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Responsible Research and Innovation in Science Education: the IRRESISTIBLE Project

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Abstract
The EU funded IRRESISTIBLE-project (Project Coordinator: Jan Apotheker, University of Groningen, Netherlands) develop activities designed to foster the involvement of high school and elementary students and the public in Responsible Research and Innovation (RRI). In the project, awareness about RRI is raised in two ways: increasing content knowledge about research by bringing topics of cutting edge research into the program; fostering a discussion among the students on RRI issues about the topics that are introduced. Responsible Research and Innovation focuses on six key issues: Engagement, Gender equality, Science education, Ethics, including societal relevance and acceptability of research and innovation outcomes , Open access, Governance. The project combines formal and informal teaching to familiarize schoolchildren with science. Sixteen partners in ten countries are involved and coordinated by Science LinX. Each participants will establish a community of learners (CoL). The communities include school teachers together with university experts in the field of science communication and science centre staff. Each CoL will develop materials that the teachers will use at their own schools and students will develop an exhibit for a science centre in their own country.
Once they have completed their teaching module, the teachers will each train five colleagues, in using the developed modules from the first year. Ultimately, this project will train almost ten thousand pupils to consider the social impact of scientific research.

Keywords
Responsible Research and Innovation, Science Education

1. Responsible Research and Innovation

Since 2010 the focus of the Science in Society framework of the EU has been the development of a framework for Responsible Research and Innovation (RRI). Responsible Research and Innovation asks for a close cooperation between society and research (Rome Declaration, 2014; Contribution of FP6 and FP7 to RRI; 2014). One of the first requirements for such a framework is the contact between the different stakeholders. In the project IRRESISTIBLE we raise the awareness about the relation between research and society among young people with a special focus on school students and their teachers as intermediates. For the purpose of the project the 6 aspects of RRI shown in table 1 have been considered and will be addressed throughout the project activities.

Table 1. Aspects of RRI and the use in the project modules

Engagement	Joint participation of researchers, industry and civil society in the research and innovation process
Gender Equality	Unlocking the full potential of society
Science Education	Creative education to foster the future needs of society

Ethics	Including societal relevance and acceptability of research and innovation outcomes
Open access	Free, online access to the results of publicly funded research
Governance	The responsibility of policy makers to develop harmonious models for RRI

2. The IRRESISTIBLE project

The IRRESISTIBLE project designs activities that foster the involvement of students and the public in the process of responsible research and innovation. We raise awareness about RRI in two ways:
• Increasing content knowledge about research by bringing topics of cutting edge research into the program
• Fostering a discussion among the students about RRI issues about the topics that are introduced.

The chosen topics listed in table 2 are based on cutting edge science within the universities of the partners and are characterized by a high societal relevance. The chosen topics connect and overlap with topics normally covered in secondary school curricula. For every topic, a lead partner is given; however, they will be developed and implemented in different countries throughout the project.

Table 2. Lead partners for the chosen topics

Netherlands	Healthy ageing
Portugal	Genomics and oceanography
Germany	Oceanography and climate change
Finland	Climate change
Israel	Renewable energy sustainability
Romania	Solar energy and specific nanomaterial
Turkey	Nanoscience
Greece	Nanoscience applications
Italy	Nanotechnology
Poland	Nanotechnology (catalysis)

3. Enhancing teacher professional preparation

The main focus of the project IRRESISTIBLE is on teacher professional preparation. All partners have experience in both pre- and in-service teacher training. Through teacher preparation a longer lasting effect will be established than working only with different students year after year. Teachers who have used educational material successfully will be using this material in consecutive years.
In the teacher training process formal and informal learning environments will be connected.

Informal environments can be used in different ways in the educational process:
• Attract positive attention from students towards a subject;
• Introduce content knowledge in a different way;
• Allow discussion with stakeholders about RRI issues;
In the formal learning environment the teachers will adapt existing material into a new format in which
• students are motivated;
• interest from both boys and girls is promoted;
• students take responsibility for their own learning;
• topics are introduced that demonstrate the overlap between different fields of science.

4. 5E format expanded to 6E format

The 5 E method has different steps. In the first three (Engage, Explore, Explain) content knowledge is studied and learned. In the last two steps (Elaborate, Evaluate) the focus is on discussing the RRI issues regarding the topic studied.

Between these last two steps we have introduced an extra step, Exchange, involving the development of an exhibition by the students. Students devising and presenting an exhibition is a means of transforming science from product to process (Hawkey, 2001). During these exhibits' preparation, learners will ask questions, use logic and evidence in formulating and revising scientific explanations, recognizing and analysing alternative explanations, and communicate scientific arguments.

Through the construction and presentation of exhibits on Responsible Research and Innovation both teachers and students are introduced to a different type of science from the one that is usually presented in science classes. Most of the formal science education focuses on a conventional, noncontroversial, established and reliable science.

