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EDUCATION AND RESPONSIBLE RESEARCH AND INNOVATION (RRI): INTERNATIONAL PERSPECTIVES

Edited by
MARTA ROMERO-ARIZA

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E-mail: sisyphus@ie.ulisboa.pt

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Sisyphus — Journal of Education aims to be a place for debate on political, social, economic, cultural, historical, curricular and organizational aspects of education. It pursues an extensive research agenda, embracing the opening of new conceptual positions and criteria according to present tendencies or challenges within the global educational arena.

The journal publishes papers displaying original researches—theoretical studies and empiric analysis—and expressing a wide variety of methods, in order to encourage the submission of both innovative and provocative work based on different orientations, including political ones. Consequently, it does not stand by any particular paradigm; on the contrary, it seeks to promote the possibility of multiple approaches. The editors will look for articles in a wide range of academic disciplines, searching for both clear and significant contributions to the understanding of educational processes. They will accept papers submitted by researchers, scholars, administrative employees, teachers, students, and well-informed observers of the educational field and correlative domains. Additionally, the journal will encourage and accept proposals embodying unconventional elements, such as photographic essays and artistic creations.

Education and Responsible Research and Innovation (RRI): International Perspectives

Introduction by Marta Romero-Ariza (Editor)

What kind of science education is required in a world deeply influenced by science and technology? How can we contribute to Responsible Research and Innovation (RRI) through science education? Are students and teachers prepared to address current socio-scientific challenges? What kinds of pedagogies foster the skills and values required for taking a critical position in the discussion of socio-scientific problems? Which teaching and learning activities prepare students to actively contribute to the development of smart and creative solutions? These and others are some of the key questions underlying this special issue devoted to education and RRI.

In the presentation of this special issue, I will start by drawing attention to current socio-scientific issues (SSI) in order to set the stage for the introduction, justification and definition of the RRI concept. Then, I will comment on the different papers embedded in this issue providing a comprehensive overview of how any of them contributes to the discussion of RRI and its educational implications.

We are living in a fascinating age, where scientific advances are hugely expanding our capacities as human beings and the opportunities we have ever had to transform and shape the world around us. We cannot only observe galaxies but travel to the space; far from observing cells through the microscope, we are able to repair damaged cells with nanorobots; genetic engineering offers a wide range of possibilities, from the modification of organisms, to the development of highly specific gene therapies, nevertheless raising important social and ethical concerns.

Besides giving rise to exciting cutting edge advances science is transforming life in the planet at a personal, local and global scale, not only expanding opportunities but also bringing about new challenges, risks and uncertainties.

Current technological applications are significantly changing the way we live, learn, communicate and work. Nowadays we can do things that our grand parents could not even imagine. Almost anyone is carrying out a digital agenda, a photographic camera, a GPS and a set of other useful applications packed in a small mobile phone. These devices allow us to see and speak to people in other continents, buy and sell goods, order bank operations and access valuable information, among other things. But, is there any environmental and health risk associated to the production and use of mobile phones? Is everyone aware of the social and economical implications related to the use of those devices? Along with the affordances of mobile phones there is a set of negative effects. Just one of the multiple faces of the problem is that the rise in the importance of coltan, as a mineral crucial for the fabrication of these electronic devices, is having serious consequences in Congo, one of the main suppliers. It is due to the mining conditions under which the mineral is extracted and the subsequent social and political implications (Humphreys, Sachs & Stiglitz, 2007; Mantz, 2013). Are young people aware of these issues? Does education play any role in the education of critical and informed citizens able to evaluate the benefits and risks of current technological applications?

Coming back again from a concrete example to the general scenario, scientific advances are positively influencing a wide range of domains such as medicine, transports, energy, agriculture and food. However, along with the benefits, these advances often raise ethical concerns or have detrimental side effects on other areas such as health or environment, which must be tackled. Taking this into account, research and innovation should be aligned with current societal challenges: health and wellbeing; food security; sustainable agriculture; a fair distribution of resources; secure clean and efficient energy; smart, green and integrated transports; mitigation of climate change and environmental actions and sustainability (European Commission, 2017).

According to the European Commissioner for Research, Innovation we can only find the right answers to the challenges we face by involving as many stakeholders as possible in the research and innovation process (Geoghegan-Quinn, 2012). In this line, RRI is defined as "a process where societal actors work together, via inclusive participatory approaches, 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" (European Commission, 2015, p. 69).

Ethical acceptability, social desirability and sustainability are the three main aims of RRI (Von Schomberg, 2013). How to contribute to the accomplishment of RRI aims is an open question, which is being approached from different fields. International projects such as RRI tools, IRRESISTABLE or PARRISE are making unique contributions in this line. In the present issue we provide room for the discussion of interesting pieces of work carried out within some of those RRI international projects.

In an attempt to contextualised RRI in science education Lundström, Sjöström and Hasslöf (2017) relate the essence of RRI to some of the key concepts in science education such as scientific literacy, nature of science and SSI, emphasizing the collaboration between scientists and students as an important approach to provide a more RRI-oriented science education.

Romero-Ariza, Abril y Quesada (2017) keep on the discussion on how to best prepare citizens to address current challenges and outline the foundation of a science education model for RRI in line with the one developed within the European project PARRISE (Levinson and the PARRISE consortium, 2017). The model integrates different trends in science education and discusses the potential of authentic SSI scenarios to encourage students to map controversy and take informed and responsive actions. In addition, the quality of a set of science teaching materials designed for preparing students for RRI is evaluated according to the underlying model.

Other contributions to this special issue present research related to the development and implementation of educational interventions closely related to RRI. Zafrani and Yarden (2017) emphasise the 'activist' component in RRI-oriented interventions. These authors investigate the development of students' identities as activists as they participate in a high-school project aimed at resolving the problem of global hunger. Findings indicate that the students' identities as activists were supported through participation in highly contextual and emotionally charged experiences and through the ability to fill roles that were perceived as integral and authentic to the students. In addition, they discuss the potential of a well-structured activity to assist students in deeply engaging with responsible actions.

Following a Design-Based Research Methodology within the EU-funded IRRESISTIBLE project, Dias and Reis (2017) study the impact of IBSE activities integrating Web 2.0 tools on the development of knowledge and skills necessary for an active citizenship regarding RRI. Results reveal different didactic strategies for science education in secondary school and allowed the development of new knowledge regarding the implementation of these strategies in school context.

With a focus on preparing pre-service teachers for RRI-oriented science education we can find several contributions to this special issue. Linhares and Reis (2017) present a case study involving 19 pre-service teachers, which intends to identify the potentialities and the limitations associated with the development of interactive exhibitions on socio-scientific issues as a strategy to empower future teachers for sociopolitical action. Results illustrate how "Geoengineering: Climate Control?", an interactive scientific exhibition developed within the IRRESISTIBLE project create opportunities for students to work collaboratively, take responsibility and participate in activism initiatives, promoting the development of competences important for scientific literacy and active involvement in sociopolitical action.

Romero-Ariza, Quesada y Abril (2017) emphasise the key role of teachers in promoting RRI through science education and presents the design and evaluation of a teacher professional development in this line. The training course, builds on teachers' beliefs, provides opportunities to experience the educational potential of RRI-oriented interventions, makes explicit links to the science curriculum and supports the development of specific teaching skills necessary to enact the underpinning science education model. The analysis of pre-post results shows a positive evolution of participants' beliefs in line with the science education model being promoted. Additionally, the authors present the validation of several instruments to evaluate the impact of the TPD program on teachers' beliefs.

In line with previous work and pretty aware of the importance of providing validated research instruments, Blonder, Rap, Zemler and Rosenfeld (2017) trace the development, validation and use of a questionnaire for evaluating teacher and student attitudes regarding RRI. The use of the RRI questionnaire is demonstrated through the presentation of teacher and student data taken before and after the implementation of RRI-based modules, developed in the EU-funded Irresistible Project, with a special focus on preparing teachers and students for "RRI-based thinking" regarding science and technology advances. Based on this work, the authors suggest that the RRI questionnaire can be used to assess the development of attitudes regarding RRI across diverse populations of teachers, students, scientists, consumers and other members of the general public.

Marta Romero-Ariza

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Responsible Research and Innovation in Science Education: The Solution or The Emperor's New Clothes?

Mats Lundström
mats.lundstrom@mah.se | Malmö högskola, Sweden

Jesper Sjöström
jesper.sjostrom@mah.se | Malmö högskola, Sweden

Helen Hasslöf
helen.hasslof@mah.se| Malmö högskola, Sweden

ABSTRACT

The European Commission has for the past 10 years emphasised the importance of "Responsible research and innovation" (RRI). RRI is an approach that anticipates and assesses potential implications and societal expectations with regard to research and innovation, with the aim to foster the design of inclusive and sustainable research and innovation. Despite efforts to support RRI projects, however, little attention has been given to RRI in science education and science education research over this period. This article problematises the concept RRI and its relation to some of the key concepts in science education, comparing and discussing it in relation to scientific literacy, nature of science and socioscientific issues. The meeting between scientists and students is emphasised as a key issue to address, if RRI is to be regarded as an important part of science education.

KEY WORDS

Responsible research and innovation (RRI), Scientific literacy, Nature of Science (NOS), Socioscientific issues (SSI), Science education.

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Investigação e Inovação Responsáveis em Educação em Ciência: a Solução ou *a Roupa Nova do Imperador*

Mats Lundström

mats.lundstrom@mah.se | Malmö högskola, Suécia

Jesper Sjöström

jesper.sjostrom@mah.se | Malmö högskola, Suécia

Helen Hasslöf

helen.hasslof@mah.se| Malmö högskola, Suécia

RESUMO

A Comissão Europeia tem enfatizado nos últimos 10 anos a importância da Investigação e Inovação Responsáveis (IIR). A IIR é uma abordagem que antecipa e avalia as potenciais implicações e as expectativas societais no que diz respeito à investigação e inovação, com o objetivo de fomentar o desenvolvimento de uma investigação e inovação inclusiva e sustentável. No entanto, apesar dos esforços para apoiar os projetos de IIR, durante este período pouca atenção foi dada à IIR na educação em ciências e na investigação em educação em ciências. Este artigo problematiza o conceito de IIR e a sua relação com alguns dos conceitos-chave da educação em ciências, comparando-o e discutindo-o relativamente à literacia científica, à natureza da ciência e às questões sociocientíficas. O encontro entre cientistas e estudantes é enfatizada como uma questão-chave a abordar, se a IIR for considerada uma parte importante da educação em ciências.

PALAVRAS-CHAVE

Investigação e Inovação Responsáveis (IIR), Literacia científica, Natureza da ciência, Questões sociocientíficas (QSC), Educação em ciências.

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Responsible Research and Innovation in Science Education: The Solution or The Emperor's New Clothes?

Mats Lundström | Jesper Sjöström | Helen Hasslöf

INTRODUCTION

The concept of *Responsible Research and Innovation* (RRI) has during the past years been emphasised in policy documents and in different kinds of project declarations, and notably those emanating from the European Union (EU) and European Commission (EC) (EC, 2017; Von Schomberg, 2013). The European Union and European Commission view Responsible research and innovation as "an approach that anticipates and assesses potential implications and societal expectations with regard to research and innovation, with the aim to foster the design of inclusive and sustainable research and innovation" (EC, 2017). RRI is consequently seen as of particular importance for citizens' involvement in the development of society. In other words, the concept of RRI expresses the ambition that not only scientists, economists or politicians should engage in determining which research should be supported, and that these choices concerning our future are instead considered of vital interest for all citizens to engage in. RRI thereby becomes a highly important issue, also from an educational perspective.

EU currently supports the development of RRI through different educational activities such as teacher education programmes and other RRI activities (EU, 2017). It has been one of the highlighted goals within science education supported by the European Commission. One example is the PARRISE (Promoting Attainment of Responsible Research & Innovation in Science Education) project (grant agreement 612438), from which some examples will be offered below. RRI implies that various societal actors (researchers, citizens, policy makers, business, third sector organisations, etc.) are aware of each other's thoughts 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 society. In practice, RRI is implemented as a package that includes: multi-actor and public engagement in research and innovation; enabling easier access to scientific results; the take up of gender and ethics in the research and innovation content and process; as well as formal and informal science education (EC, 2017).

In this article, we discuss and problematise if the ambitious aims with RRI are possible to achieve. The discussion will be made mainly from an educational perspective, in view of the important role school and education play in reaching RRI. The article starts with a summary of different aspects of RRI, where definitions, history and consequences are discussed. After that, three important concepts in science education (scientific literacy (SL), nature of science (NOS) and socio-scientific issues (SSI)) will be presented and compared to RRI. All these concepts are, just like RRI, typical "boundary objects" that almost everyone can agree on, but which are given different meanings by different individuals (Sismondo, 2009). As will be shown below, although the four concepts display many similarities, they also have differences. Some of these differences are linked to the fact that RRI is mainly a policy concept, whereas NOS and SSI are mainly used to describe a specific content and orientation of science education. SL could today be described as both a policy and a scholarly concept. However, for all the concepts there are ongoing discussions about their meaning (see further below). This article aims to contribute in particular to the discussion concerning the meaning, awareness and possible outcomes of RRI in science education, in comparison to the three other concepts. It also aims to discuss synergies and opportunities between RRI and the other three concepts.

DEFINITIONS OF RRI, HISTORY OF RRI AND SCIENCE UNDERSTANDING

RRI as a concept has a rather short history (see further below) (Owen, Macnaghten & Stilgoe, 2012). In view of the key role that research and innovation policy plays for Europe, and for different societal actors, it is not surprising that definitions of RRI are richly discussed. The most widely used definition of RRI is that it is 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 (in order to allow a proper embedding of scientific and technological advances in our society). (Von Schomberg, 2013, p. 9)

With this definition, the stress on “mutual responsiveness” differs from previous ways that new knowledge connected to science and innovation have been developed and spread to citizens. Stahl (2013) discusses how research has traditionally been seen as an extension of human knowledge, and thus as a moral and public good that did not need to be questioned. Nevertheless, history demonstrates how research and innovation have been used in ways that were not for moral and public good (e.g. European Economic Area, 2001, 2013), for instance during wars and technical accidents, something Stahl thinks RRI might prevent. In other words, he describes RRI as a means to ensure desirable and acceptable research outcomes. Stahl argues that RRI should be defined as a meta-responsibility or higher-level responsibility. Also Wickson and Carew (2014) regard RRI as a reimagining of the traditional linear model between science and society, where science merely informs society about new research and innovations and the society after this information evaluate the outcomes of the research or innovation. Wickson and Carew contend that even if RRI is not the first attempt to reconceptualise relationships between environments conducting scientific development and society at large, there is still not any satisfying way to describe or evaluate such relationships. Among other factors, a lack of common standards make it hard for stakeholders, such as researchers, project managers or research funding organisations to discuss, document and plan for RRI efforts.

To summarise, RRI is regarded as both a process and a product, where all actors (including citizens) who could be affected by current research or innovation should be aware of all processes and products of research and innovations. However, researchers and innovators carry the greatest responsibility for this to be fulfilled.

A short historical overview of how the concept RRI has emerged is made by Owen et al. (2012) and Stahl (2013). They describe how the concept has roots in discussions between researchers from different fields concerning ethical, legal and social implications of research. They mention genomics as one such field, where these discussions were intensified during the beginning of the 21st century. From 2006 onwards, public authorities such as the National Research Council and the European Commission increasingly highlighted RRI, for instance through the research framework Horizon 2020 (Owen et al., 2012; Stahl, 2013). During these years, views on RRI have developed from discourses of socio-technical integration, to also include policy approaches to managing ethical issues with science and innovation, within subjects such as genetically modified organisms, synthetic biology and geoengineering (Owen et al., 2012). Owen et al. suggest that there is an increased willingness

> to discuss challenge and rethink linear models of science and innovation policy and social contract for science. (p. 752)

In this way, RRI discourse covers both academic contributions and policy interventions (Stahl, 2013).

