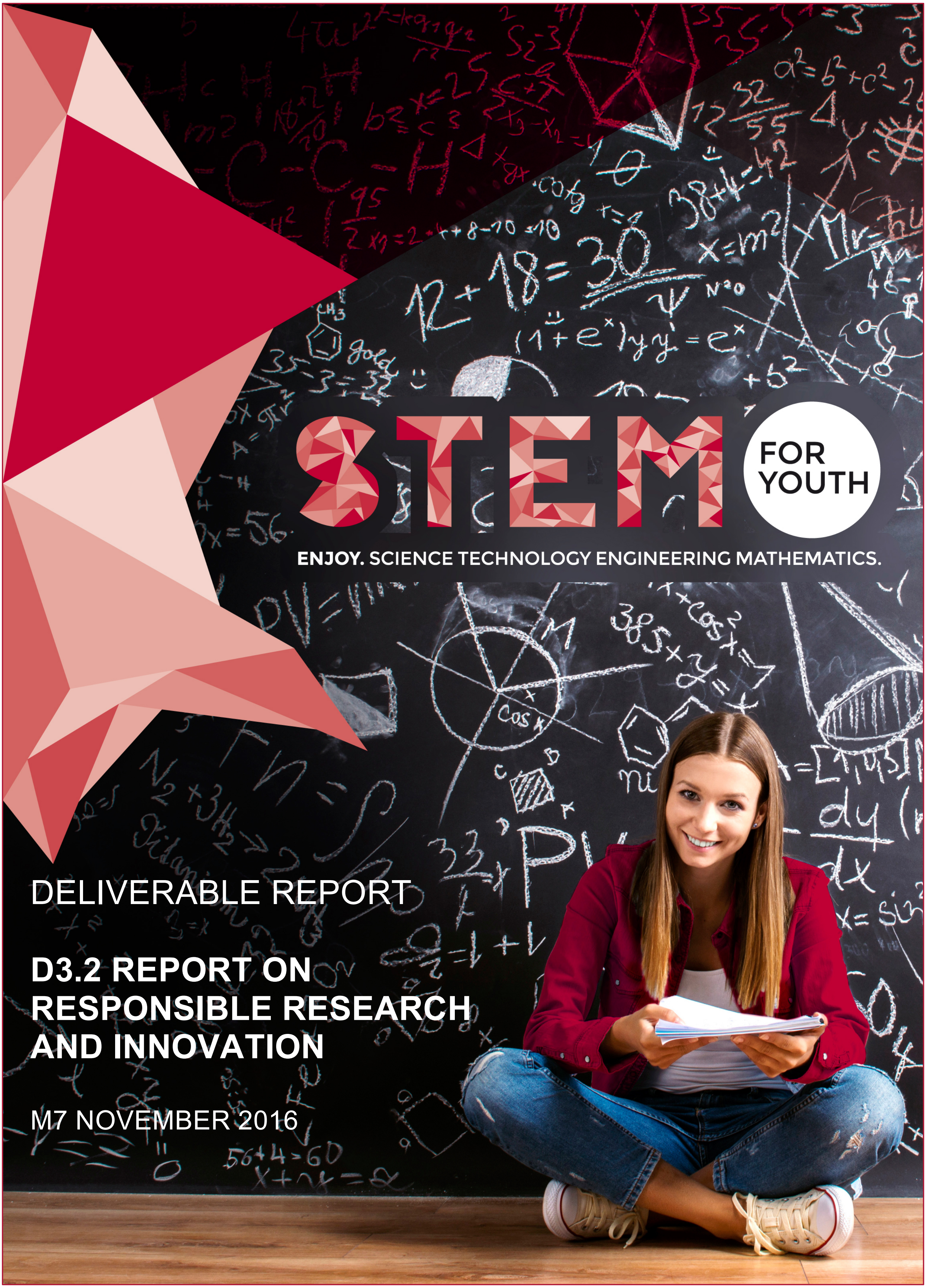

STEM FOR YOUTH

ENJOY. SCIENCE TECHNOLOGY ENGINEERING MATHEMATICS.

DELIVERABLE REPORT

D3.2 REPORT ON RESPONSIBLE RESEARCH AND INNOVATION

M7 NOVEMBER 2016

PROJECT DETAILS

PROJECT ACRONYM	STEM4YOU(th)
PROJECT TITLE	Promotion of STEM education by key scientific challenges and their impact on our life and career perspectives
GRANT AGREEMENT	710577
START DATE	1 May 2016
THEME	SWAFS

DELIVERABLE DETAILS

WORK PACKAGE NO. AND TITLE	WP3: Research of Learning Methodologies and Educational Tools
WORK PACKAGE LEADER (No. and short name)	7-UB
DELIVERABLE NO. and TITLE	D3.2 Report on Responsible Research and Innovation
PARTNER IN CHARGE OF DELIVERABLE (no. and short name)	7-UB
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REPORT DETAILS

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REVIEWED BY	Mirosław Brzozowy, Technical Project Manager (WUT)
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TABLE OF CONTENT

1. EXECUTIVE SUMMARY

The objective of the STEM4you(th) project is to produce a comprehensive, multidisciplinary series of courses presenting key STEM discipline challenges to support young people, primarily high school students aged 12-19, in their formal and informal education.

"Introducing the RRI perspective in STEM education: 10 big ideas" is the Deliverable 3.2 Report on Responsible Research and Innovation of the STEM4you(th) project which seeks to describe aspects related to Responsible Research and Innovation (RRI) that might be relevant to the STEM4you(th) project. This deliverable is framed within the WP3 Research of learning methodologies and educational tools, devoted to investigate, develop and customize the learning methodologies related to the project's content. Proposing a focus on RRI for this WP is explained by the importance for students to become aware of the fundamental aspects of RRI, so they will use them in their future careers in research, education, business and citizenship.

WP3 includes a first state of the art on learning methodologies and tools, with a selection of interactive educational methods, reported in Deliverable 3.1 Report on learning methodology and tools. Based on that, D3.2 seeks to reflect on RRI in STEM education and how it relates to the learning methodologies and tools identified in D3.1. Specifically, the report includes in its first section **RRI: A short introduction** a brief summary about what RRI is and which are its antecedents. In the second section **RRI in STEM education: What and why?** a discussion about why including RRI perspective in STEM education is important and what implications would this new perspective imply. In the latter section, a more nuanced definition is proposed than is hitherto available of STEM education pillar. Finally, the last section **10 ideas to include the RRI perspective in STEM Education** offers a useful guide of ten big ideas about how RRI perspective could be brought to STEM Education, considering the pillars and processes that characterize the RRI paradigm and linking these big ideas with the methodologies identified by D3.1.

These ten big ideas and the implications they entail will be taken into account in Deliverable 3.3 Methodology and educational tools, which will describe in details how to present the course topics and how the tools will support the topics' communication.

2. RRI: A SHORT INTRODUCTION

The term Responsible Research and Innovation (RRI) has gained importance in the last five years within the political discourses agenda related to the Research and Innovation (R&I) field, especially in Europe. While the concept could not be considered anew, RRI could be seen as an attempt to integrate various perspectives and practices dealing with the ethical, legal and social implications of research, seeking to overcome their perceived limitations and the need to be more aligned to major societal challenges (Owen, Macnaghten & Stilgoe, 2012).

