Nanotechnology for Information

Colophon

irresistible

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, ACTOVITY 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

www.irresistitle-project.eu

Coordinator: j.h.apotheker@rug.nl

SEVENTH FRAMEWORK PROGRAMME

1

The Module

This is an educational module targeted for secondary-school students and developed by teachers in physics and chemistry, together with educational professionals and scientists of the University of Bologna. This module includes also the links to some attachments that should be useful for the teachers and that could be used also by the students.

The module is developed within the framework of the European project IRRESISTIBLE – *Engaging the Young with Responsible Research and Innovation* – **www.irresistible–project.eu**.
In this project, awareness about Responsible Research and Innovation (RRI) is raised by bringing topics of cutting edge research into the teaching program and fostering a discussion among the students on RRI issues about the topics that are introduced. The features of Responsible Research and Innovation can be summarized in the following issues: Engagement; Gender equality; Science education; Ethics; Open access; Governance. Example of how these issues prove to be relevant in contemporary science research are given later in this guide.

In this module the cutting-edge field is “Nanotechnology”; in particular it is focused on the nanotechnology studies carried out to get information from the interaction light/matter (luminescent nanosensors) and on the RRI aspects relevant to this specific field of research.

This module is organised in 6 chapters, named *Engage, Explore, Explain, Elaborate, Exchange* and *Evaluate*. This organization derived from the *5E-model for Inquiry-Based Science Education.* This is a method for inquiry-based science learning, that we adapted adding a 6th E (Exchange). By using this method, students are actively involved in the subject and are stimulated to search for information themselves.

A basic feature of the project is to combine formal (at school) and informal (at an exhibition, science centre or festival) teaching to familiarize schoolchildren with science. For this purpose, an expert from science museum is also part of the CoL (Community of Learners) working at the module.

During the module, with the help of science centre staff, students elaborate an exhibit for the general public highly focused on RRI.

1.1. The 6 dimensions of RRI

In the project, the underlining idea is that both research and innovation should be closely linked to society and societal needs. Six key concepts, or dimensions, that are indicated in the report of Sutcliffe (2011) are used as starting point in order to provide a solid base to discuss how the research that is being introduced to the students links to these issues.

1. Engagement

The first key to RRI is the engagement of all societal actors - researchers, industry, policymakers and civil society – and their joint participation in the research and innovation process, in accordance with the value of inclusiveness, as reflected in the Charter of Fundamental Rights of the European Union. A sound framework for excellence in research and innovation entails that the societal challenges are framed on the basis of widely representative social, economic and ethical concerns and common principles. Moreover, mutual learning and agreed practices are needed to develop joint solutions to societal problems and opportunities, and to pre-empt possible public value failures of future innovation.

2. Gender Equality

Engagement means that all actors – women and men – are on board. The under-representation of women must be addressed. Research institutions, in particular their human resources management, need to be modernized. The gender dimension must be integrated in research and innovation content.

3. Science Education

Europe must not only increase its number of researchers, it also needs to enhance the current education process to better equip future researchers and other societal actors with the necessary knowledge and tools to fully participate and take responsibility in the research and innovation process. There is an urgent need to boost the interest of children and youth in maths, science and technology, so they can become the researchers of tomorrow, and contribute to a science-literate society. Creative thinking calls for science education as a means to make change happen.

4. Open Access

In order to be responsible, research and innovation must be both transparent and accessible. This means giving free online access to the results of publicly-funded research (publications and data). This will boost innovation and further increase the use of scientific results by all societal actors.

5. Ethics

European society is based on shared values. In order to adequately respond to societal challenges, research and innovation must respect fundamental rights and the highest ethical standards. Beyond the mandatory legal aspects, this aims to ensure increased societal relevance and acceptability of research and innovation outcomes. Ethics should not be perceived as a constraint to research and innovation, but rather as a way of ensuring high quality results.

6. Governance

Policymakers also have a responsibility to prevent harmful or unethical developments in research and innovation. Through this key we will develop harmonious models for Responsible Research and Innovation that integrate public engagement, gender equality, science education, open access and ethics.