However, the desire to make science more understandable and available for all individuals has an even longer history. Various attempts in this direction have been made during at least the last 60 years. Under different slogans and with slightly different goals, compulsory science education has been highlighted as a key to the future. Knowledge connected to science has been regarded as a solution to many problems faced by individuals and societies (e.g. Roberts, 2007). It has also been considered essential that citizens accept and support research and innovation projects, since a great deal of public money is spent on such projects. The ambition to make science more accessible is often expressed in terms of "science for all" or citizenship, a standpoint that emphasises not only expert knowledge but also democratic engagement in decisions involving highly technical considerations. The thoughts behind science for all are multiple. Often, the purpose has been to address individual needs in various ways, for instance in decision-making. The individual's capacity to make informed decisions is frequently articulated as scientific literacy (SL). In this way, scientific knowledge is regarded as important for the individual, but also for a society and its development. It is also crucial that individuals understand how science can improve our society and how scientific knowledge is generated, validated and accepted. Questions quite similar to RRI have thus been highlighted in both society and in science education (Allchin, 2014; Driver, Leach, Millar & Scott, 1996; OECD, 2003; Roberts, 2007).

CONSEQUENCES OF RRI

One of the important factors with RRI is the focus on responsibility. Owen et al. (2012) express this as a co-responsibility, where researchers, civil society organisations, industry and policy-makers have an obligation to include all groups that may be affected by new technologies in the research and innovation processes. Through inclusive and deliberative processes, science and innovation should lead to socially desirable and socially accepted ends (Owen et al., 2012). The goal is to open up for democratic processes. However, such democratic processes are not easy to follow or measure. Wickson and Carew (2014) stress the articulation of quality criteria and indicators of RRI. They believe this is crucial if RRI should be understood and operationalised by researchers, research funders, innovators and other stakeholders. These quality criteria should, according to Wickson and Carew, focus on complex and multidimensional real-world problems and incorporate collaboration and mutual learning between researchers and stakeholders. Actors who drive and monitor innovation should also evolve a method that reflects on the problem and its contexts from a range of perspectives, and that responds on other actors' opinions. Several attempts to reach common quality standards have been made during the last decade, but no collective standards have been established to date (Jacob et al., 2013; Wickson & Carew, 2014).

Even if responses by organisations and researchers to the introduction of RRI has been mostly positive, there are some questions that have been raised within the science community. Owen at al. (2012) discuss if RRI can lead to a tension between the principle of participation and that of scientific freedom. They argue that this problem might be more noticeable for science compared to innovation, but they also give successful examples in which organisations and societies cooperate with researchers, for instance concerning diseases, such as Alzheimer's or issues as sustainable development. Furthermore, Owen et al. also bring forward another potential problem: there is a risk that RRI might be regarded as part of a competition and that a range of motivations in various parts and levels of the EC accentuate this competition, for instance by economic reasons. Owen et al. further emphasise that RRI has largely remained a political discussion that is not really established in society as a whole.

As mentioned above, Stahl (2013) sees strengths with RRI. However, he also mentions the reliance on knowledge of the future. There are fundamental epistemological limitations, which can be difficult to handle, and Stahl believes that this can lead to technological determinism. Also Von Schomberg (2013) raises certain problems with RRI, and argues that the most crucial advancement of RRI will depend on the willingness of stakeholders to work together toward socially desirable products.

The establishment of powerful agendas such as RRI will also affect educational research. It is interesting to reflect on the extent to which political policies actually should be allowed to dominate educational research or, for that matter, any kind of research. We can see some examples where political authorities to a certain extent control educational research. For instance, at a time when other funding has decreased, funding from the EU connected to Inquiry Based Science Education (IBSE) has been an important financial contributor (EU, 2017). Even if many such projects have mainly been development projects, aimed for in-service and pre-service training, they have offered a possibility for researchers to come together. During the European Science Education

Conference, ESERA, in Dublin 2017, 12 large European projects were displayed. Several presentations and posters were also the result from research projects with their origin in projects funded by EU and EC. Reported research has been made in connection with Teacher Development Programmes (TPDs) with both pre-service and in-service secondary school science teachers, such as in the previously mentioned PARRISE project. The TPDs in PARRISE were developed based on the so called SSIBL-model developed by Levinson and the PARRISE consortium (2017). The TPDs includes aspects of RRI, SSI, citizenship education, and inquiry-based science education.

On the one hand, it can be argued that such research projects would probably not have been carried out without funding from the EU; they help the research society within education to come together to develop education. On the other hand, it is clear that the kinds of projects (e.g. IRRESISTIBLE, PARRISE) that the EU finds interesting will also be those areas where much educational research will be performed. In this way, EC and EU to a certain extent decide the research agenda in education.

IS THIS SOMETHING NEW?

As mentioned above, the concept RRI was introduced at the beginning of the millennium. Other research fields and researchers have paid attention to similar questions, in which knowledge in science and about science are regarded as decisive. An example is the notion of the "risk society", put forward by Beck (1992, 1999). Beck considers that civilisation today has to face numerous risks. It therefore becomes a matter of assessing the outcomes of society's attempts to improve our lives. Changes and innovation result in both expected and unexpected consequences, so that we are constantly obliged to deal with risk. Researchers must therefore communicate their research with the public, while education needs to prepare citizens to handle these risks (Elmose & Roth, 2005). Foresight activities are key aspects in RRI, even if the future is hard to predict (Stahl, 2013). Risk analysis has to be made on several levels and by all actors. The risks will not be seen in the same way on an individual level, compared to a societal level. Nor will risks be seen in the same way by all citizens, even if they have received the same information (Lundström, 2011). RRI is built upon a model where everybody is involved in discussing both risks and positive outcomes, and it is additionally assumed that participants in such discussions will feel that they have been listened to.

So is this rethinking of a linear model possible to achieve? The ambition presupposes, among other conditions, a society where citizens in different ways keep themselves updated concerning research and innovations. It is also supposed that stakeholders feel responsibility to stir this process. This transformation of how research and innovations are negotiated can be summarised as a shift from science in society, to science for society and science with society (Owen et al., 2012). Several similar processes, based on joint discussions between actors driving scientific developments and various societal groups have appeared over the past decades (Grunwald, 2014). Science-Technology-Society studies, literacy projects and technology assessment are examples of attempts to bring together science and society. All of them aim to understand each other's agenda for a better society, as well as supporting participation from different actors.

EVALUATION OF RRI

On a practical level, it is difficult to see how RRI should be organised and evaluated (Stahl, 2013). Von Schomberg (2013) questions if it even is possible to define what should be considered desirable outcomes and impacts of research and innovation. It is not always easy to see who should be responsible for designating who can participate in or evaluate different projects or programmes. Not all individuals can take part of all projects. The question therefore remains how different actors can "participate" in research and innovation projects. Since RRI includes both processes and products, not only participation itself, but also the assessment process demands a public engagement during longer periods. The most important question concerning evaluation is according to Wickson and Carew (2014) whether preconditions, processes, or products of research and innovation (or people populating all three) should be evaluated. Stahl (2013) suggests viewing RRI as a space constituted by activities, actors and norms, whereas Von Schomberg (2013) instead regards RRI as a strategy of stakeholders. Accordingly, he points out stakeholders as responsible for RRI, similar to earlier mentioned suggestions by Stahl (2013) of meta-responsibility or higher-level responsibility. However, neither Stahl's nor Von Schomberg's models give a clear answer to the question how evaluation should be carried out in practice.

Earlier attempts with ethical councils or similar arrangements have not always been successful. Despite both laws and guidelines, the research community sometimes seems to fall short of the aim to secure ethical principles in research projects. There are recent examples where researchers and the research community have clearly failed to ensure ethical conduct. One such rather new example in a Swedish context is the so called Macchiarini scandal. Paolo Macchiarini is an Italian surgeon and researcher who was considered as a pioneer in the field of regenerative medicine. He used the patient's own stem cells together with synthetic materials as trachea transplants. Macchiarini was a visiting researcher at Karolinska Institutet in Sweden. Today, Macchiarini is no longer seen as successful. A majority of the patients who received his trachea transplants are died, and Macchiarini is accused for falsifying both his academic credentials and his results. The Macchiarini scandal is an example where a highly respected and highly ranked university failed to follow ethical guidelines in an appropriate way.

RRI IN SCIENCE EDUCATION RESEARCH

Education is naturally an important part of RRI. Thus, education is mentioned in different policy projects related to RRI (e.g. Owen et al., 2012; Stahl, 2013). Owen et al. (2012) believe that funders have a leading role to play from an educational perspective. They regard funders as responsible to meet the expectations which have been placed on RRI through programmes of education and training. By contrast, Stahl (2013) emphasises the individual researcher's engagement.

So far, RRI is an almost non-used concept within science education research, despite the efforts from the EC to bring the concept on the agenda in educational contexts.

Publications within the field have not taken this aspect on board. A search in the databases of four internationally well-known science education journals (International Journal of Science Education; Science Education; Science & Education; Research in Science Education) give no hits where "Responsible Research and Innovation" is mentioned in the title or abstract. Even if there are many other journals within science education research, this gives a hint of the relative scarcity of studies related to RRI within science education research. So why is this the case?

To be able to discuss this question, it is necessary to see which other concepts exist, which in some respect present similarities to RRI, and that have been the object for studies within science education research. This is important since the use of other similar concepts could influence the establishment of a new concept like RRI. In fact, a summary inspection reveals that several key concepts exist that present some points in common with RRI, and which have been elaborated on during many years. Among these, the most influential are probably: scientific literacy (SL), nature of science (NOS), and socio-scientific issues (SSI). These three concepts are richly described and investigated within science education research. They all in some way give attention to similar aspects as RRI, even if they are not identical.

SCIENTIFIC LITERACY

Scientific literacy (SL) is defined by Driver et al. (1996) as knowledge about science knowledge, or scientific concepts, scientific processes and situations or contexts. Roberts (2007) further opened up the concept to include more *about* science, and its role in society. Every citizen must understand how science influences society, and vice versa. As we noted earlier with respect to RRI, some criticism has been voiced concerning the goal of making every citizen able to reason about what research should be supported or allowed. Very similar criticisms and discussions have taken place with respect to SL. A number of similarities can in fact be found between an individual's scientific literacy and knowledge concerning RRI. In both cases, it is important to understand both scientific processes and products, make informed decisions and to take into account also ethical and societal aspects. One possible difference concerns how action is involved in the two concepts. In RRI this is totally clear, while implications for action in SL are somewhat blurred, although later definitions of SL do take action into account (Roberts, 2007). Roberts puts forward a *Vision II* of SL, where democratic aspects and decision-making are emphasised as part of scientific literacy. Also Levinson (2017), stresses the democratic aspects of SL. He argues that

> science education towards scientific literacy should provide the means for informed citizens to participate in democratic decision-making on contemporary techno-scientific issues. (p. 76)

Similarly, Sjöström and Eilks (2017) recently suggested a *Vision III* of SL and science education, emphasising socio-political-philosophical values and critical global citizenship.

This vision has also been described as "critical scientific literacy" (El Halwany, Zouda, Pouliot & Bencze, 2017; Sjöström, Frerichs, Zuin & Eilks, 2017), a term which was explicitly used by Hodson (2009, 2011) in his visionary books concerning the future of science education. If Vision II of SL focuses on socialization, Vision III of SL goes a step further and focuses on subjectification and emancipation. Dos Santos (2009) writes:

> beyond the purpose of humanistic science education to prepare citizens for the technological society [Vision II], it is necessary to have a clearer view of science education as having sociopolitical function. (p. 362)

Vision III includes worldview perspectives, socio-political-environmental perspectives, as well as responsible actions (Sjöström & Eilks, 2017).

NATURE OF SCIENCE

Discussions concerning the nature of science (NOS) also bears similarities to RRI, especially with respect to those aspects of NOS that concern human elements of science. For other major aspects concerning tools and products of science and science knowledge and its limits, respectively, the similarities are less obvious (McComas, 2017). Leden (2017) describes the field in the following terms:

> NOS being a field where perspectives from history, philosophy, and sociology of science meet and play roles in the interpretations of how values, believes, norms, and traditions interact with scientific knowledge and the processes connected to its development. (p. 9)

As in RRI, NOS emphasises interactions between scientific knowledge and processes (Lederman, 2007). To understand NOS means to understand how science works and how knowledge produced by researchers engaged in scientific inquiry is a part of society, and influenced by norms and values. Even if there is no complete consensus concerning how NOS should be defined or the terminology to be used, Allchin (2014) concludes that it is all about how understanding about science should help students as citizens in contemporary society to participate in decision-making and make decisions. This form of understanding about science is also an important aspect of RRI.

SOCIO-SCIENTIFIC ISSUES

Finally, the concept socio-scientific issues (SSI) underlines quite similar issues, but mainly from an educational perspective. Working with SSI gives the students a possibility to investigate a problem in society. Ratcliffe and Grace (2003) describe SSI

> to be one which has basis in science and has a potentially large impact on society. (p. 1)

SSI have attracted attention in science education in recent years and have been proposed as an appropriate means to discuss and learn about the connection between science and society. Instead of learning many concepts in the beginning of studying a discipline, SSI teaching starts with a problem or a question that can be perceived as significant and important by the students. Ratcliffe and Grace argue for the influence of our priorities, values and beliefs when taking action on a personal level. Such values and beliefs are also important in RRI.

Within science education research, extensive research about SSI has been conducted during the past decade (Zeidler, 2015). Sadler (2009) suggested to select SSI for science education, which encourages personal connections between students and the issues discussed, explicitly addresses the value of justifying claims and exposes the importance of attending to contradictory opinions. Such a version of SSI-teaching emphasises relevance (both personally and societally), ethics, civic engagement and character formation (Zeidler & Sadler, 2008).

Recently, Levinson (2017) in this journal compared SSI with other science-society education approaches like STEM (Science-Technology-Engineering-Mathematics), SAQ (Socially Acute Questions), and STEPWISE (Science & Technology Education Promoting Wellbeing for Individuals, Society & Environments). He described the educational purpose of STEM as providing human capital, that of SSI as development of scientific knowledge needed for socio-scientific reasoning, that of SAQ as developing a critical discourse, and that of STEPWISE as knowledge for action for socio-ecojustice.

On the other hand, Simonneaux (2014) has discussed a continuum of different versions of SSI, using a scale from "cold" to "hot" variants. Cold-type SSI education is quite traditional science teaching with some socio-contextualisation. It is characterised by monodisciplinarity and focus on content learning. Hot-type SSI, on the other hand, also emphasises transdisciplinarity and political citizenship, in addition to epistemic values. As mentioned in the introduction, just like the other concepts compared in this article, SSI can be understood as a "boundary object". However, it may be debatable whether it is reasonable to include as much in the SSI concept as Simonneaux (2014) did. We would argue that it may be more appropriate to work with a somewhat narrower definition, like the one Levinson (2017) refers to, where SSI is still a "boundary object" but where there is little more consensus about what is meant with the concept. Within a narrower definition, cold-type SSI might better be termed "context-based", while hot-type socio-ecojustice-oriented SSI could be covered by concepts such as Socially Acute Questions (SAQ). This is also the term that Simonneaux has used for "complex SSI" in most of her publications. In the rest of this article, we will use the term SSI in the narrower sense of the mainstream type outlined by Sadler and Zeidler (2009), which also Levinson (2017) referred to in this journal.

