their advantages and disadvantages from the perspective physicist, chemist, doctor, biologist, humanist, the businessman and the representative of the government.

As mentioned, each Committee of Experts must assume a different role. Following are some suggested questions awaiting response:

- *Doctors* - How will influence the use of nanotechnologies the health state of individuals and what measures need to be taken in regard to working with ferrofluids? What are the cautions needed when work with ferrofluids? It can be used in medicine?
- *Biologists* - What are the positive and negative aspects of nanotechnologies on the biosphere? In particular, what environment problems can generate using of ferrofluids and what applications can have?
- *Physicists and chemists* - What are nanoparticles? What is nanotechnology? What is a ferrofluid? How to produce ferrofluids? What are the cautions for their production and safely use? What are their properties?
- *Humanists* - What were, over time, the positive and the negative consequences in using the new technologies? Do you consider as ethical creating the new materials and rearranging matter? How will change the society through the use of nanotechnology for tracking peoples, animals and materials around the world?5
- *Businessman* - What business opportunities do you identified regarding ferrofluid applications?
- *Government Representatives* - analyze the legal aspects of using nanotechnologies, development opportunities created by their use and the eventual financing of research in the field.

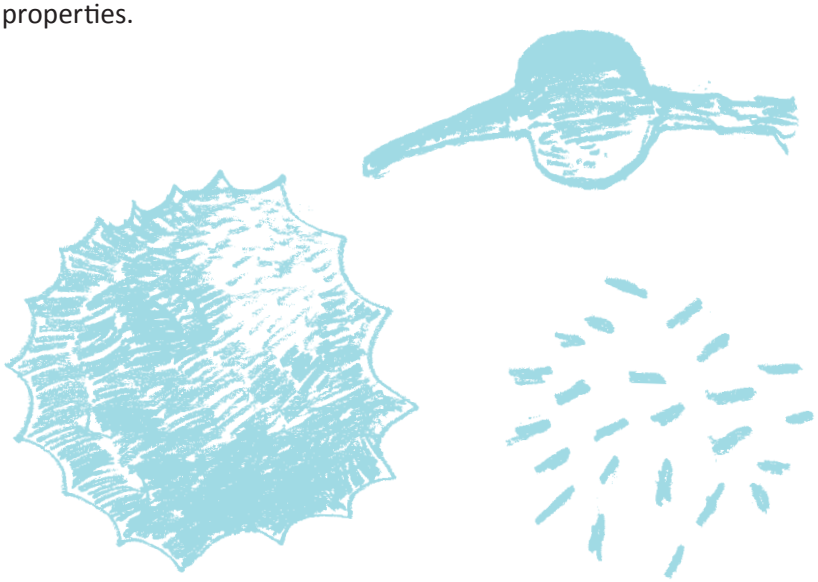
Teaching and learning strategies

Procedural resources:

- Methods and procedures: SERC Method (Academic Controversy Structured), deliberation, conversation, explanation, observation, exercise;
- Means of organization: 5 groups, frontal, individual;

Material resources: computer, projector, flipchart, text support.

For learning activities proposed in the teaching, it is assumed that students have the knowledge, skills and abilities related to: magnets, chemistry, magnetic field and materials with magnetic properties.



3.1. Lesson 1

Moment 1: Investigation of real-life situations. (10 min)

Teacher:

- Ask students to mention significant technological breakthroughs of the history.
- Using the above answers, ask students an answer to the following question: How and which of these technologies have changed people's living?
- "Already we live in a world where our food selections are monitored by grocery stores, our cars are tracked on highways, with video monitors, where electronic keys are coded so that our employers know when we enter and leave the building, our conversations are monitored and our movements are tracked even in shops."
- Continue discussion, asking students to think on the following:

1. How does this electronic surveillance make our lives safer?

2. Are there places or times when such monitoring is not in our interest, but serving someone else to make money?

Moment 2: hypotheses (10 min)

Teacher:

- Ask students to think on the advantages and disadvantages of this new technologies, as results from the following 4 scenarios;
- Ask them to decide the following:

1. What aspects of our society are affected by these new nanoscale technologies?
2. Who is affected by the use of these?
3. Who wins and who loses if these technologies are used?
4. Who should decide if the technology is used or not?

