Available online at www.revistaromaneasca.ro

e-ISSN: 2067 – 9270 ISSN–L: 2066 – 7329

Revista Românească pentru Educație Multidimensională

2016, Volume 8, Issue 2, December, pp. 71-87

The Embedment of Responsible Research and Innovation Aspects in European Science Curricula

Kathy KIKI-PAPADAKIS & Foteini CHAIMALA

Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

Covered in:
EBSCO, ERIH PLUS, CEEOL, DOAJ, Ulrich Pro Quest, Cabell, Index Copernicus, Ideas RePeC, EconPapers, Socionet, Journalseek, Scipio

©2016 The Authors. Published by LUMEN Publishing House.
Selection and peer review under the responsibility of LUMEN Publishing House.

How to cite: Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

DOI: 10.18662/rrem/2016.0802.06

The Embedment of Responsible Research and Innovation Aspects in European Science Curricula

Kathy KIKI-PAPADAKIS[1], Foteini CHAIMALA[2]

Abstract: The recent and current discourse on education policy across Europe places great emphasis on the importance of incorporating aspects of Responsible Research and Innovation (RRI) in science education. A key aspect of education policy is that citizens should become better equipped to enquire into and understand socio-scientific issues, as well as to apply scientific knowledge and ethical values in order to form evidence-based opinions. The question of how the intentions of policy-makers can be translated effectively into educational practice, however, has yet to be answered. Against this background, the present paper will investigate how aspects of RRI can be embedded in the curricula of science education in various European countries. The framework we will present illuminates both the intentions of policy-makers and current practices with regard to RRI within science curricula. It also helps map such policies and strategies in the area of science education across Europe. In the context of the ENGAGE project, this framework has been used as a tool for analysing the RRI components of curricula in the science education of students aged 11–16. The analysis is based on data gathered in 2014, takes into account prospective reforms and covers 11 European countries. The results of the analysis illustrate the potential of this framework as a tool for investigating how RRI can be embedded in science education and for exploring the space for intervention that policy-makers have. They also show that this framework can shed light on how the intentions of policy-makers and current practices with regard to RRI interrelate and on how moving from "words to deeds" can be achieved in a meaningful and constructive manner.

Keywords: RRI; Science Education curricula; Analytical Framework; Space for intervention.

---

[1] Principal Researcher, Foundation for Research and Technology Hellas (FORTH), Greece, katerina@iacm.forth.gr.

[2] Collaborative Researcher, Foundation for Research and Technology Hellas (FORTH), Greece, haimala@iacm.forth.gr.

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

1. Introduction

In recent years, reframing “Science in Society” as “Science for Society, with Society” has gained priority on the European policy agenda (Owen et al., 2012). Responsible Research and Innovation (RRI) is an emerging concept within the framework of “Science for Society, with Society.” This concept expresses the concern that the processes and products of research should be acceptable to society and relevant to public needs. Responsible research and innovation has been mainly conceptualized as an inclusive approach to research and innovation that calls on several societal actors (e.g., researchers, citizens, policy-makers, businesses, third-sector organizations) to interact in the course of research and innovation. The vision that this concept embodies is to align the process and outcomes of research and innovation with the values, needs and expectations of European society as a whole (EC, 2014).

The concept of RRI relates and is relevant to all scientific domains, especially to that of science, technology, engineering and mathematics (which are collectively referred to as “STEM”). The importance of RRI in these domains arises from the fact that emerging technologies in STEM are closely connected to a host of ethical questions and choices (Sutcliffe, 2011); it is also reflected in the increasing number of studies that contribute to the RRI discourse or examine RRI from the more specific perspectives of particular STEM domains. Most of these studies concern various areas of technology and research, as, for example, the study by Douglas and Stemerding (2013) in synthetic biology, that by Owen and Goldberg (2010) in engineering and physical sciences or that by Stahl et al. (2013) in information and communication technology.