THE THREE CONCEPTS AND RRI

In this section, we will further discuss the similarities and differences between RRI and the three concepts of SL, NOS and SSI outlined above. The aim with this discussion is to scrutinise if RRI can bring something new and useable into science education, or if RRI just is the same thing, "dressed in the Emperor's new clothes". SL, NOS and SSI have all been of importance in science education research for at least the last 20 years. Especially SL has received considerable attention and has been introduced in curricula all over the world. SL is also a concept which underlies frameworks as PISA (Dillon, 2009; OECD, 2003; Sadler & Zeidler, 2009). All these three concepts describe, at least in some way, perceptions of what is desirable in certain forms of *citizenship*. The concepts rest on the shared assumption that by being scientifically literate, understanding how science works and how it is important in societal questions, the individual will be able to argue and make better founded decisions. As in RRI, these three concepts have strong democratic aspects. They all also have a contextual feature, especially SSI. Dependent on the situation, science can play different roles and different knowledge is needed in different situations. At first glance, the three concepts additionally seem to cover a large portion of what science education is supposed to cover according to different curricula. We can also observe that curricula have been revised and drafted to address these aims, expressed in various national and international policy documents.

However, there are some differences between the three concepts. NOS has strong connections to the broad field of science studies, which is an interdisciplinary research area that seeks to situate scientific expertise in broad social, historical, and philosophical contexts (Sismondo, 2009). SL is a part of the literacy movement (Norris & Phillips, 2003), which started with reading and writing, but nowadays is discussed in every school subject. Of the three concepts, SSI is the only one that is used almost only in science education. However, also this concept had its background outside science education in a field called *controversial issues education*, that started developing in the 1960s (e.g. Long & Long, 1975). Studies in science education demonstrate the difficulties with attempts to involve real-world problems (e.g. Lundström, 2011) in the science classroom. Even if science education strives to work with complex problems, it has been difficult for students to understand what science really is, how it works and the diversity within science (Lederman, 2007). These results indicate that science education today does not totally reach the goal of educating citizens who are scientifically literate.

As mentioned earlier, the RRI concept promotes societal actors to engage together in research and innovation processes in order to better align both the process and its outcomes with the values, needs and expectations of society. We think here is the major possibility to establish RRI within science education. By establishing close connections to different educational institutions, researchers might have the possibility to create situations where students, teachers, teacher educators and researchers discuss RRI. This face-to-face meeting between students and researchers might also give the possibility to raise scientific literacy among students. Our own experience from doing this is encouraging. Through inviting scientists to both teacher education programmes and to primary and secondary schools, both in-service teachers, pre-service teachers and students could discuss directly with the scientist. These encounters enable to develop issues of RRI, and possibilities to further develop these processes and different perspectives with the students. During the PARRISE-project a Swedish scientist who worked with nano-technology development and risks, brought in important perspectives of RRI to our teacher workshops. The scientist for instance discussed the distribution between money spent on research to develop new nano-technology products (90%) compared to risk research within nano-technology (10%).

Another area where RRI could develop science education is the interpretation of data. Studies demonstrate how individuals often have problems with interpreting data (Bond, Philo & Shipton, 2011). If a collaboration is established with scientists as mentioned above, it will give an opportunity to practise to interpret data, but also to discuss with scientists how data can be interpreted in different ways. One such example could be climate data, an area that is much discussed and where debates occur concerning how to interpret and value data.

DISCUSSION

The idea of RRI builds upon a wish that people in a larger community, as for example the European Union, should share similar values, thoughts and wishes about the future. It relies on a desire that many individuals should make the same assessment when obliged to choose between economic, societal, technical or other perspectives. Is this Utopia possible to reach? Of course not, but on the other hand RRI is, just like SL, NOS and SSI, a boundary object, where the meaning of the concept is continuously under discussion and development.

Ideally, RRI relies on a unified view between different actors about the research and innovation process. The different actors must discuss and reach a decision that people can accept and see as possible. This might be hard to achieve in practice, since many questions do not have a clear straight answer and different actors will stress different questions and answers. But despite such difficulties, as mentioned earlier, Owen et al. (2012) have demonstrated how collaboration between scientists and organisations can be successful. We think this can also be the case between scientists and both formal and informal education.

If education should develop RRI skills, there are some aspects to be considered, however. Several studies point out the difficulties with transferring different types of school knowledge into other contexts outside school (e.g. Lundström, Ekborg & Ideland, 2012). Several years ago, Roth and Lee (2004) made the suggestion that science education should participate in various social activities and contexts outside school. Perhaps RRI could reconsider this suggestion and influence science education to work even more with real case studies. From our exploration and comparison between the different concepts, we have concluded that RRI does not bring in fundamentally new ideas to science education, but instead highlight parts that have been neglected. Nonetheless, the meeting between the researcher or innovator and student or teacher could offer new perspectives. The possibility to meet researchers with different perspectives in connection to inquiry based science education, we consider as a fruitful possibility to promote RRI and open the science classroom for deliberative discussions about different perspectives of research and innovation. This has of course been done to a certain degree already. Within the PARRISE project, the combination of inquiry based science education where questions were framed by SSI-issues, in combination with encounters with researchers in the actual new-technology area, shows encouraging experiences to approach RRI within science education (Sjöström, Hasslöf & Lundström, 2017). RRI may be a top-down policy concept, embedded in interpretive challenges, but it might be a mistake to throw it away, as to blurry or complex concept, at least in relation to science education. Why? Because in a way, the challenges of RRI mirror the challenges that contemporary innovations of science and technology face. It puts science education in relation to the dynamics of societal challenges of rapid science innovations and emerge the ethical and political dimensions of science and technology. We do not have, and do not strive for any ultimate method of how to address RRI in relation to science education, but we look forward to further experiences and research in the science education field to develop the discussion of RRI further. We believe all actors have a lot to learn from such initiatives, and that arranging opportunities for face-to-face encounters of this kind would be in line with the core goals expressed by the EC with respect to RRI, namely: "multi-actor and public engagement in research and innovation, enabling easier access to scientific results, the take up of gender and ethics in the research and innovation content and process" (EC, 2017).

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Design and Evaluation of Teaching Materials for Responsible Research and Innovation

Marta Romero-Ariza
mromero@ujaen.es| Universidad de Jaén, Spain

Ana María Abril
amabril@ujaen.es| Universidad de Jaén, Spain

Antonio Quesada
antquesa@ujaen.es| Universidad de Jaén, Spain

Abstract

The analysis of the classroom activities produced by a sample of 121 pre-service teachers provides evidence about the impact of a teacher professional development program to promote responsible research and innovation (RRI) through science education. Most of the activities produced by participants were related to curricular content knowledge, contributed to the development of key competences and defined learning objectives in line with current science education standards and RRI. Many of the classroom activities (78,6%) includes good or excellent maps of the controversy related to relevant socioscientific issues and high quality questions for scaffolding students' work. Additionally, 60,7% of the activities got high marks in the evaluation of authenticity and their potential to encourage science students' to make informed decisions and undertake an active role in societal issues concerning scientific and technological advances.

Key Words

Science Education, Scientific literacy, Socioscientific Issues (SSI), Responsible Research and Innovation (RRI), Teaching resources.

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Conceção e Avaliação de Materiais Pedagógicos de Investigação e Inovação Responsáveis

Marta Romero-Ariza
mromero@ujaen.es| Universidad de Jaén, Espanha

Ana María Abril
amabril@ujaen.es| Universidad de Jaén, Espanha

Antonio Quesada
antquesa@ujaen.es| Universidad de Jaén, Espanha

RESUMO

A análise das atividades em sala de aula produzida por uma amostra de 121 futuros professores apresentam evidências sobre o impacto de um programa de desenvolvimento professional do professor para promover a investigação e inovação responsáveis (IRR), através da educação em ciências. A maior parte das atividades produzidas pelos participantes estavam relacionadas com o conhecimento do conteúdo curricular, contribuíram para o desenvolvimento de competências essenciais e definiram objetivos de aprendizagem em linha com os padrões atuais da educação em ciências e da investigação e inovação responsáveis (IRR). Muitas das atividades em sala de aula (78,6%) incluem bons ou excelentes mapas de controvérsia relacionadas com questões sociocientíficas (QSC) relevantes e com outras questões pertinentes de apoio ao trabalho dos alunos. Além disso, 60,7% das atividades obtiveram pontuação elevada na avaliação da autenticidade e no seu potencial para incentivar os estudantes de ciências a tomarem decisões informadas e empreenderem um papel ativo no que diz respeito a questões societais relacionadas com os avanços científicos e tecnológicos.

PALAVRAS-CHAVE

Educação em ciências, Literacia científica, Questões sociocientíficas (QSC), Investigação e Inovação Responsáveis (IRR), Recursos didáticos.

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INTRODUCTION AND PURPOSE

Our 21th societies are facing major challenges: health and wellbeing, food security, sustainable agriculture; secure clean and efficient energy; smart, green and integrated transports, mitigation of climate change, environmental actions and sustainability, etc. (European Commission, 2017). Undoubtedly, many of the current societal challenges will require innovative solutions that have a basis in scientific research.

Science education plays a crucial role in the generation of well-prepared scientists to undertake the development and nurture the innovation that will be essential to meet the economic, social and environmental challenges that the world faces. Along with the preparation of future scientists, science education should promote scientific literate citizens able to actively participate in the debate of socio-scientific issues and make informed decisions in areas concerning the impact of human activities on the planet and the implications of scientific and technological advances.

Furthermore, in our technological and scientific societies it is necessary to ensure Responsible Research and Innovation (RRI). This term refers to the concern of making sure that the processes and products of science are well aligned with the values, needs and expectations of society (Burget, Bardone & Pedaste, 2017; Levinson, 2017). The participatory nature of RRI requires scientific literate citizens, who understand the nature of science and can discuss the risk and uncertainties associated with particular technological and scientific applications.

Scientific literacy as an educational goal may be defined by responding to the question 'What is important for young people to know, value and be able to do in situations involving science and technology?' (Organisation for Economic co-operation and Development, 2016, p. 18). In this line, some authors have discussed scientific literacy in relation to current challenges in science education and the pedagogical methods required to bring about the desired learning outcomes (Romero-Ariza, 2017).

After recognising the crucial role of science education in addressing the previously mentioned challenges, there is a need to further discuss which pedagogical approaches and teaching materials are appropriate to promote the knowledge, skills and dispositions required to actively participate in RRI and how can we best prepare teachers to bring them into the classroom.

Within the European project PARRISE (Promoting Attainment of Responsible Research and Innovation in Science Education), the main goal of this work is to discuss a science education model for RRI and to analyse the quality of a set of teaching materials according to this model.

THEORETICAL BACKGROUND

In this section we will draw on the specialised literature in order to define the main constructs involved in the science education model, which underpins the present work.

RESPONSIBLE RESEARCH AND INNOVATION

Responsible Research and Innovation has received increasing attention in academic publications and international projects such as RRI tools, IRRESISTABLE or PARRISE, after being a focus of interest in European Framework Programmes. Those programs intend to enhance cooperation between science and society and strengthening public confidence in a *science for and with society* (Geoghegan-Quinn, 2012).

In previous decades, ELSA in Europe (ELSI in the US), which stands for Ethical, Legal and Social Aspects of emerging sciences and technologies may be considered a precursor of RRI (Zwart, Laurens & van Rooij, 2014). ELSA studies meant to provide a social and ethical complement to major technology development programs and acknowledged that scientific expertise cannot be the sole basis for the development of new technologies. On the contrary, society should be involved from the offset to discuss risk and promote responsibility safety and security (Forsberg et al., 2015). Additionally, ELSA was supposed to bring about a more anticipatory approach that would focus on the processes of innovation rather than on the final products (Zwart et al., 2014).

Burget et al. (2017), in their literature review of 235 RRI-related articles found out that while administrative definitions were widely quoted in the reviewed literature, they were not substantially further elaborated. However they identified four distinct conceptual dimensions of RRI: inclusion, anticipation, responsiveness and reflexivity and added two emerging ones: sustainability and care.

Conceptualising RRI as a movement to promote science for and with society, Von Schomberg (2013) highlighted three 'anchor points': ethical acceptability, social desirability and sustainability. These anchor points can be recognised as the main aims of RRI to be accomplished through four key processes: diversity and inclusion, openness *and transparency*, *anticipation and reflectivity* and *responsiveness and adaptive change*.

In figure 1 we represent our understanding of the complex integration of RRI aims and processes.

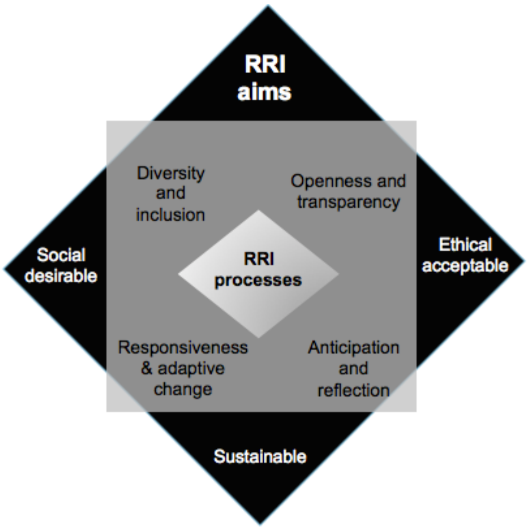

Figure 1. Aims and processes of RRI.

The aims and processes of RRI have been identified as an overarching context to design a science education model that could address those societal challenges (Levinson, 2017). We will take this overarching context as the referent point to shape educational interventions aimed at preparing individuals to actively contribute to RRI. The underlying science education model will be discussed in the following section.

A SCIENCE EDUCATION MODEL FOR RESPONSIBLE RESEARCH AND INNOVATION

In line with the European project PARRISE, we support a science education model for RRI that combines different pedagogical approaches: Inquiry-Based Learning (IBL), Socio-Scientific Issues (SSI) and Citizenship Education (CE). The model is known as SSIBL (Levinson, 2017). SSIBL stands for Socio-Scientific Inquiry Based Learning (SSIBL). The PARRISE project intends to empower teachers to enact such a model in order to equip their students with the knowledge, skills, values and dispositions necessary to actively participate in RRI.

The term Socio-scientific Issues (SSI) refers to problems that often arise in our world and have a scientific and/or a technological component. They are considered as issues or problems because there is no consensus on how they might be best solved and have inherent moral and ethical connotations (Levinson, 2006). To work on SSI, students have to identify and interpret data, to recognize different factors and effects and to take into account diverging opinions (Sadler, 2004). Examples of SSI are the use of human embryos, the production of genetically modified crops, the deployment of alternative energy resources, the environmental effects caused by socially useful materials or the climate effects caused by carbon dioxide emissions. The specialised literature shows that SSI increase students' motivation and engagement in science learning and offer powerful scenarios to develop critical thinking and the understanding of the nature of science and its implications (Lederman, Antink & Bartos, 2014; Sadler & Dawson, 2012; Vázquez-Alonso, Aponte, Manassero-Mas & Montesano, 2016; Venville & Dawson, 2010). SSI are easily recognised by students as real-world scenarios related to contemporary issues, thus bringing a sense of authenticity and relevancy to the science classroom. Furthermore, SSI can be approached through IBL, even though they might be seen as more comprehensive and complicated than scientific problems.