Moment 3: Planning investigations (30 min)

- Divide students into groups of five students representing committees of experts in certain areas. In order to assess the impact of nanotechnologies on society itself, constitute Committees, formed by five experts: 1) physicists and chemists; 2) doctors; 3) biologists; 4) The humanists (psychologists, sociologists, historians); 5) businessman; 6) Government representatives.
- Each group will have a list of questions to which they will have to respond.

3.2. Lesson 2

Moment 1: Introducing the Deliberation Question (10 min)
Professor launches question for deliberation, writing on the blackboard content:
"It is appropriate use of nanotechnologies, especially those based ferrofluid?"

- Provides text support with information about nanoparticles, nanotechnologies and ferrofluids;

Comment: "Information about the new applications of nanotechnologies appear almost daily in the media and these new products; this can be a start in discussions about ethics and intimacy."

- Students are asked to tell their definition of ethics and intimacy;
- Encourage students to think about "shades of gray" which may influence our decisions to use the new technologies.

Comment: "For example, if technology allows tracking of people might not want to monitor the movement of all visitors to our country, but we might want to monitor a patient with Alzheimer's disease."

- Q: What responsibility we have as citizens to participate in making decisions on the use of new technologies?

Moment 2: Drafting the Report Individual (40 min)
Teacher:

- Each member of the group – depending on its role - will draw up a report (maximum one A4 page) summary in which its opinions (as expert) on using the nanotechnologies, by answering to these questions:

Doctors - How will influence the use of nanotechnologies the health state of individuals and what measures need to be taken in regard to working with ferrofluids? What applications of ferrofluids can be used in medicine?
Biologists - What are the positive and negative aspects of the nanotechnologies in the biosphere field? In particular, what are the environmental issues that you can appear using ferrofluids? What are the useful ways to use them?
Physicists and chemists: - What are nanoparticles? What is nanotechnology? What is a ferrofluid? How to produce ferrofluids? What are the relevant measures to be taken in regarding production and use of its safety? What are the properties of ferrofluids?
Humanists - What were, over time, the positive and the negative consequences in using the new technologies? Do you consider as ethical creating the new materials and rearranging matter? How will change the society through the use of nanotechnology for tracking peoples, animals and materials around the world?5
Businessman - What business opportunities do you identified regarding ferrofluid applications?
Government Representatives - analyze the legal aspects of using nanotechnologies, development opportunities created by their use and the eventual financing of research in the field.

3.3. Lesson 3

Moment 1: Analysis of the individual reports in expert groups and experimental activities (30 min)

- Each Committee will publish a report on how nanotechnologies affect society, about their advantages and disadvantages from the perspective expert;
- Discussions in every of each expert group of arguments presented by each group member.

Note: physicists and chemists Committee is divided into two groups; one of the two groups will work deliberation, the other will carry out experimental work, which involves creating a quantity of ferrofluid and determine its magnetic properties;

Moment 2: Making of Group Report (20 min)

- Creating a joint report which justify the a final decision on the nanotechnologies;
- The choice of a way to present a final conclusion: movie, poster, PowerPoint presentation, collage, drawing, etc. (as homework). This will refer to the most powerful argument which supporting the decision of the Committee of Experts.

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

Moment 1: Presentation of group reports and the decision of each Committee of Experts, based on the final product (30 min)

- Opinion of the Committee of Experts on final product will be presented and discussed in class.

Moment 2: The expression of personal and business assessment (10min)

Students express personal opinions about every question and answer to questions such as:

- What were the areas of agreement?
- What was new for you?
- What principles of democracy do you find in text? (the right to work, the pendix
- right to a clean environment, the right to physical integrity, the right to supply an economic activity)?
- What are the consequences of using nanotechnologies for health of the peoples, the environment and society?
- Everyone think like that? What is your opinion about the others thinking?
- What solutions were find in other countries?
- What is the connection between the lesson and my citizenship? It can affect me?
- What can I do if I will be a person with responsibilities?