Several working definitions of RRI (European Commission, 2015a) have emerged from the diverse recent initiatives and projects dealing with different approaches to the RRI frame (e.g. RRI Tools, PARRISE, HEIRRI or EnRRICH projects), emphasizing different concepts or ideas. In these definitions, RRI is referred to as a new paradigm for research and innovation, emphasizing the pillars on which it is based and its influence to the R&I policies. However, definitions also referred to it as a practice or a new way of doing research and innovation. We believe that this distinction is key to approaching the RRI concept from an educational perspective. To go more deeply into both views, we briefly discuss them below:

RRI paradigm

As a paradigm for the R&I activity, RRI has grown from traditional views that just emphasize the role of society in science to the more recent "Science *for* the society" perspective that was the seed of the RRI framework: "*Responsible Research and Innovation agendas that meet citizens' and civil society's concerns and expectations and by facilitating their participation in Horizon 2020 activities. The engagement of citizens and civil society should be coupled with public outreach activities to generate and sustain public support for Horizon 2020"* (European Parliament and Council, 2013). Today, a more comprehensive view of the relations between Science and Society encompasses the idea of "Science *with* the society" which is the baseline of the RRI framework: "*Responsible research and innovation means that societal actors work together during the whole research and innovation process in order to better align both the process and its outcomes, with the values, needs and expectations of European society. RRI is an ambitious challenge for the creation of a research and* *innovation policy driven by the needs of society and engaging all societal actors via inclusive participatory approaches*' (European Commission, 2014).

Described as above, the paradigm shift towards an RRI perspective is mostly due to the recognition of the need for participation and engagement of society in R&I from a democratic perspective. As such, most working definitions of RRI emphasise the importance of participation introducing the idea of inclusiveness or participation of all involved agents: *'Decisions in research and innovation must consider the principles on which the European Union is founded, i.e. the respect of human dignity, freedom, democracy, equality, the rule of law and the respect of human rights, including the rights of persons belonging to minorities* (Council of the European Union, 2014).

Other working definitions of RRI, however, emerge from a different standpoint. Focused on the ethical aspects of research, these views stand from the reflection on what acting responsibly means in R&I: '*the coupling of research and innovation with responsibility (…) acknowledges that the nature of science is linked to dealing with risks and uncertainties of scientific research and innovation in a responsible way' (PARRIS Project)*. This ethical approach to RRI brings to the equation the concept of reciprocity and sustainability in RRI together with the need for an openness to public scrutiny ('*a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products'* (von Schomberg, 2012))

RRI as a practice

Other definitions of RRI emphasise how RRI must be done instead of explicitly discussing what the RRI perspective could provide to R&I activities. In this sense, RRI is defined or understood as a desirable practice of the R&I community, as *'ways of proceeding in research and innovation that allow those who initiate and are involved in the processes of research and innovation at an early stage (A) to obtain relevant knowledge on the consequences of the outcomes of their actions and on the range of options open to them and (B) to effectively evaluate both outcomes and options in terms of moral values (including, but not limited to wellbeing, justice, equality, privacy, autonomy, safety, security, sustainability, accountability, democracy and efficiency) and (C) to use these considerations* *(under A and B) as functional requirements for design and development of new research, products and services'* (van den Hoven & Jacob, 2013).

What appears as important under this perspective of RRI as a practice, is the characteristics or requirements of the RRI processes, generally described as anticipatory, inclusive, reflexive and responsive. Within the *RRI Tools Project*, these process requirements for any R&I to be framed in the RRI paradigm are defined as follows:

1. **Diversity & inclusion**

   Diverse and inclusive RRI processes should involve a wide range of stakeholders in the early development of science and technology, both for democratic reasons and to broaden and diversify the sources of expertise and perspectives involved in science. In this respect, inclusive practices should lead to diverse practices. In reverse, diverse practices are more likely to be inclusive.

2. **Anticipation & reflection**

   Anticipation means understanding that there will be impacts of research and innovation - intended and otherwise - and making it possible to explore how will they affect different groups and individuals in society. Reflection means thinking about the motivation, purposes and potential implications of R&I, including the uncertainties that are involved with it, and how they are shaping what is being proposed and what is being done.

3. **Openness & transparency**

   Openness and transparency are conditions for accountability, liability and thus responsibility. This is an important factor in establishing public trust in R&I. More openness does not automatically lead to more trust. But it allows groups and individuals not normally involved in R&I to make their opinions known, even if they disagree with the researchers and innovators concerned.

4. **Responsiveness & adaptive change**

   Responsiveness means being able to take account of what society needs and wants. RRI involves a capacity to change or shape existing routines of thought and behavior, as well as the overlying organizational structures and systems, in response to changing circumstances, new insights and stakeholder and public values.

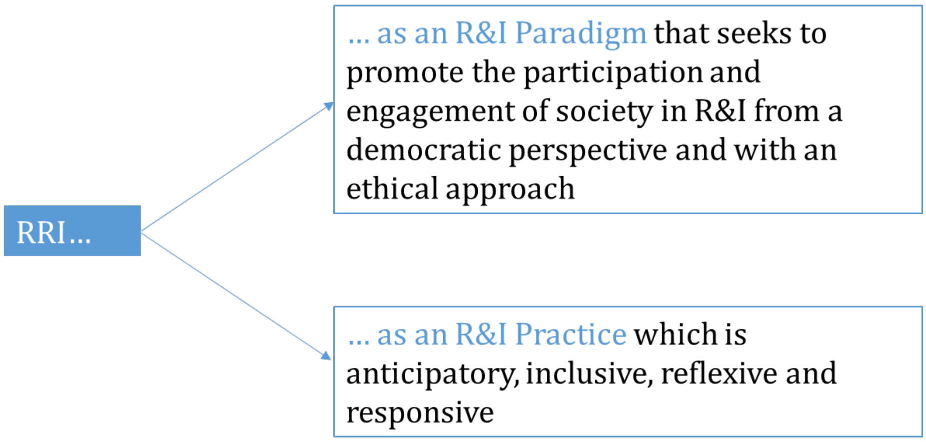


Figure 1. Two perspectives from which to talk about RRI

On top of both the paradigmatic and practical definition, RRI appears to be always linked to six powerful policy agendas or pillars, each with their own potential to realize responsibility in research and innovation (RRI Tools project definitions):

- **Ethics:** Focuses on (1) research integrity: the prevention of unacceptable research and research practices; and (2) science and society: the ethical acceptability of scientific and technological developments.
- **Gender:** Gender equality in RRI is about promoting gender-balanced teams, ensuring gender balance in decision-making bodies, and always considering the gender dimension in research and innovation to improve the quality and social relevance of the results.
- **Governance:** To reach the future that is both acceptable and desirable, governance arrangements should be: (1) robust and sufficiently adaptable to the unpredictable development of research and innovation (de facto governance); (2) be familiar enough to align with existing practices in research and innovation; (3) share responsibility and accountability among a large variety of actors and provide instruments to foster this shared responsibility.
- **Open access**: Addresses issues of accessibility and ownership of scientific information. Free and earlier access to scientific work might improve the quality of

scientific research and facilitate fast innovation, constructive collaborations among peers and productive dialogue with civil society.

- **Public engagement:** The process of R&I is collaborative and multi actor: all societal actors (researchers, citizens, policymakers, industry, educators, etc.) should work together during the whole research and innovation process in order to align its outcomes to the values, needs and expectations of the European society.
- **Science education:** Focuses on (1) enhancing the current education process to better equip citizens with the necessary knowledge and skills so they can participate in research and innovation debates; and (2) increasing the number of researchers (promote scientific vocations)

As a summary of all the diverse definitions stated above and in an attempt of relating them for a more operational understanding of the RRI term, we outlined a scheme that includes:

What RRI looks for (**RRI as a paradigm**)?

How it seeks to achieve it (**RRI as a practice**)?

What is it based on (**RRI pillars**)?