Inquiry-based Learning (IBL) has been advocated as an appropriate pedagogy to improve science education for decades (National Research Council, 2000, 2012; European Commission, 2007, 2015). There is research evidence of inquiry having a positive effect on students' interest in science (McConney, Oliver, Woods-McConney, Schibeci & Maor, 2014), the development of process skills and adequate view of the Nature of Science (Capps & Crawford, 2013; Lederman, Lederman & Antink, 2013), as well as the meaningful understanding of key science topics (Minner, Jurist Levy & Century, 2010).

As previously mentioned, the SSIBL model is based on three pillars: SSI, IBL and Citizenship Education (CE). Therefore, the other educational approach integrated in our science education model for RRI is citizenship education. CE takes into account the moral and social function of education and articulates the personal, interpersonal and the socio-political levels. This approach can make a relevant contribution to the education of critical, responsible and responsive citizens able to thoughtfully discuss SSI and support RRI. According to Veugelers (2001) critical-democratic citizenship education encompasses a learning process characterized by being:

- Reflective: individuals reflect on their own ideas and values and where they come from, as well as own their own learning process.
- Dialogical: learners discuss with each other, share different perspectives, and analyze social, cultural and political power relations.
- Democratic: individuals have concern for others and recognize the importance of building joint arguments and decisions.

The characteristics and main affordances of any of the described pedagogical components offer a resulting science education model with an interesting potential to address current societal challenges.

In the interpretation and enactment of the SSIBL model, we have placed special emphasis to three key features: authenticity, mapping the controversy in SSI and taking action.

Authenticity is related to the importance of linking education with current societal challenges and educating scientific literate citizens prepare for an active contribution to RRI. In the SSIBL model teachers are encourage to organise the learning process around authentic questions. According to the theoretical framework developed by Levinson for the PARRISE project, authentic questions include the following features. They:

- proceed from questions which interest and engage students (personal authenticity) and through which they express a wish, and choose, to find collective answers (social authenticity);
- involve real-world, complex, 'wicked problems' (Hipkins, Bolstad, Boyd & McDowall, 2014; Hume & Coll, 2010);
- are controversial in nature because there is often no overall agreement about solutions or even ways to frame the question;
- are questions or issues that emerge from young people spontaneously or, more likely, with sensitive support from teachers;
- presuppose change in that questions are asked about matters or issues which can be improved, e.g. made both more personally and socially desirable.

How such questions are raised is central to effective pedagogy in SSIBL and they can be initiated by discussing with students a recent new or a controversial issue affecting their lives.

Mapping controversy is related to individuals' capacity to explore a socio-scientific issue in an open way, taking into account different arguments (scientific, social, ethical, economical, environmental…); balancing benefits, risks and uncertainties; and evaluating conflicting points of views from different perspectives (individual/local/social). This description matches with several key processes in RRI: inclusiveness, open and transparency, and reflection and anticipation. Additionally, mapping the controversy is essential to ensure the three aims of RRI: social desirability, ethical acceptability and sustainability.

Finally, encouraging students to make informed decisions and take responsible actions is crucial to educate active and engaged citizens prepared to contribute to RRI.

In the following section, we will describe how we have drawn on this theoretical model to design a teacher professional development program. The aim of the course was to provide them with the knowledge and skills necessary to enact the SSIBL model, with a special focus on the design of teaching materials. We will describe the context and the sample of study, as well and the instrument and the method applied to evaluate the impact of the intervention on teachers' capacity to design good SSIBL classroom activities.

METHODS

In the following we describe the context, sample, instruments and methodology of analysis applied in the present study.

CONTEXT AND SAMPLE

The study was carried out with a sample of 121 pre-service teachers (65 female and 56 male), taking part in a 60 hours undergraduate course on science education, offered throughout a whole semester (from February to May). Participants were on their fourth year of a university program to become primary school teachers and had already had other subject on science education the previous year.

INTERVENTION

Participants in this study were subjected to an intervention based on a Teacher Professional Development (TPD) model previously validated (Ariza, Quesada, Abril & García, 2016). The TPD model has been specifically designed to equip teachers with the knowledge, skills and values necessary to promote Responsible Research and Innovation through science education and was consistent with the theoretical framework developed within the European project PARRISE.

The model entailed a wide range of teacher professional development activities, which encourage participants to adopt different roles: *teachers as learners, teachers as reflective practitioners* and *teachers as designers*. The TPD intervention consisted of 6 sessions of 2h each.

The two first sessions offered participants the opportunity to experience the educational potential of SSIBL as students. They were introduced to a SSI scenario and asked to inquiry, map the controversy, deliberate in small groups and present their results and conclusions *as learners* to the rest of the class. These two first sessions of the intervention respond to what is described in the specialised literature as an immersion TPD technique (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003).

After the immersion experience, pre-service teachers were asked to take the role of *reflective practitioners* and identify the learning outcomes related to the SSIBL activity they were engaged as students. They were required to define the learning outcomes in terms of content knowledge and competences. A debate about the educational potential of this type of pedagogy compared to more traditional methods was then conducted.

The four following sessions were mainly focused on the development of specific teaching skills to design good classroom activities consistent with the science education model being promoted, a science education model aimed at equipping future citizens with the knowledge, skills and values necessary to actively contribute to RRI.

Before starting the design phase, teachers were provided with specific recommendations and quality criteria to guide the development of the SSIBL classroom activities: They were asked to have a look at the media and select a recent new dealing with a relevant socio-scientific issue, which could be of special interest to their future students. They should inquiry about the selected topic and map the controversy in order to identify key aspect to discuss, advance possible students' difficulties and prepare guiding questions to support effective inquiry and reasoning. Special emphasis was placed on the identification of different types of arguments (scientific, social, ethical, economical, environmental…), the evaluation of contrasting points of views (benefits/risks, individual/local/global) and the critical examination of bias and reliability concerning the sources of information.

Additionally, pre-service teachers had to look for specific links with the science curriculum, define learning outcomes and discuss how they would assess those learning outcomes related to the SSIBL activity being designed.

Finally they should describe how they would use this SSI scenario for promoting critical thinking, responsible decision-making and scientific literacy in their students.

Quality criteria concerning all the above-mention aspects of the design process were discussed with pre-service teachers in advance, and were later used for self-evaluation. Those criteria are part of the instruments applied for the analysis of the classroom activities designed by participants.

METHODS AND INSTRUMENTS

The classroom activities designed by participants were analysed using a qualitative approach involving two researchers. The analysis was conducted through successive cycles any of them involving first an independent analysis by each researcher and then a joint revision of results in order to refine categories, negotiate meanings and ensure inter-rater reliability (Silverman & Marvasti, 2008).

Initial categories were established in a deductive way to reflect the underlying theoretical model described in section 2.2. An instrument to evaluate the quality of contributions in any category was developed through iterative cycles of implementation and revision as described below:

The first cycle of analysis resulted in a 42% percentage of agreement between the two independent researchers. A revision of the way the quality criteria for each category had been defined resulted in a new version of the evaluation instrument. This revised version was applied to a new cycle of analysis, which produced 57% percentage of agreement between raters. The revision of the scale in the instrument and a new cycle of analysis resulted in 95% of agreement between raters. At this point, the instrument was validated and the remaining 5% of disagreement was resolved by discussion, reaching consensus. Table 1 shows the final version of the instrument used for the analysis of the SSIBL classroom activities designed by teachers.

Table 1

Instrument for the analysis of the SSIBL classroom activities designed by teachers

Category	Quality criteria
Authenticity	Good use of media (videos, ads…) to introduce SSI relevant to students. Well adapted to students' age and interests. Motivating/engaging. Positive and negative views.
Mapping Controversy	Related to scientific/technological advances and controversial. Different dimensions are analysed in an accurate/critical way (scientific, social, economical, environmental, health) Counter arguments are taken into account: it might include different interest's groups, evaluation of benefits/risks; individual/local/global) Critical stance concerning reliability and bias of information
Curriculum	Consistent and specific links to the school curriculum (Competences, standards, content…) Curricular elements are defined in an correct way Learning goals are consistent with the SSIBL approach
Assessment	Assessment criteria and processes are consistent with the learning goals and the SSIBL approach. Assessment criteria are defined (expressed) in an appropriate way.
Scaffolding	The questions for scaffolding: · draw attention on key aspects · advance potential students' difficulties and guide students · promote students' reflection and argumentation · are well formulated
Taking Action	Students are asked to conduct activities or make products that require informed decision making and/or action taken.
Evaluation	The self-evaluation results in concrete suggestions for the optimisation of most of the key features of the SSIBL model (relevancy, mapping controversy, scaffolding, curriculum, decision-making and action-taken…)

Note: According to the way quality criteria for each category are met, contributions can be described as: 1=non-existent/non-acceptable; 2=deficient; 3=acceptable; 4=good; 5=excellent.

RESULTS

The analysis of the artefacts produced by participants in our teacher professional development program provides evidence about the impact of the course on teachers' ability to develop SSIBL classroom activities. The classroom activities have been designed according to a science education model aimed at equipping future citizens with the knowledge, skills and values necessary to actively participate in RRI. In the following, we will discuss the main outcomes of the analysis conducted by two independent researchers applying the instrument described in table 1.

Participants selected a wide range of SSI topics based on recent news or controversial issues being discussed in the media. Two groups of participants selected climate change and zoos as the topic for their classroom activities, and three groups design activities related to pollution and environment. The rest of participants selected different topics. Table 2 shows the different topics chosen for the design of the SSIBL classroom activities analyses in this work:

Table 2

Topics selected for the SSIBL activities designed by pre-service teachers

Topics selected for the design of the SSIBL activities	
The blanket that cools in summer	Pollution in Madrid
Zealandia, the hidden continent	Cancer
For or against cow milk	About Kebab
Sugar and processed food	Hooked on sugar
Violent games	Zoos yes or no?
Implications of new technologies	Healthy food
The electricity bill	Pollution and environment
Coke	Cannabis yes or no?
Should zoos be banned?	Pollution
Wolves and their importance in ecosystems	Genetically modified food
Experimentation with animals	Thaw in Antarctica
Climate change: anthropogenic or natural?	Children à la carte
The discovery of a new planetary system	Tap water of bottled water?
Would you donate organs in life?	Climate change

Table 3 displays the results of the content analysis of the SSIBL classroom activities according to the categories and quality criteria of the evaluation instrument presented in table 1.

Table 3

Frequencies for each of the dimensions and categories analysed in the SSIBL classroom activities

	Frequency %				
Dimension/category	**Non-existent/ non acceptable**	**Deficient**	**Acceptable**	**Good**	**Excellent**
Authenticity	3.6	17.9	17.9	28.6	32.1
Mapping controversy	7.1	3.6	10.7	42.9	35.7
Curriculum	0.0	0.0	3.6	32.1	64.3
Assessment	3.6	25.0	25.0	21.4	25.0
Questions	3.6	7.1	10.7	42.9	35.7
Taking action	3.6	17.9	17.9	10.7	50.0
Self-evaluation	14.3	14.3	14.3	32.1	25.0

DISCUSSION

In the following we will comment on the main results starting by presenting the connection between the classroom activities designed by teachers and the Science Education Standards in Spain. Afterwards, we will discuss to what extent the teaching materials analysed meet the quality criteria related to the key aspects of our science education model: authenticity, controversy mapping and action taken.

The content analysis shows that the category best evaluated by experts is related to the identification of links with the existing curriculum. 96,4% of the activities got high marks being evaluated as good (32,1%) or excellent (64,3%) in this respect. Conversely, none of the tasks were considered deficient or not acceptable in relation to its connection with the school curriculum. Most of the activities produced by participants were related to curricular content knowledge, contributed to the development of key competences and defined learning objectives in line with current science education standards and the SSIBL model. This result is quite relevant considering that teaching is heavily curriculum-driven and an innovative pedagogy that cannot be aligned with existing curricula will be hardly sustainable. Additionally, it reveals that our TPD program has been successful in raising teachers' awareness of the educational potential of the SSIBL approach in terms of meeting curricular recommendations and standards.

In relation to authenticity, only 3,6% of the activities designed by teachers did not draw on media or relevant news to introduce the SSI to be investigated. This result reveals the emphasis placed on authenticity when developing a science education model for RRI. Authenticity is related to the importance of connecting science education with socio-scientific issues close to students' lives and daily experience. Teaching science focussing on those issues makes it meaningful and relevant to students. Inquiring on SSI provides students with interesting opportunities to better understand the foundation and implications of current scientific and technological advances and make subsequent decisions, what is closely connected to their potential contributions to RRI as informed citizens.

In this line, we have trained teachers in the use of media (news, videos and advertisements) to introduce SSI in the classroom and bring a sense of authenticity and relevance into the science classroom. Additionally, those resources may be used as a hook to introduce the topic and provoke students' engagement. The analysis of participants' artefacts shows that 60,7% of the SSIBL activities designed by pre-service teachers were considered as good or excellent concerning authenticity and relevance.

Teachers' capacity to map the controversy and prepare questions to support students' inquiry, reasoning and argumentation were also highly evaluated by experts. 78,6% of the classroom activities developed by participants include a good or excellent map of the controversy and high quality questions for scaffolding students' work. Controversy mapping requires individuals' capacity to explore a socio-scientific issue in an open way, taking into account different arguments (scientific, social, ethical, economical, environmental…); balancing benefits, risks and uncertainties; and evaluating conflicting points of views from different perspectives (individual/local/social). This description matches with several key processes in RRI: inclusiveness, open and transparency, and reflection and anticipation. Additionally, mapping the controversy is essential to ensure the three aims of RRI: social desirability, ethical acceptability and sustainability.

Responsiveness or action taken is the other of key features of the SSIBL model emphasized in our TPD course. We discussed with teachers the importance to educate responsible and engaged citizens able to take an active role in RRI by providing students with opportunities to take informed positions and responsive actions in relation to current SSI. As a result, teachers designed activities that encourage students to make videos and brochures to disseminate their informed opinions to the school, parents or local community, write letters to organisations and institutions or make concrete proposals about how to improve a particular aspect of their lives (their electricity bill, their sugar consumption, etc.). In this respect, our analysis shows that 60,7% or the classroom activities developed by the participants were considered good or excellent to support students in taking action about a particular SSI. These kinds of activities promote active and engaged citizens.

CONCLUSION

We have worked with a sample of 121 pre-service teachers in the development of classroom materials aligned with a science education model intended at equipping future citizens with the knowledge, skills and dispositions to actively participate in RRI. The science education model places special emphasis to three key aspects: authenticity, mapping controversies and taking actions. Based on the theoretical foundation of the model, the evaluation instrument validated (see table 1) and the results discussed in the previous section, we conclude that most of the classroom activities designed by teachers developed the three key features of the model in a good or excellent way, what is a relevant result considering current societal challenges and the need to educate citizens for RRI.

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Becoming a science Activist: A Case Study of Students' Engagement in a Socioscientific Project

Eran Zafrani

eran.zafrani@weizmann.ac.il | Weizmann Institute of Science, Israel

Anat Yarden

anat.yarden@weizmann.ac.il | Weizmann Institute of Science, Israel

ABSTRACT

Complications arising from socioscientific issues (SSI) call for immediate and responsible action and warrant students' activism on science-related issues. These issues therefore provide a solid learning context for the advancement of responsible research and innovation (RRI) in science education. This study investigates the development of students' identities as activists as they participate in a high-school project aimed at resolving the problem of global hunger. Drawing from practice-linked identity theory, we present the narratives of two students to examine how they came to embrace the identity of activist. Findings indicate that the students' identities as activists were supported through participation in highly contextual and emotionally charged experiences and through the ability to fill roles that were perceived as integral and authentic to the students. We discuss the potential of a well-structured activity to assist students in deeply engaging with responsible actions.