Moment 3: Evaluation (10 min)

Target competences

Derived competence	Learning activities
1. 1 identification of specific information on web sites;	Generate a quick list of these technological advances and record them on the board.
2.1. characterization of magnetic interactions and effects of the magnetic field;	-Each Committee investigates the implications of ferrofluid applications
3.1. analyzing for and against of using nanotechnology, especially those based on ferrofluids;	- Discuss about how new technologies affect individual personality, moving to our privacy. - Mention both positive and negative consequences of technology and record them on the board; -Students identify interesting aspects, establish relevant facts, identify unanswered questions, establish importance of each aspect, and consider possible solutions; - Define concept of ethics;
4.1. substance classification according to their magnetic properties	- Establishing magnetic properties of the prepared ferrofluid;
5.1. The analysis of the selected information related to the proposed questions; 5.2. adopting the decision: for or against (individual and group) on use of nanotechnologies;	-Students identify interesting aspects, establish relevant facts, identify unanswered questions, determine the values of each stakeholder, and consider possible solutions; -Students deliberate by SERC method.
6.1. obtaining, experimentally, a given amount of ferrofluid; 6.2. determine the physical properties of ferrofluid obtained experimentally (behavior in magnetic field);	- Physicists and chemists team made a specified quantity of ferrofluid; - establish the magnetic properties of the preparation;

7.1. an exchange of views about the right towork, the right to a healthy environment, the right to life and physical integrity, as well as the right to exercise an economic activity in a democratic society; 7.2. publishing a report showing individual decisions and arguments related; 7.3. presentation made to the collective decisions of students in class;	- Expert Comities establish the final position of the group, supported by the strongest argument FOR/ AGAINST; - short presentations of those fundamental rights provided in the Constitution that can be violated; - Each member of the group - depending on the role chosen - will draw up a report (maximum one A4 page) in summarizing their opinions (expert) as regards the suitability of nanotechnologies; -Each Committee present colleagues through a group speaker the final decision, reflected in the final product.
8.1. analysis of the consequences on the use of nanotechnology for society and environmental quality; 8.2. Optimal decisions on the use of nanotechnologies.	-Each Committee investigates the implications magnetic applications ferrofluids; -Students working on the final product and a collective report, which reflects the position of the expert group.

3.5. Evaluation

Formative assessment of students concerns (mentioned objectives of this approach):
• Understand the terms and concepts proposed;
• The quality of information retrieval / investigations;
• Clarity enhanced disclosure;
• Participation in various stages of activity;
• Power of argument;
• Justification opinions;
• The quality of the final presentation;
• Meet the deadlines given.

Assessment strategy

Assessment is based on evaluation of four tools shown in the following tables (Tables A, B, C and D). We determined that the total score of the three assessment tools to be 90 points, distributed as follows:
- Evaluation of group work - 24 points;
- Self-assessment - 18 points;
- Communicative competence assessment - 48 points;
- Evaluation of the experiment - 18 points.
10 points is given by default. The final grade is obtained by dividing the final score to 10.

Assessment tools

Due to the theme chosen by us, we believe that a full evaluation of the efforts of students may be done using Tables A and B for classes 1, 2 and 3. Lesson 4 we consider it important to assess on the basis of Table 3, specifically designed to respect the specifics of this lesson.