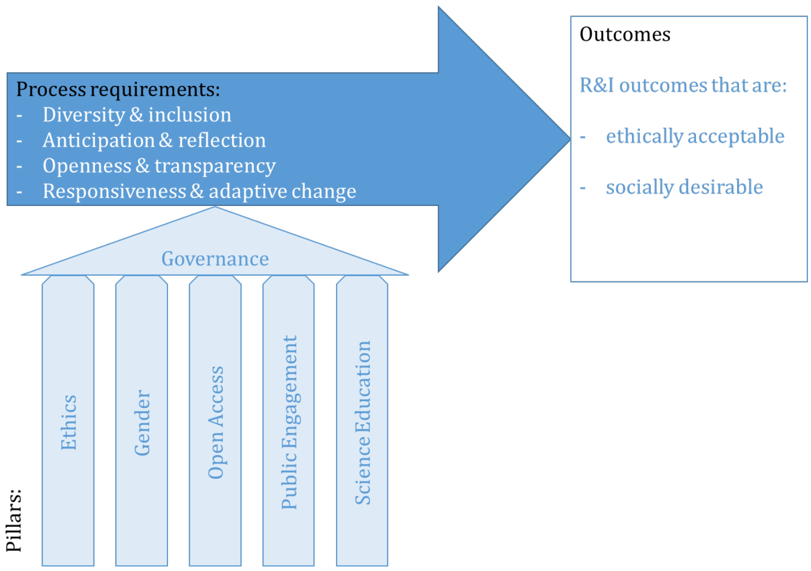


Figure 2. RRI elements: outcomes, process requirements and pillars

3. RRI IN STEM EDUCATION: WHAT AND WHY?

As introduced above, education, and particularly Science Education is one of the pillars necessary for RRI to become both a feasible paradigm and practice for R&D. Firstly, because (in)formal education from pre-school years to university and life-long learning, is generally referred to as a privileged strategy to bring RRI into action. In every meeting, conference, paper and brochure on RRI the role of education is emphasised, either, for instance, as citizens' literacy for critical decision-making, as researchers' preparation for engaging in RRI R&I or as communities' awareness of their role in R&I. Secondly, because despite the RRI perspective being applicable to all research and innovations (that is, referring also to social or humanistic research), existing RRI calls, projects and tools refer mostly to the positivistic or technologic research field.

The idea of STEM education within RRI counts on alternative and/or complementary, either explicit or implicit, definitions which are not always product of a real reconceptualization of STEM education from the RRI perspective. In this sense, while some views emphasize the need of increasing the number and improving the profile of research professionals others urge for a more STEM literate citizenship. The Report "Science Education for Responsible Citizenship" (European Commission, 2015b) also recommends that greater attention should be given to promoting RRI and enhancing public understanding of scientific findings and the capabilities to discuss their benefits and consequences.

Beyond their differences, these definitions coincide with the fact that they are more focused on *why* STEM education can contribute to the RRI paradigm instead of on *what* it actually implies to introduce the RRI perspective in STEM education and *how* it can be done to achieve the expected outcomes. In this sense, using the distinct definition of RRI as both a *paradigm* and as a *practice* presented above, we propose a more nuanced definition of the STEM education pillar in the framework of RRI that starts from current views of STEM education.

3.1 The starting point: STEM Education today

There is large consensus in the educational community that the main objective of current STEM education is to guarantee STEM literacy of all citizens. From the competence-based educational framework shared at European level (European Commission, 2007; OECD, 2005), STEM literacy is seen as the acquisition of STEM competences. In other words, it is the ability to put STEM knowledge into the everyday practice of making informed decisions and solve relevant problems.

The STEM competence-based framework goes beyond traditional views of STEM education. It implies enlarging our view of STEM content (what to teach) and redesigning the STEM methods to learn it (how to teach). Regarding what to teach, the important emerging question is which specific STEM knowledge all citizens need to put into practice. Recent academic and policy documents in STEM education advocate for a new view of STEM knowledge that goes beyond traditional images of purely conceptual contents. In this new view of STEM content, both the procedural and epistemic dimensions of STEM knowledge are included (OECD, 2016) for youngsters to participate in a set of STEM practices (such as asking scientific questions or explaining scientific phenomena) (National Research Council, 2012)). This implies an understanding of and ability to participate in what STEM is and how it is done. Interestingly for the RRI viewpoint, this is not only knowledge of STEM but also about STEM: about the nature of the human enterprises we call Science, Technology, Engineering and Mathematics.

Regarding how to teach, one can wonder how can knowledge of and about STEM (knowledge that includes both concepts but also epistemologically adequate STEM procedures and practices) be acquired. The answer to these questions might be found among those scholar ideas that contemplate how people learn both generally and in the STEM field particularly (Donovan & Bransford, 2005). These ideas are simple to declare but have proven difficult to arrange in practice.

They are:

1) that we learn from what we already know and are able to do
2) that we learn with others, both equals and more experienced than us

3) that we learn by becoming actively involved both cognitive and emotionally

4) that we learn within the context of challenging activities that require from us extended knowledge and practices.

Not surprisingly, there is a variety of innovative methods in STEM education that share a focus on students' active participation, hence being compatible with the aforementioned ideas on STEM learning. Effective STEM teaching and learning methodologies emphasise STEM practices instead of products, allowing people to participate in genuine science modelling, inquiry or argumentation processes, or in product development.

3.2 What does the RRI perspective mean in STEM Education?

Since the RRI paradigm is changing both our views of STEM R&I activity and how it is to be developed, the inclusion of RRI perspectives in STEM Education challenges both the above definitions of what and how to teach STEM today in important ways. In other words, a re-conceptualisation of STEM education from an RRI perspective requires to decide which new STEM contents and practices are required and what sort of STEM educational scenarios students should experience.

> *The inclusion of the RRI perspective in STEM Education challenges both **what** and **how** to teach*

3.2.1 What to teach?

Regarding the what to teach in STEM from an RRI perspective, the aforementioned distinction between RRI as a paradigm and RRI as a practice becomes useful, as each view of RRI implies different changes to the STEM content (European Commission, 2015b).

- Changes in content about STEM to introduce the RRI paradigm in:

For future citizens and researchers to be able to appreciate and participate in RRI processes the over-arching RRI paradigm should be made known, comprehensively and reflectively. Dealing with this epistemic content on the new nature of R&I within the RRI perspective implies discussing and critically reflecting with the students on how the RRI pillars have or have not been considered as well as how RRI processes are being (un)successfully used in their own and others' experiences of STEM R&I. An example is a critical analysis of current research cases, including the view on these activities as necessarily participatory and ethically uncompromised.

- Changes in the content of STEM to introduce the RRI paradigm in:

Beyond understanding the philosophy behind the RRI approach, STEM education should furthermore allow the development of STEM practices in line with the RRI process requirements. For instance, in Science education this means shifting the focus from the development of students' ability to ask scientific questions to do so in a participatory manner, or in engineering education to capacitate students to anticipate ethical, cultural or environmental impacts when planning and designing solutions.

Rethinking *what* to teach in STEM from an RRI perspective implies:

- **Changes in content *about STEM* to introduce the RRI paradigm:** new nature of R&I within the RRI perspective
- **Changes in *content of STEM* to introduce the RRI paradigm:** development of STEM practices following the RRI process requirements

3.2.2 How to teach?

Regarding the how to teach in STEM from an RRI perspective, it is necessary to highlight that not all current STEM educational innovations based on students' active engagement (thus considered effective for STEM) promote the RRI perspective in the classroom. On the contrary, the introduction of the RRI perspective implies challenging these methodologies to tackle in specific and productive ways the abovementioned RRI contents. This implies, on the one hand, to use approaches that leave room for the discussion and reflection about RRI, either based on the students' own activities or in relation to real research examples. This could be achieved, for instance, by promoting students' reflection on socio-scientific dilemmas.

On the other hand, it also entails including RRI process requirements when delegating tasks to students, so that they themselves get into the practice of it. Since the inclusion of RRI process requirements makes more sense in contexts that emulate the activities carried out by the R&I STEM communities, it seems relevant to include proposals that seek to actively engage students in real R&I projects. Genuine inquiry-based learning or well-designed project-based activities are an opportunity for students to get involved and to experience an R&I activity. However, including RRI process requirements implies enriching these proposals with specific approaches. Projects based on citizen science or service-learning or approaches addressed to tackle equity in STEM (e.g. STEM self-efficacy development among under-represented communities in STEM fields) are possible ways for including the RRI perspective to R&I students' experiences.