KEY WORDS

Socioscientific issues (SSI), Responsible Research and Innovation (RRI), Activism, Identity.

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Tornando-se um Ativista da Ciência: um Estudo de Caso Sobre o Envolvimento dos Estudantes num Projeto Sociocientífico

Eran Zafrani
eran.zafrani@weizmann.ac.il | Weizmann Institute of Science, Israel

Anat Yarden
anat.yarden@weizmann.ac.il | Weizmann Institute of Science, Israel

RESUMO

As complicações que advêm das questões sociocientíficas requerem ações imediatas e responsáveis e uma garantia de ativismo estudantil em questões relacionadas com a ciência. Estas questões fornecem, assim, um contexto de aprendizagem sólido para o avanço de uma Investigação e Inovação Responsáveis (IIR) em educação em ciências. Este estudo investiga o desenvolvimento da identidade dos estudantes como ativistas ao participarem num projeto da escola secundária destinado a resolver o problema da fome global. Com base numa teoria da identidade, ligada à prática, apresentamos as narrativas de dois estudantes, para analisar a forma como eles adotaram a identidade do ativista. Os resultados indicam que a identidade dos estudantes como ativistas fundamenta-se na participação em experiências altamente contextuais e carregadas de emoção e na capacidade para desempenhar papéis que foram percebidos como autênticos e íntegros pelos estudantes. Discutimos o potencial de uma atividade bem estruturada para ajudar os alunos a envolverem-se profundamente em ações responsáveis.

PALAVRAS-CHAVE

Questões sociocientíficas (QSC), Investigação e Inovação Responsáveis (IIR), Ativismo, Identidade.

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INTRODUCTION

Today, science constitutes a dominant and pervasive aspect of the lives of individuals and societies (Bencze & Carter, 2011). This is exemplified by continuing discussions in the public sphere that focus on current issues, such as climate change, access to clean water, food shortages, genetic modification, and other critical issues that demand our immediate attention. The impact and reach of these issues extend beyond the dimensions of professional science to include political, economic, cultural and social dimensions (Sadler, 2009), and they are therefore typically termed socioscientific issues (SSI). Given their acute social urgency, it is imperative that all citizens—scientists and non-scientists alike—strive to garner knowledge related to SSI and, subsequently, engage critically and responsibly to offer scientifically informed solutions where social implications appear to exist (Kolstø, 2001; Zeidler, Sadler, Simmons & Howes, 2005).

The coupling of responsible scientific conduct and public involvement is represented by a novel concept termed responsible research and innovation (RRI), which emphasizes the importance of advancing science for the benefit of society through a process of negotiation and deliberation with the citizens who are expected to be affected by these new advances (Owen, Macnaghten, & Stilgoe, 2012). Being a relatively new concept, and because of the proximity between the two, attempts at promoting RRI in science education were primarily linked to SSI learning (Evagorou & Mauriz, 2017).

In science education, the need for responsible engagement with emergent concerns calls for preparing students to take informed actions and to work together toward providing a safer world; this can be effected by acting and inflicting a change on the implications arising from new scientific advances and technologies, as often reflected in SSI (Barton & Tan, 2010b; Bencze & Carter, 2011; Lee, Chang, Choi, Kim & Zeidler, 2012).

Current studies of SSI learning are primarily concerned with the examination of measurable discrete learning outcomes that are expected to be affected by the negotiation of SSI in the classroom, including: students' informed decision-making tendencies (Chang & Lee, 2010), development of reasoning skills (Sadler & Zeidler, 2005), and development of an understanding about the nature of science (Sadler, Chambers & Zeidler, 2004). These studies provide a wide base for understanding students' learning about SSI, but there are further areas to explore. For example, discussions in the literature about school-based activism are, more often than not, limited to the action itself, whereas questions as to how and why students might be willing to participate in such actions are marginalized (Barton & Tan, 2010a). This fragmented literature base has led to insufficient assessment of students' tendencies to engage in science activism. To engage students in such activism, we need to better understand why they choose to act on certain issues and how their actions affect them personally. More specifically, we need to better understand the connection between students' sense of self and the activity in which they are engaged. Therefore, important issues for exploration are the students' cultural experiences and the personal identities that emerge as they act upon SSI (Zeidler et al., 2005).

It follows that we need an investigation of the ways in which students' actions are connected with their personal identities and motives, and a determination of how we might advance the education of students who are willing to participate in civic action on SSI. The primary purpose of this study was therefore to explore the ways in which students practice and build their identities through their participation in a school-based socioscientific project involving an active effort to eliminate malnutrition in underdeveloped countries. Here, the construct of identity formation with a relation to practice is suggested as an analytical lens to examine students' participation and their related engagement with science activism.

ACTIVISM IN SCIENCE EDUCATION

The ever growing body of scientific knowledge and the resulting development of new, and sometimes risky, technologies are greatly challenging our lives and the environment (Lee & Roth, 2002). For these challenges to be managed responsibly and in communicative coordination with those who are being affected by them, citizens' participation is essential.

In the EU, calls for increased attention in science education to elements of social and environmental responsibility in scientific research have recently gained prominence (Owen et al., 2012). These calls emphasize the concept of RRI in science education. RRI stresses the importance of communication between the different societal stakeholders, including scientists, governments, non-governmental organizations, businesses and the public at large, toward responsible involvement of citizens in the processes of scientific developments that could affect today's society (Levinson & The-PARRISE-Consortium, 2014). This concept is therefore structured on the idea that science should be conducted *for society*, i.e., while considering societal needs, and *with society*, i.e., in a process that involves deliberative discussions among the different stakeholders (Owen et al., 2012).

For communication between science experts and the general population to be effective, citizens should be able to understand the challenges and implications embedded within new scientific advances. This mandates a scientifically literate society that is able to participate in, and guide research and innovation in a responsible manner. In science education, the negotiation of SSI can therefore serve as a good learning context for the advancement of RRI as it encourages students to gain knowledge about current scientific dilemmas and their impacts on society, and to take a participatory and active stance toward these issues (Evagorou & Mauriz, 2017; Zeidler et al., 2005).

Advancing the notion of scientific understanding for responsible citizenship is, therefore, a central concern of the science education community. In support of such demands, Dos Santos (2009), for example, proposed a humanistic perspective on science literacy that emphasizes students' social action for the common good. He argued that science education should reflect on issues of social injustice and inequity and consequently, be aimed at the transformation and creation of a better society. Hodson (2003) emphasized the importance of students' activism as integral to the promotion of scientific literacy. Similar to Dos Santos (2009), he argued that we need to consider scientific literacy as a concept that should promote students' “capacity and commitment to take appropriate, responsible and effective action on matters of social, economic, environmental and moral-ethical concern” (Hodson, 2003). Another clear view of scientific literacy for civic change can be found in Aikenhead's (2006) position which highlights social responsibility and students' practical actions.

These conceptualizations of scientific literacy share an objective and a vision of science education that encourage students to take participatory action on issues that involve science and society. However, promotion of participatory and active citizenship has not made significant strides in actual classroom practice (Hodson, 2003). This is in part because in current practice, SSI instruction is mostly constrained to a presentation of the social dilemma, with no attempt to promote students' meaningful participatory engagement or action (Bencze & Sperling, 2012; Zeidler et al., 2005). For instance, Lee et al. (2013) implemented a learning unit on genetic modification technology with the aim of promoting students' feelings of accountability and willingness to act on SSI. Their unit did not include an active participation component; although the students in their study became more sensitive to the societal dimensions of scientific dilemmas simply by discussing SSI, they experienced challenges in demonstrating a willingness and efficacy to participate in an action toward SSI resolution. This type of action paralysis has been reported in similar studies in the context of climate change (Sternäng & Lundholm, 2011) and general environmental issues (Connell, Fien, Lee, Sykes, & Yencken, 1999). These empirical results call for the implementation of actual action into the learning practice of SSI.

Moreover, when students are actually asked to take participatory action, as in the case of public campaigns, the actions themselves are often mandated and little to no consideration is given to why such actions are required and how they should be carried out (Birmingham & Calabrese Barton, 2014). Mandating an action neutralizes the inherent complexity of SSI in that it imposes particular behaviours on students. Therefore, this course of action sidesteps the fundamental recommendation that science education reflect individual students' world views (Zeidler et al., 2005) and points of interests (Barton & Tan, 2010a) when addressing SSI. Such a conceptualization of action in science views students as a homogeneous group rather than valuing their unique personalities and views.

This homogeneity-producing approach to activism takes away students' freedom of opinion and expression, and their ability to contribute to society by acting upon the world in manners of their choosing. Such an approach disregards the essentiality of students' unique views and identities when deciding how and why to take action. In this paper, we join the recent calls in science education to take students' lives, worlds and identities into account when considering courses of action regarding SSI.

Arguing for a more pluralistic and personalized approach to science learning and science-related activism, several science education researchers have argued that increased attention should be given to the role of identity development in students' engagement in and with science (Barton & Tan, 2010a; Kozoll & Osborne, 2004; Roth & Lee, 2004; Sadler, 2009; Zeidler et al., 2005).

In their proposed framework for SSI instruction, Zeidler et al. (2005) suggested that the inherent social implications embedded in SSI can potentially bridge school science and students' individual lived experiences and identities. Therefore, they argued, it is beneficial to encourage the expression of diverse opinions and world views in the science classroom and to allow students to bring forth their own identities into the science-learning experiences. Empirical data to support such recommendations were presented by Kozoll and Osborne (2004), who conducted a study of the meaning of science to the lives of migrant agricultural workers. Their results explained how engagement with science can be more significant to participants when they are given the ability to include aspects of their own lives and identities into science learning, thus allowing them to be more successful in school science.

This notion, that attention to students' own lives and identities is essential to engagement with science, was then further developed to include specific links to activism in science. For example, Carlone and Johnson (2007) analysed the narratives of 15 women of colour to examine the persistence of minorities in science-related careers through the lens of identity-based research. Their results showed that when participants were able to tie their science skills to altruistic values, they could consolidate a strong science identity which ultimately contributed to their persistence in science-related careers. Roth and Lee (2004) investigated an educational program which involved students learning science through participation in an environmental project set in their community. They argued that activism on local science-related issues transforms not only the local community but also the identities of the participants themselves. When students acquire knowledge by contributing to their community, they argued, it can pave the way to lifelong participation and learning of science. Similar results were presented by Barton and Tan (2010a), who argued that students' participation in a science project that includes a component of activism for the benefit of their community shapes students' identities in ways that allow them to position themselves as “community science experts”, further deepening their desire to learn science.

In this study, we join these researchers in the belief that there is a link between the process of students' identity development and their willingness to engage in activism. We first examine how the construct of identity is addressed in the current literature. We then focus on a unique form of identity development linked to a specific practice, in what Nasir and Hand (2008) termed *practice-linked identities*. This unique construct articulates the process in which a person constructs and embraces an identity through participation in an activity.

Although it gets wide recognition, the literature does not present a consistent definition for the term *identity*. Whereas a number of theorists perceive identity as a global stable construct that a person carries across settings and contexts (Brewster, Suutari & Kohonen, 2005), others perceive it as a local construct that shifts in relation to the setting, practice, and context in which it is built (Gee, 2000; Nasir & Hand, 2008; Sadler, 2009). Here, we join the latter and use identity in its locally constructed definition. In this context, Gee (2000) offered a useful description of identity by describing it as the "kind of person one is recognized as being, at a given time and place". This conception of identity highlights its context-dependent nature, and how it shifts in relation to different social settings and is affected by a person's relations with the world and with other people. In other words, as individuals participate in new experiences, Gee argued, their identities may be modified or changed.

Gee (2000) identified the importance of one's relationships with other individuals and social participation as fundamental to the process of identity development. That is because one cannot act as a particular "kind of person" (enacting an identity) in a void; to be recognized as a certain kind of person, they must require a context and the participation of other individuals. Wenger (2000), in his theory of communities of practice, continued along the same lines of understanding to frame the connection between the self and social participation, but elaborated on specific connections between the self and a given practice. He argued that one cannot simply identify oneself and be recognized as a competent practitioner unless one has the ability to display said competence in his or her respective social environment (Wenger, 2000). For example, teachers entering the science classroom should be able to demonstrate a certain knowledge, speak in a certain language and act according to prescribed professional norms for others to identify them as competent teachers. Thus, being in a practice requires knowledge and skills which define the discipline that the person is practicing. Therefore, for a person to identify oneself as a practitioner, he or she must acquire this new set of skills.

Identity is therefore a powerful construct that might hold explanatory power for the examination of students' activism because it could explain how and why individuals value an activity and its goals. Therefore, in this study, we frame activism in science as a practice and argue that, as with any other practice, those who participate in science-related activism construct and consolidate their identities by creating new relationships, displaying competence, and creating shifts in how others recognize them.

It is important to note that members of a community display different and individual forms of participation. In addition, not all practices are equal with regard to their ability to support identity development (Nasir & Hand, 2008). Such differences in participation are emphasized in the recent work of Nasir and Hand (2008) that highlights the notions of individual participation and supportive environments for identity development. In that work, the authors introduced the term *practice-linked identities* to describe the connection between the individual and the practice. They described practice-linked identities as "identities that people come to take on, construct and embrace that are linked to participation in particular social and cultural practices" (Nasir & Hand, 2008). The connection between the individual and the practice can be assessed by three identity resources that, the authors argued, are important for engagement with the practice (Nasir & Hand, 2008):

- *Access to the domain* – defined as "the extent to which participants have the opportunity to learn both about the practice as a whole and about the specific tasks and sub-skills that make up the domain."
- *Integral roles* – defined as "the extent to which participants are held accountable for particular tasks in a practice and are expected to become competent and even expert in a subset of activities that are essential to the practice."
- *Opportunities for self-expression* – defined as "ways that students can incorporate aspects of themselves into the practice." (Nasir & Hand, 2008, p. 148)

Here, we argue that as students participate in practices that offer access to the domain of activism, integral roles, and opportunities for self-expression, they may be able to embrace identities that are linked to participation in science activism.

THE STUDY

To illustrate the study of students' engagement with science-based activism, we qualitatively examined the narratives of two students, Yonatan and Karin (pseudonyms). The basis for our analysis was grounded in Nasir and Hand's (2008) theory of practice-linked identities. We specifically used their three types of identity resources (access to the domain, integral roles, and opportunities for self-expression) to examine the students' activism as participants in a school-based SSI project, by exploring the following research questions:

- What available identity resources encouraged students' engagement with the practice of science-related activism?

- What activity structure can foster the development of identities that support activism?

RESEARCH CONTEXT

The *Spirulina* project is a voluntary program for high-school students in Herzeliya Gymnasium in Tel Aviv. The project originated during a citizenship class given by the school principal, who also leads and fully backs the project. This program explores the potential of the cyanobacteria *Arthrospira*, commonly known by the name *Spirulina*, in addressing the problem of world hunger. While the use of this organism as a protein source is being investigated, the production of *Spirulina* for agriculture remains expensive (Borowitzka, 1999). This feature makes it a less than desirable organism for agriculture. Therefore, the students were challenged to find optimal conditions to accelerate the growth of *Spirulina* in low-tech environments such that anyone who wants to can grow the *Spirulina* on their own.