In contrast, only few publications examine RRI in the context of science education (Bayram-Jacobs, 2015), although policy-makers name science education as one of the six focal areas of RRI. As is evident in the rhetoric these policy-makers employ, science education within the RRI framework has a prominent and multifaceted role. One aspect of its role is to equip future citizens with the skills that enable a better understanding of science and technology so that they can participate actively in informed decision-making and knowledge-based innovation. Encouraging this kind of participation will furthermore enable them to contribute towards the creation of a science- and technology-literate society. A second aspect of its role is to provide society with researchers who are equipped with the

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

necessary knowledge and tools to fully participate in the research and innovation process in a responsible manner. In that respect, science education can help address the need for a skilled workforce in the fields of STEM that will contribute to economic prosperity and growth (EC, 2014).

Against this background, this paper examines RRI within the context of science education. We begin with a review of the existing literature in order to identify how the relationship between RRI and science education is manifested in practice. Our review indicates, first, that the question of how policy intentions can be translated into educational practice is still open and second, that opinion on which aspects of RRI are relevant to education is fragmented. Following the review of the literature, we present an analytical framework for investigating the space for intervention available to policy-makers who aim to embed aspects of RRI in science education curricula across Europe. Our framework facilitates the thorough understanding of intended policy and actual practice with regard to embedding RRI in science education; it also helps map the policies and strategies that are already in place in science education across Europe. This framework has already been used in the context of the ENGAGE project as a tool for analysing science education curricula for students aged 11–16 in relation to various aspects of RRI. We report the outcomes of the curriculum analysis we conducted using data from 11 countries; namely, the UK, Greece, Germany, France, Romania, Spain, Norway, Switzerland, Lithuania, Cyprus, as well as Israel. Of these, 10 countries are EU members, while the 11th, Israel, is an associated state. Our results illustrate the potential of the framework as a tool for exploring the space for intervention available to policy-makers who aim to embed RRI in science education.

2. How the relationship between responsible research and innovation (RRI) and science education is manifested in practice

Several broad definitions of Responsible Research and Innovation (RRI) have been proposed in recent studies. Within the growing literature on this topic, the most widely cited definition of RRI is that put forward by Von Schomberg (2013, p.19), who defined RRI as "a transparent and interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process. However, despite the popularity of this definition, there is no unified vision of what RRI is, what it entails, what makes it effective and how it can be

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

accomplished. Different researchers and policy-makers may have a different perception of what RRI means in practice. Nevertheless, all accounts have one thing in common: they all include the idea of societal engagement and stakeholder involvement, on the assumption that the processes and outcomes of research and innovation should be socially desirable and ethically acceptable (Stahl, 2013); that is, aligned to the values, needs and expectations of society.

From the perspective of policy-making, aligning research and innovation to the values, needs and expectations of society is crucial in order to address the so-called "grand" challenges that the EU faces; namely, to promote smart, sustainable and inclusive growth, to find ways to create new jobs and to offer a sense of direction to our societies (EC, 2010). Addressing these challenges requires that future citizens have a better understanding of science and technology, if they are to participate actively in informed decision-making and knowledge-based innovation. It also requires that future researchers be equipped with the necessary knowledge and tools to fully participate in and take responsibility for the processes of research and innovation (EC, 2015).

Science education, defined as creative education that can foster the future needs of society (Sutcliffe, 2011), has a key role to play in this respect: it is through science education that the prospective actors of research and innovation—both researchers and citizens—can become adequately equipped to understand socio-scientific issues and apply ethical values, scientific knowledge and skills of inquiry to form evidence-based opinions. It is for this reason that science education has been identified by policy-makers as one of the six key components of the RRI framework.

The literature on the relationship between RRI and science education is limited, mainly to policy documents and reports. One such report, published recently by an expert group, examines "Science Education for Responsible Citizenship" (EC, 2015). This report is primarily targeted at policy-makers in science education and sets out the main challenges that society faces and how science education can help Europe meet these challenges. The report presents a framework of six key objectives that science education ought to pursue in order to promote responsible citizenship. It also makes a number of recommendations to policy-makers in the area of education both on a national and an EU-wide level. The report also focuses on the systemic changes that have to be made in various educational contexts to generate a sustainable effect across EU societies and

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

within communities. The main objectives of the framework for "Science Education for Responsible Citizenship" (EC, 2015) are presented in Table 1.