Sources

- http://ec.europa.eu/research/science-society/document_library/pdf_06/responsible-research-and-innovation-leaflet_en.pdf
- EU (2012). Responsible Research and Innovation: Europe's ability to respond to societal challenges

1.2. Learning goals and outcomes

The module described in this guide aims at raising students' awareness of RRI aspects in contemporary research and innovation by focusing on nanotechnology studies carried out to get information from the interaction light/matter (luminescent nanosensors).
The module develops both content and RRI aspects.

a) Learning outcomes related to nanotechnology and nanosensors

At the end of the module, a student should be able to:

- explain how the fundamental laws of chemistry underpin the development of nanotechnology
- describe what nanosensors are and what they can be used for
- describe the importance of chemistry to design, prepare and use nanosensors
- describe how a luminescent nanosensor works
- understand that nanotechnology and nanosensors are present in several sectors of everyday life
- recall and describe different type of natural and artificial nanosensors
- convey to other people the importance of nanotechnology in our society for the human beings and the environment

b) RRI learning outcomes of the module

At the end of this module, a student should be able to:

- describe to a classmate the reasons why luminescent nanosensors are used and the possible advantages and hazards for human beings and the environment (*ethics*)
- discuss whether men and women in society will be equally involved in the development and use of nanosensors (*gender equality*)
- consider the importance to access to the information concerning the possible applications of nanosensors and the implication of their use and production, both for human beings and environment (*open access)*
- understand the importance to design nanosensor and to use them sensibly *(science education)*
- recognize the different actors involved in the development and use of nanosensors (*engagement*)
- understand that nanosensor, like other science products, have been designed for and with society (*governance*)

1.3. IBSE (Inquiry Based Science Education) and the 6E model

Engage

This phase has the purpose of awaken the interest of students – motivating them to be engaged in subsequent tasks – and identify their prior knowledge about the topic(s) under study. Teacher must use problems that can awaken student's curiosity and lead them to formulate research questions.

Explore

This phase is intended to allow students to get actively involved into topic(s) and build knowledge – performing tasks such as research and experimental activities, formulate hypotheses, plan and execute preliminary investigations. At this stage students have the opportunity to be directly involved with the phenomena and materials related to the topic(s) of research – questioning, analyzing data and reflecting on the results. The teacher should act as a facilitator, providing materials and helping students to keep focus.

Explain

This phase aims at creating the opportunity for students to share with their peers and/or with the teacher what they have learned so far – making use of an appropriate scientific language. It is intended that during this process students reflect on their scientific misconceptions, being able to build new correct ones. This time is an opportunity for teacher to introduce and explore further the scientific concepts – by promoting a greater understanding on students, which will allow them to explain with greater ease and accuracy what they have learned.

Elaborate

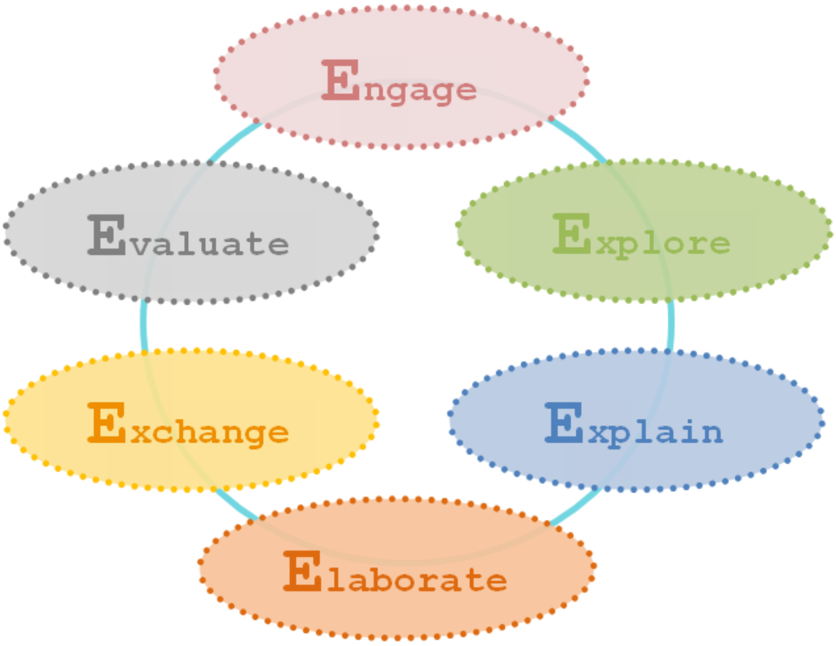
This phase aims at shifting to RRI-questions. Students will confront researchers with challenges to be answered by the scientists. The teacher should stimulate students to use their acquired competences for confronting themselves with scientists and then to work in peer-to-peer situations.