5. Community of Learners

For the teacher training IRRESISTIBLE will use Communities of Learners (CoL). Communities of Learners have proven to be a powerful means of training teachers (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). Within the Community of Learners each group has a different role: teachers have expertise with working in the classroom; science educators have a large theoretical background about education; science centres have experience in informal learning activities; researchers are experts in cutting edge science research; and people from industry are aware of the way science is used in industry.

Our Communities of Learners include experts from the field of formal and informal education, both in research and practice. The first step will be to adapt existing material on teaching and learning about Responsible Research and Innovation for school and out-of-school learning environments.

Topics will be cutting edge research taking place in the local universities, and will be supported by the researchers that will be part of the Communities of Learners. Cutting-edge scientific and technological matters highlight a "borderline science", that is controversial, preliminary, uncertain and under debate.

The controversial dimension refers to "differences over the nature and content of the science such as the perception of risk, interpretation of empirical data and scientific theories, as well as the social impact of science and technology" (Levinson, 2003).

Apart from content knowledge about the research related to the local curriculum, focus will be on the Responsible Research and Innovation aspects that will be integrated in the adapted teaching modules in an IBSE approach.

Each teaching module will:
1. Introduce an everyday situation/ subject (in order to make the topic contextualized and relevant to students),
2. use an IBSE approach, advances to the observing, classifying, experimenting and explaining the phenomena and the properties that are relevant to the chosen application,
3. address the broader issues related to the application in question: societal and environmental implications, ethical issues, and other RRI aspects,
4. include instructions for teachers on how to use the module and utilize the platform (e.g. exemplary schedule for the course, suggestions for lesson plans…),
5. provide additional reading material on the topic in question, to be included in the textbooklike information source for teachers and students,
6. suggest how students can design exhibits that

a. present the chosen subject (the same one as in the teaching module),
b. highlight the phenomena and properties relevant to that application,
c. addresse the societal and environmental implications and related ethical issues.

Each Community of Learners will include 4 to 5 teachers, next to the researchers and experts of outof-school learning. As indicated by Shulman, both experienced and novice teachers can participate fruitfully in these communities (Shulman & Sherin, 2004). After the professionalization in the first phase of the project, these teachers will in turn act as coach another Community of Learners with again 4 to 5 new teachers or partner schools to introduce the modules from the first round and coach these new teachers to use the modules in their own classrooms or teaching practise lessons. This phase will be designed according to the local education system and the common teacher training system in each of the partners. After the first two rounds, at least 25 teachers in the region of the partners will have used the materials and become familiar with using the informal learning setting of the partners' science centre, involving on average 1000 students after the first two years of the project in each country. In total the project will reach at least 40 teachers in the first year, around 250 in the second year and will involve about 1000 students in the first round and about 10000 students in the second round of the project.
Each partner will use the material from at least two other partners, so that the material will be thoroughly evaluated. In the third year a compilation of the modules will be edited and will be published as a pdf file through www.scientix.eu. This material will not only contain the student's material but also a teacher guide, based on the experience of the coache-teachers. Each partner will make lectures about the content knowledge concerning the cutting edge research available for teachers by publishing the materials on the web[1].
The Communities of Learners will use Inquiry Based Science Education techniques that have proven to be effective (Eisenkraft, 2003; Martin-Hansen, 2002) and will work on modules to be used in the classroom. The Communities will be using a 6E template as a shared way to introduce content knowledge about the chosen topic. The teachers and the other experts will learn how to use these techniques by fitting the existing material into the 6E and IBSE format. They will then use this material in the classroom, if necessary being coached by the local experts in formal education.
Modules will be adapted based on the experience in the classroom. These modules will then be used in the second round. As each partner will produce a module at the end of the first round, the teachers from round 2 can choose from 10 modules which module they would like to work with. The teachers from round 1 will act as coach and will introduce the teachers from round 2 into the format used for teaching. The science centres will use or adapt their exhibition to draw attention towards the role of the research studied for society. Such an exhibition is also meant to catch the attention of the general public, supported by different dissemination activities. For the students this may be a starting point for their enquiry RRI project. In the second part of the modules the science centres will play an important role in the RRI discussions.

6. Participants
In each country the university participants work in collaboration with a science centre.
In Table 3 the universities and their science centre partners are indicated.

Table 3. Universities and science centre partners

University of Groningen - ScienceLinX	Local coordinator : Jan Apotheker (Principal Investigator)
Weizmann Institute - The Clore Garden Centre	Local coordinator: Ron Blonder

1 An example may be found on http://qtvideo.service.rug.nl/comvachem/itunes_deel_1-ryan.mov; http://qtvideo.service.rug.nl/comvachem/itunes_deel_2-ryan.mov