Table 1. The objectives of Science Education for Responsible Citizenship (EC, 2015)

Objective 1	Science education should be an essential component of a learning continuum for all, from pre-school to active engaged citizenship.
Objective 2	Science education should focus on competences with an emphasis on learning through science and shifting from STEM to STEAM by linking science with other subjects and disciplines.
Objective 3	The quality of teaching, from induction through pre-service preparation and in-service professional development, should be enhanced to improve the depth and quality of learning outcomes.
Objective 4	Collaboration between formal, non-formal and informal educational providers, enterprise and civic-society should be enhanced to ensure relevant and meaningful engagement of all societal actors with science and increase uptake of science studies and science-based careers to improve employability and competiveness.
Objective 5	Greater attention should be given to promote RRI and enhancing public understanding of scientific findings and the capacities to discuss their benefits and consequences.
Objective 6	Emphasis should be placed on connecting innovation and science education strategies, at local, regional, national, European and international levels, taking into account societal needs and global developments.

In the light of the ongoing discourse among policy-makers on the potential of science education to foster RRI goals, a considerable number of national and EU-funded research projects have been set up to promote RRI in the context of science education. The vast majority of these projects aim to raise awareness of what RRI is among teachers and students of science. These projects offer to participants, among other things, teaching tools and other resources, as well as opportunities for teacher training. Table 2 lists the EU-funded research projects on RRI in the context of science education that are currently under way. Bayram-Jacob (2015) conducted a study on the

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

role of RRI in science education drawing on data from these projects, all of which are concerned with the implementation of RRI in science education. One of the main findings of Bayram-Jacob's study is that the common goals of all such projects are to promote scientific literacy and kindle an interest in science among students, as well as to foster the growth of a responsible society and a positive relation between research and society. The author concluded that the latter two goals are important components of any project aiming to implement RRI in science education (Bayram-Jacob 2015).

The same study also examined the proposed pedagogies for implementing RRI in science classrooms. Generally, the predominant method is inquiry-based learning; in the projects on integrating RRI in science education that Bayram-Jacob (2015) studied, the most commonly used strategies are discussion, argumentative discourse and scientific reasoning. These strategies are considered most appropriate for promoting students' critical thinking, problem-solving skills and questioning abilities, which are important for pursuing the aims of RRI.

Table 2. Current European projects on RRI and science education

Project	Aim/Focus
Irresistible	To design activities that foster the involvement of students and the public in the process of [RRI and] to raise awareness on RRI by increasing pupils' content knowledge about research." Combining "formal (school) and informal (science centre, museum or festival) educational approaches" will help "introduce relevant topics and [cutting-edge] research into the programme." Thus, the project will familiarize pupils with science and foster a discussion on RRI issues. http://www.irresistible-project.eu/index.php/en/
Ark of Inquiry	Raise youth awareness to RRI, as well as build a scientifically literate and responsible society through IBL. Develop a pedagogical framework that promotes pupils' awareness of RRI and increases their awareness and understanding of conducting "real" science. Combine existing inquiry-based activities and environments from various national and international projects that are related to RRI aspects and make them widely available through the Ark of Inquiry platform. Build a supportive community and teacher training to support pupils' inquiry-based activities in a manner that attracts pupils' interest in science and RRI. http://www.arkofinquiry.eu/homepage

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

Heirri	To integrate the concept of RRI in higher science education, develop training materials, and pilot new training courses" focused on problem-based learning that will be implemented in universities and science centres across Europe. http://heirri.eu/
Parris	Collect and share existing best practices across Europe and design learning tools, materials and in- and pre-service training courses for science teachers that are based on the Socio-Scientific Inquiry-Based Learning (SSIBL) approach. Empower science teachers and teacher educators through in-service and pre-service courses in professional development based on available best practices. Enable an "international community of learners" to reflect on and improve the selected best practices from an RRI perspective in teaching and learning. http://www.parrise.eu/About-PARRISE
Engage	To equip the next generation to participate in scientific issues to change how science is taught. Development of materials and training on pedagogical tools to help teachers to support students in understanding four emerging areas and develop ten inquiry skills. https://www.engagingscience.eu/en