Exchange

This stage involves planning and building an interactive exhibition of the products of research. It is intended that students share with the community the results of their investigations – products may take different formats (poster, game, video, among others). It is an opportunity for students to communicate to a wider audience the new knowledge built. This phase is in close relation with the Empowerment phase, since it should promote awareness and sensitize others to the topic through the exhibition.

Evaluate

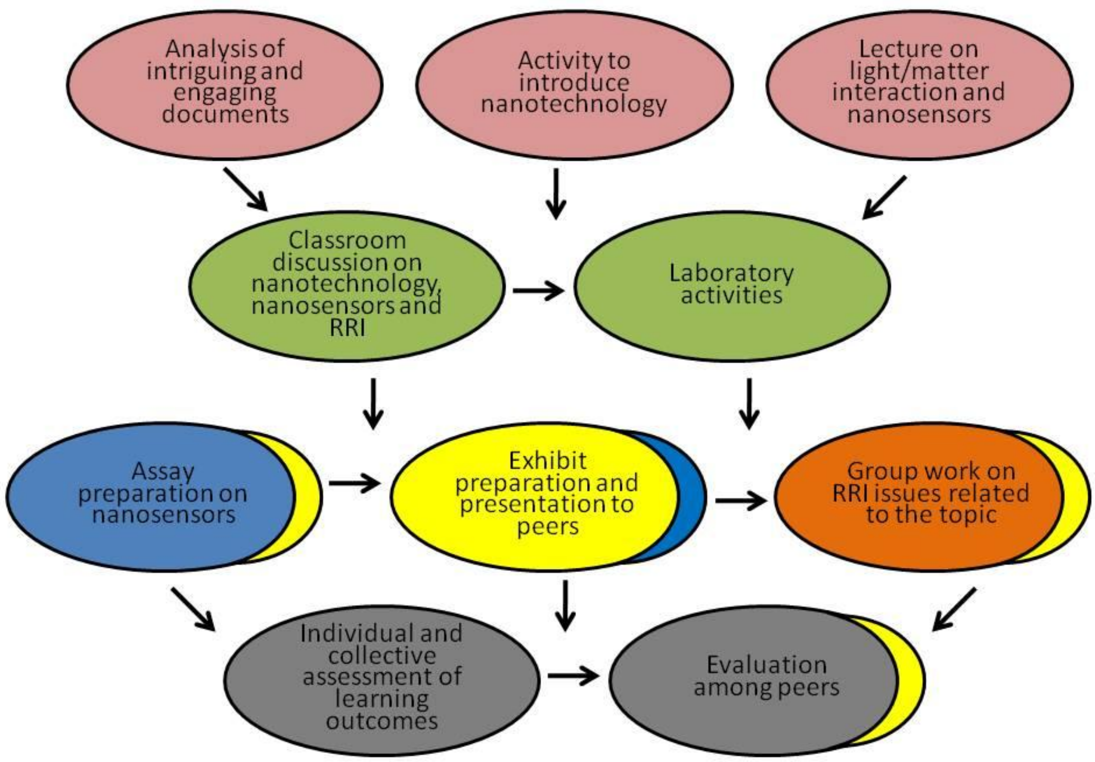
At this stage students have the opportunity to assess their knowledge and skills, while the teacher has the opportunity to assess the progress of their students in relation to the learning objectives established. The evaluation process focuses, in particular, in the students and in the creation of opportunities for them to reflect on their performance – making use of self-assessment. This stage goes along all the phases of the module. Indeed, students have multiple opportunities to reflect on their performance, difficulties and results.



The following map synthesizes the flow of the different activities proposed for the module. The activities are labelled according to the 6E Model as indicated in the map caption. Some activities play a multiple role according to the 6E Model and, for this reason, in the map the activities are marked with more than one colour; however, for the sake of simplicity, in the following description each activity is assigned to only one of the 6E.

Map of the Module

Engage Explore Explain Elaborate Exchange Evaluate



2

Engage

Introducing the project and analyzing an intriguing document (3h)

The features of the IRRESISTIBLE project, in general, and of the module in particular, are introduced to the students.

The module starts with a lesson during which the relations between the fundamental laws of chemistry and innovative technologies, i.e. nanotechnology, are stressed. After the lesson the students see a video by Harold Kroto: Lavoisier and Mendeleev. Between atoms and molecules modern chemistry is born.

