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Raising Youth Awareness to Responsible Research and Innovation through Inquiry Based Science Education

From time to time, publications appear which discuss the greatest achievements of the last century, scientific successes from the past ten years, describing the development trends, prophesying the development of science and civilization in the future, together with threats and opportunities connected to them. The example of such a publication is a report authored by Andrew Maynard and Tim Harper entitled *Building a Sustainable Future – Rethinking the Role of Technology Innovation in an Increasingly Interdependent, Complex & Resource-constrained World,* which was presented during the annual *World Economic Forum* meeting in 2011 (Maynard, Harper 2011). It characterizes both developmental challenges, such as for example: increasing water deficiency, growing demand for energy, health, and food, limited resources, climate changes and trends including: global citizenship, social life in a world dominated by technology, demographic changes, increasing mobility (Figure 1).

The authors mention a number of technological innovations that have changed our world – from vaccines, new drugs and medical diagnostic methods, through getting energy from the nuclear fission and the combustion of biofuels to superconductors and intelligent materials (Figure 2).

In the next step, they indicate the "means" thanks to which these innovations were possible and which participate in the development of the above-mentioned trends. They include e.g. nanotechnology, computational chemistry, robotics, bio-interfaces, Web2.0.

In recent years, the European Union put special emphasis on carrying out and introducing the above-mentioned research and innovations in a responsible manner (*Responsible Research and Innovation* – RRI). The reason of such approach was presented by e.g. Hilary Sutcliffe, the director of MATTER (http://www.matterforall.org), in her report for the European Commission. One of the arguments is the need to take advantage of the lessons of the past and the need to avoid previous disasters, such as the large-scale use of asbestos and CFCs, and the fear of unexpected and/or

irreversible consequences of new discoveries, resulting inter alia from the increasing scale of influences and time pressure during the decision making process. Another factor supporting the need for RRI is a growing distrust for the achievements of science among the public, which may be due to the high advancement of knowledge necessary to understand the innovations introduced.

Figure 1. Global trends (Maynard, Harper 2011)

Technology Innovations			
Vaccines	Carbon sequestration	Smart grids	Better health diagnostics
Advanced sensors	Soil management	Smart materials	High conductivity materials
Next generation electronics	Efficient resources use	Bottom-up manufacturing	Safer nuclear power
Point of use energy generation	Climate control	Renewable energy sources	Substitute materials
Better food preservation	Resilient crops	Immersive communications	Targeted pesticides
Smart drugs	Increased land productivity	High value crops	Biofuels
Water desalination	Thermal insulators	Efficient resource extraction	Water separation
Strong, lightweight materials	Irrigation	Disease management	Sustainable production processes
Automated traffic management	Better batteries	Advanced prosthetics	At-source water purification

Figure 2. Technology innovations (Maynard, Harper 2011)

Responsible Research and Innovation is characterized by:

1. The choice of research topics and product innovations in terms of achieving (as a consequence of their use) social or environmental benefits.
2. Constant commitment (from the beginning to the end of the innovation process) of society, including non-governmental organizations and other groups that are aware of the public good.
3. Evaluation and effective prioritization of impact, risks and opportunities – social, ethical, and environmental, now and in the future, in parallel to consideration of technical and commercial aspects.
4. Supervision mechanisms, better anticipation of problems and better management of problems and opportunities, as well as the ability to adapt and react quickly to variations in circumstances and changes in the state of knowledge.
5. Openness and transparency as an integral part of the research and innovation process (Sutcliffe 2014).

As in case of many other new initiatives coming partly from outside of the society of researchers from the natural sciences field (but affecting them directly), the following questions immediately arise in the research community: why do I have to inform the public about my research? And who actually should I inform? What will the benefits be? Would it not be just propaganda activities? What if someone from outside the group of scientists question the research that I am working on**? Is RRI a false or illusory need, or rather an essential component of growth and progress?** It is a natural and healthy symptom of a critical approach to reality. It is not a negative attitude to the question of responsibility for ongoing research, but rather caution in adopting new regulations and recommendations. The thing is worthy of a wider discussion.

It is also worth stressing that even without the pressure from the European policymakers, the scientific community has been trying to define the standards of practice through the so-called *Codes of Conduct* for years, for example *The Chemical Professional's Code of Conduct* prepared by the American Chemical Society. According to this document, people involved in professional chemistry confirm their responsibility in relation to the public (e.g. "Public comments on scientific matters should be made with care and accuracy, without unsubstantiated, exaggerated, or premature statements"), the science of chemistry (e.g. they should "understand the limitations of their knowledge, and respect the truth"), the profession (e.g. "Conflicts of interest and scientific misconduct, such as fabrication, falsification, and plagiarism, are incompatible with this Code"), their employers (e.g. chemists should "perform the work honestly, competently, comply with safety policies and procedures, fulfil obligations, and safeguard proprietary and confidential business information"), their employees, students, colleagues (e.g. "they should show consistent respect to colleagues, regardless of the level of their formal education and whether they are from the industry, government or academia, or other scientific and engineering disciplines"), clients, and the environment (e.g. "they have a responsibility to

understand the health, safety and environmental impact of their work, to recognize the constraints of limited resources, and to develop sustainable products and processes that protect the health, safety, and prosperity of future generations").