As the account of these projects shows, science education can serve as a vehicle for RRI processes and outcomes and as a means of raising awareness of the principles of RRI among teachers and students. More specifically, in that context, science education could play a prominent role; namely it could help realize the RRI vision and thus help address the grand societal challenges that European countries face. In that respect, policy-makers often refer to "science education *for* RRI", which emphasizes the systemic changes that have to be made in the context of science education in order to raise awareness and promote RRI. On the other hand, the related concept of "science education *on* RRI" expresses the relationship between RRI and science education differently, in that it places emphasis on raising awareness of RRI among science educators and students. To achieve this goal, it is necessary to develop and provide teaching resources and to promote pedagogical strategies that are relevant to RRI.

Both perspectives are of indisputable value to the stakeholders involved in science education; nevertheless, some of their aspects make it difficult for policy-makers, researchers and science educators to progress from intention to implementation: first, neither perspective explains how these actors can achieve the broad policy objectives of "Science Education

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

for Responsible Citizenship" in practice. Second, there is a lack of concerted effort to promote science education in RRI; more specifically, there is no coherent, comprehensive approach to deciding which aspects of RRI should and could be incorporated in science education and how this could be achieved.

Our approach to bridging the gap between the intentions underlying the RRI framework and actual educational practice emphasizes the need to investigate the space for intervention; in other words, the scope for embedding aspects of RRI in science education curricula across Europe. For that purpose, we have developed an analytical framework to shed light on the intentions of policy-makers and actual practice—i.e. on how these policies enable the integration of RRI in educational curricula—and to help map the policies and strategies in place in science education across Europe. We will present this framework in the following section of this paper.

3. Framework for analysing science curricula in terms of RRI

To develop the framework for analysing curricula in science education in terms of RRI, we drew on "engaged theory," which belongs to the broad tradition of critical theory. Engaged theory has been described as a methodological framework for understanding social complexity, which moves from detailed empirical analysis about things, people and processes of the world to abstract theory about the constitution and social framing of those things, people and processes. Engaged theory is reflexive is a number of ways [and] provides an integrated set of methodological tools for developing different theories of things and processes in the world (Cooper, 2002).

3.1. The elements of the analytical framework

The framework covers (a) different national educational contexts, (b) six major areas of focus (c) three levels of systematic analysis. Table 3 presents the major areas that the framework covers and the rationale for including each such area in our study.

Table 3. The major areas of the analytical framework

Areas of focus	Rationale for inclusion
Science Education	Relevant data provide information about the way science is taught at different educational levels across countries:

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

background	disciplinary, interdisciplinary or multidisciplinary; RRI is by definition interdisciplinary.
Recent curriculum changes in relation to RRI	Several European countries are currently or have recently been engaged in educational reforms, especially in science and technology education. We seek to gain an overview of the changing educational scenery, focusing on whether or not changes in curricula are in line with the RRI philosophy and, if so, to what extent. Gaining such an overview allows the identification of opportunities for or obstacles to incorporating RRI in science education.
Curriculum objectives and expected outcomes in relation to RRI	Our aim is to gain an understanding of the objectives and outcomes of curricula in relation to the knowledge, skills, values and personal development of students, and of the criteria by which students are assessed.
Curriculum content and RRI	We seek to understand whether or not national curricula focus on and/or prioritize thematic areas that are related to socio-scientific issues, technology, values, or the nature of science and, if so, to what extent.
Pedagogical processes and RRI	Examining the pedagogical processes that are proposed in different curricula and those that are actually implemented in the classrooms will help us assess whether or not pedagogical strategies such as IBL and argumentation (which relate to RRI objectives) are evident and prioritized in the curricula of different European countries.
Context (informal settings, society) and RRI	We seek to assess the strength of possible connections between formal science education (which is provided in schools) and informal science education in relation to RRI; in other words, to what extent formal pedagogical strategies for promoting RRI are linked to similar informal strategies in scientific communities and society at large and to what extent students actively participate in such communities, are aware of and support RRI initiatives.

