irresistible

Responsible Research and Innovation (RRI)

Lotus Effect 2

Universitatea Valahia din Targoviste

Lotus effect

Surface allows self-cleaning

An educational module for the chemistry, phisics and biology -lessons for primary (4th grade) and lower 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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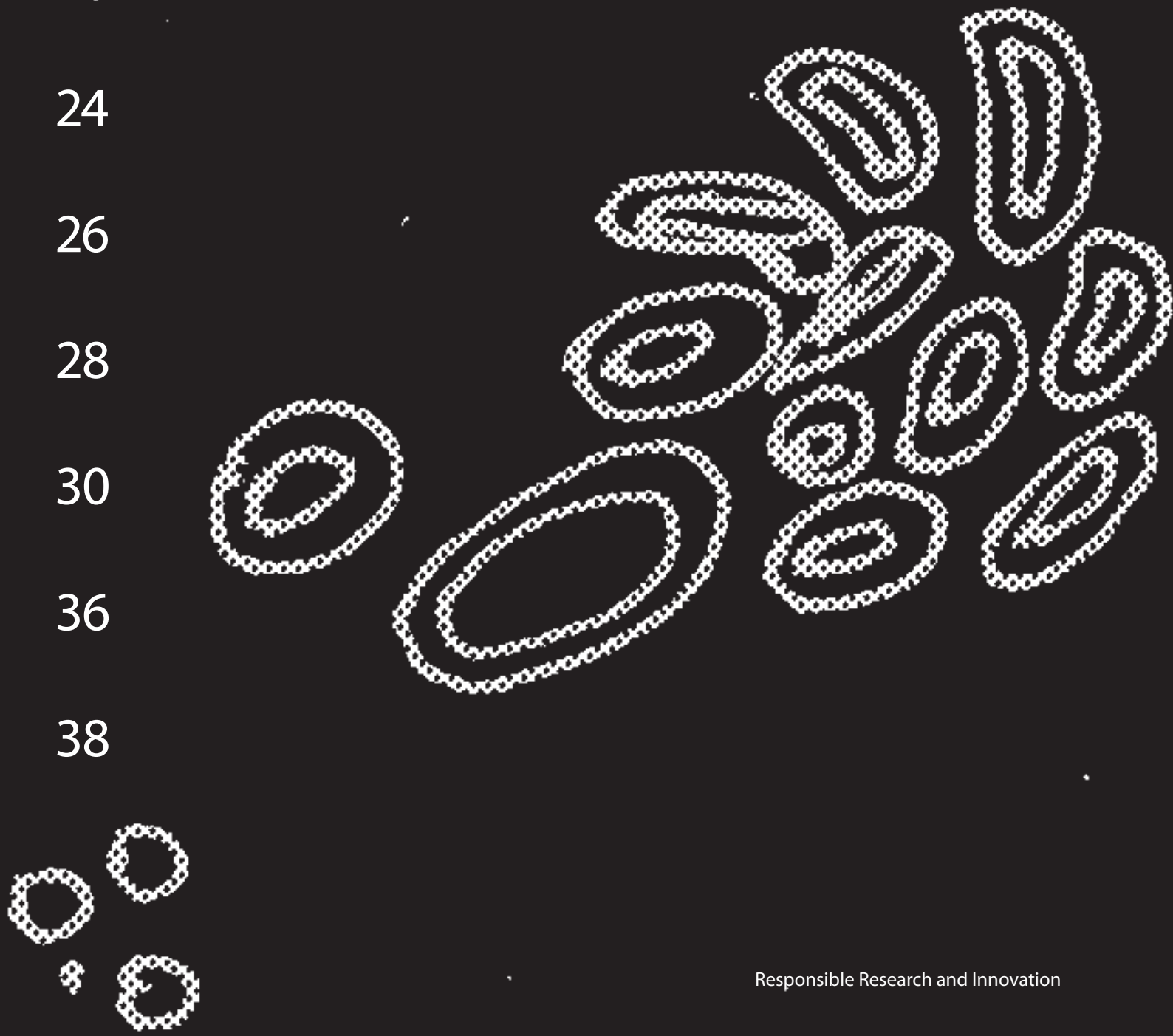


1 Overview

Lotus effect

Educational activities subsumed on theme Lotus effect offers students the opportunity to learn this effect from nanotechnologies perspective.

The aim of these educational activities is to develop pupils' conscious and responsible attitude towards the importance of using natural properties of nanomaterials in various industries. In this regard, there will be developed experiments for showing structural and functional properties of several natural nanomaterials and discussions centred on topics related to responsible research.

The proposed experiments aim is to analyse a series of innovative materials completely hydrophobic or stainless, as a result of nanotechnology which used nature as an inspirational source, in this case, the lotus leaf. It will be analysed the property of super-hydrophobicity of these leaves, as a result of surface chemistry and macro and nano topography.

The proposed experiments aims to:

- Study and test lotus leaf properties (from biology, physic and chemistry perspective)

- Highlight the properties of nanomaterials that are applications of Lotus effect, both in terms of strengths and limits of nanotechnology and in terms of responsible research and innovation

Overview

Grade/Educational level	primary (4th grade) and lower secondary school levels
School subject	Sciences/Biology
Learning unit	Vegetative organs of a plant
Module theme(s)	**Lotus effect**
Specific competences	1. understanding and explaining phenomena, processes, materials, procedures encountered in everyday life; 2. investigation of phenomena, processes, materials to establish structural and functional elements and correlations between them; 3. explaining the importance of phenomena, processes, materials for particular areas of activity; 4. valorisation of theoretical acquisition of problem solving situations, to formulate explanations, to conduct investigations and report results; 5. evaluation of consequences of the action of processes, materials on persons and on environment.

Derived competences	1.1. identify specific structural features of the lotus leaf and lotus effect (p - primary, l.s. – lower secondary); 1.2. use laboratory equipment, information technologies for studying the lotus leaf and lotus effect; 2.1. identification of structural elements (anatomical and morphological) of lotus leaf (l.s.); 2.2. recognition on SEM images of structures involved in self-cleaning effect (p, l.s.); 2.3. explaining the self-cleaning mechanism (l.s.); 2.4. analyse the correlation between structure (morphological) and function of the lotus leaf (cleaning effect) (p, l.s.); 2.5. analyse and interpret the observations / data derived from the investigative work; 3.1. exemplify concrete situations of life in which Lotus effect is useful (p, l.s.); 3.2. highlight the importance, at industrial-scale, of the Lotus effect applications (p, l.s.); 4.1. communication, in written and oral form, of results of the investigation, using appropriate scientific terminology; 5.1. analyse the benefits and limitations of using Lotus effect; 5.2. expressing personal opinion, associated with a responsible attitude regarding the impact on the environment of the use of such materials (p, l.s.); 5.3. expressing personal view about the importance of involving social actors in scientific research in nanoscience (p, l.s.)
Required preconditions	Knowledge of anatomy / morphology of vegetative organs, the role of the main types of plant tissues. (l.s.); hydrophobic / hydrophilic properties of the various materials (p, l.s.); angles classification (p, l.s.); Skills for the use of laboratory instruments, effective communication, teamwork; Attitudes of respect for truth; valorisation of scientific knowledge; Respect for oneself, for others and for the environment; interest in the various types of communication.