The students grew the *Spirulina* in repurposed plastic bottles (Fig. 1) and open pool-like containers. Senior students (11th or 12th grades) were responsible for teaching the cultivation method to newcomers (9th or 10th grades). Some students also got to travel to different schools in Israel, as well as to remote places abroad, such as South Africa and Rwanda, to teach their method to others. Thus, the students not only developed the growing method for *Spirulina*, they were also responsible for communicating their findings to others, locally, nationally and globally.

Figure 1. The *Spirulina* cultivation array Herzeliya Gymnasium.

CRAFTING STUDENTS' NARRATIVES

The data that assisted us in crafting the students' narratives included interviews, observations of students in practice and additional newspaper clippings. This use of multiple data sources alowed for triangulation of data and was used as a strategy for the validation of results. Individual interviews were conducted using the three-interview model described by Seidman (2013), which emphasizes the importance of understanding individuals’ actions within a particular context, as well as the meanings that they ascribe to their actions. The first interview focused on the broader context of the students' participation, the second interview focused on the concrete day-to-day details of their experiences, and the third interview focused on the participants' reflections. In the latter interview, we asked the students to generate a map illustrating the important events and experiences that summarize their participation in the project. Interviews lasted for 30 to 40 minutes and were transcribed verbatim. Additional observations allowed us to explore the students' actions in actual practice.

The first phase of our analysis included a process of focused coding. The codes for this phase were grounded in Nasir and Hand's (2008) theory of practice-linked identities and included the broad themes: access to the domain, integral roles, and opportunities for self-expression in practice. The second phase of our analysis included a process of open coding. The codes for this phase were generated using a grounded theory approach. Categorization was carried out independently by two researchers and a dialogue between the researchers was conducted to assure the accuracy of the categorization (Rolfe, 2006).

Below, we present Yonatan and Karin's narratives. As they were provided with access to the domain, integral roles and opportunities for self-expression, students' identities as activists seemed to be supported by their practice-linked identities.

YONATAN'S NARRATIVE

Yonatan (17 years old) was an honours student in the 11th grade who majored in Physics and Computer Science during the 2015–2016 academic year. Yonatan held a high status in the *Spirulina* project and presented himself as the "next generation" of students who will run the project, a title that other students participating in the project also attributed to him. We now tell his story with respect to Nasir and Hand's (2008) definitions of access to the domain, integral roles, and opportunities for expression.

ACCESS TO THE DOMAIN

Yonatan used multiple resources to gain knowledge in the domain of the *Spirulina* project. The most dominant of these resources was the field trip to Rwanda, where he and other leading students (accompanied by the school principal and one other adult) worked with government officials, schools, and community health centres to promote *Spirulina* cultivation in Rwanda. In his map of critical events, Yonatan summarized his experiences in the form of a plot with dependent and independent variables (Fig. 2), the former being the meaning of the project to him, and the latter, time, as marked by significant events. Most evident in his graph is the steep incline in meaning which marks the trip to Rwanda.

When he explained why the trip was so important to him, Yonatan described the overwhelming adverse human conditions that he witnessed in the Sub-Saharan country. For him, this field trip was not only valuable for the experience in itself, but also as a way of gaining knowledge about the issue at hand. Ultimately, this experience assisted Yonatan in grasping the legitimacy of the project's aims:

> We were very close to the people living there [in Rwanda], and that means seeing people in the streets, seeing how they live, seeing the slums. All of it made me realize that this could happen to anyone…all of a sudden, I started to realize that these gaps should not exist, and if I can do something to change it, then why shouldn't I? It was

most intense when I met young kids. It evoked something in me, that once, I too was a young child, and it could have been me [in their place]. (Yonatan, first interview, 7 Jan 2016)

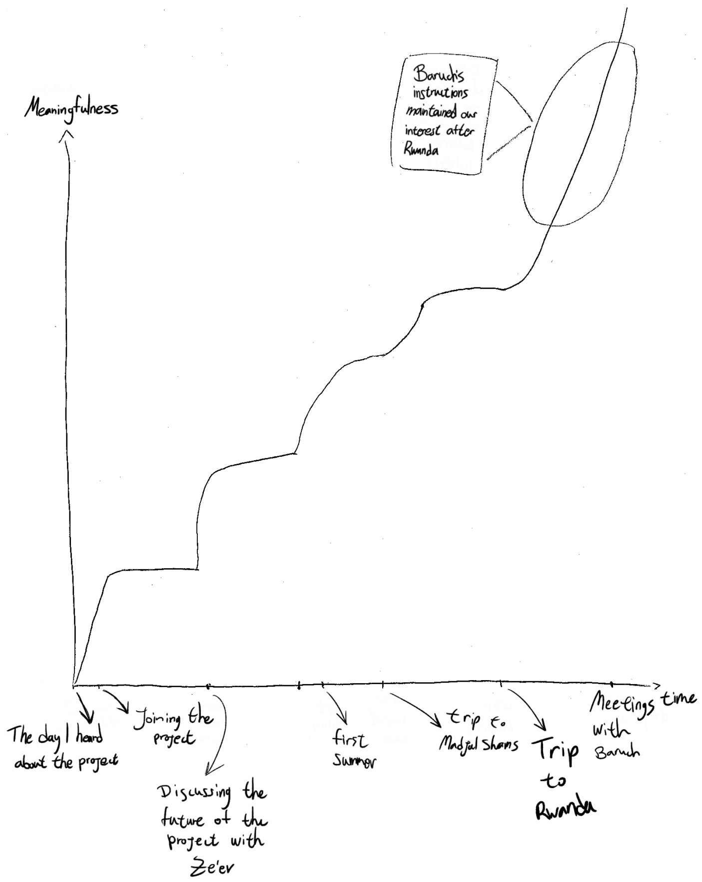

Figure 2. Yonatan's map of critical events.[1]

Witnessing the conditions in Rwanda first-hand was informative for Yonatan as he was able to experience some of the harsh conditions there, such as water shortages and poor living conditions. In his descriptions, Yonatan tended to focus on the human element of the issue and placed the welfare and comfort of the suffering parties at the forefront, while also applying empathic emotions and imagining himself in the same situation. It appears then, that the trip to Rwanda was informative to Yonatan in a socio-affective manner. That is, it allowed him to identify empathetically and care for those who are suffering from malnutrition. Yonatan made direct connections between the knowledge that he gained through these experiences and his ability to feel empathic toward others, and this led to his willingness to be active for the benefit of

[1] All students' maps were translated from Hebrew to English by the authors.

the global community. Thus, Yonatan's ability to identify with the values and goals of the activity, and therefore to be willing to act, was permitted by the opportunity to gain extensive knowledge about the social situation in Rwanda.

For Yonatan, exposure to this new knowledge also revealed a considerable gap between what he expected to achieve from his participation in the project, and what he could actually achieve. His way of minimizing this gap was to develop a new trajectory for his own professional aspirations—to become a physician:

> In Rwanda, I saw a lot of people who required immediate help, and the process of teaching others about the *Spirulina* is very long, during which time people are still dying. However, if you are a physician and you have medical knowledge, then you can give people immediate help and this is something that I would really like to do. (Yonatan, first interview, 7 Jan, 2016)

Yonatan concluded that he could engage in immediate action as a physician, and, as a consequence, aspired to become one. Yonatan's participation in the project thus provided him with enough support to close the gap between who is now and who he aspires to be.

INTEGRAL ROLES

The activity structure of the *Spirulina* project required many competencies from the students: researching and developing the growing method, cultivating the already growing *Spirulina*, instructing others about the method, meeting with municipal and government officials as well as with NGO officials, and fundraising. All participating students filled all of these positions but, naturally, some students felt more comfortable in some positions than others.

When Yonatan joined the project, his involvement was relatively moderate and he stated that he did not really believe that the project could ever succeed. However, he soon discovered a personal interest that was attributed to his role as an instructor in the project. This role was significant and carried with it an audience outside the school. Thus, it also made Yonatan a public representative of the program and a central member of the *Spirulina* project. Moreover, when he started to teach others, he said, he began to realize that the project could actually succeed and that his personal values and moral aspirations could be realized.

Yonatan received a unique opportunity to expand his role as instructor when he was asked to join the school delegation to Rwanda. The purpose of this delegation was to instruct Rwandan students about the *Spirulina* growing method with the intention of establishing the same operation in these schools. In the course of one week, the students taught Rwandan students from three different schools, as well as some Rwandan farmers. Practicing this role made Yonatan understand that solving a humanitarian issue can be challenging. He was particularly frustrated by the end result of the instructions. Yonatan described lacklustre behaviour on the part of those he was trying to help, who, as he perceived it, either rejected the students' attempt to help, or passively wished to remain dependent for their survival on the students' assistance. When asked about his take-home lessons from the trip to Rwanda, Yonatan expressed his reservations:

> We are here at our school and we have this facility [where we grow *Spirulina*], but out there, we can't transfer it to others. I had some doubt with regard to the project, but it passed because I figured that you just have to keep trying. (Yonatan, second interview, 5 Apr 2016)

Being an instructor carried higher risks than other roles, because the success or failure of the project's goal to resolve global hunger depended mostly on the dissemination efforts of the students. Yonatan even defined his experiences as an instructor as "being on a mission". The risks associated with his performance as instructor provided authenticity for Yonatan and it mattered in a significant way. This authenticity led to Yonatan's decision to "keep trying" and keep acting. Some of Yonatan's own ideas to improve his instruction were to "add some humour or bring some graceful examples" into the instructions, or to "mingle with the children" before the instructions. The role of an instructor thus carried a deep sense of accountability, which encouraged Yonatan to overcome the challenges he faced and to improve his instruction skills.

OPPORTUNITIES FOR SELF-EXPRESSION

The reason that Yonatan initially joined the project was that it aligned well with his own personal ideology. He said, "I saw a lot of responsibility in it, one that I already felt, a responsibility toward the world." Being allowed to bring his own personal moral values into the daily practice of the project made it easier for him to participate in the actions of the project:

> I think that, if it's someone else's concern, it's my concern as well. And if there's someone who can't live because he doesn't have food, then I can't enjoy my food. And if someone who has to work all day has to give up his studies, I feel that my studies are not worth much. (Yonatan, first interview, 7 Jan 2016)

Yonatan emphasized how his participation in the project was an expression of who he is. His moral concerns served as a driving force to act responsibly to resolve global issues. The contrast between his life and the lives of the Rwandan citizens was an existential challenge for him, but he was able to chip away at this challenge by participating in the project. Therefore, simply by acting in a context that relates to his values, he was given a voice for his own ideology.

KARIN'S NARRATIVE

Karin (18 years old) was a highly successful 12th-grade student who majored in Arabic Studies and History during the 2015–2016 academic year. She joined the *Spirulina* project at the end of the 9th grade, one of the first to join. Like Yonatan, Karin entered the project with some concerns regarding its applicability, but over time, she became its most vocal advocator. She was interviewed by several national newspapers and online news websites to promote the project and to bring it to other people's attention. Similar to Yonatan, Karin's is a case of identity development through a process of interaction with the resources afforded by the *Spirulina* project. However, unlike Yonatan, Karin was not a science major, and as such, her story was about seeking new ways to learn and engage with science. Therefore, participating in the project allowed her to see science as more connected to the person she is.

ACCESS TO THE DOMAIN

Similar to Yonatan, Karin viewed the trip to Rwanda as a critical experience. Karin also had the opportunity to travel to Cape Town, South Africa, with the aim of teaching South African students and citizens about the *Spirulina* cultivation method. However, in her interview she mostly focused on the field trip to Rwanda. In her map of critical events and experiences, she regarded both field trips as significant and important to her and to the project but added that the trip to Rwanda was also a "traumatic experience which left a huge mark on me" (Fig. 3).

Though Karin was familiar with the situation in Rwanda before the trip, witnessing it directly was a completely different experience:

> It was like the poverty you only see in photos. [We saw] kids with no shoes, bloated bellies, without teeth, little kids that should have been bigger [for their age]. It was really difficult. (Karin, first interview, 12 Jan 2016)

Much like Yonatan, when Karin described her experiences in Rwanda, she tended to place humanitarian considerations at the forefront, with empathy and concern for others as the central features. Upon returning from Rwanda, Karin expressed her desire to quit the project. The trip was too much for her to go through without proper preparation. Eventually, she decided to stay because she recognized that the issue was too urgent to ignore:

> [The trip] made us realize that this is really urgent and existing, and it is not something that you can postpone [acting on] because people are dying from it, now!...For me it was really difficult, but for the project, it really gave us a boost in terms of understanding how we need to act. (Karin, second interview, 7 Apr 2016)

Karin's argument for action relied mostly on humanitarian concerns which mediated her course of action on the issue of malnutrition in underdeveloped countries. This humanitarian lens shaped how she talked about the project, and it was made available to her as a result of her participation in the trip to Rwanda. Like Yonatan, her access to knowledge about the issue was increased by having the opportunity to directly witness the human condition in Rwanda, which in turn, promoted her willingness to act on the issue.

INTEGRAL ROLES

Karin considered her role as instructor to be important and integral and over time, it became the role she most identified with. In her map of critical events, Karin used the words *teach* or *train* when describing most of the events (Fig. 3). Most of her effort for the project was invested in advancing her lecturing skills. She continuously stated that her commitment to teaching others provided a stimulus for her to deepen her own knowledge on the subject, which was often embedded in scientific domains. She described the importance of learning the material so that she could give better instructions:

> We want to teach others, and there is no way to teach others without knowing it thoroughly…if you understand it then it means that you can explain it. (Karin, first interview, 12 Jan 2016)

Karin described the personal learning potential when acting as an instructor, but she also wanted to expand her general, as well as scientific knowledge of the subject because she felt accountable in terms of filling the role of instructor to the best of her ability. The reason that she felt so responsible was that the instructions were deemed to be an essential part of achieving the goal of the *Spirulina* project, which is to reduce global hunger. This agenda was described in a school-issued flyer entitled: *"Students teaching students about the alga Spirulina"*:

> The idea is to transfer the knowledge (like in a relay race) so that others can teach more people, instead of just taking care of themselves.

The notion that instructing others is a legitimate form of action was thus reflected in the official agenda of the project. The students believed that through these instructions, they could give the local population the necessary tools to relieve their nutrition-related problems. This therefore made information dissemination an integral part of the project, which increased Karin's feelings of accountability to expand her knowledge and to perform better as an instructor.

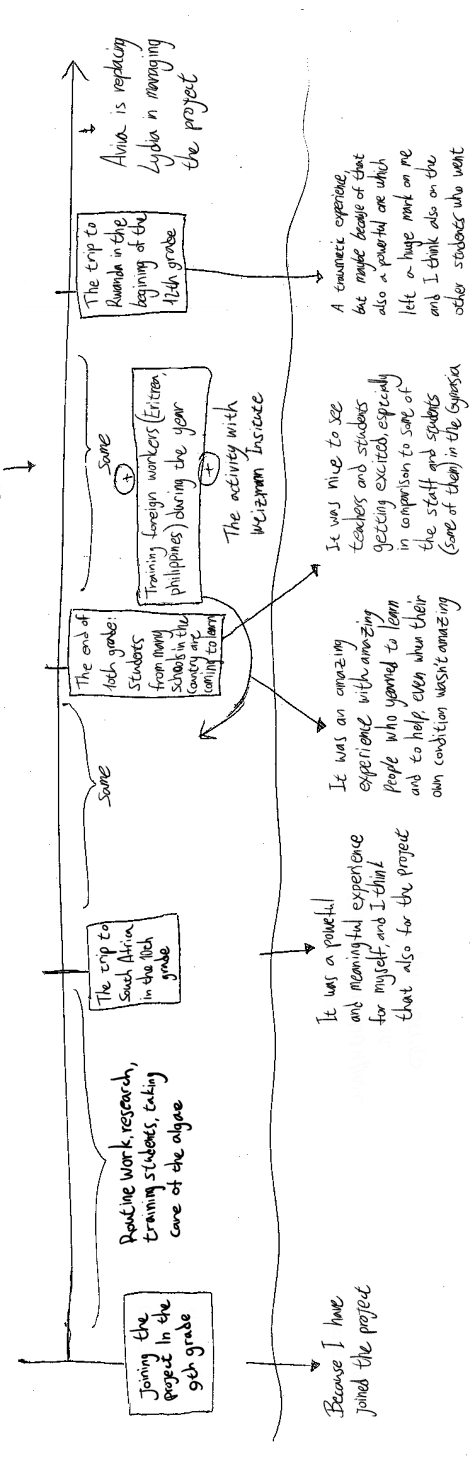

Figure 3. Karin's map of critical events.