Rethinking *how* to teach in STEM from an RRI perspective implies:

- To favour teaching and learning methodologies that **emphasise the practices** instead of the products of STEM, allowing people to participate in genuinely science inquiries or product development
- To use approaches that leave room for the discussion and **reflection about RRI**
- To include **RRI process requirements** when proposing students' tasks

3.2.3 Transversal skills

In addition to specific STEM contents and practices, the competency based framework emphasises the importance of including the development of transversal skills such as cooperative work, communication or entrepreneurship in the STEM classrooms. Moreover, introducing the RRI perspective in STEM education challenges our understanding of these transversal competencies and how to include them while teaching or learning in STEM. For instance, the transversal competency of being able to work with others acquires new meanings, such as introducing an inclusive gender dimension (other genders, different stakeholders) as well as a participatory one (working with research personnel or the main users of the product being developed).

> Introducing the RRI perspective in STEM education challenges also transversal competences and how to include them (e.g.: including gender and participatory dimensions to the transversal competency of being able to work with others)

3.3 Why is the RRI perspective in STEM Education important?

Redefining what the RRI perspective means to STEM Education allows for a better understanding of why including the RRI perspective in STEM education is important. Introducing the RRI paradigm as a content and as a practice could confirm the speculation of STEM Education as one pillar for realizing RRI. However, returning to current definitions of STEM Education from the RRI perspective we think that the existing narrative should be contrasted. While agreeing with the views signalling the urgency for an improvement of STEM literacy among citizens as well as the need for enlarging the amount of research professionals in the STEM field, we think that more importantly the RRI paradigm calls for an increase in their overall quality. That is, in the diversity, capacity and values shared by the research community.

Specifically, we consider that the inclusion of RRI perspective in STEM Education would have an impact on both levels:

- **For all students:** increasing their STEM literacy and helping the development of their transversal skills to develop awareness about RRI, understanding of the RRI framework, and to be able to actively participate in as well as value the RRI processes.
- **For future researchers:** raising interest and diversity of students in STEM fields (particularly under-represented groups such as women and disadvantaged students) by emphasising the human dimension brought forward by the RRI perspective in STEM and capacitating them in the application of the RRI process requirements (with increasing complexity along the educational path).

The inclusion of RRI perspective in STEM Education would have an impact at both levels:

- **For all students:** increasing their STEM literacy to develop awareness on RRI, understand the RRI framework, and be able to actively participate in and value of particular RRI processes.

- **For future researchers:** raising interest and diversity of students in STEM fields and capacitating them in the application of the RRI process requirements

4. 10 IDEAS TO INCLUDE THE RRI PERSPECTIVE IN STEM EDUCATION

Idea 1. RRI reshapes what to teach in STEM

Idea 2. RRI challenges the methodologies to be used in STEM education

Idea 3. Learning RRI asks for first-hand experiences

Idea 4. RRI needs explicit and critical reflection in STEM classes

Idea 5. Motivation is the key for RRI practice in STEM education

Idea 6. Gender is an issue in STEM teaching

Idea 7. Inclusion is a driving force for STEM learning

Idea 8. RRI perspective needs a systemic approach that overcomes STEM disciplines

Idea 9. Transparency and openness should be the new cultures in STEM education

Idea 10. STEM education in RRI must deal with the uncertainty that is a part of our future

Idea 1. RRI reshapes what to teach in STEM

STEM contents and practices should be rethought to include the RRI perspective.

All STEM contents and practices could be addressed from an RRI perspective. However, this requires rethinking them and focusing on those aspects that are relevant from an RRI perspective. In the RRI paradigm as a new R&I framework, the RRI process requires new dimensions to be considered in STEM practices and new meanings of transversal skills that will reshape what to teach in STEM classrooms. For instance, the concept of energy by itself is not a content including an RRI perspective although it nevertheless entails several ethical (when for instance we introduce nuclear energy) and societal challenges (when we introduce renewal energies) that allow dealing with it from an RRI perspective if chosen to do so. In this regard, allowing students to work towards providing answers to questions such as 'Whether and where should a new nuclear plant be located?', bringing the content of energy resources and energy consumption to a plausible context for dealing with it from an RRI perspective.

Examples:
Contents about STEM to introduce the RRI paradigm:

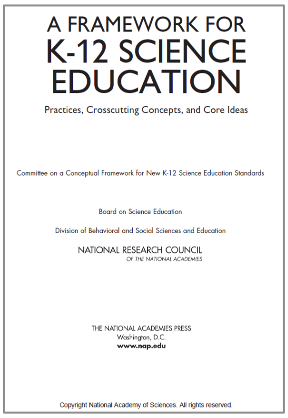
ENRRICH promising practice: SRI – Social Responsibility of the Engineer
"The goal of this exercise was to propose our students an intense experience of group work with a challenge dimension. We wanted them to put into perspective their scientific achievements while associating a societal dimension. Social responsibility of the engineer is a very important aspect of training at INSA, that's what we wanted to highlight."
+ More information

TUDelf Course on Responsible Innovation
"This massive open online course (MOOC) discusses the concept of responsible innovation, its meaning and its significance, by

addressing the societal implications of new technologies. It also shows how we might incorporate ethical considerations into technical innovations. The course is for all those interested in relationships between technological innovations, ethics and society."

+ More information

Contents of STEM to introduce the RRI paradigm:

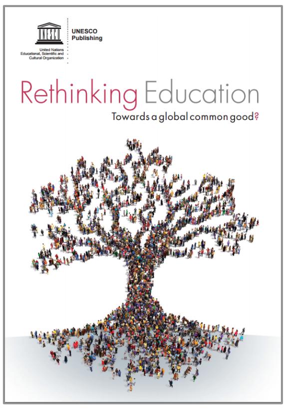


A Framework for K-12 Science Education. Practices, Crosscutting Concepts and Core Ideas

"The overarching goal of this Framework for K-12 science education is to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology."

+ More information

Transversal skills:



Rethinking Education. Towards a Global Common Good?

"The changes in the world today are characterized by new levels of complexity and contradiction. These changes generate tensions for which education is expected to prepare individuals and communities by giving them the capability to adapt and to respond. This publication contributes to rethinking education and learning in this context."

+ More information

Identified risks: Given the fact that generally the effective achievement of STEM Education objectives is closely related to the methodologies used to do so – making the active STEM teaching and learning approaches the more desirable ones - the inclusion of RRI perspective has sometimes been identified as only being linked to the implementation of innovative methodologies at STEM schools. However, the challenge of including the RRI perspective in STEM Education has to be seen as a two-step process: first, it implies to think over the objectives of including the RRI perspectives in STEM education (what do we want students to know and to be able to do) and, second, how to tackle these objectives in an effective way. In this regard, understanding that RRI is a new STEM R&I paradigm that is changing our view on the nature of STEM and the ways it is carried out poses the first big challenge: to rethink what needs to be taught before deciding which approaches to use to do so.

Idea 2. RRI challenges the methodologies to be used in STEM education

The RRI perspective is neither a STEM educational methodology nor is it promoted per se by using innovative STEM educational methodologies.

Teaching and learning methodologies promoting students' direct experience of the RRI process could allow addressing both the explicit reflection on the RRI aspects as well as the acquisition of the necessary competencies and skills for participating in an RRI process. Some innovative methodologies could be considered as suitable approaches to promoting this direct RRI experience since it has at its heart to foster agency and participation in STEM related practices. Nonetheless, just as with the content, including the RRI perspective implies the intentional inclusion of the RRI process requirements as well as dealing with its pillars in any methodology we choose to use.