In order to make the society familiar with the RRI concept, the European Commission introduced this topic into the grant competition, e.g. within the framework of activities coordinating and supporting the FP7-SCIENCE-In-SOCIETY-2013-1 programme, 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. In this competition, the grant project named IRRESISTIBLE (*Including Responsible Research and innovation in cutting Edge Science and Inquiry-based Science education to improve Teacher's Ability of Bridging Learning Environments*) received funding. It is coordinated by the University of Groningen (The Netherlands) with a Polish partner – the Jagiellonian University (Faculty of Chemistry and the Museum of the Jagiellonian University – Collegium Maius).

The aim of IRRESISTIBLE is to design the activities that will foster the involvement of students and the public in the process of Responsible Research and Innovation through: developing teaching materials, providing training courses, organizing projects and student competitions, preparing interactive exhibitions. The awareness of RRI will be raised in two ways: by increasing content knowledge about research by bringing topics of cutting edge research into the teaching program of science subjects; and through fostering a discussion among the students about RRI issues both in formal teaching (at school) and in informal teaching (in science centres, museums, and science festivals).

What distinguishes the IRRESISTIBLE project from other educational projects is the close cooperation of scientists and people involved in education. Teams were formed in each country, called the *Community of Learners* (CoL). Such communities are formed not only by upper secondary school teachers and natural science educators, but also by designers of interactive exhibitions (employees of scientific museums, science centres) as well as scientists. "A Community of Learners can be defined as a group of people who share values and beliefs and who actively engage in learning from one another – each partner is both a learner and a teacher; learners from teachers, teachers from learners, and learners from learners." [4] Everyone, learning from each other, will collaborate in the development of teaching modules to work with students at schools and for informal education purposes. In the second phase of the project, the task of teachers – participants of the first CoL (team of learners) – will be to train the next five colleagues from the school teaching staff (Figure 3).

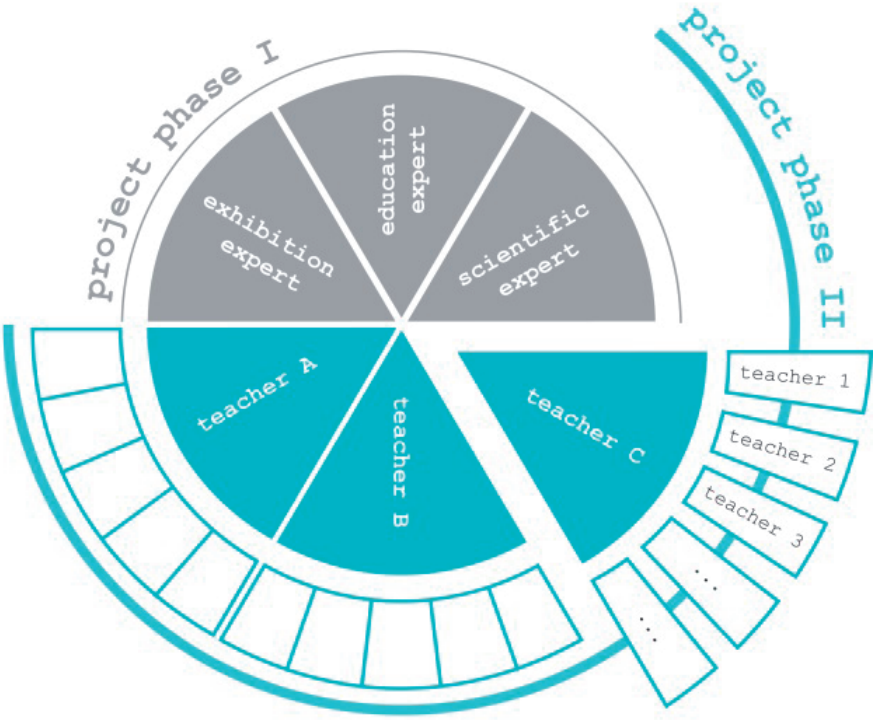

Figure 3. Two phases of work of the teams of learners of the IRRESISTIBLE project

Six key issues of RRI will be included (in an appropriate scope for a particular educational project) within the IRRESISTIBLE:

- Engagement – joint participation of researchers, industry and civil society in the research and innovation process,
- Gender equality – unlocking the full potential of society e.g. through the modernization of human resources management in scientific entities,
- Science education – increasing the interest of children and adolescents in natural science, science and technical sciences; education that equips future scientists and general public with the necessary knowledge,
- Ethics – respect for fundamental rights and the highest ethical standards, increase of societal relevance and acceptability of research and innovation outcomes,
- Open access – free, on line access to the results of publicly funded research,
- Governance – the responsibility of policy makers to develop harmonious models for RRI (*Responsible Research*...).