As with Yonatan, Karin found an outlet for her own personal values in the project. What was appealing to Karin was that the project's declared goals aligned with her own perceptions of morality and values. She could therefore easily identify with the issue and the cause, which she perceived as acute and urgent, accordingly. For example, she said:

> Children are dying. I don't think that there's a more noble and important cause. (Karin, second interview, 7 Apr 2016)

This alignment between the project and her own beliefs made it easier for her to relate and feel a sense of belonging which, as a consequence, made her a more productive member in the project. By being a member in such a project, Karin also had a sense of belonging to a caring community in which her values and courses of action were perceived as normative. She spoke about this during one of her interviews (Weitz, 2015):

> Being part of the project made me want to become a better person, and I think that this is what brings us together. The people I meet through the project are people who are trying to make the world a better, fairer, more equal place. Being surrounded by this company fills me with optimism. (Karin, interview to Maariv website, 19 Feb 2015)

Being a member in the project provided Karin with the ability to connect with other students who share the same world view, thereby producing support within this community for her participation. It was in this group structure that she felt that her values and opinions mattered, which in turn, made it easier for her to voice them. She was therefore allowed to be a member in a space that respects who she is, which made engagement in an action more feasible.

Karin also found opportunities for self-expression specifically through her role as an instructor. She used a flexible form of science information, that of drawing scientific diagrams, as a way to communicate her understanding of the subject. This use of skills was most handy when teaching audiences who struggled with language barriers. In the summer between Karin's 11th and 12th grade, and before her trip to Rwanda, a delegation of Rwandan farmers came to her school to learn from the students how to cultivate the *Spirulina*. Karin presented an introduction in which she explained scientific concepts such as photosynthesis and the water cycle. During the instruction, she carefully drew a diagram showing the sun's rays affecting the *Spirulina* culture and indicated the positive effect by drawing the sun with a smiley face (Fig. 4). She then explained how in very warm weather, water from the medium will evaporate, requiring the farmers to add water to the medium. She emphasized the evaporation effect in her diagram by drawing wavy lines coming out of the *Spirulina* bottle.

Figure 4. Karin (centre) adding hand-drawn diagrams to her instructions.

Karin's drawings allowed her to engage with science by utilizing her drawing skills. For her, drawing graphical representations of different scientific concepts served as a way to express herself using a graphical medium. Karin's drawings were recognized as a means of enhancing instruction outcomes and she repeated this technique when she felt it was needed. This form of self-expression was thus welcomed by both her peers and the audiences of her instructions.

DISCUSSION AND CONCLUSIONS

For science to be conducted *with* society and *for* society future citizens must be able to better understand scientific concepts and the impact of scientific and technological innovations on their lives (Levinson & The-PARRISE-Consortium, 2014; Owen et al., 2012). The role of science education in promoting this goal is therefore to educate students on the interactions between science and society so that they will be able to participate more actively in discussions about scientific and technological innovations. Here, we further argued that students should also be able to take a more active stance that include an action towards the resolution of these social complications in a way that benefits the general wellbeing of others. Therefore, throughout this investigation, we attempted to contribute to the existing research on activism in science education.

The primary purpose of this study was to explore the ways in which students practiced and constructed their identities through participation in a school-based socioscientific project that included activism. We explored the narratives of two students who participated in a school effort to reduce global hunger by finding optimal conditions for the cultivation of *Spirulina*. Our analyses showed that for Yonatan and Karin, similar resources supported their practice-linked identity development in the *Spirulina* project. Both were able to experience the humanitarian issues in Rwanda first-hand. This was probably the strongest resource provided to the students as it was connected to most parts of both students' narratives. Our findings suggest that having this wide access to knowledge of an issue initiated and motivated both students to take action. By taking on roles that were important to the success of the project, the students found meaning in their participation, which led to increased feelings of accountability and a desire for competency. Students also felt valued for who they are and for their ideas. This feeling was further expanded as the project's declared goals reflected their own feelings and values with respect to global hunger.

The cases of Yonatan and Karin are interesting to study together because though they share common themes, their experiences in the *Spirulina* project were also unique. Yonatan found humanitarian value and personal purpose in his participation in the project that set into motion his desire to find a career in a science-related field in which he could practice his activism. Karin, on the other hand, was not a science major, but she found a new appreciation for science and new ways to engage with science through contextual experiences that were valuable to her.

While encouragement of students to take social and political action continues to be a difficult task, our findings attempt to show how a specific activity structure and experiences may help students identify themselves as science activists. Utilizing a practice-linked identity lens to examine students' participation in activism allowed us to observe outcomes that could otherwise have gone undetected or been ignored. Our findings showed that both Yonatan's and Karin's identities as competent and active players were directly linked to the experiences and roles afforded by the unique structure of the *Spirulina* project. Looking across their narratives, what emerged was the structure of the project, and how it supported the development of the students' identities as activists.

STRUCTURING AN ACTIVITY FOR IDENTITY DEVELOPMENT

Exposure to socially and emotionally loaded experiences that were presented in a contextually rich environment allowed the students to view global hunger as embedded in real-world events. Consequently, these experiences may have assisted them in cultivating feelings of care and empathy toward others. Contextualization of situations in SSI learning has been shown to generate emotions and a sense of responsibility in students (Molinatti, Girault, & Hammond, 2010). Here, when Karin and Yonatan negotiated courses of action, both tended to focus on the suffering of the individuals they encountered, and the feelings that emerged during these encounters were the main reason for their unique persistence in acting as members in the activity. Giving them the opportunity to experience and discuss real-world issues and problems allowed them to see the amount and severity of these issues in ways that provoked their feelings of social responsibility, therefore supporting their science-related activism. Building an activity in a contextual environment around an issue that promotes emotional involvement may therefore lead to students adopting a more active and responsible role (Fig. 5).

Though it calls for further research, this is consistent with past investigations that explored links between learning science in the context of SSI and the development of a moral character. For example, Zeidler and Schafer (1984) showed that when students were asked to make decisions on scientific dilemmas that involved people from the students' lived experiences, their decision-making regarding the issue was often directed by feelings of care and compassion. They argued that when students identified an emotionally charged issue, they tended to show increased moral sensibility. Berkowitz and Simmons (2003) further argued that providing students with the necessary skills to engage in social activism requires science educators to provoke moral emotions such as care and empathy in the science classroom. It is important to add that learning in contextualized environments reinforced by emotions may radicalize students' decision-making processes (Molinatti et al., 2010). Further exploration of the relationship between contextual social participation, the development of pro-social feelings and activism is therefore warranted.

Figure 5. Contextual experiences as catalysts to students taking action.

In addition, these contextual experiences can create opportunities for students to fill roles that are embedded in real-life situations. As instructors, Yonatan and Karin were integral players in the practice of the *Spirulina* project. Essentially, this role brought real authentic tension into their daily practice as it carried with it a sense of responsibility for the success of the project as a whole. Both students signed on to the idea of being activists though this role, which seemed to promote their competence as instructors and as activists. Their experiences illustrate how through this role, they were provided with a strong sense of what being a science activist is. Yonatan reported frustration about the end results of his actions, thus acknowledging that a different path of action is required. In Karin's' case, instructing others bolstered her scientific literacy and even though she was still not completely interested in science by the end of her participation in the *Spirulina* project, her engagement with science was influenced by the authenticity of her role in the activity. For both students, acting as instructors allowed them to express their opinions through actions in line with their own personal values. Therefore, beyond being integral for the success of the project, the role of instructor in and of itself included gateways for domain-specific knowledge and opportunities for self-expression.

As students took on roles that allowed for these opportunities, their willingness to act seemed to be supported. We could therefore argue that for a role to be considered engaging and appealing, it may need to incorporate the three elements of practice-linked identities: granting access to the domain, being integral, and permitting opportunities for self-expression. Other studies have presented similar arguments. For example, Barton and Tan (2010b) examined how students create their own pathways to learn science by authoring and expanding the roles that they play in the classroom to better fit their definitions of self. They argue that in filling these roles, knowledge about science becomes more accessible to the students and empowers them to take action. Somewhat similarly to the students in Barton and Tan's (2010b) study, Yonatan and Karin came to believe that through filling meaningful roles they could bring about a change in the world. Carefully structuring learning environments to allow the emergence of these types of roles may therefore have the potential to allow students to participate more actively, regardless of their initial interest and willingness to act.

In summary, like past studies on science-related activism (Barton & Tan, 2010b; Roth & Lee, 2004), this study found that participating in contextual activities seems to help students better engage in responsible actions for science-related issues. Here, the students' activism was supported by the filling of integral and meaningful roles that mattered to the students, as well as to the success of the project as a whole. Both Yonatan and Karin expressed their sense of self as being associated with their activism and with their desire to impact the future of the global community. These are good indicators of their activism competency and developed identities as activists.

LIMITATIONS

This study examined two cases of honours students who participated in science-related activism. The fact that only a small number of students from a narrow demographic range were examined constitutes a considerable limitation of this study. In addition, because of the small group of participants and the qualitative nature of the data, general claims could not be made about other students. Students were also afforded unusual and expensive resources to enrich their engagement with activism, circumstances that are generally less available to the student population at large. Therefore, this study does not attempt to provide solutions for students experiencing action paralysis; rather, it shows the value and feasibility for students of activism in science education.

IMPLICATIONS

Yonatan and Karin's narratives on the *Spirulina* project and their roles as science activists present a compelling and nuanced description of how offering students opportunities to develop their identities as science activists can support students willingness to act responsibly through, and informed by, science. However, these findings should be viewed in consideration of the limitations of the study. As mentioned, the activity described in this study is expensive and complex to manage at the school level. In this context, previous studies showed how contextual learning exercises in the form of simulations of real-life situations and role-playing activities can lead to students' increased social responsibility and knowledge about social issues (Krain & Shadle, 2006; Navarro, 2009), therefore providing a simpler way for the incorporation of contextual learning into day-to-day teaching and learning practices. Further studies are required to determine if the findings from our study, namely increasing students' engagement with activism by ensuring access to knowledge, integral roles and creating opportunities for individuals to express themselves in practice, are generalizable to other, more accessible, activities.

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O Desenvolvimento de Atividades Investigativas com Recurso à Web 2.0 no Âmbito da Investigação e Inovação Responsáveis

Carla Pacifico Dias
cmpcdd@gmail.com | Externato Cooperativo da Benedita, Portugal

Pedro Reis
preis@ie.ulisboa.pt | Instituto de Educação da Universidade de Lisboa, Portugal

RESUMO

Uma educação científica que se restrinja à transmissão do conhecimento científico torna-se insuficiente para capacitar os alunos como cidadãos ativos capazes de planear e realizar ações democráticas visando a resolução responsável de problemas sociais.

O objetivo deste estudo, seguindo uma Metodologia Design Based Research, desenvolvido no contexto do Projeto IRRESISTIBLE financiado pela UE, foi desenvolver conhecimento sobre o impacto das atividades IBSE - integrando ferramentas da Web 2.0 - no desenvolvimento de conhecimentos e competências necessárias para uma cidadania ativa em investigação e inovação responsáveis sobre questões sociocientíficas (QSC). O estudo permitiu obter diferentes estratégias didáticas para a educação científica no ensino básico e novos conhecimentos sobre o desenvolvimento dessas estratégias no contexto escolar.

PALAVRAS-CHAVE

Educação em Ciências, Inquiry-based science education,
Investigação e Inovação Responsáveis (IIR), Web 2.0.

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The Development of Research Activities Using WEB 2.0 in the Context of Responsible Research and Innovation

Carla Pacifico Dias
cmpcdd@gmail.com | Externato Cooperativo da Benedita, Portugal

Pedro Reis
preis@ie.ulisboa.pt | Instituto de Educação da Universidade de Lisboa, Portugal

Abstract

A science education restricted to the transmission of scientific knowledge becomes insufficient to empower students as active citizens capable of planning and undertaking democratic actions aiming the responsible resolution of social problems.

The purpose of this study, following a Design-Based Research Methodology and developed in the context of the EU-funded IRRESISTIBLE Project, was to build knowledge about the impact of IBSE activities – integrating Web 2.0 tools – in the development of knowledge and skills necessary for an active citizenship regarding responsible research and innovation on socio-scientific issues. The study allowed to obtain different didactic strategies for science education in secondary school and new knowledge regarding the development of these strategies in school context.

Key words

Science education, Inquiry-based science education, Responsible Research and Innovation (RRI), Web 2.0.

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O Desenvolvimento de Atividades Investigativas com Recurso à Web 2.0 no Âmbito da Investigação e Inovação Responsáveis[1]

Carla Pacifico Dias | Pedro Reis

> A investigação científica, seja qual for, tem sempre em si uma finalidade social. Não se pode conceber a investigação científica como algo que diga respeito apenas a um indivíduo ou a um grupo restrito: toda a descoberta, toda a conquista, todo o avanço nesse campo deve ser comunicado a toda a humanidade, porque interessa a toda a humanidade.
>
> Ciari, 1979, p. 46

INTRODUÇÃO

Na última década tem-se assistido a um maior apelo para uma educação científica e tecnológica mais politizada, através da qual os alunos devem não só reconhecer questões ambientais e sociocientíficas complexas, muitas vezes polémicas, e formularem a sua própria posição, a respeito dessas mesmas questões, mas também prepararem e participarem em ações sociopolíticas. Devem formular opiniões críticas sobre como as prioridades da investigação são determinadas, como é feito o acesso à ciência, como a ciência pode e deve ser conduzida e como a ação realizada a nível individual, grupo e/ou a nível da comunidade, pode influenciar políticas e práticas sociais (Hodson, 2014; Reis, 2014).

É essencial formar alunos críticos, informados cientificamente, interessados pelos assuntos sociocientíficos e sócio-ambientais, de modo a conseguirem analisar o que os rodeia de forma crítica e fundamentada. A vivência de situações de aprendizagem que envolvam tomada de decisões, discussão, desempenho de papéis diferentes, argumentação, investigação, experimentação, explicação e interpretação, exigem do aluno um pensamento mais crítico, um olhar mais profundo para os acontecimentos e, consequentemente, um desenvolvimento de conceções mais complexas sobre questões sociais e ambientais em que a ciência aparece, na maior parte das vezes, como central. Para tal, é necessário envolver os professores num novo modo de entender a ciência, levando-os a adotar estratégias de ensino-aprendizagem inovadoras (Galvão et al., 2011).