Table A - Group work evaluation

Criteria	1	2	3	4
The student accept his responsibilities or roles within group	The student does not meets any of tasks for which he is responsible. These are carried out by the colleagues from the group	The student perform rarely any of the tasks for roles which he is responsible. Often he / she needs the others to remind the duties.	The student perform frequently tasks / roles for which he is responsible. The student has rarely need the others to remind the duties.	The student meets tasks / roles for which he is responsible. The student does not need for the others to remind the tasks
Leading efforts	The student presents rarely useful ideas when work in group and don't keep the work rhythm	The student contribute to the group, though, sometimes he gets distracted	The student contribute to the working group and is responsible for his duties	The student contribute to work group and stimulate his colleagues to participate. His contribution is crucial for group success.
Relationship with his group colleagues	The student shows indifference on exercising a leadership with an negative impact on the group.	The student appear interested, but he don't interfering with the dynamics of working group	The student shows Interest, keep up with the group work dynamics and bring a positive contribution	The student interact positively with others or presents leadership skills with positive impact on group operation
Decision making	The student does not try to resolve any problem or to help colleges	**The student does not presents any solution, but he is willing to try solutions presented by others.**	The student brings important contributions in order to improve solutions presented by others.	The student actively try to find solutions and presents solutions for the problem.
Time management	The student does not end tasks on time and as a result the group cam not comply deadlines.	**The student does not end tasks on time. Although the group can receive new deadlines, quality work in group is affected by his behaviour**	The student stops the completion of task, but in the end he finish in time and the group may follow the deadlines.	The student can manage his time accordingly, in order to achieve tasks on time.
Oral participation	The student does not participate or not allow others to speak.	**The student participate quite often, preventing oral participation of the others**	The student may hear his colleagues, but sometimes talks too much. He do not allow others to speak	The student can hear and speak in a balanced manner.

Table B - Self assessment

Criteria	1	2	3	4
Responsibil-ity for tasks or roles within the group	I have not done any of the roles / tasks for which I was responsible. The task was made by colleagues in my group.	I rarely do any of the tasks / roles for I was responsible. Often, the others need to remind me my tasks.	I frequently do the tasks / roles for that I was responsible. I rarely need the others to remind me my tasks	I realized tasks / roles for I was responsible. No need for anyone to remember me my tasks.
Type of personal intervention	I rarely presented useful ideas during group work. I have not kept rhythm with the working group.	I promptly contributed at group work even if sometimes I was distracted.	I contributed to the work of the group and I was responsible for my tasks.	I contributed to the group work and I stimulated participation of my colleagues. My contribution was important to have success in work group.
Relation with my classmates	I looked whether or I had a nega-tive impact on group.	I do not have interfered with my working group.	I had a positive contribution on my group.	I positively interacted with others or I used my positive leadership skills with a impact positive on my work group.
Decision making	I didn't tried to resolve any problem or my colleagues helped me.	I didn't have any kind of solution, but I was willing to try solutions presented by others.	I brought important contri-butions in order to im-prove solutions presented by others.	I actively searched to find solutions to solve all the problems.
Time management	I'm not finished my tasks timely and therefore my group could not follow deadlines.	I'm not finished my tasks at time. Although the group could still receive deadlines, the quality of group work it was affected from my behavior.	I'm not finished my tasks at the time, but I finally could finish on time and group could meet deadlines.	I have succeeded manage the time and finished my tasks on time.
Oral participation	I do not participated or I was always chatty, allowing participation of the other col-leagues.	I participated quite often, preventing them the others to participate.	I listened, but sometimes I talked too much, preventing the others to speak.	I listened and I spoke into a balanced way.

Table C - Communication competency assessment (group presentation assessment)