	Educational methods and procedures	discovery learning, heuristic conversation, explanation, exposure, problem solving, case study, experiment, demonstration, scientific investigation, brainstorming, systematic observation, portfolio
Procedural resources (educational strategy)	Educational means	• Paper towels, 100% polyester textile fragment, piece of fir wood, pine wood fragment treated with protective varnish, natural wax fine film, aluminium foil, glass pane, cabbage leaf, vine leaf, lotus leaf (E1); • pane of glass, stainless steel spoon, 100% cotton fabric, polyester fabric (at least 80%), nanotex material, vegetable oil, natural berry juice, chocolate, Stain solution (vanish), window cleaner, water (E3) • microscope, fixed microscopic preparations (O1); • projector, laptop, digital images.
	Forms of activity organization	frontal, in groups, individual
Estimated time		4 lessons / extracurricular activities

For the learning activities proposed under the theme Lotus Effect, it is assumed that students know:

- **general information about nano-science;**
- **internal composition of leaves (botanical concepts);**
- **general properties of materials and their behavior towards water;**
- **manipulation techniques of laboratory instruments;**
- **PC usage techniques.**

Short Theoretical Background

The hydrophobic ability of the Lotus leaves relies on their structure. The leaves' surface has a micro/nano double-layer structure. First layer of the lotus leaf is covered with little protrusions (papillae) 10-15 µm apart from each other with radius of 5-10 µm. Each protrusion is covered with bumps of a hydrophobic, waxy material that are roughly 100 nm in height. When water droplets are applied to the lotus leaf, they sit lightly on the tips of the hydrophobic protrusions. The wax prevents water drops from getting into the papillae interspaces and as a result only %2– 3 of the drops' surface contacts with the leaf.

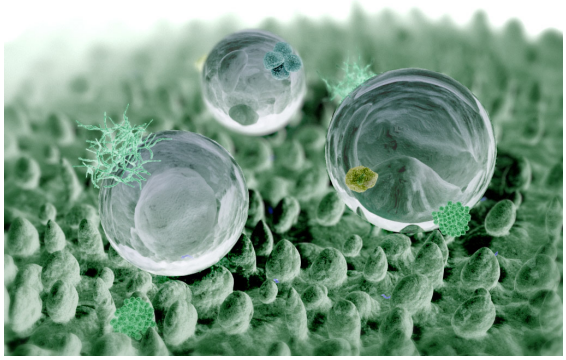


figure 1
Computer graphic of a lotus leaf surface
Source: https://en.wikipedia.org/wiki/Lotus_effect

The contact angle at which a liquid meets a solid surface is also responsible for the water-repellent property. As the contact angle gets smaller (<90o), the droplets become flatter and the surface gets wetter. As the contact angle gets larger (>90o), the area between the droplet and the surface becomes smaller and this leads to a drier surface. The waxy bumps on the papillae (micro/nano double-layer structure) form a contact angle of 157°. This reduces the strength of adhesion and vests the lotus flower with a hydrophobic surface. Hence, the water is not allowed to wet the surface and is easily displaced. (Source: http://vlab.ntse-nanotech.eu/NanoVirtualLab/dataentitys/show/664).

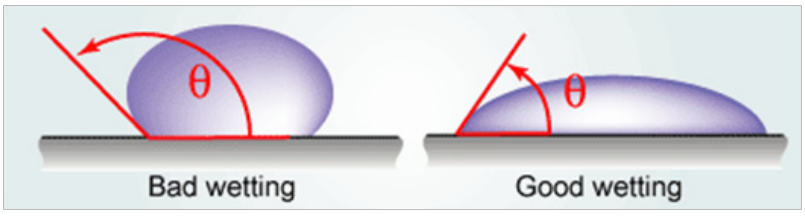


figure 2
θ is the contact angle. As the contact angle gets smaller (<90°), the droplets become flatter and the surface gets wetter. As the contact angle gets larger (>90°), the area between the droplet and the surface becomes smaller and this leads to a drier surface.
Source: http://futureprospects.wordpress.com/2010/05/17/the-lotus-effect/