To make students realize that the properties of matter depend on its size and to introduce nanotechnology a practical activity can be performed (Attachment 1).

Advice concerning the risks associated to nanomaterials are provided by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). The students are asked to visit the website.

Then the students are introduced to the chemical aspects of the light/matter interaction by a teacher/expert presentation (Attachment 2).

A simple way to introduce the concepts of atom and molecule to the students

There is a close parallelism between language and chemistry. Atoms are the letters of chemistry, and the periodic table is the chemistry alphabet.

A combination of letters according to the rules of language forms a word, a combination of atoms according to Nature's laws forms a molecule.

Atoms, like letters, are indispensable, but they do not have much meaning by themselves. As in a language words are the smallest units with a meaning, in chemistry molecules are the smallest entities that can play a function: they are indeed the smallest entities of matter that have distinct shapes, sizes and properties.

Every word is constituted by an aggregate of letters with its own structure, in the sense that the members (the letters) are in an established relationship that gives a unique and specific meaning to the aggregate. Similarly, a molecule is an aggregate of atoms that has its own structure. The relationship between the atoms (relative positions and interactions) imparts unique and specific properties to the aggregate.

Therefore, like words, molecules contain specific pieces of information, that can be seen as "the meaning" of a molecule. Furthermore a molecule, like a word, can convey a different message or information depending on the context in which it is.

Both words and molecules can have a strong impact on our life. Both the word "rose" and the molecule responsible for the perfume of a rose give us a pleasant sensation. Words and molecules can be sweet, bitter, light, heavy, sour, cutting. There are words and molecules that can save or kill a life.

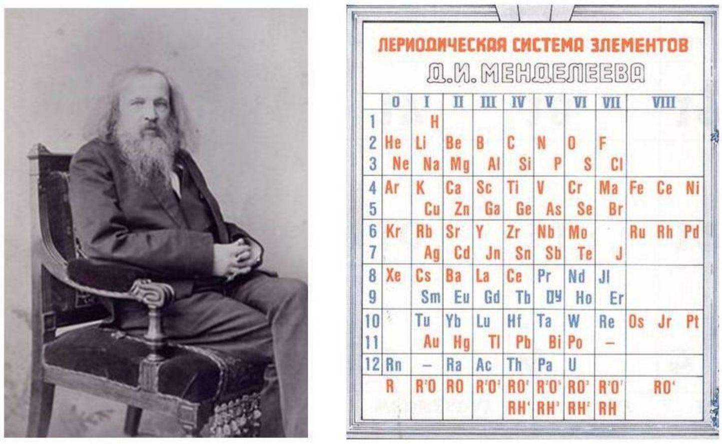
There is another important analogy between language and chemistry. The meaning of a word depends not only on the number and types of letters by which it is formed, but also on the order of the letters. For example, in Italian by using 2*a*, 1*g*, 1*i*, 1*l*, 1*o*, 1*r*, 1*t*, 1*v* we can write two words with very different meanings, *giravolta* (complete turn) and *travaglio* (torment).

Analogously, the same atoms, namely 2*C*, 6*H*, 1*O*, constitute the molecules of methyl alcohol and dimethyl ether that have the same formula, C_2H_6O, but very different properties because of the different order in which the atoms are linked together.

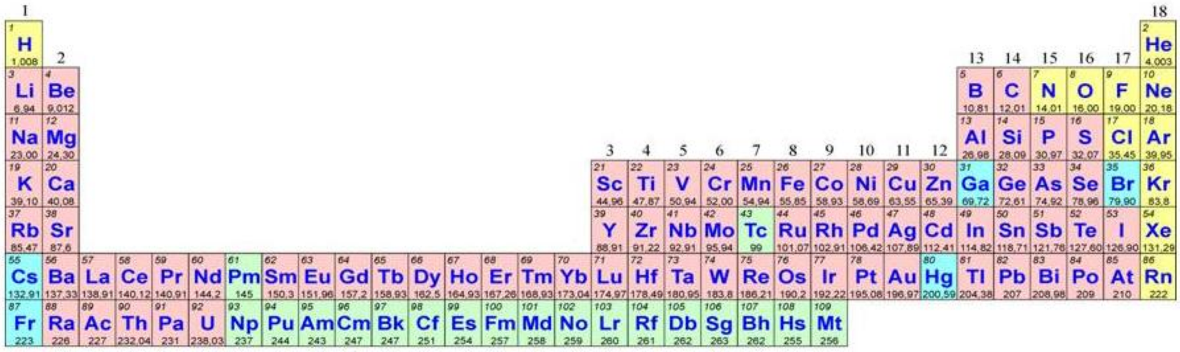
Both words and molecules can be disassembled and then reassembled to give rise to other words or molecules. The Latin poet Lucretius was a master in doing that with words. But Nature is much better. Our body is a book in which some molecules are continuously erased and other written: our skin is fully replaced in a month, our liver is renewed every six weeks.