We examined the following thematic areas on three levels of analysis: recent curriculum changes in relation to RRI, curriculum objectives and expected outcomes in relation to RRI, curriculum content and RRI, and pedagogical processes and RRI. The three levels of analysis are: (a) the

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

macro-level of what policy makers envisage, (b) the meso-level of how schools mediate the implementation of policies, and (c) the micro-level of actual implementation in the classrooms. We decided to apply multilevel systematic analysis in order to uncover potential conflicts between intentions and implementation. An overview of the four areas we studied on these three levels of analysis is presented in Table 4.

Table 4. The areas of focus under the three levels of systematic analysis

	Focus in relation to RRI		
Area of focus	Macro-level	Meso–level	Micro-level
Science education background	Disciplinary, multi-disciplinary, or inter-disciplinary approach to teaching science.		
Recent curriculum changes in relation to RRI	Envisioned changes in the curriculum (e.g., focusing on socio-scientific issues and values or the nature of science).	Changes in teacher training (e.g., promoting methodologies based on inquiry or argumentative discourse).	Changes in the implemented science curriculum (e.g., focusing on socio-scientific issues, promoting the development of skills rather than comprehension).
Curriculum objectives and expected outcomes in relation to RRI	Objectives and outcomes of the envisioned curriculum (e.g., acquisition of scientific knowledge, development of scientific skills, development of values).	Objectives and outcomes of Continuous Professional Development (CPD) courses (e.g., acquisition of scientific knowledge, development of scientific skills, development of values).	Objectives and outcomes in students formal assessment (e.g., acquisition of scientific knowledge, development of scientific skills, development of values).

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

Curriculum content and RRI	Examine whether the proposed curriculum contains or prioritizes RRI (e.g., socio-scientific issues, technology, values, nature of science).	Examine whether the proposed CPD courses contain or prioritize RRI (e.g., socio-scientific issues, technology, values, nature of science).	Content evident and/or prioritized in students' formal assessment (socio-scientific issues, technology, values, nature of science).
Pedagogical processes and RRI	Examine whether the pedagogical methods to be used in the proposed curriculum contain or prioritize RRI (e.g., IBL, argumentative discourse).	Examine whether the proposed pedagogical methods for CPD courses contain or prioritize RRI (e.g., IBL, argumentative discourse).	Examine whether the proposed pedagogical methods to be implemented in classrooms contain or prioritize RRI (e.g., IBL, argumentative discourse).
Context (informal settings, society) and RRI	Actors that promote and implement RRI initiatives; connections between schools (general and vocational) and providers/sources of informal education.		

3.2. Method of analysis

To facilitate the thorough understanding of intended policy and actual practice and to help map the policies and strategies in place from different multidimensional perspectives, we applied the following method:

(a) Horizontal analysis across three levels, focusing on prominent issues such as what priorities policy sets, how the mechanisms that mediate implementation are managed and how implementation is carried out (see Figure 1).

(b) Vertical analysis across the main areas of focus, examining what conclusions can be reached in each case about the opportunities for incorporating aspects of RRI in science education and the challenges that need to be met (see Figure 2).