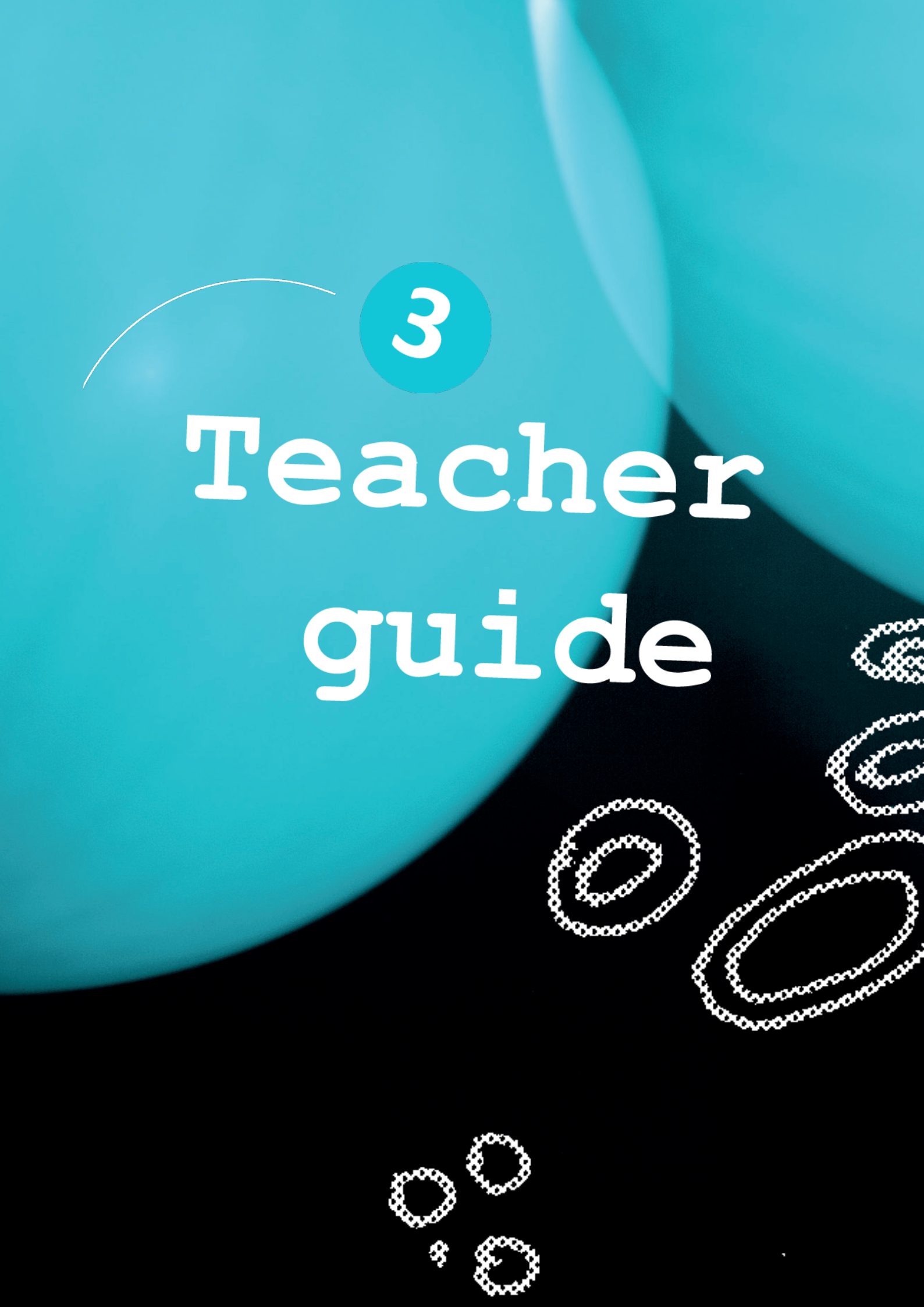
Educational scenario

Steps of teaching approach/time management	Derived competences (codes)	Teacher activity	Learning activities**
1. Engage	4.1, 5.1, 5.2, 5.3	- plans learning activities - provides students the bibliographic list show students websites, link for documentation - distributes students in groups - establishes with students, the phases of scientific inquiry-based learning	- students develop a ppt presentation and a small exhibition to present the uses, at industrial level, of Lotus effect - create an account on Facebook – Prolotus – to state their opinion about Lotus effect applications in nanotechnology, to promote new findings in the field, to present limits and benefits of using nanotechnology
2. Explore	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5	- presents the real problem to be investigated - presents the requirements specific to investigative activity carrying - inform students about registration, organization, processing and, at the end, presentation of information (after each activity a product will be created) - process labour protection rules; - provides students the material needed to perform microscopic observations and experiments, monitors and guides students during the course of the experiments	- handle laboratory instruments - emit hypotheses, make experiments - record collected data - fill tables, charts - check the solutions identified
3. Explain	1.2, 2.1, 3.1	- provides students questionnaires, tables, explain how to fill in it - offers students support in structuring information obtained; - provide feedback to students - offers support in restructuring / completing / correcting the information obtained by capitalizing on feedback provided and assessing the socio-scientific value	- check theories, fill sheets, tables - disseminate in group/class the scientific knowledge identified - provide feedback to peers - restructure/ complete / correct knowledge, in relation to the feedback received and socio-scientific value

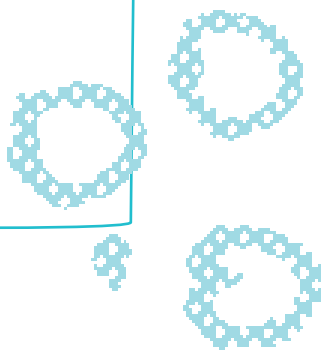
Learning activities**	Educational strategy			Evaluation
	Educational methods and procedures	Means of education	Forms of organisation	
- the products of the activity - PPT, posters, mini- models of lotus leaf epidermal papillae, Facebook account; - knowledge – related to novelties in nanotechnology field. - technical skills (of using, handling media tools)	conversation, explanation, questioning, brainstorming	PC, projector, list of bibliographic material, posters, mini-model of lotus leaf	frontal	oral evaluation, systematic observation, evaluation grid - G3
- knowledge – related to morphology / anatomy of several leafs of different plant species, knowledge related to the existence of several types of forces acting on a drop of water, related to the behaviour of various materials under the action of water - activity products - images, pictures made during the experiments, microscopic observations - skills of handling laboratory instruments	brainstorming, experiment, explanation, questioning, discovery learning, scientific investigation	- paper towels, 100% polyester textile fragment, piece of fir, pine wood fragment treated with protective varnish, natural wax fine film, aluminium foil, glass pane, cabbage leaf, vines leaf, lotus leaf (E1) - window glass, stainless steel spoon, 100% cotton fabric, polyester fabric (at least 80%) nanotex material, vegetable oil, natural berry juice, chocolate, Stain solution (vanish), glass cleaner, water (E2) - microscope, fixed microscopic preparations (O1)	in groups, frontal	practical tests, systematic observation, evaluation grids – G1, G2
- tables, questionnaires	conversation, explanation, questioning	table layouts, cards, questionnaires	frontal, in groups	oral assessment, systematic observation, evaluation grids - G5, G6

4. Elaborate	3.1, 3.2, 5.1, 5.2	- organizes a motivating learning environment, stimulating, likely to place the student in the position of responsible researcher - invites researchers, experts, etc., who students can ask questions to deepen understanding of the topic addressed	- each group of experts (business men, chemists, biologists) will examine the Lotus effect in different areas of research, in terms of advantages / disadvantages - students, „experts" in various scientific problems, consult the opinions of scientists, to learn (before to prepare reports)
5. Disseminate / Share / Present / Expose	5.1, 5.2, 5.3	- manage discussions - designs, together with students, an exhibition that will be open in Museums and / or libraries. Within that it will be exhibited posters, videos, models and other items made by students - coordinate the selection process of most relevant/representative students works	- the experts present the reports, products of investigative work performed, argue their choices, assumptions, conclusions - participate to the selection process of most relevant / representative students works
6. Evaluate	5.1, 5.2, 5.3	- evaluate portfolios, check the extent to which students have achieved sustainable procurement, in terms of targeted finality - assure joining of assessment with auto assessment and peer - assessment	- fill the grids G5, G6, G7 and the distributed forms

- “experts” reports, supporting documentation	questioning, conversation, discussion	sheets of flip-chart, markers, images, experts' reports	in groups, frontal	oral assessment, systematic observation, survey, evaluation grid -G4
- “experts” reports, reports supporting documentation	explanation, case study, problem solving, debate	reports, worksheets, PC, projector	in groups, frontal	oral assessment, systematic observation, evaluation grid – G4
- filled evaluation grids: G5, G6, G7	conversation, explanation	questionnaires, SWOT analysis table	individual	oral assessment, portfolio assessment scales - G5, G6, G7


3
Teacher guide

Teacher guide



This educational activity

allows students to acquire / to form new knowledge / skills / attitudes regarding:

a) characteristics of natural materials according to the way they behave to water (hydrophilic, hydrophobicity);

b) highlighting these characteristics in specific experiments;

c) importance and use of natural nanomaterials in industry or other fields;

d) environmental responsibility through the use of such materials;

e) responsibility towards scientific research;

f) respect for responsible scientific research work;

g) civic responsibility of every individual about taking responsible decisions with environmental impact

Learning results

At the end of the **first lesson**, the students will be capable to:
- identify the hydrophilic / hydrophobic behaviour of different materials;
- experiment hydrophilic or hydrophobic behaviour of various materials from nature;
- explain the nature of the lotus self-cleaning ability.