Some methodological approaches for promoting students' active participation and inclusion of the RRI perspective could be the introduction of citizen science at school, discussions about socio-scientific issues, service-learning and the use genuine inquiry-based learning. All these methodologies, that can overlap in many ways, are already recognized by their potential for effectively addressing STEM contents but also having specific characteristics that can be easily linked to RRI processes and pillars.

- Citizen Science:

A possible definition of Citizen Science refers to a practice involving the participation of the public in the activities of scientific research (Socientize, 2014) In this way, citizens actively contribute to research, whether through intellectual effort, knowledge, tools or resources. Participants can thus provide data, raise new questions and collectively create a new scientific culture. Generally speaking, a recent report (European Commission, 2015c) stated that Citizen Science can contribute to RRI as it reinforces public engagement and can re-direct research agendas towards issues of concern to citizens.

Promoting Citizen Science in STEM education, allowing students to participate in real research activities, is an opportunity to present science as a social activity, allowing students to acquire co-responsible habits and attitudes. Undoubtedly, Citizen Science projects are a perfect context in which to promote certain STEM practices to students. Moreover, if the research in which students are participating is framed with the RRI paradigm, these practices would be nuanced under an RRI perspective and explicit reflections about the research characteristics and how they fit those of the RRI paradigm could be easily promoted. A recent publication (Perelló, 2016) demonstrated that the introduction of Citizen Science in Secondary schools allowed a remarkably good acquisition of scientific competencies. This work also supported the idea that Citizen Science projects shall be introduced in schools with multidimensional and multidisplinary perspectives that allow for a context-based learning and enable students to handle shared concerns related to their own neighborhoods through a hands-on approach.

- Socio-Scientific Issues:

Socio-Scientific Issues (SSI) are those that significant numbers of people would argue about, without necessarily reaching a conclusion or consent. They are socio-scientific problems that are ill-defined and value-led, invoking aesthetic, ecological, economic, moral, educational, cultural, religious and recreational values that are constrained by missing knowledge (Chiapetta, Koballa & Collette, 1998). Used in STEM education, SSI are seen as good contexts in which to allow students to deal with ambiguities, challenging their decision-making and developing their capacity to constructively argument. Argumentation is a fundamental discourse of science: one that can engage students in the social practices of science and one which can help them understand the connection between science and everyday life (Driver, Newton & Osborne, 2000). Well defined SSI projects in STEM education could allow addressing some relevant RRI characteristics such as anticipation and reflection or responsiveness and adaptive change.

- Service-learning

In service learning, students co-work to address a community problem using a multidisciplinary approach. It combines community service with curriculum-based learning. Effective service learning includes: authentic learning goals, response to community needs, youth decision-making, and analytic reflection (European Union, 2016). These kind of approaches, together with citizen science, are good contexts in which to propose community driven researches so that the community may actively participate in the research activities in partnership with the researchers.

- Inquiry-based learning:

The predominant perspective in STEM education in the last twenty years has been the idea that science should be taught as a process of inquiry. This implies allowing students to develop the abilities necessary to realize scientific inquiry (e.g. design and conduct scientific investigations, use appropriate tools and techniques to gather, analyse and interpret scientific data etc.). A step forward within this approach is the idea of teaching science as a practice that includes inquiry as well as processes of explaining (modelling) and argue based on evidence (argumentation). This approach seeks to promote among students a better understanding of the nature of STEM disciplines among students while also enhancing their motivation for them. Considering the shifts that RRI is causing on our view about the nature of R&I, the perspective of teaching STEM practices is crucial if we want students to understand the RRI paradigm and to be able to be engaged in it.

Other innovative methodological approaches could become good contexts for addressing some RRI contents if tuned accordingly since they have high potential for updating STEM education. Non-conventional learning environments, including those based on the use of **ICTs (Information and Computer Technologies) and Social Media**, could contribute to fostering students' motivation and interaction - key educational elements for both STEM learning and RRI school practice. On the one hand, non-conventional learning strategies have been argued to positively influencing students' motivation. Approaches such as **gamification** and **play-based or manipulative and hands-on proposals** (such as experiments but also those framed in the maker movement, enhanced by using creative technologies) have a confirmed positive impact on students' motivation. Moreover, the use of ICT or Social Media tools enhances students' interaction with other stakeholders such as STEM professionals. This interaction is crucial, not only for addressing some of the key aspects of how students learn, but also because they, when used in specific ways, can contribute in providing students with more participatory activities framed with the RRI paradigm. Finally, **learning progress monitoring systems** (LPMS) and **adaptive learning tools** could allow students to develop their self-regulation and metacognition, crucial for learning as well as contribute to fostering responsiveness and adaptive change (see D3.1 for more detail).

- **Examples:**

Citizen Science

Citizen science: education and research

"In the framework of this project, we propose the practice of citizen science as an innovative mechanism for science, technology and mathematics learning. This practice, expanding in the English-speaking world, engages the public in scientific research tasks. It seeks to share the method, data collection and outcomes with a broad spectrum of the population thanks to the use of new technologies and smart phones with the aim of improving the scientific training of the population, the sustainable management of resources and spaces, and, lastly, the acquisition of co-responsible habits and attitudes towards the environment. This is possible through a platform composed of five research groups of Catalonia from different areas, already doing citizen science but, at the same time, eager to increase their impact by sharing resources and experiences."

+ More information

Socio-scientific issues

Preparing Elementary and Secondary Pre-Service for Everyday Science (PreSEES)

"The aim of the PreSEES project is to engage elementary and secondary pre-service teachers in critical discussions of everyday science through socio-scientific issues, and prepare them to teach SSI."

+ More information

Promoting Attainment of Responsible Research & Innovation in Science Education (PARRISE)

"The PARRISE (Promoting Attainment of Responsible Research & Innovation in Science Education) project aims at introducing the concept of Responsible Research and Innovation in primary and secondary education. It does so by combining inquiry-based learning and citizenship education with socio-scientific issues in

science education. The project also aims to collect and share existing best practices across Europe and develop learning tools, materials and in/pre-service training courses for science teachers based on the SSIBL (Socio-Scientific Inquiry Based Learning) approach."

+ More information

Service-learning

Apps for Good

"Apps for Good unlocks the confidence and talent of young people through creative learning programmes, in which students use new technologies to design and make products that can make a difference to their world. Apps for Good equips students to research, design and make digital products and take them to market. But apps are not the point of what we do. Our goal is to produce more able, self-confident, collaborative young people, ready to make a difference to their world. Most children are consumers of technology; we want them to become makers using technology."

+ More information

Inquiry-based learning

"Fourteen universities from twelve different countries have worked together over four years to promote the implementation and use of inquiry-based learning in mathematics and science. PRIMAS has developed materials for direct use in class and for professional development. In addition, we have run professional development activities and have supported professional networks in each of the partner countries. PRIMAS has also worked with stakeholders such as policymakers, school leaders and parents to create a supportive environment for inquiry-based learning."

+ More information

Identified risks: A first precaution to be considered when proposing methodologies fit to include the RRI perspective in STEM education has to do with current challenges faced by STEM education in general. The first being the fact that in some cases, **methodologies are not commonly understood**, leading to very different approaches using the same label. A clear example is the case of inquiry-based learning, which is usually identified with 'hands-on' approaches but lacks the emphasis on the development of a scientific thinking that seeks to develop and refine an explanation or a model. Beyond this general flaw, and focusing on the inclusion of RRI perspective in STEM education, there is **a general trend to directly link innovative methodologies with RRI perspectives**. As previously argued, when correctly designed and implemented, innovative methodologies may result effectively in teaching and learning STEM but in order to guarantee the latter they must also effectively tackle RRI contents as well as being accordingly tuned (including RRI process requirements and pillars).