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

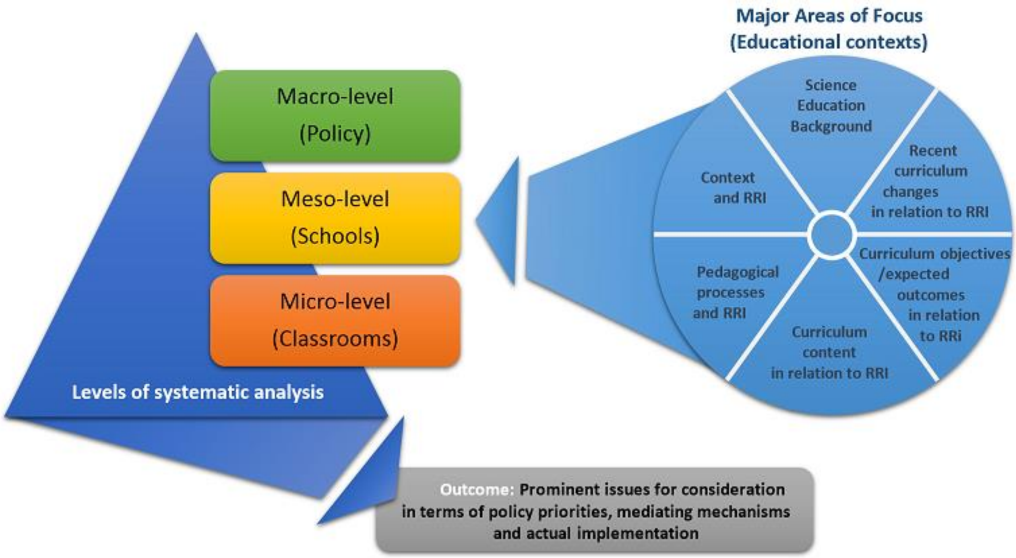
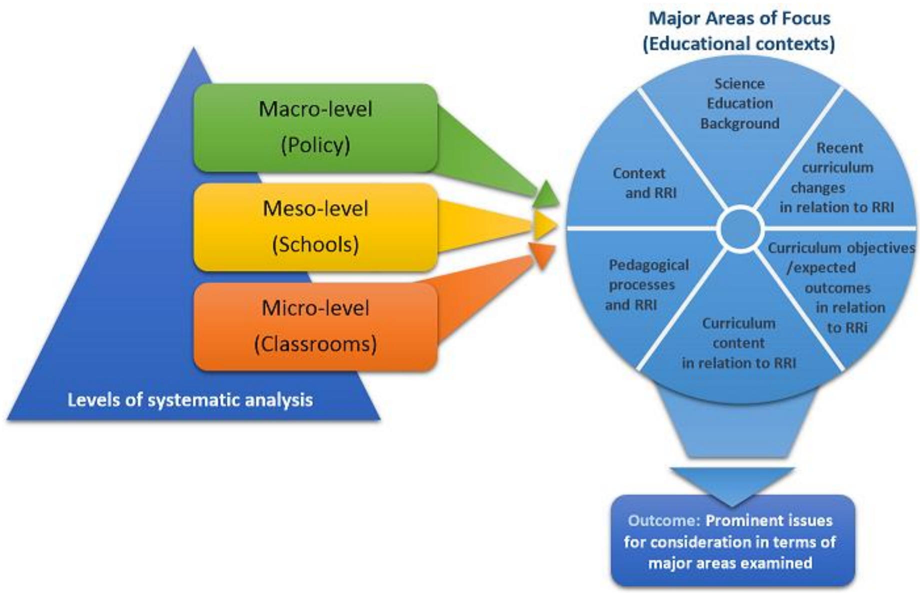


Figure 1: Schematic illustration of the analysis, in terms of the three levels



of systematic analysis

Figure 2: Schematic illustration of the analysis, in terms of the major areas of focus

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

4. Validating the framework as a tool for analysing science education curricula across Europe

As we mentioned earlier, the analytical framework presented in this paper has already been used as a tool for the analysis of curricula in science education (for students aged 11–16) in the context of the ENGAGE project. The analysis covered 11 European countries (UK, Greece, Germany, France, Romania, Spain, Norway, Switzerland, Lithuania and Cyprus, as well as the associated state of Israel). It is based on data gathered in 2014 and takes into account planned changes and reforms. With the aid of the analytical framework, which determined the dimensions of the educational context under investigation, a questionnaire was drafted to be used as a tool for gathering information in the surveys. The questionnaire was modified iteratively in the course of a cycle of improvements and feedback from the partners of the ENGAGE consortium.

In the process of completing the questionnaire, the respondents drew on their processional experience of RRI, as well as on data on the national curricula of the countries they represented and on previous research; they furthermore consulted RRI experts in their own countries. To start with, the completed questionnaires were analysed on the basis of national data, which resulted in 11 case studies; one for each participant country.[3] Subsequently, the researchers involved identified the differences and commonalities between the 11 participants and synthesized the information that the national case studies provided into a more general report. Table 5 highlights the main outcomes of this analysis with respect to the six areas of focus that the analytical framework addresses.