At the end of the **second lesson**, the students will be capable to:
- observe images of nano double-layered structure of the hydrophobic layer of lotus leaf (p,l.s.);
- argue importance of leaf structure in performing a function;
- differentiate, on SEM images, the structures involved in hydrophobicity characteristics;
- list the types of forces that cause formation of droplet types (l.s.);
- compare similar forces action on the surfaces of different textures (l.s.);
- experiment the effects of changing the angle of water - solid surface contact which determines the auto-cleaning (p, l.s.);
- experiment hydrophilic or hydrophobic behaviour of various materials from nature (p, l.s.);
- experiment the way of cleaning of various materials with different texture and structure.

At the end of the **third lesson**, the students will be capable to:
- explain the importance of using Lotus effect in various industries;
- present the advantages / disadvantages of applying this effect in various branches of human activity;
- express personal views on the principles of research ethics;
- express a personal point of view to the use of nanotechnology, demonstrating an attitude of respect for the environment.

At the end of the **fourth lesson**, the students will be capable to:
- present products of their work as PPT or mini-exhibition, targeting the most recent advances in nanotechnology, with applications of Lotus effect;
- create a Facebook account - Prolotus - in order to express their views about the advantages of using nanomaterials (in this case the effect Lotus) in various fields;
- promote a responsible attitude towards the environment, in relation to the use of nanotechnologies.

Recommended training modalities

Lotus Effect teaching activities involve valorisation of basic knowledge specific to the following school subjects: biology, physics and chemistry.

By the promoted teaching strategies, especially inductive, deductive and heuristic ones, students will form / develop skills / abilities of exploration, investigation, communication and work effectively in groups, analysis and synthesis, evaluation and anticipation etc. Students will realize also the need to respect ethical principles and values in making research and innovation.

3.1. Lesson 1

In the first lesson, students are introduced to a number of concepts (to be used during other lessons) related to the behaviour of different surfaces in relation to water.

Moments of lesson no. 1

a) Defining terms hydrophilic / hydrophobic (p, l.s.)
Educational methods and procedures: brainstorming, heuristic conversation
Means of education: flipchart sheets, markers
Forms of activity organization: frontal
Description of the investigative demarche
By the use of brainstorming, the students are asked to define the terms hydrophilic and hydrophobic, noting the terms on the flip-chart sheet. Subsequently, they will identify, in class, a series of materials that have hydrophilic or hydrophobic properties.

b) Experimentation of hydrophilic / hydrophobic behaviour of various natural materials in order to identify materials with characteristics of hydrophobicity (p,l.s.) (E1)
Educational methods and procedures: experiment, conversation, explanation, questioning, case study
Means of education: experiment procedure (E1), quizzes, paper towels, 100% polyester textile fragment, piece of fir, pine wood fragment treated with protective varnish, natural wax fine film, aluminium foil, glass pane, cabbage leaf, vines leaf, lotus leaf, water, clock (stopwatch);
Forms of activity organization: dyads

Experiment procedure (E1)

Materials provided will sit on perfectly flat surfaces.
With a pipette, it will be distributed 5 drops of water in the same place, on each sample. It will be recorded the time needed for water absorption, where applicable. The observations will be written in the tables, and, where appropriate, other collateral observations will be written.

Table 1

Material tested	Time needed for water absorption

Description of the investigative demarche

Students are organized in dyads and they receive the materials needed to run experiments. During the course of the experiment, students follow the work procedure and fill the data in appropriate tables, answering, when asked, to the questions listed below.

1. What happens to water drops on each surface?
2. What material has absorbed the water most quickly?

Table 2

„Love“ water	„Hate“ water
1. e.g. – paper towels	1. e.g. – lotus leaf
2.	2.
3.	**3.**
4.	4.
5.	**5.**
6.	**6.**

3. What explanation you consider would be?
4. On a scale of 1 to 10, put the materials used in the experiment performed according to the behaviour in relation to water. 1 corresponds to material that absorbed the water completely and fastest and 10 to the one who completely "rejected" the water.
5. Centralize in the table below the data obtained to the previous item:
6. What conclusions can you formulate?

c) Experimentation of the effects of modifying the contact angle (water-solid surface) which determines the cleaning, in order to establish the importance of surface nature in making cleaning effect (p, l.s.) (E2)

Educational methods and procedures: experiment, explanation

Means of education: procedure E2, paper towels, 100% polyester textile fragment, piece of fir, pine wood fragment treated with protective varnish, natural wax fine film, aluminium foil, glass pane, cabbage leaf, vines leaf, lotus leaf, water, images of water / solid surface contact angle
Forms of activity organization: groups of 4 students, frontal
Description of the investigative demarche
Students are organized into groups of 4 and receive the materials needed to run experiments. During the course of the experiment, students follow the work procedure and record data in appropriate tables, answering when asked, to the questions listed below.

Experiment procedure (E2)

Having the samples of the materials provided, the students will observe the appearance of water droplets on different surfaces. Materials sits on perfectly flat surfaces, drop water with pipette, until the appearance of the drop can be seen on all surfaces.

1. Water droplets have the same shape on all surfaces?
2. Try to "draw" the form of the water droplet on various surfaces.
3. What happens with the water droplet if we move / incline any surface?
4. There are surfaces on which water droplet moves, even if the area remains in constant position?
5. What do you consider is the effect of this movement?

In order to explain, physically, the cleaning effect, the students are provided also with images of contact angles of a drop of water on various surfaces.
The data will be recorded in a table similar to the next one:

Table 3

Surface	Contact angle value	Behaviour (hydrofoil/hydrophobic)
e.g. fir	≤300	Hydrofoil

In order to explain the self-cleaning effect, the students will receive images that convey the cleaning modality of a surface depending on the shape of the water droplet.