Idea 3. Learning RRI asks for first hand experiences

Learning on STEM processes and about STEM from an RRI perspective implies that these ideas and competences should be experienced first-hand in teaching and learning

Based on the knowledge of how people learn, it is equally significant to hear how R&I has to be done from the RRI perspective as well as experiencing a research process that fits with the RRI paradigm and reflect on its characteristics. Teachers seeking to include RRI perspective in their STEM classroom should facilitate situations in which students can experience for themselves what a collaborative participation in a research process entails (either real or adapted to school context) and reflect metacognitively about such process (its similarities and differences with real research, for instance).

- **Examples:**

irresistible

Including Responsible Research and innovation in cutting Edge Science and Inquiry-based Science education to improve Teacher's Ability of Bridging Learning Environments (IRRESISTIBLE)

"The goal of the project IRRESISTIBLE is to design activities that foster the involvement of students and the public in the process of Responsible Research and Innovation (RRI). The project aims to raise awareness on RRI by increasing pupils' content knowledge about research. This will be achieved by combining formal (school) and informal (science centre, museum or festival) educational approaches to introduce relevant topics and cutting edge research into the programme. By this methodology pupils will be familiarized with science, thus fostering a discussion on RRI issues."

+ More information

20 Tips for High-school Students Engaging in Research with Scientists

"This article provides a list of 20 tips for high school students who are interested in taking part in the research process. Its creation was a collaborative effort between research project participants (students, teachers, scientists), and thus it departs structurally from other scientific articles. The 20 tips come from the participants'

experiences in a research collaboration between students and researchers. As such, they can inform similar projects but should not be taken as guidelines on how to establish such collaborations."

+ More information

Identified risks: *Since RRI paradigm may be seen as a content to be taught, there is the risk* ***to understand RRI only as a conceptual content that has to be transmitted to students****. From the perspective of RRI as a practice, and in line with current competency-based educational frameworks, practices should be emphasized above the focus on STEM products. This requires active participation of students to promote their cognitive and emotional involvement in genuine R&I processes.*

Idea 4. RRI needs explicit and critical reflection in STEM classes

It is necessary to give room to explicit reflection on the value and limitations of RRI in learning contents about and of STEM

Beyond simply allowing students to experience first-hand STEM practices from an RRI perspective, it is necessary to give room while learning about STEM practices and STEM in general to explicit reflection on the values and limitations of RRI. The students need help making the connection between their ideas and experience and RRI ideas. This not only implies designing and implementing rich contexts and activities in which to include RRI perspective, process requirements and pillars (e.g. propose mixed gender teams in a classroom STEM project) but to explicitly reflect about the specific characteristics that have to do with the RRI perspective and how they link to real R&I activity (discussing with students, for one, the benefit of the gender approach for the process and outcomes of the project). Promoting this reflection among students from a critical point of view could also contribute to their own critical reasoning.

Examples:

Teaching Geoethics Across the Geoscience Curriculum *"GeoEthics encompasses the values and professional standards required of geoscientists to responsibly work in the profession and in service to society. The training of scientists in ethics has traditionally been focused on the Responsible Conduct of Research. However, GeoEthics encompasses many more dimensions, including personal and professional behaviors as well as responsibilities to society and to stewardship of Earth. Resources are provided to help students expand their understanding of ethical situations that may arise in their careers, and to give them the tools they need to appropriately address these issues."*

+ More information

Roll the RRI Dice: a game to spark good training conversations or creating case stories

"To create playful situations during an RRI Training to provoke reflection among participants and to create stories and scenarios." This game has been developed in the frame of the RRI Tools project.

+ More information

Identified risks: There is no doubt that the inclusion of the RRI perspective in STEM classroom implies an important effort, with changes in the content and methodologies to be considered. The result of this effort can bring about rich activities and contexts with very promising potentialities. However, **the implicit RRI characteristics may not be as obvious to students** and need to be highlighted and reflected upon, tied to the RRI paradigm in order to guarantee that students take them to heart.

Idea 5. Motivation is key for RRI practice in STEM education

Students' motivation is a key educational element that is crucial for both RRI school practice and STEM learning. Inclusion of non-conventional learning environments, both in formal and informal education, could be used to boost initial motivation for STEM within an RRI perspective.

Non-conventional learning strategies and environments, such as those based on artification, gamification or the maker movement could be highly motivating for STEM students. Either embedded in formal education or in extracurricular activities, students are attracted by novel situations where powerful tools such as humour, narratives, play, aesthesis and high technology, among others, are used in a relaxing environment where STEM learning may happen but it is not perceived as the only goal.

These environments also provide the opportunity to other professionals apart from teachers to come in close contact with students and serve as role models. Whether these are scientist who are also visual artists, engineers that develop games or artists that are interested in STEM, such fresh professionals represent people with various interests; STEM perhaps not being the only one but surely has a role. When these powerful and rich learning scenarios are embedded with RRI principles, not only implying the inclusion of new content and processes, but also provide for another layer of motivation in being involved since such activities often involve fun with the desire to be useful to society and others. It has been demonstrated that an increase of intrinsic motivation is the first stone of meaningful learning (Omrod, 2014). It indeed positively affects cognitive processes, leads to increase effort and energy, strengthens persistence in challenges or problem solving activities and enhances performance.

Examples:

perforM

Participatory Engagement with Scientific and Technological Research through Performance

"The PERFORM project aims to develop young people's conceptions and awareness of science, scientists and scientific research. But it looks to move beyond merely

increasing scientific and technological knowledge to developing a reflective knowing of science in which young people can consider its purposes, values, and how it becomes reality. Learning science involves a re-structuring of perception and through this young people might come into new relationships with the subject, and perhaps themselves, in establishing their identity with the subject. To these ends scientific researchers, performers and young people will work together in schools in developing performance- based activities. It is hoped that the collaboration will increase young people's engagement with science, its values and the processes of research."

+ More information

MalariaSpot:An Online Game for Analyzing Images of Infected Thick Blood Smears

"Malaria is one of the most serious threats to global health. At present, the standard way of diagnosing this disease (with more than 200 million cases of malaria a year and killing half a million people) is to count the number of parasites in blood samples using a microscope. A process that can take up to 30 minutes. And there are not enough specialists in the world to diagnose all cases of malaria. MalariaSpot is a project that wants to solve this problem with citizen participation. We converted the diagnostic process into a video game and investigated techniques for combining player results so that we get a reliable result. The first research was with MalariaSpot in 2012. We applied the idea to Tuberculosis in 2014 with the TuberSpot game. And now we launch MalariaSpot Bubbles to try to differentiate between different species of parasites."

+ More information

Identified risks: Extrinsic motivation could be beneficial to boosting engagement towards STEM and RRI in those students that are not naturally inclined towards these fields; the initial surprise factor, however, decreases easily if the activity is not designed to take into account what we know about STEM learning. In addition, we should be cautious of the fact that **a STEM activity is not effective in promoting STEM and RRI learning simply because it is motivating within the RRI paradigm.** In fact, it is intrinsic motivation (motivation towards learning, per se, for the enjoyment to learn new things) that is clearly associated with increase in learning outcomes above extrinsic motivation (motivation for the formal aspects of the activity, associated with its novelty, etc.). In other words, if a teaching strategy does not endure in its interactivity beyond the beginner novelty, it will not help in increasing STEM literacy or capacity for RRI in students.

Idea 6. Gender is an issue in STEM teaching

Introducing the gender perspective in the science classroom implies deep changes both in what to teach, in how to teach and in why to teach that are more profound than the mere balancing numbers or political-correctness policies.

Introducing a gender perspective in STEM education is a complex challenge. Timid attempts in this direction have limited educators to the awareness of the importance of using a gender-neutral language or to consider a gender balance when organising student groups. Research in the field, however, shows that the problem of not including a gender perspective is not just a superficial one that could be overcome with cosmetic changes.