The field of chemistry is much broader than the field of any language. In Italian there are about 160 000 words, whereas million types of molecules can be found in Nature and million types of artificial molecules have been synthesized by chemists. Leonardo da Vinci did not know chemistry; nevertheless, his sentence *"Where nature finishes producing its species, there man begins with natural things to make with the aid of this nature an infinite number of species"* is quite appropriate to comment the outstanding development of chemistry.

Chemists, indeed, started as explorers of Nature, but very soon they also became inventors and today they continue to play such dual role. As a consequence, chemistry is at the same time a book that we can read and a collection of white sheets that we can write. A large part of the book has not yet been read (undiscovered natural molecules and processes) and the number of white sheets to be written (artificial molecules and processes) is endless.



The original Periodic Table as proposed by Mendeleev in 1869



The extended version of the Periodic Table (2015)

Sources

- Harold Kroto "Lavoisier and Mendeleev. Between atoms and molecules modern chemistry is born": https://www.udemy.com/lavoisier-and-mendeleev-harold-kroto/
- SCENIHR: https://ihcp.jrc.ec.europa.eu/glossary/scenhir
- Attachment 1: Activity to introduce nanotechnology
- Attachment 2: Chemistry and interaction of light and matter

Link to attachments: https://www.dropbox.com/sh/zses6l5sk5vok1h/AACghKeRjnZXJEyeWEKY4kCba?dl=0

Assignment 1

The students are asked to answer the following questions.

- Have you ever heard of nanotechnology before?
- If yes when and concerning what?
- What does “nano” mean in scientific contexts?
- Write the name of something that has the dimension of some nanometers

Assignment 2

The students are invited to prepare a list of questions for experts in nanotechnology who can be contacted by email, blog ,or facebook pages

3

Explore

Classroom discussion, planning of inquiry on nanosensors, and practical work (4h + 3h)

This activity starts with individual work during which each student gathers data concerning nanotechnology and nanosensors by using internet sources.

Then, working in small groups, students try to formulate questions on nanosensors (see assignment). It is suggested that the style of questions follows the six Ws, or better five Ws and one H, strategy. This strategy comes from journalism and indicates the right way to give information: what happened, why, when, and where it happened, who was involved and how the fact occurred.

Students draft the expected answers that put together should give exhaustive information about nanosensors. The best questions and related answers are selected to be shared and discussed with the whole class.

The activity ends with practical work performed in small groups:

Schweppes and UV-light (Attachment 3)

Luminol and forensic analysis (Attachment 4)


Students at work in the laboratory

Sources

- Experiments on luminescent nanosensors: https://youtu.be/eJ5nvhJjYPY
- Attachment 3: Schweppes
- Attachment 4: Luminol

Link to attachments:
https://www.dropbox.com/sh/zses6l5sk5vok1h/AACghKeRjnZXJEyeWEKY4kCba?dl=0

Assignment 1

Questions to be answered by the individual students and discussed with the whole group:

- *What is a sensor?*
- *What does nano means in science?*
- *What is a nanosensor?*
- *How do nanosensors work?*
- *Why are nanosensors useful?*
- *Why is the bottom up (chemical) approach important in nanotechnology?*
- *Where can nanosensors be used?*
- *When have been created nanosensors?*
- *Who created nanosensors?*
- *Who can use nanosensors?*

Assignment 2

The students are requested to write a report on the experiments carried out

4

Explain

Students prepare an essay on nanosensors (2h)

A presentation is given to the students by an expert on the importance of light in our life and from the technological point of view.