Table 5: Emerging issues of the curriculum analysis pertaining to the 6 areas of focus that were addresses in the analytical framework

Area of focus/dimensions of educational context in relation to RRI	*Emerging issues pertaining to each dimension.*
Science	A number of countries have a highly centralized educational

[3] These case studies are reported in the document D1.1. RRI, which is available at http://www.engagingscience.eu/

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

Education Background	system (e.g., Greece, Romania and France), which may not give teachers sufficient autonomy to use extracurricular material in the classroom in addition to textbooks. However, using such material is necessary, given that the RRI concept is relatively new and has not yet been incorporated in textbooks.
Recent curriculum changes	Several countries are currently or have recently been engaged in educational reforms, focusing on science education. In some of the participant countries, such changes seem to be in line with the principles and thematic of RRI (e.g., in France for the age group 11–13, in Romania and Israel for the age group 13–16). In other participant countries, educational policy continues to focus on fundamental academic knowledge (e.g., in Greece and the UK).
Curriculum objectives and expected outcomes	In many participant countries (e.g., in the UK, Germany, Greece, France and Romania) content-based objectives (such as the acquisition of content-based knowledge) are prioritized in comparison to more RRI-oriented objectives (such as establishing certain values). In the vast majority of participant countries, the formal assessment of various aspects of RRI is inadequate.
Curriculum content	Information on the content of national curricula, student assessment and teacher training in each participant country is provided in Table 6.
Pedagogical processes	With regard to the policies and implementation of inquiry-based learning, the picture is mixed: in some countries (e.g., in the UK, Lithuania, Romania and Norway) this type of learning is part of the curriculum and teachers seem to be well familiar with the pedagogical practices involved. In other countries (e.g., in Greece and Switzerland) the reverse is the case. In most countries inquiry based methodologies are not frequently implemented in the countries of both cases. Similarly, in most of the participant countries, argumentation does not feature in the curriculum nor do teachers implement or are familiar with relevant pedagogical approaches.
Context (informal settings, society)	Although there are key actors that implement and promote RRI initiatives in all participant countries, there are few links between formal (i.e. schools) and informal settings in the areas of both general and vocational education.

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

Table 6: Curriculum content that is relevant to RRI framework in each country

Country	*Curriculum content relevant to RRI*
UK	For the age group 12–16: resources on genomics, genetic engineering, stem-cell research, reproductive technologies, biodiversity, new materials (e.g., graphene), life-cycle assessment, and nanotechnology. For the age group 11–14: resources on the nature of science.
Greece	For the age group 11–15: resources relating to socio-scientific issues and technology.
Germany	For all age groups: aspects of technology, society and science, as well as the values and nature of science may be evident but not prioritized either in the curriculum or in teacher training.
France	For the age group 11–12: resources related to technology. For the age group 13–15: resources related to values.
Romania	For the age group 11–12: resources related to socio-scientific issues, the values and nature of science. For the age group 13–16: resources related to socio-scientific issues, technology and the nature of science.
Israel	For the age group 11–12: resources related to socio-scientific issues and technology. For the age group 12–16: resources related to technology.
Spain	For the age group 14–16: resources related to the values and nature of science.
Norway	For the age group 11–16: all content.
Switzerland	Relevant resources are more likely to be used in the classroom for the age group 11–14 than for the age group 15–16.
Lithuania	For the age group 11–16: resources related to socio-scientific issues and values.
Cyprus	For all age groups: content related to the nature of science.

The insights gained by the analysis of school curricula in 11 European countries provide background information on how RRI fits in the framework of each national curriculum and on how easy or difficult it would

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

be in each country to implement a curriculum and pedagogy that foster RRI. More specifically, the analysis revealed which aspects of this curriculum and pedagogy are already part of most teachers' current practice and which are absent. It also helped identify opportunities that one should take advantage of and the barriers to implementing practices that aim to promote RRI in science education.