Research studies have identified diverse forms of gender-bias in schools (for instance, in teachers' actions), which reflect the social gender-bias elsewhere. Examples such as allowing male students to dominate the discourse in STEM classrooms; giving feedback of different significance to boys (mostly on the content) and girls (mostly on the format) or attributing academic success to talent (for boys) or effort (to girls), among others (Scantlebury, 2007). These gender-biased actions add to the social discourse regarding STEM, strongly fuelled by stereotyped images of scientist and engineers that alienate most girls and especially those from disadvantage groups. The message young women most often receive is that STEM is not for them, either because their identity as females does not correspond to the image of STEM professionals and/or because they do not consider themselves good enough for STEM.

Other educational strategies, however, are being used in the STEM field to introduce the gender perspective in a more comprehensive and profound manner. The different orientations of these projects range from those that want to introduce a gender perspective within the STEM curriculum itself (for instance, discussing the historical discrimination of women in STEM fields or making visible those areas and knowledge in which women have largely but silently contributed - such as obstetrics in medicine or dyeing in chemistry etc.). Other projects are working on the professional orientation on women towards STEM, for instance, organising long-term mentoring between female STEM professionals and young girls. Finally, some projects want to face the self-limiting factors, such as low perception of self-efficacy in STEM or working in the compatibility of a feminine and STEM self-image from early years onward.

Examples:

Hypatia PROJECT

Criteria for gender inclusion

"The approach taken to communicating science and to engaging girls into STEM careers has evolved over time and it is very interesting to see how. To understand it, Marianne Achiam and Henriette Tolstrup Holmegaard have produced this "Criteria for Gender Inclusion" report. However this is much more than just this. In this report, the authors analyse past and present of European projects that have addressed these issues, showcase best practices and develop some guidelines to guide us through a practical approach that consider these gender theories. This document is key to understand the approach of this project to the task of bringing more young people to STEM careers. We will not write a long post. Just take 30 minutes of your time to read the report. You'll want to share it with colleagues, friends and above all, it will make you reflect on the way you are approaching the issue."

+ More information

TWIST Teachers Guide One Size Fits All? Enhancing Gender Awareness in Teaching

"This TWIST teachers guide aims to be a source of inspiration for science centers, museums and others wanting to offer a professional teacher development programme on gender awareness in schools, with a specific focus on primary school science teachers. The programme it describes was designed for teachers working with children aged 8–14. The guide offers information, guidelines, good practices and tips to inspire users to develop their own effective programmes. It focuses on awareness of preconceptions about boys and girls, including how to deal with these preconceptions in daily teaching practice."

+ More information

Serena Game

"The project Serena aims at developing and evaluating a serious game providing individualized feedback to female adolescents (13-15 years) regarding their vocational competencies in the innovative field of renewable energy technologies. The serious game will use a point and click adventure to provide the girls with opportunities to explore the exciting working areas of technological vocations, and in doing so, to master typical challenges technicians are faced with when working in the renewable energy sector. The serious game is expected to contribute to (a) the acquisition of knowledge and competencies regarding technological vocations, in particular their typical tasks and challenges, (b) the development of interest in this vocational field, and (c) the increase of confidence in their abilities."

+More information

Identified risks: The inclusion of girls as well as a diversity of other people through an intersectional approach (diversity of cultural, economic and social background, ethnic, religious, etc.) is not only a matter of ethics and values but mostly a matter of quality. Interestingly, research in economics (Schiebinger, 2008) shows that the lack of a gender perspective has an economic impact due to the fact that it is ill-conceived research. Iconic examples in the literature refer to the problems of the usage of only standardised male-like dummies for safety tests or the costs of realising that a drug is damaging for women after 20 years from a study with mostly male samples. In addition, companies demand different profiles of STEM professionals to have more creative and imaginative teams, capable pf soft-skills as well as hard ones and which can easily relate and communicate with the other sections of the company. **This balanced value-lead and quality-centred view on gender/diversity is a far more interesting standpoint for introducing a gender perspective in STEM education than only the value-driven one.**

Idea 7. Inclusion is a driving force for STEM learning

RRI perspective asks for social inclusion and inclusion turns out to be a powerful driving force for motivating STEM learning since it better addresses shared societal challenges

According to the literature in the field, discrepancies between youths' own identity and STEM careers' stereotyped identity (male, white and brainy), family "science capital" (science-related qualifications, understanding, knowledge -about science and 'how it works'-, interest and social contacts -e.g. knowing someone who works in a science-related job, as defined by the project ASPIRES.) and students' self-efficacy in STEM (their believes on their own capacity and competence in the field) are three major causes of students' disinterest in STEM subjects (Archer, 2013). This situation triggers off serious inequalities because it generates a homogeneous profile of those who go on to study STEM subjects (those who highly identify themselves with the STEM identity) and silencing the voice of diverse actors, like working-class groups and other under-represented collectives not only into STEM fields but also as full-pledged citizens. This reality goes against the RRI requirements of diversity and inclusion, diminishing the capacity of R&I community to include points of view that could help to anticipate, reflect and give answer to any risk or challenge faced during the R&I process.

In this regard, STEM education can play a major role by allowing students, whichever race, gender or socio-economic background, to feel empowered enough to participate in STEM enterprises and, more specifically, in RRI processes.

Examples:

SIS-Catalyst Diversity & Inclusion Map

"SiS Catalyst's Diversity & Inclusion (D&I) map is for organisations and practitioners involved in science-engagement programs for children. It helps users develop high-quality programs that are attractive for children from different social backgrounds."

+ More information

Inventors for change

"Inventors4Change wants to provide children with tools, techniques and knowledge that let them invent the changes they want to see in the world. It consists of a network of schools and organizations which use Technologies for Creative Learning and Digital Media tools to foster Invention-Based Collaborative Learning among children from different countries. The project is particularly focused on children from underserved communities and children's inventions are inspired by Sustainable Development challenges."

+ More information

3DNovations

"3DNovations are a range of immersive 3D virtual reality solutions that revolutionise training, collaboration, research and community/customer services and enable people with autism and other complex needs to participate in and contribute to research and innovation. 3DNovations deliver high social value and impact directly and indirectly by increasing access to vocational training and employment for people with autism as more organisations and individual use services like 3DNovations and implement more Responsible Research and Innovation practises."

+More information

Raising students' perceived self-efficacy in steam to provide opportunities for all (STEAM4U)

"The STEAM4U project aims to promote equity in STEAM education by enhancing 10-14-year-old students' self-efficacy (perception of their own capabilities) in these fields and their own knowledge on the concept of self-efficacy to empower them to better assess their capacities. Self-efficacy is not that easy to raise, as it has been constructed over years and demands providing students with experiences of success in STEAM-related activities from early years and increasing. The project will promote the exchange and cooperative work of representatives of several European organizations in charge of initiatives focused on empowering young people in the STEAM fields within an equity perspective to develop a common European framework to promote self-efficacy in STEAM-related activities."

+More information

Identified risks: As for the gender perspective, inclusion in STEM education should consider not only the ethical perspective but also the quality of R&I. Inclusion can become a key factor to improve R&I and STEM learning outcomes but **inclusion needs to be carefully introduced into classrooms with some pre-designed mechanisms**. Additionally, schools are not generally inclusive due to the existing socio-demographic biases being strongly dependent on the neighborhood of each school. In such a case, strategies favoring social inclusion might demand some of the activities to be ran outside of the classroom context and in collaboration with other organizations.

Idea 8. RRI perspective needs a systemic approach that overcome STEM disciplines

STEM and STEAM interdisciplinary/multidisciplinarity (merging STEM disciplines among themselves and with the arts and humanities) are particularly rich scenarios to introduce the RRI perspective with an emphasis on its systemic nature.