The slides of this lecture is given in Attachment 5, where the specific topics addressed are:

- Light absorption is responsible of the color of the things (slides 4-9)
- Artificial sources of light (slides 10-11)
- Light absorption is responsible of the light emission exhibited by some substances (slides 12-13)
- Characteristics of the luminescent nanosensors (slide 14)
- Possible applications of luminescent nanosensors (slides 15-20)
- Light absorption can induce changes in the shape of appropriate molecules (slide 21)
- Light absorption can cause in specific substances a color change: photochromic substances (slides 22-23)
- Light emission can be a consequence of chemical reactions: chemiluminescent reactions (slide 25)
- Light absorption can cause the occurrence of reactions that in the dark cannot take place: photochemical reactions (slide 26)
- The importance of the photochemical reactions in nature and in the technological field (slides 27-46)
- Some considerations on the technological development (slides 47-51).

Then, students have to prepare an assay on the investigated nanosensors by working both in small groups and at home.

Sources

- Attachment 5: The importance of light in our life and for technology

Link to attachment:
https://www.dropbox.com/sh/zses6l5sk5vok1h/AACghKeRjnZXJEyeWEKY4kCba?dl=0

Assignment 1

The students are requested to write an essay on nanosensors

5

Elaborate

Group work on RRI and nanosensors (2h)

In the elaboration phase the attention shifts to RRI. First the students discuss the RRI dimensions connected to a technological issue of the everyday life (e.g., students can start thinking about cellular phones and shampoo). Then the students, working in small groups, are requested to pose questions related to nanosensors: each group discusses two dimensions of RRI concerning the addressed topic and poses as many questions as possible about the two selected dimensions. Then the groups share and discuss together their results.
Finally students identify challenges related to nanosensors to be answered by the scientists.

Sources

- RRI concerning nanosensors: https://youtu.be/l4SqBYIKLCI

Assignment 1

Design and development of a presentation (e.g. poster, power point presentation) to convey the content knowledge about nanosensors and RRI

Students showing their poster at the Irresistible meeting held in Bologna (2015)

6

Exchange

Exhibit preparation and presentation(4h + 3h)

In this phase students, working in small groups, design an exhibit, which can be displayed in the science centers or at school. Posters or other presentation modes may also be used.

In order to design the exhibit, a visit to a museum and the interaction with the museum staff is likely to result very helpful.

Some of the deliverables produced by the younger students for their exhibit have been posted on the web site of the school (see link in Sources).

The older students decided to adapt a soccer table to play a game in which the players discuss the RRI aspects concerning the use of nanotechnology and nanosensors (game rules: attachment 6; game video: attachment 7)

Sources

- Link to the school website: http://www.iisnobili.gov.it/index.php?option=com_content&view=article&id=656:progetto-ricerca-e-innovazione-responsabili-nanotecnologie-e-nanosensori-luminescenti&catid=25:altri-progetti
- Attachment 6: soccer table rules
- Attachment 7: soccer table video

Link to attachments:
https://www.dropbox.com/sh/zses6l5sk5vok1h/AACghKeRjnZXJEyeWEKY4kCba?dl=0

A group of students presenting their work at the Irresistible Meeting held in Bologna (2015)

Students after their presentation at the Irresistible meeting with some of the project partners

6-Exchange

7

Evaluate

Evaluation of the module activities

Self and hetero evaluation will be present at different moments of the module. At least three aspects concerning the module activities need to be evaluated:

- Features of the group’s work (exhibit, power point presentation, etc.)
- Single student reflections and learning (focus groups)
- Cooperation of the students to the whole process

The following grids are examples of evaluation tools concerning these three aspects.

Table 7.1

Rubric to evaluate the presentation

Dimension	Excellent		Good		Sufficient		Insufficient	
Text	Rich in information; clearly and logically explained	4	The most important information is present	3,5	Only basic information is contained	3	No information or/and major errors	1
Graphic and animations	Graphic clear and consistent with the text. Effective animations	2,5	Partially clear graphic and partially consistent images	1,5	Poor graphic, misspellings	2	A lot of errors	1
Punctuality	Delivery on the agreed day	1,5	1 day late (agreed with the teacher)	1	1 days late	0,5	Later than 2 days	0
Exposition	Confident and effective communication	2	Fairly confident communication	1,5	Not confident communication	1	Ineffective communication: the student reads the slides and/or parts are missing	0

Table 7.2

Rubric to evaluate the exhibits

	Level 1	Level 2	Level 3
Scientific Content	No basic science concepts are presented	Only some basic science concepts are presented	The exhibit is strongly based on the scientific concepts
RRI	There is no mention of RRI	There is a weak connection of RRI to the exhibit (only 1 or 2 key concepts are addressed)	There is a strong connection of RRI to the exhibit
Interactivity	The object is static	The object is moderately interactive	The object is highly interactive
Creative, original, and aesthetic aspect	Not very appealing and original	Moderately appealing and original	Very appealing and original exhibit
Design and selection of exhibit	The selection is made by the teacher	The design of exhibit is selected by majority	A consensus is reached about the design of the exhibit
Cooperation among the students	The exhibit is realized by few students	There were two or three leaders in the class who distributed the roles	The role of each student in the realization of the exhibit is assigned by exploiting the specific competences of each one

A group of students filling the format to evaluate the cooperative project

Assignment 1

Evaluation of the cooperative project on nanosensors and RRI

Class .... date ....