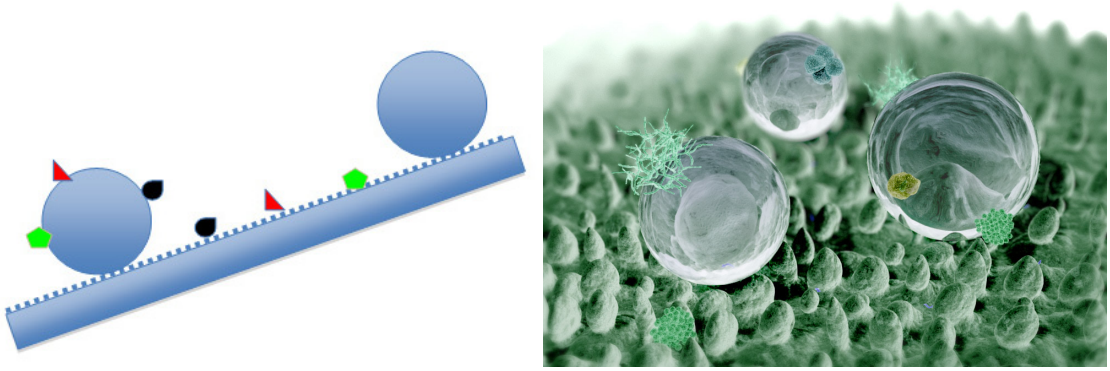


figure 3
Diagram summarising the connection between roughening and self-cleaning:
- left - a droplet of water removes dirt from a surface thanks to the Lotus effect (Image source: http://www.rolith.com/applications/self-cleaning);
- right - Graphical representation of contaminants and water droplets on a lotus leaf (Image credit: by William Thielike, Wiki commons, Creative Commons ShareAlike 3.0.).

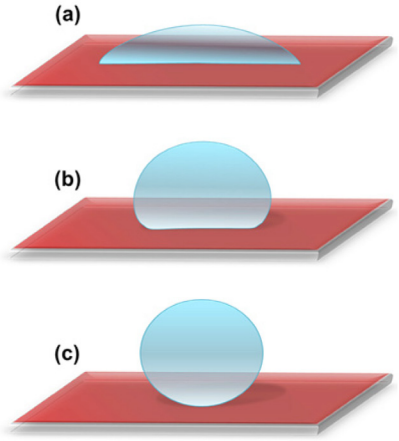


figure 4
A schematic showing (a) hydrophilic surface with water contact angle less than 90°; (b) hydrophobic surface with water contact angle greater than 90° and (c) superhydrophobic surface with water contact angle larger than 150° (Image credit: by Sanjay S. Latthe, Chiaki Terashima, Kazuya Nakata and Akira Fujishima, Superhydrophobic Surfaces Developed by Mimicking Hierarchical Surface Morphology of Lotus Leaf, Molecules 2014, 19(4), 4256-4283, URL: http://www.mdpi.com/1420-3049/19/4/4256/htm.

3.2. Lesson 2

In the second lesson, under the guidance of the teacher, students will perform a series of investigations that are based on microscopic observations of fixed preparations with cross sections of foliar limbo for two or more species of plants (lotus, spruce, apple); observation on SEM images, in order to identify structures that occur in the self-cleaning effect and a number of comparative analyzes in order to establish the correlation between the structure of a material and its ability to be cleaned.

Moments of lesson no. 2

a) Making microscopic observations on fixed preparations with cross sections of foliar limbo for two or more plant species in order to identify morphological particularities that impose a specific functionality (O1)
Educational methods and procedures: microscopic observation, explanation, demonstration
Means of education: fixed microscopic preparations
Forms of activity organization: dyads
Description of the investigative demarche
Students will perform microscopic observations on fixed preparations containing foliar limb cross sections of several species in order to establish their structural features. On each desk there will be one microscope and the set of fixed preparations that students will use.
Students of lower secondary school level:
- identify particularities of upper epidermis at foliar lamina level at various species
- explain the differences between the epidermis.

b) Observations on SEM image of the structures involved in self-cleaning effect (p, l.s.)
Educational methods and procedures: observation, explanation
Means of education: SEM image of nano double layered structure of the lotus foliar lamina
Forms of activity organization: frontal
Description of the investigative demarche
Students from both levels make macroscopic observations using SEM images on digital media, to identify structures involved in self-cleaning effect.

1. What happens to water drops on each surface?
2. What material has absorbed the water most quickly?
3. What explanation you consider would be?
4. On a scale of 1 to 10, put the materials used in the experiment performed according to the behaviour in relation to water. 1 corresponds to material that absorbed the water completely and fastest and 10 to the one who completely "rejected" the water.
5. Centralize in the table below the data obtained to the previous item:

c) Experiment the cleaning modality of various materials with different texture and structure, to identify the advantages of using nanotechnologies in textile industry (p, l.s.) (E3)

Educational methods and procedures: experiment, explanation, demonstration

Means of education: window glass, stainless steel spoon, 100% cotton fabric, polyester fabric (at least 80%) nanotex material, vegetable oil, natural berry juice, chocolate, stain solution (vanish), glass cleaner, water

Forms of activity organization: groups of 4 students

Description of the investigative demarche

Each group of 4 students will receive materials needed to run the experiments, will conduct the experiment according to the procedure and will write the data into appropriate tables. Students will explain phenomena / processes in the experiment by answering the questions below.

Experiment procedure (E3)

The materials will be placed on flat surfaces. On each of these, it will be "drawn", with a marker, 9 small squares: on three of them it will be distributed with pipette, 3 drops of natural berry juice, on the next three - vegetable oil and on the last three - melted chocolate. Subsequently, each type of stain will be treated with water, stain cleaner (vanish) and glass cleaner, leaving to act for 5 minutes.

The observations will be written in tables like the next one:

Table 3

Material	Stain type	Cleaning solution	Observations
E.g. - cotton	Juice	**Water**	
		Vanish	
		Window cleaner	
	Oil	**Water**	
		Vanish	
		Window cleaner	
	Chocolate	**Water**	
		Vanish	
		Window cleaner	

1. What have you observed?
2. What could be the explanation?
3. What conclusions can you formulate?

3.3. Lesson 3

A third lesson is a debate like activity in which students will be divided into three groups of experts - scientists, businessmen, politicians. Each of the three groups of experts will have to study, from its own perspective (of the scientist, the businessman and politician), the implications of nanotechnology (including nano applications of lotus effect) in the daily life of citizens. They will argue the need to use these materials, utility and their advantages. The experts will produce reports which, subsequently, they will present it and argue it in front of other colleagues.