Modules of teaching materials for teachers and students will be based on the IBSE – Inquiry Based Science Education implemented in the context of modern, responsible research and innovation. The 6Es method will be applied in the project activities with students:

- **E**ngage – Students are introduced to the subject by a visit to the local science museum, studying exhibits related to the research subject. They use web-activities to learn more about the subject.
- **E**xplore – They go to a lecture by the researcher about the research being done at the university. In class they discuss the connection to the curriculum and identify questions about the subject (step 1 in IBSE)
- **E**xplain - They now start the second part of the IBSE, finding answers to their questions, either by experiments or by finding the necessary knowledge. In the classroom their answers are transformed into the knowledge they need to answer the question asked. It is also indicated which knowledge is needed within the curriculum.
- **E**laborate – The idea of RRI is introduced and applied to the research subject that was studied. On the web, in the science centre or during a visit to the university these issues are discussed by the students with the researchers.
- **E**xchange - The students build an exhibit/poster in which they demonstrate the RRI issues they have identified. The exhibits are collected in the science centre and displayed there. The exhibits can be judged, so the best exhibits may receive a prize.

The subject of the proposed courses will include a number of different areas, in which the project partners are specialized:

- Healthy ageing – food, food production (University of Groningen, the Netherlands),
- Genomics and oceanography (Universidade de Lisboa, Portugal),
- Climate changes from the perspective of fields dealing with the atmosphere and oceanography (IPN in Kiel, Deutsches Museum in Monachium – Germany, University of Jyväskylä, University of Helsinki, Finland),
- Renewable energy sustainability (Weizmann Institute of Science – Izrael, Valahia University Targoviste – Romania),
- Nanoscience applications (Bogazici University – Turkey, University of Crete, Eugenides Foundation Greece),
- Nanotechnology (University of Palermo, University of Bologna, Italy),
- Catalysis in environmental protection (Jagiellonian University, Poland).

Just as the scientific and economic community is sometimes sceptical about RRI, also in the teaching community in Poland the following questions arose: can nanomaterials and technologies be taught at school? Is it not a level of polytechnic/ university education? – here, those who were interested were invited to take a look at the example at the website of the "Time for Nano" project – http://www.timefornano.

eu/pl/. The Warsaw University of Technology was one of the participants of this project. Where can a place for new content in a seemingly overloaded and strictly defined by learning outcomes Polish teaching curriculum be found? - this is where one of the solutions seems to be a simple use of this modern subject as a context for nature classes in upper-secondary schools, for classes dealing with the scientific methods, science dilemmas, etc. What can be a source of knowledge for a teacher on topics that he/she did not have a chance to become familiar with during the studies? Answers to all these questions will be provided successively at the website of the project: http://www.irresistible-project.eu.

References

Maynard A., Harper T., 2011, *Building a Sustainable Future – Rethinking the Role of Technology Innovation in an increasingly interdependent, Complex & resource-constrained world.* Report for World Economic Forum Global Agenda Council on Emerging Technologies, .

Sutcliffe H., *A report on responsible Research and Innovation,* http://ec.europa.eu/research/science-society/document_library/pdf_06/rri-report-hilary-sutcliffe_en.pdf (16.04.2014).

The Chemical Professional's Code of Conduct, ACS, https://www.acs.org/content/acs/en/careers/profdev/ethics/the-chemical-professionals-code-of-conduct.html (16.04.2014).

Culture of learning, Learning and the Adolescent Mind, http://learningandtheadolescentmind.org/ideas_community.html (16.04.2014).

Responsible Research and Innovation. Europe's ability to respond to societal challenges, http://ec.europa.eu/research/science-society/document_library/pdf_06/responsible-research-and-innovation-leaflet_en.pdf (16.04.2014).

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Abstract

This paper refers to an idea of Responsible Research and Innovation (RRI) and methods of its promotion. The educational project IRRESISTIBLE, proposed in the 7th Framework Programme, has been described there. The need for some kind of research code of conduct comes among others from the need to avoid past disasters, such as the large-scale use of asbestos and CFCs, and from the fear of unexpected and/or irreversible consequences of new discoveries. What distinguishes IRRESISTIBLE from other educational projects is the close cooperation of various groups, such as: teachers, science educators, researchers and museums in the so-called Community of Learners. The teaching materials developed will refer to cutting edge science discoveries and facilitate the introduction of RRI issues using Inquiry Based Science Education (IBSE) at schools and in the framework of non-formal education (implemented in the cooperation with museums and science centres). This paper raises a series of questions related to the introduction of modern research into schools, e.g. whether nanotechnology can be the context for teaching the basic chemical and physical

concepts, already included in the school curriculum, such as the issue of scale, size depending properties etc.

Key words: Responsible Research and Innovation, educational projects, informal education, Community of Practice

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