Criteria	1	**2**	**3**	**4**
Correctly use of scientific concepts or information.	Groups uses frequently incorrect scientific concepts or information.	Sometimes group uses incorrect scientific concepts or information.	Group use correctly scientific concepts or information.	The group presentation reveals a competent scientific or information.
Argument justification	Students cannot cover some aspects of the work. They have lack of knowledge or abilities.	Many students have poor knowledge relating to tasks content or they are not able to sustain their arguments.	Most of the students have adequate knowledge on tasks content and can sustain exposed arguments.	All students from the group have deep knowledge on tasks content and can sustain exposed arguments.
Language	They use a poor language, make grammatical and pronunciation mistakes. Presentation and the use of incorrect scientific concepts.	Some of the students do grammatical mistakes and sometimes, pronunciation of scientific concepts is incorrect.	They use a appropriate language, without grammar or pronunciation. Also, they use correct scientific concepts.	They use a rich and complex language with no mistakes spelling or pronunciation. Also, they use correct scientific concepts.
Coordination between member groups	Deficiencies in coordination between students. The presentation of the group is unstructured.	Poor coordination between students group. Some of them did not worked on group presentation.	Coordination is satisfactory. With all these, some of them have not worked with other on group presentation.	Excellent coordination between all students. Presentation is well structured and follows a consistent line.
Clarity and objectivity	Presentation has no clarity and objectivity. It doesn't highlight the most important problems.	Presentation is clear, but it lacks in objectivity. Many details are not relevant presented.	Presentation clear, but based on details not relevant.	Presentation clear and objective that highlights the most important issues.
Presentation of information	Students read information instead of exposing it.	Students read most of the information instead of exposing it.	Students expose information, but read some of the notes.	Students in the group expose all information.
Capacity to increase engagement	Poor presentation, making colleagues impossible to engage in it	Poor presentation, not always enough interesting to keep colleagues engage in it.	Some crises during presentation, but colleagues are engaged enough to continue.	Good presentation, that can keep colleagues engaged in it.

Audiovisual support	The presentation did not make use of any audiovisual element to support it, not even for main idea (images, graphics, videoclips)	The presentation have a poor audiovisual support.	The presentation has some audiovisual elements, but these are not fully explored.	The presentation use quality audiovisual elements to support the main idea (Images, graphics, videoclips).
Creativity	Total lacks in creativity regarding methodology or materials used.	There are some creative ideas in presentation and exposed ideas.	There are many creative ideas in presentation and exposed ideas.	The presentation and materials are fully of creative ideas.
Time management	Presentation not respects all time limits planned (either too short or too extensive)	Presentation expands considerably over deadlines of time planned	Presentation expands less over deadlines of time planned.	Time management is excellent
Voice tonality	Low voice, monotonous, without inflections or expressiveness	Big oscillations in voice level; lacks in expressiveness	Voice tones appropriate most of the time presentation. Shows inflection and expressiveness	Appropriate voice tone during presentation. Good coordination between voice and audiovisual support.
Using relevant information, including their own life experience	Used information is not relevant and is not related to their own life experiences.	Some information is relevant and use life experiences of the group members in some cases.	Most information is relevant and use life experiences of the group members in some cases	All information is relevant and fully use life experiences of the group members

Table D - Experiment assessment

Criteria	1	**2**	**3**
Arranging materials	The materials needed to run the experiment are incomplete and randomly arranged.	The materials needed to run the experiment are present on the work, but are randomly arranged.	All materials are present on the work and are properly arranged.
Compliance with work protocol (data collection)	Experiment stages do not follow the order of protocol.	Experiment stages are hesitant conducted, late, but fair.	All of the experiment stages are respected and using of instruments is due without hesitations.
Data processing	There are errors in data table.	The data in the table are correct, but the table is incomplete.	The table contains complete and accurate data.
Data interpretation	No conclusions after the completion of the experiment	Not found any conclusions after the completion of the experiment.	Conclusions clear, complete
Cooperation and participation in the group	He (she) refuse to cooperate.	Supports cooperation in 50% of cases.	Constantly participate and cooperate in all group actions.
Demonstration of leadership skills	She(he)'s withdrawn all the time.	Take part, but stands out as a leader.	Get involved, taking a leading role.