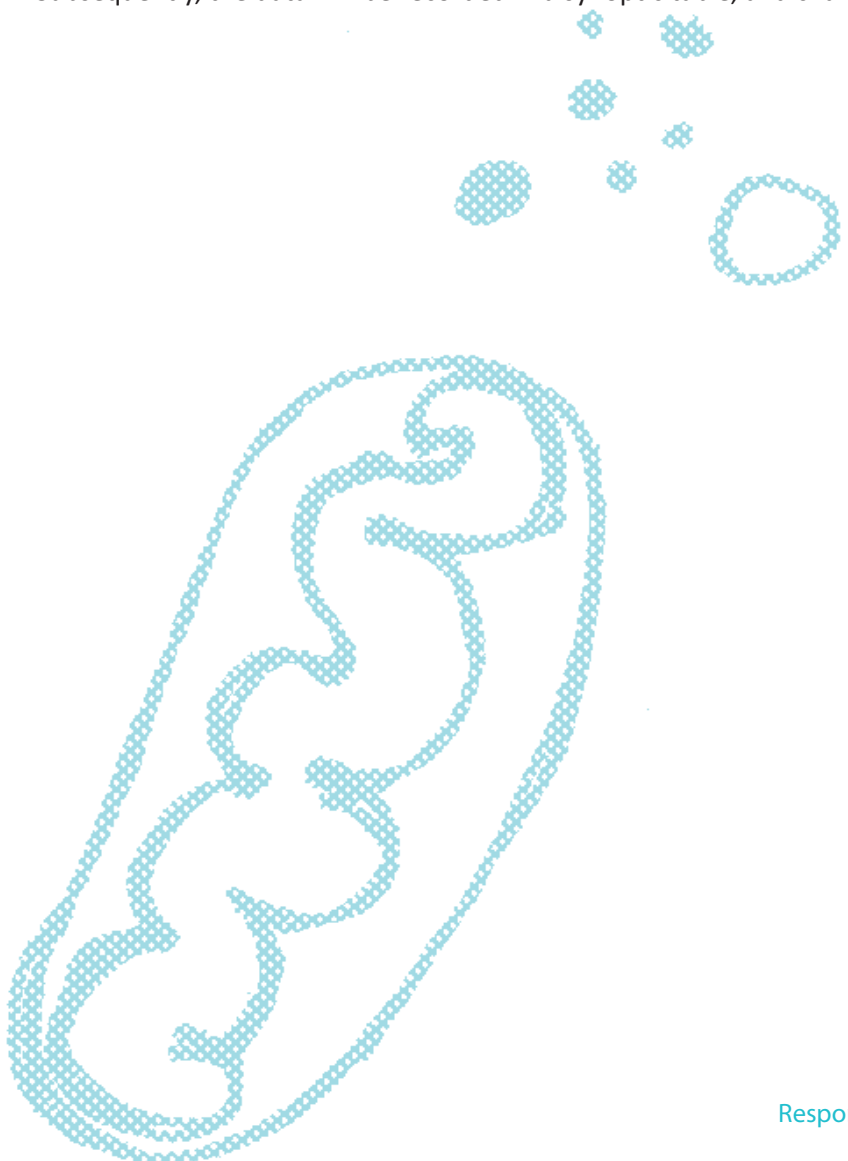
Moments of lesson No. 3

a) **The launch of the problem** - approach from a certain perspective of implication of the use of nanotechnologies (with specific applications of the lotus effect), to civic and moral responsibility of students. (p, l.s.)
Educational methods and procedures: case study, problem solving
Means of education: documentation sheets, group report
Forms of activity organization: in groups of experts
Description of the investigative demarche
The teacher proposes students to study, from a certain perspective, a problem of the use of nanotechnologies. To achieve this objective, students opt for one of the expert groups, make documentation activities and participate to the report elaboration.
To prepare the report, the experts, no matter what type, will consider the following:
- Scientists - will prepare a brief history of nanotechnology, will present the advantages of their use in scientific research, will analyze the positive / negative impact on daily life, will make a presentation of how nanotechnologies and nano products contribute beneficially or not to environment protection, will raise questions of ethics and morality in research in nanotechnologies;
- businessmen - will make a presentation of the application fields of nanotechnology, from the perspective of the manufacturer / supplier of nano products, will analyze the impact of the marketing of such products (nanotextile, coatings, textiles, military industry, materials for the medical and pharmaceutical), will analyze the advantages / disadvantages of the launch of nano products (in financial terms);
- politicians - will present the manner in which promotion of scientific research can be a strategy for attracting political capital, will make a plan to promote scientific research, will argue the usefulness of this plan, will illustrate the manner of politicians intervention, as policy makers, in nanotechnologies.

b) **Comparative analysis and conclusions** – analysis of expert groups reports in order to establish the utility, advantages, disadvantages, opportunity, necessity, impact of the use of nanotechnologies, particularly of nano products of effect Lotus applications.
Educational methods and procedures: conversation, explanation, case study

Means of education: flipchart sheets, markers, questionnaires, synoptic tables
Forms of activity organization: frontal
Description of the investigative demarche
After presentations of expert groups, students will clarify a number of issues:
- Which arguments of expert groups are strongest? (lists)
- To what extent the use of the appropriate argument (for me personally) manages to convince me? (Categorize the answer - at all, to a very small extent, to a small extent, to some extent, to a large extent, totally)
- What was lacking the one that didn't convinced me, as argument? (specify)
- How can it influence me any of expert argument? (Categorize the answer - at all, to a very small extent, to a small extent, to some extent, to a large extent, totally)
- Under what circumstances, any expert can determine me to change my mind? (specify)
- To what extent can I, as a citizen, to influence the decision of any of the three types of experts? (Categorize the answer - at all, to a very small extent, to a small extent, to some extent, to a large extent, totally)

Each student will receive a questionnaire that will contain the above questions.
Subsequently, the data will be recorded in a synoptic table, and charts will be made.



3.4. Lesson 4

The fourth lesson is a practical activity in which students present the latest novelties, preparing a mini-exhibition with Power-Point presentations or posters promoting nano products as applications of Lotus effect, and a Facebook account - Prolotus - through which expresses views about the benefits of using nanotechnology, showing a responsible attitude towards the environment, in terms of nanotechnologies usage.

Moments of lesson No. 4

Educational methods and procedures: explanation, conversation
Means of education: PPT, PC
Forms of activity organization: frontal
Description of the investigative demarche
Students receive, before carrying out the work on the Lesson 4, a task consisting in preparing posters or PPT to present the novelties in the field of nanotechnology, with applications of Lotus effect, the debated theme. The teacher will distribute to students, prior to the activity, a bibliographical list to be consulted so they can successfully fulfil the proposed task. Students will be divided into 3 groups and they will elaborate and present PowerPoint presentations, posters and a Facebook account where they will express their views in relation to knowledge in the field of nanotechnology, to applications of Lotus effect and about the benefits of using nanotechnology, showing a responsible attitude towards the environment, from the perspective nanotechnologies usage.