Name .... Role in the group ....

Title of the project ....

Short description of your contribution to the work

....

Signature of all the group-mates for agreement

Signature ....
Signature ....
Signature ....
Signature ....

If you have to redo this project what would you change to get better results?
....
....
....

How could the group work more effectively next time?
....

8

References

Recommended bibliography on RRI and IBSE

- Bybee, R. (2002). Scientific Inquiry, Student Learning, and the Science Curriculum. In R. W. Bybee (2002) (Ed.), Learning science and the science of learning (25-35). Arlington, VA: NSTA Press.
- Bybee, R. (2006). Scientific inquiry and science teaching. In L. Flick, & N. Lederman (Eds.), Scientific inquiry and nature of science: Implications for teaching for teaching, learning, and teacher education. Dordrecht: Springer.
- Bybee, R. et al (2006). BSCS 5E Instructional Model: origins and effectiveness. http://bscs.org/sites/default/files/_legacy/BSCS_5E_Instructional_Model-Full_Report.pdf
- Bybee, R. W. (2009). The BSCS 5E Instructional Model and 21st Century Skills. http://itsisu.concord.org/share/Bybee_21st_Century_Paer.pdf
- Grunwald, A. (2011). Responsible Innovation: Bringing together Technology Assessment, Applied Ethics, and STS research. Enterprise and Work Innovation Studies, 7, 9-31. http://www.itas.kit.edu/pub/v/2011/grun11c.pdf
- Hargrave, J. (2013). Museums in the Digital Age. http://www.arup.com/~/media/Files/PDF/Publications/Research_and_whitepapers/2013_Arup_FRI_MuseumsintheDigitalAge_final_web.ashx

- Hawkey, R. (2004). Learning with Digital Technologies in Museums, Science Centres and Galleries. http://halshs.archives-ouvertes.fr/docs/00/19/04/96/PDF/hawkey-r-2004-r9.pdf
- Heath, C. & D. vom Lehn. (2009). Interactivity and Collaboration: new forms of participation in museums, galleries and science centres. In Ross Parry (ed.). Museums in a Digital Age. Routledge: Milton Park, 266-280.
- Hofstein, A. & Rosenfeld, S. (1996). Bridging the gap between formal and informal science learning. Studies in Science Education, 28, 87-112. http://www.bobpearlman.org/BestPractices/Israel/Bridging%20the%20Gap.pdf
- NSTA. BSCS 5E Instructional Model http://learningcenter.nsta.org/files/PB186X-4.pdf
- Owen, R., Macnaghten, P. & Stigoe, J. (2012). Responsible research and innovation: from science in society to science for society, with society. Science and Public Policy, 39(6), 751-760.
- Sutcliffe, H. (2011). A report on on responsible research and innovation. http://ec.europa.eu/research/science-society/document_library/pdf_06/rri-report-hilary-sutcliffe_en.pdf

- Link to the attachments: https://www.dropbox.com/sh/zses6l5sk5vok1h/AACghKeRjnZXJEyeWEKY4kCba?dl=0


ACID RAIN DETECTOR
SUN SHIELD
SMOKE DETECTOR
COLD SWEAT
ULTRAVIOLET SENSOR
POLLUTION ALERTER
GAMMA GOGGLES
RADIO FOR CANCER NEWS
PRESSURE MONITOR
CONFUSED EXPRESSION
FIBER COUNTER
GEIGER COUNTER
VERY CLEAN AIR
PARTICULATE MONITOR
SOLAR STORM ALARM
UNKNOWN MONITOR
MONITOR MONITOR
RADON DETECTOR
BELT-PAK FDA LIST
SUNSCREEN SPRAYER
PLENTY OF EXERCISE
STRESS REGULATION MONITOR
SOMETHING TO TRIP ON