5. Conclusions and Implications

We embarked on our study with the ambitious goal to contribute to bridging the gap between intended policy and actual practice in the area of RRI in the context of science education. The ongoing discourse on the role of science education in promoting and realizing RRI processes and outcomes lacks insights into how broad policy objectives are to be translated into objectives relevant to educational practice. On the one hand, many current EU-funded projects aim to raise awareness of RRI among science educators and students. On the other hand, this effort remains fragmented and lacks a comprehensive and coherent approach to deciding which aspects of RRI should and could be incorporated in science education. In this paper, we argue that in order to promote science education that fosters RRI it is necessary to investigate the space of intervention available to policy-makers who aim to incorporate RRI in science education. For that purpose, we developed and presented an analytical framework that helps map intended and actual practice with regard to RRI, as it is reflected in the curricula of 11 European countries. We demonstrated the potential of this framework as a tool of analysis by providing data on relevant outcomes, which we gathered from a cross-national analysis of curricula in these countries. Which policies and instruments can help foster RRI is still under investigation (Owen et al, 2013). We hope that our findings may provide useful information that can shed light on how the intentions of policy-makers and current practices interrelate.

References

Bayram-Jacobs, D. (2015) RRI: What is it? How to integrate in Science Education. Retrieved from https://www.researchgate.net/publication/279204567_RRI_What_is_it_How_to_Integrate_in_Science_Education

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06

Douglas, C.M.W., Stemering, D. (2013). Governing Synthetic Biology for Global Health through Responsible Research and Innovation. *Systems and Synthetic Biology*, 7(3), 139-150.

European Commission (2015). Science Education for Responsible Citizenship. Retrieved from http://ec.europa.eu/research/swafs/pdf/pub_science_education/KI-NA-26-893-EN-N.pdf

European Commission (2014). *Science with and for Society*. Retrieved from https://ec.europa.eu/programmes/horizon2020/en/h2020-section/science-and-society

European Commission (2010). Europe 2020: Commission proposes new economic strategy in Europe, Press release. Retrieved from: http://europa.eu/rapid/press-release_IP-10-225_en.htm

Owen R., Stilgoe J., Macnaghten P.M., Fisher E., Gorman M., Guston D.H (2013). A Framework for Responsible Innovation. In R. Owen., J. Bessant and M. Heintz (Eds), *Responsible Innovation*, John Wiley, London; p.27-50.

Owen, R., Macnaghten, P.M., Stilgoe, J. (2012). Responsible Research and Innovation: from Science in Society to Science for Society, with Society. *Science and Public Policy*, 39 (6), 751-760.

Owen, R., Goldberg, N. (2010). Responsible Innovation: A pilot Study with the U.K. Engineering and Physical Sciences Research Council. Risk analysis, 30 (11), 1699-1707.

Stahl, B., Jirotka, M., Eden, G. (2013). Responsible Research and Innovation in Information and Communication Technology: Identifying and Engaging with the Ethical Implications on ICTs. In R. Owen., M. Heintz, and J. Bessant (Eds), *Responsible Innovation*. Chichester, UK.

Stahl, B. (2013). RRI: the role of privacy in an emerging framework. *Science and Public Policy,* 40 (6), 708-716

Sutcliffe, H. (2011) *A report on Responsible Research and Innovation for the European Commission*. Retrieved from https://ec.europa.eu/research/science-society/document_library/pdf_06/rri-report-hilary-sutcliffe_en.pdf

Von Schomberg, R. (2013). A Vision of Responsible Research and Innovation. In R. Owen, J.Bessant and M. Heitz (Eds), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*. London: John Wiley & Sons, Ltd. Retrieved from http://www.rri-tools.eu/documents/10184/106979/VonSchomberg2013_AVisionofRRI.pdf/f39a800d-6a51-4ad8-89bf-f962714a1454

Kiki-Papadakis, K. & Chaimala, F. (2016). The Embedment of Responsible Research and Innovation Aspects in European Science Curricula. Revista Romaneasca pentru Educatie Multidimensionala, 8(2), 71-87. Doi: http://dx.doi.org/10.18662/rrem/2016.0802.06