Targeted competences

Derived competence	Derived competence
1.1. identify specific structural features of the lotus leaf and lotus effect (p, l.s.); 1.2. use laboratory equipment, information technologies for studying the lotus leaf and lotus effect;	- observations, on SEM images, of the lotus leaf - microscopic observations on fixed preparations
2.1. identification of structural elements (anatomical and morphological) of lotus leaf (l.s.); 2.2. recognition on SEM images of structures involved in self-cleaning effect (p, l.s.); 2.3. explaining the self-cleaning mechanism (l.s.); 2.4. analyse the correlation between structure (morphological) and function of the lotus leaf (cleaning effect) (p,l.s.); 2.5. analyse and interpret the observations / data derived from the investigative work;	- observations, on SEM images, of the lotus leaf - microscopic observations on fixed preparations - emphasising experiments of the cleaning effect
3.1. exemplify concrete situations of life in which Lotus effect is useful (p,l.s.); 3.2. highlight the importance, at industrial-scale, of the Lotus effect applications (p, l.s.);	- emphasising experiments of nano-textiles properties - exhibition with images which presents industrial applications of lotus effect
4.1. communication, in written and oral form, of results of the investigation, using appropriate scientific terminology;	- explanations of the results obtained, using specific terminology
5.1. analyse the benefits and limitations of using Lotus effect; 5.2. expressing personal opinion, associated with a responsible attitude regarding the impact on the environment of the use of such materials (p, l.s.); 5.3. expressing personal view about the importance of involving social actors in scientific research in nanoscience (p,l.s.)	- debate on the benefits and limitations of nanomaterials and nanotechnologies; - explanation of promoting of, using of nanotechnologies in various industries

3.5. Evaluation

Suggestions for formative assessment of students are:
a) The evaluation will cover both each student acquisitions and group work and group activity products;
b) The evaluation will be done for each lesson, in terms of targeted competences and objectives;
c) The evaluation will analyze aspects of social and personal development of students.

Formative assessment of students' concerns:
- identification of specific structural features of the lotus leaf and lotus effect (p, l.s.)
- use of laboratory equipment and instruments, information technologies for studying the lotus leaf and lotus effect
- identification of structural elements (anatomical and morphological) of lotus leaf; (l.s.)
- recognition of structures involved in self-cleaning effect on SEM images (p,l.s.)
- explanation of the self-cleaning mechanism; (l.s.)
- analysis of the correlation between structure (morphologically) and lotus leaf function (cleaning effect); (p,l.s.)
- analysis and interpretation of observations / data derived from the investigative work;
- exemplification of concrete situations of life in which lotus effect is useful (p,l.s.)
- highlighting the importance at industrial-scale of applications of Lotus effect; (p, l.s.)
- communication, written and oral form, of the results of the investigation, using appropriate scientific terminology;
- analysis of the benefits and limitations of using lotus effect;
- expression of personal opinion, associated with a responsible attitude, regarding the impact of the use of such materials (p, l.s.) on the environment;
- expression of personal opinion view about the importance of involving social actors in scientific research in nano-sciences (p,l.s.)

Assessment strategy

1. **Predictive evaluation** will be done in Lesson no. 1, when the students' background knowledge and skills are targeted, as prerequisites to acquire new knowledge and the formation of new skills. This approach will be developed at the moment of knowledge and skills updating.
2. **Formative evaluation** will be integrated into every lesson and will be done so:
- by oral questioning
- by systematic observation of activities carry out by the students (measurements, notes, instruments handling, proposed protocol steps compliance, determinations, etc.), by check of the data collected, by systematic observations of student behaviour during the proposed activities
- by project (power-point presentation, posters, Facebook account)
3. **Summative assessment** – is present mainly in the 3rd and 4th lesson, being conducted by the portfolio, self-assessment grids, peer and oral quizzes.

Assessment tools

G1 – Evaluation grid of the manner of realization of experiments, the skills to use laboratory instruments, involvement in task fulfilment, involvement in group work. (L1, L2)

Activity sequence	Evaluation criterion	Grades		
		Satisfactory	Good	Very good
Experiment achievement (E1,E2,E3)	- the arrangement of the materials used	- materials needed to run the experiment are incomplete and randomly arranged	- materials needed to run the experiment are present on the working table, but they are randomly arranged	- all materials are present on the working table and are properly arranged
	- compliance with the labour protocol	- steps of experiment does not follow the order of protocol	- the steps of experiment are undergo hesitantly, in late, but correctly	- experiment steps are followed and manipulation instruments is made without hesitation
	- tables completion	- the data from tables contain errors	- the data from tables are correct, but the table is incomplete	- the table contains correct and complete data
	- establish the conclusions (data interpretation)	- no conclusions after the completion of the experiment	- not all the conclusions of the ongoing experiment are present	- clear and complete conclusions
Cooperation within the group	- ability to cooperate and participate in the group	- the student refuses to cooperate	- accepts cooperation in 50% of cases	- constantly participates and cooperates in group actions
	- demonstration of leadership skills - guiding the group through creative thinking and help those who needed assistance	- the student is always withdrawn	- participates, but not as a leader	- get involved, take a leading role, helps his colleagues, when necessary
	- assuming the role / tasks within the group	- the student is reluctant to assume a role in the working group	- accepts his role in the group, but tends to fulfill his colleagues tasks too	- assumes the role within the group, fulfill the tasks.

G2 – Evaluation grid of the skills to use the microscope (O1)
For microscopic observation of fixed preparations (O1) – foliar limb, the skills to use the microscope are assessed (L2)

Activity sequence	Evaluation criterion	Grades		
		Satisfactory	Good	Very good
Preparation of materials needed for microscopic observation	- selection of microscopic preparations from catalog - microscope preparation (correct positioning towards the light source, regulatory verification)	- choose preparations at random, not those required - place the microscope without taking into account the properly positioning	- choose only part of the preparations required - the microscope is positioned properly, but the orientation towards the light source is hindered by various obstacles	- preparations are selected correctly - preparation and proper positioning of the microscope
Realization of microscopic observation (manipulation of microscope and microscopic preparations)	- correct positioning of fixed preparation to microscope - objectives adjustment, image preparation	- microscopic preparations are misplaced - does not make the appropriate adjustment	- fixed preparations are positioned correctly, but the change of fixed preparation with another is done with hesitation - image after adjustment is sometimes unclear	- properly positioning, as well as preparation change -correct adjustment, clear image
Lotus preparation – other species comparison	- establishing similarities / differences	- hardly succeeds to establish similarities / differences between microscopic preparations	- succeeds to establish only a part of similarities / differences between microscopic preparations	- identifies all the similar/distinct elements of the preparation
Data interpretation	- establishing conclusions	- establishes conclusions only with help	- establishes the conclusions, but do not clearly present it	- clearly establishes the conclusions and communicates it properly

G3 – Evaluation grid of the Power Point presentations (L4)

Activity sequence	Evaluation criterion	Grades		
		Satisfactory	Good	Very good
Elaboration of the Power-Point presentations, according to the proposed plan	- ability to comply with the proposed plan	- meets 20% of the plan	- meets 70% of the plan	- fully meets the plan
Development and exploitation of information	- the proper use of data - the selection of relevant data	- errors in data use in 50% of the slides - uses in 50% of the slides data of low relevance	- presents 20% of the slides with redundant data - 20% of the slides contains data not so relevant	-presents conclusive data to over 80% of the slides - the presentation contains data of relevant significance
Interpretation of data obtained	- the use of logical reasoning - argumentation of use of that reasoning - correct interpretation of the data	- data are present, but there is no interpretation - ambiguous presentation of reasoning - inaccurate or misinterpreted data in 40% of cases	- interprets data correctly in 50% of cases - presentation of reasoning, but hesitant argumentation - presentation of reasoning, but hesitant argumentation	- presentation of reasoning, but hesitant argumentation - argumentation of use of a particular reasoning, with evidences in 80% of cases - correct interpretation of the data in requested situations
Establishing conclusions	- the existence of clear conclusions	- conclusions exists, but not shown in the end	- the conclusions are present, but are rendered in an hesitant way	- clear, obvious and logical conclusions