We intend also to quantify the group as a whole, using the following scale to describe what happened during the deliberations:

None Some Most All
1 2 3 4

1. Students spoke directly with each others._____
2. Students focused on the deliberate question._____
3. Students expressed, heard, respected, understood and analyzed different opinions ._____
4. Students asked clarification questions, if necessary ._____
5. Students had sufficient information and time to deeply understand ._____
6. Students logically used relevant information, including their life experience ._____
7. Students were involved intellectually and emotionally._____
8. Students have taken a argued decision. _____

Appendix 1. Scenarios

Scenario 1: Nano Labels

"Researchers are currently developing nano-sized barcode that can be used to label invisible almost everything is made. They are able to monitor sales by type of customer or geographical regions, signal theft and commodity stocks held by shops and warehouses. "

- What do you think about this idea to label goods produced?
- Do you care if people know what brand of underwear buy?
- What if the labels would put the bullets or explosives, the police could track and locate criminals or terrorists?
- What would be the advantages and disadvantages if you could track a food from farm to mouth?
- It would be a good idea for manufacturers to put labels on compact discs nano, so make sure CDs are legal? Thus there negative concerns of the music industry pursue music you buy?
- If we can tag and monitor the flow of money, how could this be used in ways beneficial and harmful?

Scenario 2: Nano Health

"An area under development in nanotechnology, is building sensors that can be used to monitor your health. The aim is to produce small sensors that can be injected into the blood stream, making it possible to monitor a wide range of health indicators, including the heart, blood pressure, blood sugar, cholesterol, and the presence of viruses or bacteria. "

- What are the advantages and disadvantages of using these nano-sized monitors that would be injected into your body?
- How this type of monitoring system could be useful for diabetics or people with heart problems?
- What happens if the monitor would send an alarm if you eat high-fat foods, such as sweets? Would this be a useful tool to help you track your diet?
- It would be useful to have such a monitor that could signal the protein level, if you have not eaten or you lack essential vitamins?
- There are groups of people who could benefit most from these types of monitors than other groups?
- If the monitors would be expensive, you agree to be allowed wealthy people to purchase them if they are not available to the poor?
- If a large number of monitors from different people could be networked, data could be used, defending privacy issues. What might result from this type of application?
- If you could signal a sharp increase in the number of people affected by the flu or colds, you change the view?

• Have you considered the possibility that foreign tourists be monitored to ensure that no such new diseases are not brought to our country? What would be the implication of this policy?

• Would you agree that, through remote sensors to monitor this person without their own consent?

Scenario 3: Nano Environment

"Environmental scientists can now monitor the health of the water, soil and air, using remote sensors. Researchers are now finding new ways to make these sensors smaller and smaller, with the aim of creating invisible sensors that could provide data on the health of the whole ecosystem. "

- You want to follow by sensors the levels of pollutants, pH and oxygen?
- If you could create sensor networks, how would you feel with them in the forest near you?
- But having a house full of tiny sensors that could detect motion, temperature changes and the presence of pollutants?
- You agree to release clouds of sensors that could monitor global warming?
- What do you think about tracking endangered species by placing a sensor in each animal and health monitoring its movement and its lifetime?
- You can purchase sensors that monitor house, apartment, or workplace to make sure that the air has a good quality?

Scenario 4: Nano Journey

"One idea that has been proposed is to create a smart dust could be put in paint, pavements and ceilings that could monitor the movement of people. Thus we monitor movement in shops, airports, railway stations, streets and hotels. "

- Should monitor the movement of people, widespread?
- If such monitoring would enable us to identify terrorists would be more ethical?5
- It is acceptable monitoring children as a way to keep them safe?
- If your grandfather would have Alzheimer's disease, you want to monitor to make sure that they are not in dangerous situations?
- You want this type of sensor placed in pets, so if your pet is lost or stolen, could be re-covered? (Some pet owners have already made chips, which can be detected by animal shelters, so the owner can be notified. Other pet owners use radio collars on their dogs to follow.)
- What rules / laws should be imposed to ensure security, privacy, and freedom?
- When monitoring people without their knowledge, you find acceptable?