IPN - Deutches Museum	Local coordinator: Ilka Parchmann
Bogazici University - Turkey Science Centres Foundation	Local coordinator: Sevil Akaygün
University of Lisbon - Pavilhão do Conhecimento	Local coordinator: Pedro Reis
University of Palermo - Museum of Bali	Local coordinator: Michele Antonio Floriano
University of Jyväskylä - Natural History Museum of Central Finland	Local coordinator: Ilkka Ratinen
University of Bologna - Museum of Bali	Local coordinator: Margherita Venturi
University of Crete - Eugenides Foundation	Local coordinator: Dimitris Stavrou
Jagiellonian University - Jagiellonian University Museum Collegium Maius	Local coordinator: Iwona Maciejowska
Valahia University Targoviste - Prahova Natural Science Museum and History	Local coordinator: Gabriel Gorghiu
University of Helsinki - Natural History Museum of Central Finland	Local coordinator: Antti Laherto

7. Use of web 2.0 activities

Students are increasingly immersed in web 2.0 activities in their free time, but in school these possibilities usually are not part of classroom activities. IRRESISTIBLE-project wants to increase a meaningful use of the opportunities these new technologies offer by including it into the modules. By introducing the teachers in the use of the new technologies the project aims for a wide spread use of 2.0 activities significantly beyond the module context.

8. Evaluation

Evaluation in the IRRESISTIBLE project includes three equally important aspects. The first part of evaluation analyses the work carried out within the Communities of Learners (COL) and the impact of the teacher professional development programme throughout Europe, both through pre- and in-service teacher education.

The second part of IRRESISTIBLE evaluation focuses on the modules developed in the COL's and implemented in schools. Here, the most important method is the measurement of the impact of the modules on students' and teachers' attitudes to Responsible Research and Innovation (RRI). Gender issues and other possible group differences will be investigated, related to factors and topics identified as important in former research. The third part of evaluation is the internal evaluation of the project itself: the organisation of the project as well as the communication and collaboration between the partners during the project.

Six types of evaluation tools are included in the project: a) an on-line questionnaire addressed to all the CoL members on general aspects of concern, IBSE methodology, exhibit desing, social aspects of science education; b) an on-line questionnaire addressed to all the CoL members on RRI aspects; c) a checklist focused on the criteria for the modules addressed to one representative for each partner of the project; d) an on-line questionnaire addressed to students on RRI, exhibit design, social aspects of science education; e) case studies on exhibit development addressed to teachers (interviews) and students (focus-groups); project evaluation questionnaire addressed to one representative for each partner.

9. Responsible Research and Innovation in Nanoscience and Nanotechnology[2]

Nanotechnology is a word developed in the scientific literature, now frequently used also in common language. It is a word that stirs up enthusiasm and fear since nanotechnology is expected, for the good and for the bad, to have a strong influence on the future of mankind. To this end, considering the impact of cutting-edge research in nanoscience, a strong conceptual understanding and well established awareness of nanoscience and nanotechnology need to be developed in the society.

Everybody seems to know what nanotechnology is, but even within the scientific community its meaning is not yet well established. The nature of the involved nano sized objects is just at the basis of the different approaches of physics and chemistry to nanotechnology. Physicists are mainly interested in nanoscale objects that are simple from a chemical viewpoint and do not exhibit any specific intrinsic function (atoms, clusters of atoms, small molecules). In these cases functions arise from ensembles of such objects (i.e. nanoparticles, nanostructured materials, nanoporous materials, nanopigments, nanotubes, nanoimprinting, quantum dots…). The development of this kind of nanotechnology has already led to many innovative applications, particularly in materials science, such as the materials used in photovoltaics, in the construction of LED, and the development of carbon nanotube-based materials employed in several fields.

Chemists focus their interest on nanoscale objects that have complex chemical composition, show peculiar properties, and perform specific functions. Each single nanoscale object is, therefore, capable of performing a function that is intrinsically connected to its chemical nature and structure. Nanoscale objects of this type behave as real devices and machines at the molecular level and are present in nature where perform a variety of functions, from the light-harvesting antennae of the photosynthetic systems to the linear and rotary motors that work in our body. In the last twenty years chemists have learned to construct artificial molecular devices and machines that are expected to be of great importance in several fields. For example, they will open new ways for storing, processing, and transferring information, develop new approaches to diagnosis and therapy in medicine, find new solutions for the energy and environment problems. In addition, for many people the 'buzz word', nanotechnology, brings comfort to daily life, by innovative products and applications such as self-cleaning textile, anti-bacterial coating, and cosmetics. The scientific and conceptual background of these daily applications of nanotechnology and its social and ethical impacts should be elaborated and incorporated into science education. Nanoscience is also very well suited to demonstrate how basic concepts in science are used in state of the art scientific research. The identification and discussion with students of this basic concepts is helpful to induce interest and curiosity because these concepts are dealt with in a more concrete and effective way. As a result, the study of science laws is more appealing while, at the same time, frontier research is more tangible. This is particularly true for chemistry research, which is currently central in very diversified science areas.

The module is based on the teaching/learning materials that have been developed by the Bologna, Bogazici, and Palermo partners, which involve in their CoLs both physicists and chemists who work in the research field of nanoscience and nanotechnology and have competences in science education, history of chemistry, and dissemination.

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