G4 - Assessment tool based on the marks given, by the teacher, to the materials written by students

Activity sequence	Product evaluation criterion	Grades		
		Satisfactory	Good	Very good
Recording of experimental data collected	- elaboration of the table with the measurements made	- the data are written on separate sheets, not in the table	- the data are written on separate sheets, not in the table	- the table is correct
Data interpretation and their conclusiveness	- correct interpretation of the data	- the data are present, but inaccurate or incomplete interpretations	- in 20% of cases, data are less conclusive	- conclusive data, interpreted correctly
Scientific reasoning used in interpreting data	- the use of logical reasoning - argumentation of use of a specific reasoning - correct interpretation of the data	- the absence of a particular reasoning or use of a wrong reasoning - the absence of clear argumentation - data interpreted correctly only in 20% of cases	- the use of a partially correct reasoning - partially argumentation of reasoning - data interpreted correctly only in 70% of cases	- the use of correct reasoning - correct argumentation - correct data interpretation
Establishing conclusions	- the existence of clear conclusions	- absent conclusions of partially present	- presentation of clear conclusions, but incomplete in 70% of cases	- conclusions clear, relevant and correctly presented

G5 – Peer evaluation form

Student name and surname: _____

Project title: Lotus effect

What I liked most about activities related to this matter was.....

My suggestions on poster elaboration, Power-Point presentation (presentation mode, structure etc.) are: .....

I'm not sure what means: .....

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

Other ideas or comments:

Note: The students who make the peer evaluation will use the singular form of the first person.

G6 - Auto evaluation grid

Indicator	Grades		
	Never	Sometimes	Always
Involvement in the task			
Presentation of personal opinion			
Argumentation of personal opinion			
Launching a hypothesis			
Supporting hypothesis with arguments			
Collaboration with colleagues			
Contribution with informative materials			
Taking the initiative within the group			
Helping colleagues from group			
The tendency to find culprits for an incorrect handling, an incorrect written information			
Maintaining a relaxed atmosphere in the group			
Constant reflection on personal and group progress			

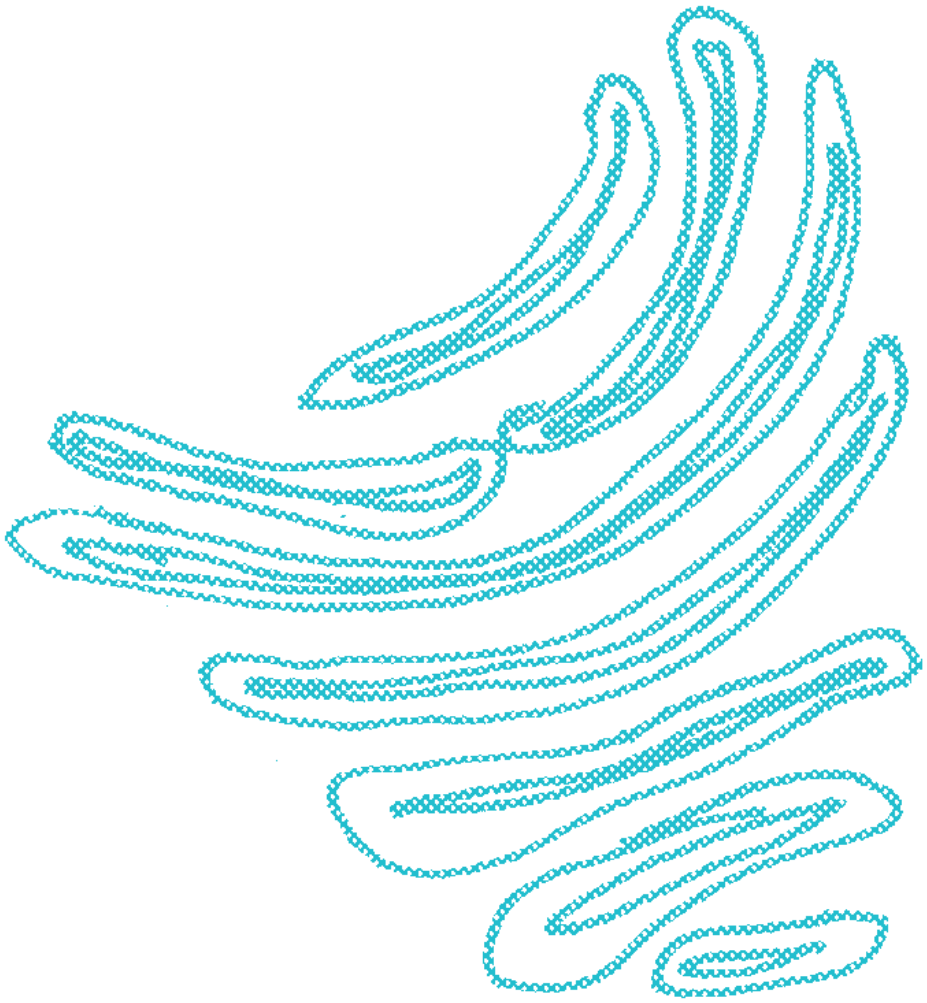
G7 - SWOT grid analysis of the manner of approaching the subject from IBSE and RRI perspective

	Help the objective fulfilment	Impede objective fulfilment
Internal origin	**S (Strengths)**	**W (Weaknesses)**
Presentation of personal opinion	**O (Opportunities)**	**T (Threats)**

4 Sources

Sources

- http://www.nanopinion.eu
- http://www.imt.ro/NANOPROSPECT
- http://iopscience.iop.org
- vlab.ntse-nanotech.eu/NanoVirtualLab/dataentitys/show/779
- www.nanowerk.com/spotlight/spotid=23516.php
- www.icpe-ca.ro/lib/files/RO_Raport%20Stiintific%202013.pd
- www.ifa-mg.ro/esfro/docs/etape/Etapa4/GT5_nanostiinte.pdf
- www.phys.uaic.ro/biofizica-si-fizica-medicala_c2018.html
- www.descopera.ro/eticheta/nanotehnologie
- www.scientia.ro/tehnologie/123-nanotehnologie.html
- www.maibine.eu/ShowMenuArticle.aspx?ID=43
- https://www.teachengineering.org/view_lesson
- www.hk-phy.org/atomic.../lotus/lotus02_e.html
- www.scientificamerican.com ›
- vlab.ntse-nanotech.eu/NanoVirtualLab/dataentitys/show/779



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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