Apendix 2: Student reflection on the activity

1. What was the most important argument FOR / AGAINST to you?

FOR	AGAINST

2. Mention a benefit that would arise from the use of nanotechnology-based ferrofluid.

3. Mentions a negative effect of using a nanotechnology-based ferrofluid.

4. Mention something that you liked in the lessons.

5. Mention something that you never liked the lessons.

6. On a scale of 1 to 10 upwards, give a note for all activities.

Apendix 3: SERC method, standard way (Structured Academic Controversy)

Step 1: Introduction

1. The teacher presents the lesson title;

2. Undergoing deliberation rules.

Step 2: Read the text

1. Each student receives a text about the theme chosen for the study (text can be offered to students and the previous time, to be read at home);

2. Students read the text individually;

3. The teacher asked them, after covering all text, share, group, interesting information / special / unusual text.

Step 3: Forming groups and discussing text

1. The class divides into groups of 4 students;

2. The teacher asks them to exchange ideas, information interesting, important, identified by each of them in the text.

Step 4: Introducing the Deliberation Question

1. It is noted that each text has a question, on which the lesson will be discussed by deliberation;

2. The question is displayed on the board or on a sheet of flip-chart and read aloud.

Step 5: Identify arguments

1. Each group is divided into two teams: A and B.

2. The A team will search the text the strongest arguments in favor of the question for deliberation; the B team will search the text the strongest arguments against the question for deliberation; teams do not communicate while identifying arguments.

Step 6: Presentation of the major arguments

A team 1. The text presents arguments supporting the question for deliberation, the team B; the latter are not allowed to express their opinion, may ask questions for clarification.

2. The B team presents arguments against Question text deliberation, the team A; the latter may ask questions for clarification, but can not say their views.

Step 7: Reversal of roles

1. The teacher explains that, to demonstrate that each side understands the other party roles must change: the A team will search the text arguments against the question for deliberation, and the B team will search the text to support arguments Deliberation question.

Step 8: Deliberations

1. Students A and B out of roles and begin to deliberate;

2. Recalls question for deliberation;

3. Each of the groups of 4 students will have to decide what position to adopt counter propionate or about the question for deliberation, for the reasons given in the text; This will be achieved through negotiations at the small group level; each student expresses views that are not required to coincide with the group's position.

Step 9: Analysis of deliberation

1. It brings together the whole class;

2. The teacher will ask many different questions on the process that took place within each group. An example of this is may be questions like: What was the most powerful argument for or against the question for deliberation? What was the position of the individual student? What were the areas of agreement / understanding? What questions still exist? Where to get information?

3. The teacher will use for open discussion, and information students have about the theme from other sources, not just from the text offered for study.

Summarizing, the steps deliberations would look like:

AAB B Read the text carefully.

(AABB) Share interesting / important text information in small groups.

(AA / BB) Plan with partner a presentation for two colleagues.

(AA-BB) Introduce two colleagues to support arguments for deliberation question.

(BB-AA) Introduce two colleagues are arguments against Deliberation Question.

(BB-AA) Introduce two colleagues to support arguments for deliberation question.

(AA-BB) Introduce two colleagues are arguments against Deliberation Question.

(AABB) Set the point of view of the group, or against the question.

AAB B Have your own point of view.

Apendix 4: Experiment form

Experiment

Theme: ferrofluids, production and determination of their properties

Name of the students, class:

1 ._____

2 ._____

3 ._____

4 ._____

5 ._____

Materials needed: toner, vegetable oil, Neodymium magnets

Procedure (http://www.youtube.com/watch?v=vsQh1AT6qUE)

1. Using a disposable medical mask, surgical gloves, gown, on a table in the chemistry lab, a student with skills for proper chemical experiments will usher in a glass a given amount of toner;

2. . In the same glass he/she will add a volume of vegetable oil approximately equal with the amount of toner introduced. He/she will stir constantly, to obtain a homogeneous liquid;

3. By means of a magnet (preferably of neodymium) it will be study the magnetic properties of the liquid and other physical properties (adhesion to the glass surface, viscosity, etc.).

4. He/she will record experimental findings and observations on possible experimental problems encountered;

5. Teacher can suggest other safety measures, other than those mentioned, depending on local lab conditions.

4 Sources

Sources

- Magnet under glass (pag. 2) - Image source: https://upload.wikimedia.org/wikipedia/commons/2/21/Ferrofluid_Magnet_under_glass_edit.jpg
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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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