Despite the fact that RRI is usually linked to scientific and technologic fields, and therefore, mainly related to STEM education, its perspective includes concerns on R&I activity in other fields, such as social and humanistic research. The inclusion of these other areas in an integrated manner with STEM serves various objectives. Firstly, it increases the levels of motivation towards STEM learning in students who highly enjoy the arts. Secondly, it is helpful in promoting creativity and capacity to interrelate disciplines and views - a well sought-after skill in particular scientific-technological profiles. Thirdly, these rich scenarios help students to realise that STEM and the artistic and humanistic world are not isolated tanks and that you do not have to position yourself in one of those only and thereafter neglect the other (the "two cultures" approach).

By enrolling students in projects where knowledge within and outside STEM is necessary, a more complex and realistic view of the world is shared with them and the RRI processes of adaptation, reflexivity, inclusion (etc.) can be more naturally tackled. These are indeed capacities highly demanded in the labor market, especially those fully immersed digital economies where innovation plays a key role. Moreover, blurring disciplines and reinforcing creativity in STEM education favours competencies and skills of future generations to holistically tackle the biggest challenges of our planet such as climate change, sustainable cities, efficient mobility or self-sufficient energy systems.

Examples:

Manchester Metropolitan University EdLab

EdLab Science Poetry

"Pupils often label themselves, or are labelled, as either artistic and creative, or scientific. In this workshop we merge two often distinct

disciplines into one activity which enables pupils to explore them in a new way. It opens pupils up to the concept that both poetry and science are ways of describing the world, and that neither one is necessarily better than the other."

[+ More information]

WOLF TRAP

Use of Arts-Integrated Activities With Mathematics Content

"Wolf Trap teaching artists explored the conceptual connections between the arts disciplines and the mathematics standards for prekindergarten and kindergarten. They designed lesson plans that described the connections and specified the objectives for both teaching and student learning. During the two years of teaching residencies, teaching artists coached teachers in the classroom as teachers implemented."

[+More information]

Identified risks: Interdisciplinarity and multidisciplinarity are powerful discourses and approaches to real problems and challenges. However, **it is very difficult to realise the power of interdisciplinarity if one does not have the expertise of applying a disciplinary view and compare the advantages and limitations of both approaches**. Consequently, despite acknowledging that students will at some point have to face problems and challenges that require a STEM or STEAM interdisciplinary approach, not all STEM education should foster this focus. Acquiring the disciplinary view of Physics, Mathematics, Engineering, Chemistry, Biology or Geology is also a very important part of a young person education in the STEM fields and a necessary experience for developing the capacity to inter-relate them among themselves as well as with the arts and humanities.

Idea 9. Transparency and openness should be the new cultures in STEM education

Reflecting with students on the importance of open access of our research production to promote a culture of knowledge sharing and co-construction.

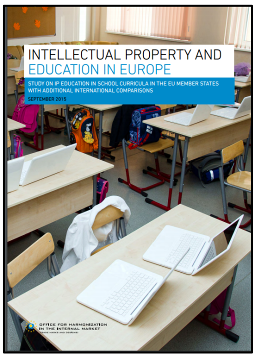
Promoting knowledge sharing and co-construction processes (opening research to other researchers and people in general) is a key pillar in RRI. Openness and transparency are demanded of today's researchers, public agencies and most probably companies in the near future. These values need to be included in STEM education so that future citizen could be "prosumers" (not only consumers but also producers) of research. Such requirements, however, have several limitations as well as ask for an additional effort in knowledge construction that needs to be taken into account in STEM education facing these challenges (e.g. citizen science or co-creation design projects).

Additionally, facilitating access to knowledge and data should be done within the limits and recommendations of an ethical approach to research. In other words, anonymity of peoples' data is more important than making available such data to others. Despite the ways of making both openness and ethics requirements compatible, students have to understand that there are compromises that limit what we can do even if it is for good reasons.

It is also important to stress that a wish to share ideas and results is compatible with the need to give credit to others for their ideas and results. When young students elaborate research projects they generally have problems related to citing and referencing other authors, generally struggling to identify which is the source of a certain information.

It is also the case that their comprehension and familiarity with the intellectual property concept is strongly mediatised and poor. Providing students with the opportunities to reflect and deal with openness and transparency dilemmas will prepare them for an RRI future either within or without STEM. Openness and transparency are relevant for RRI because they allow the research community to replicate what has been done based on the shared data as well as being accountable for the work done and allowing all stakeholders to participate in the R&I process.

Examples:



Intellectual property and education in Europe

"This study has been designed to assist educational policymakers in Member States to meet the challenge of the digital era. (…) the Office is prepared to set up a specialised network of education experts and stakeholders to help them coordinate and develop appropriate, modern resources and programmes for pupils and teachers, based on the material acquired in the study. These would include for example videos, games, tutorials, e-learning portals and other online content, which could be disseminated through the schools with the aim of helping future generations understand the central role that IP plays in the economy and society."

+More information

Identified risks: Dealing with the limitations that surround openness and transparency can be difficult in school context because it entails the monitoring of students' use of data and authorship. **A trade-off between promoting this culture of openness and transparency and a level of students' supervision must be met** in order to guarantee that students do not fall into ethical errors.

Idea 10. STEM education from an RRI perspective must deal with uncertainty as part of our future

STEM education should prepare students to face changing circumstances, new insights and diverse values when promoting their responsiveness and capacity for adaptive changes required in RRI processes

One of the main concerns of education is to help students face the challenges posed by our complex and rapidly changing world. In fact, one of such challenges is to prepare them to actively participate in RRI processes, whether as citizens or researchers, in order to provide answer to the needs of a certain society. In this regard, placing students in front of ideal problems that have been pre-designed to be tackled at schools does not help them to develop the responsive and adaptive skills needed for change or shape routines of thought or to think in diverse solutions considering several insights. Students need to be taught in environments inspired and emulated in real situations, confronting students with situations in which they need to reflect upon and to act according RRI process requirements such as anticipation, inclusion and, naturally, responsiveness and adaptive change. In STEM education, SSI are specific contexts helping students to develop their responsiveness and their capacity for adaptive change.

Examples:

FUND and PlayDecide

"FUND supports the creation of new discussion formats and games inspired by PlayDecide and their use to address issues and topics that are important at city level; it provides traning and support to individuals and organizations that want to be active in the field of debate and discussion; and it uses a series of small subsidies to catalyse collaborations at the city level between networks, organizations and individuals who want to use debate and discussion to inform local policy. PlayDecide offer tools and support especially for small organizations and individuals who want to develop participatory programs and initiatives."

+More information

Discussion Games of Xplore Health

"Xplore Health provide resources such a discussion games on 10 different topics such as Mental Health, Personalized Medicine, Skin Cancer, Obesity, Malaria, AIDS, Biotechnology revolution or Orphan Drugs. The students get into groups of about 10 to discuss the issues and decide whether they "agree" or "disagree". At the end, the students have to put the cards in order from the ones they agree with most to the ones they agree with least. This order can then be compared between the different groups, which will open up the discussion to the rest of the group."

+More information

Identified risks: Dealing with uncertain and complex environments is usually linked to tackling controversial problems for which science does not provide a unified view. In this regard, **STEM educators have to be careful to really promote contexts that allow students to form their own opinion**, avoiding the transmission of teachers' own positioning or opinions to students and allowing them to assess and critically analyse all the available information. When seeking to give students various perspectives it may be interesting to invite to classrooms domain experts that can complement teacher's tasks and skills.

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PARRISE

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PERFORM

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Socientize

http://www.socientize.eu

Other projects:

RESPONSIBLE-INDUSTRY

http://www.responsible-industry.eu/

RES-AGORA

http://res-agora.eu/

PROSO

http://www.proso-project.eu

COMPASS

http://innovation-compass.eu

PROGRESS.

http://www.progressproject.eu/

OpenAIRE2020

https://www.openaire.eu/

RESPONSIBILITY

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NUCLEUS

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