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A implementação de ações sociopolíticas sobre questões sociocientíficas e sócio-ambientais em contexto escolar tem várias implicações e requer uma transformação na prática de sala de aula nomeadamente nos tipos de atividades educativas propostas, nas formas de avaliação implementadas, nas fontes do conhecimento e de autoridade consideradas legítimas, no próprio ambiente de sala de aula e nas conceções sobre as finalidades da educação em ciências, orientações curriculares e na cidadania. O professor deixa de estar preocupado exclusivamente com a transmissão exaustiva de um conjunto de conhecimentos, assume-se como orientador, estimulador do desenvolvimento dos alunos, através da: (a) exploração de aspetos da natureza da ciência e as inter-relações entre ciência, tecnologia, sociedade e ambiente; (b) promoção de competências cognitivas, sociais e morais necessárias à autonomia intelectual e ao envolvimento ativo de soluções para esses mesmos problemas, num ambiente democrático. Os alunos devem ser capacitados para discutir e agir num contexto de sala de aula baseado no interesse e no respeito que valoriza a expressão de opiniões diferentes e estimula a ação dos alunos (Reis, 2004, 2013). As práticas, na sala de aula, promotoras de ativismo, por exemplo, estão fortemente associadas a uma conceção de cidadania que reconhece os alunos como atores sociais de pleno direito, e não simples objetos de socialização (Reis, 2013).

Compete, então, ao professor conceber situações de aprendizagem que envolvam os alunos em atividades investigativas que capacitem os alunos como construtores críticos de conhecimento (e não simples consumidores). É necessário que alunos e professores se tornem conscientes da necessidade de cooperação entre investigação científica e sociedade em prol de uma investigação e inovação que sejam, de facto, responsáveis (Projeto IRRESISTIBLE, 2014).

ENQUADRAMENTO TEÓRICO

ENSINO DAS CIÊNCIAS NUMA PERSPETIVA IBSE

Através de um ensino baseado em atividades investigativas são proporcionados aos alunos ambientes que fomentam a reflexão e o pensamento lógico e crítico sobre factos ou evidências, conduzindo à apropriação dos conceitos e fenómenos científicos e a um melhor entendimento do mundo (Bybee, 2000). Este tipo de atividades, de acordo com os princípios epistemológicos do construtivismo, estimula a autonomia e a criatividade do aluno, deixando este de ter um papel passivo no processo de ensino e aprendizagem e assumindo o de principal agente responsável pela sua aprendizagem (Rocard, 2007).

Nikolova e Stefanova (2012) enumeraram as seguintes caraterísticas da metodologia IBSE: (a) o processo de aprendizagem é impulsionado pelo interesse dos alunos; (b) o aluno é confrontado com um desafio, que o motiva a participar ativamente no processo de aprendizagem; (c) o aluno trabalha em equipa num projeto; (d) o professor orienta os alunos, interligando as metas pedagógicas, relativas aos conteúdos de aprendizagem, com a construção de competências pelo aluno, que poderão ser reforçadas pelo uso das TIC.

As atividades investigativas, numa perspetiva IBSE, surgem associadas ao modelo de aprendizagem dos 5E, constituído por cinco fases (Bybee et al., 2006): (i) Engage (envolver); (ii) Explore (explorar); (iii) Explain (explicar); (iv) Extend (ampliar); (v) Evaluate (avaliar).

Outros modelos adaptados a partir do modelo dos 5E de Roger Bybee surgiram, aos quais se acrescentaram E, como por exemplo o modelo dos 6E e dos 7E. A metodologia de ensino IBSE dos 7E, por exemplo, proposta pelo curso de formação em Portugal, no âmbito do Projeto IRRESISTIBLE (2014) resulta da ampliação do modelo dos 5E ao qual se acrescentou o (vi) Exchange e o (vii) Empowerment, em que se pretende que os alunos partilhem com a comunidade os resultados das suas investigações, o que pressupõe o planeamento e conceção de uma exposição científica interativa dos produtos da investigação desenvolvida de forma a consciencializar e sensibilizar a comunidade.

Bordenave e Pereira (2005) advogam que esta metodologia contribui para o aumento da capacidade do aluno participar como agente de transformação social, durante o processo de deteção de problemas reais e de procura de soluções originais, aspetos indispensáveis para o exercício de uma cidadania crítica e participativa.

Nos últimos anos, temos assistido a um crescente apelo para que as atividades investigativas desempenhem um papel importante no ensino das ciências de forma a responder às preocupações da Comunidade Europeia, tal como definido no relatório *Science Education Now: A Renewed Pedagogy for the Future Europe* (Rocard, 2007). Há diversos projetos de educação a decorrer no âmbito do sétimo programa da União Europeia (FP7) e pretende-se que este apoio continue através do próximo oitavo programa (FP8), assim como, com o projeto *Science and Society*. O programa *Lifelong Learning Program* também financia e continuará a apoiar as atividades de educação pela ciência.

Todos estes projetos têm como objetivo tornar as aulas de ciências e a ciência, propriamente dita, mais relevante para os alunos, no sentido de compreenderem a importância da ciência na vida quotidiana. Permitem um aumento da literacia científica, uma maior motivação e envolvimento dos alunos para a aprendizagem e uma participação mais ativa na sociedade. Por outro lado, estes projetos têm um impacto muito positivo no desenvolvimento profissional dos professores, favorecido por contextos colaborativos onde o professor tem oportunidade de interagir com outros, refletir sobre a sua prática, confrontar as suas experiências e recolher informações relevantes ao seu desenvolvimento profissional (Freire et al., 2011; Galvão et al., 2011; Reis, 2014).

Alguns destes projetos têm como propósito a ampliação dos ambientes de aprendizagem tradicionais do ensino das ciências em direção a contextos informais, e usar esses ambientes como locais de educação científica, além da reflexão sobre as práticas de ensino-aprendizagem centradas na metodologia IBSE em contextos formais e informais.

A educação científica baseada na investigação, IBSE, está a tornar-se cada vez mais comum ao nível europeu e tem provado tratar-se de um método pedagógico adequado para o desenvolvimento de conhecimentos e competências necessárias à sociedade atual. Verifica-se que, aumenta, de forma significativa, o interesse dos alunos para estudar ciências e para participar ativamente na sociedade, estimulando também a motivação dos professores.

É importante que em contexto de sala de aula se use e se aprenda a utilizar as novas tecnologias, cada vez mais, os alunos estão motivados para as tecnologias informáticas.

As ferramentas da Web 2.0 proporcionam vantagens essenciais à educação em ciências uma vez que, promovem a comunicação, o trabalho colaborativo, partilha e troca de experiências, facilidade no trabalho de investigação científica, acesso rápido a informação, contribui para o aumento da literacia científica e espírito de equipa, desenvolve o espírito crítico e a criatividade (Solomon & Schrum, 2007).

Mas é o seu papel no apoio à aprendizagem através de atividades investigativas, IBSE, que tem de ser desenvolvido. São várias as ferramentas da Web 2.0 que podem ser usadas em cada uma das fases do IBSE, de forma a apoiar as aprendizagens significativas dos alunos, tais como, para a construção de:

a) mapas de conceitos: Popplet, Spicy-nodes, CMapTools;
b) nuvens de palavras: Wordle;
c) mural digital: Padlet;
d) simulações: Phet, Virtual Labs, The Science of Addiction;
e) linhas de tempo: Dipity;
f) construção de avatares com voz: Voky;
g) ebooks: Issuu, Papyrus, ibook author;
h) posters e cartazes interativos: Glogster;
i) bandas desenhadas: Pixton;
j) podcasts: Audacity;
k) Blogue: Wordpress, Webnode, Wikispaces;
l) WebQuest; Google Earth, entre outras.
(Projeto IRRESISTIBLE, 2014)

As aplicações da Web 2.0, baseadas em ferramentas interativas e fáceis de utilizar pedagogicamente, tanto pelos alunos como pelos professores, podem simplificar e estimular o processo de interação e as aprendizagens. Quando utilizadas de forma relevante, em contexto de sala de aula, professores e alunos, podem tirar partido destas ferramentas.

Assim, a integração de ferramentas da Web 2.0 pelo professor, nas suas aulas, é essencial para o desenvolvimento integral da formação que se exige atualmente aos alunos, preparando-os para o mercado de trabalho, em constante mudança e transformação. Deste modo, os alunos devem mostrar competências que não se limitem a áreas nas quais se especializaram, mas desenvolver um espírito aberto, flexível e capaz de se adaptar.

Segundo Solomon e Schrum (2007) e Carvalho (2008), as ferramentas da Web 2.0 também proporcionam vantagens essenciais à aprendizagem das ciências, uma vez que oferecem facilidade de comunicação e vantagem no trabalho colaborativo: partilha e troca de experiências, facilidade no trabalho de investigação científica, acesso rápido a informação, contribui para o aumento da literacia científica e espírito de equipa, desenvolve o espírito crítico e a criatividade. Podem ter um efeito profundo na aprendizagem causando uma transformação na forma de pensar (Solomon & Schrum, 2007).

Investigação e Inovação Responsável, palavras muito presentes nas narrativas das políticas Europeias. A estratégia de crescimento para a U.E. "Horizonte 2020" articula uma visão para uma economia sustentável e inclusiva, proporcionando níveis elevados de emprego, produtividade e coesão social. A investigação e inovação são fundamentais para conseguir objetivos ambiciosos em temas como o emprego, inovação, educação, inclusão social e clima/energia (Sutcliffe, 2011).

Desde 2010, o principal objetivo do plano de ação *Science in Society* é desenvolver uma estratégia que responda às inspirações e ambições dos cidadãos: um quadro de investigação e inovação responsáveis (IIR) (European Union, 2012).

É objetivo da IIR criar uma sociedade em que a responsabilidade pelo futuro seja partilhada por todos e em que as práticas de investigação e inovação apontem para resultados ambientalmente sustentáveis, eticamente aceitáveis e socialmente desejáveis. IIR implica que os atores sociais trabalhem em conjunto durante todo o processo de investigação e inovação, a fim de melhor se alinhar o processo e os seus resultados, com os valores, necessidades e expectativas da sociedade. São seis os pontos-chave que permitem desenvolver harmoniosamente modelos para a investigação e inovação responsáveis (Comissão Europeia, 2012): (1) **Envolvimento** (investigadores, indústria, decisores políticos e sociedade civil) na participação e articulação do processo de investigação e inovação; (2) **Igualdade de Género** envolver todos os atores sociais independentemente de serem homens ou mulheres; (3) **Educação em Ciência** não apenas no sentido de aumentar o número de investigadores, mas na melhoria do processo atual de educação de forma a melhor "equipar" os futuros investigadores e outros atores sociais da sociedade com o conhecimento e ferramentas necessárias para participarem de forma plena e responsável no processo de investigação e inovação; (4) **Acesso Livre** às publicações científicas e dados da investigação de financiamento público, de forma a estimular a inovação e aumentar ainda mais a utilização dos resultados científicos por todos os atores sociais; (5) **Ética** não deve ser entendida como uma restrição à investigação e inovação, mas sim como uma forma de garantir uma maior relevância para a sociedade e aceitabilidade dos resultados da investigação e inovação; (6) **Governação** os políticos têm a responsabilidade para impedir desenvolvimentos nocivos ou antiéticos em investigação e inovação.

Segundo o seminário IIR que decorreu em Lisboa compreender e responsabilizar-se por desenvolvimentos que afetam profundamente a vida de todos não diz respeito só à ciência e aos cientistas. O rumo e os objetivos da investigação e inovação, a divulgação dos seus resultados, negativos e positivos, os usos de novas tecnologias e o foco na resolução de problemas prementes são questões que a sociedade tem que discutir e decidir em conjunto.

A IIR defende que o conhecimento seja aberto e acessível a todos, engloba a ética na investigação, a igualdade de género e outras formas de inclusão, o acesso livre a dados e publicações e a educação científica. E promove o envolvimento público em discussões políticas relacionadas com a ciência, a colaboração entre cientistas, especialistas em ética e cientistas sociais, iniciativas de *open source*, inovação orientada pelo utilizador ou ciência cidadã, entre outras.

É objetivo da IIR criar uma sociedade em que a responsabilidade pelo futuro seja partilhada por todos e em que as práticas de investigação e inovação apontem para resultados ambientalmente sustentáveis, eticamente aceitáveis e socialmente desejáveis.

Grande número de inovações, ao longo de décadas, sofreu oposição pública em diferentes fases do seu desenvolvimento. A investigação com células estaminais, o desenvolvimento da energia nuclear ou o aparecimento de Organismos Geneticamente Modificados (OGM) são alguns dos muitos exemplos de investigações em que segmentos relevantes da sociedade, devido à falta de informação, à prevenção ou a posições ideológicas, exerceram protestos contra o desenvolvimento dessas inovações (EU, 2012).

As necessidades e os impactes sociais e éticos de inovações desta natureza não foram integrados nem devidamente avaliados em estádios iniciais. A prática, é incorporar essas preocupações numa fase tardia da maturidade científica e tecnológica, o que conduz, muitas vezes, a perceções negativas por parte da sociedade. Assim, é premente apoiar iniciativas que promovam uma investigação mais informada e orientada para as necessidades dos cidadãos, e para uma ligação mais sólida entre os cidadãos e o setor da investigação (EU, 2012).

> Na escola pretende-se que os alunos se tornem conscientes da necessidade de cooperação entre investigação científica e sociedade em prol de uma investigação e inovação que sejam, de facto responsáveis. Para tal é fundamental que ocorra:
>
> (a) construção de conhecimento sobre investigação de temas científicos atuais, pertinentes e polémicos;
>
> (b) sejam alvo de discussão, numa perspetiva de investigação e inovação responsáveis.
>
> (Projeto IRRESISTIBLE, 2014)

Projeto europeu IRRESISTIBLE[1]

O projeto IRRESISTIBLE envolve dezasseis parceiros de dez países europeus e tem como finalidade desenvolver e disseminar atividades destinadas a promover a participação dos alunos e do público em geral no processo de investigação e inovação responsáveis, através da formação de professores.

O projeto implicou o desenvolvimento de uma Comunidade de Aprendizagem (CdA), por cada um dos parceiros envolvidos com a participação de professores de ciências, formadores de professores, cientistas que investigam nas áreas científicas de ponta selecionadas e especialistas em educação não formal, profissionais de centros e museus de ciências.

Em cada país parceiro do projeto IRRESISTIBLE, a CdA produzirá um módulo de ensino que: (a) contextualize o tema a ser investigado, introduzindo-o através de uma situação do dia-a-dia; (b) faça uso de uma abordagem de ensino IBSE com recurso a aplicações da Web 2.0, estimulando e promovendo a observação, classificação, experimentação e a explicação dos fenómenos e propriedades relevantes do tema sob investigação; (c) aborde os aspetos IIR do tema em causa: implicações sociais e ambientais, aspetos éticos, e outros; (d) inclua sugestões metodológicas para os professores acerca da implementação do módulo em sala de aula; (e) disponibilize fontes de informação adicionais sobre o tema em questão; (f) permita aos alunos planear uma exposição sobre o tema investigado. Pretende-se que esta apresente o tema investigado, realçando os fenómenos e propriedades mais relevantes e abordando as implicações sociais e ambientais, numa perspetiva IIR.

Cada módulo de atividades será testado por professores e alunos em contexto de sala de aula e envolverá o planeamento e realização de exposições científicas pelos alunos.

O projeto IRRESISTIBLE corrobora com os esforços da comunidade europeia para a educação em ciências baseada em IBSE, despertando a motivação dos alunos, em contextos sociocientíficos, e promovendo aprendizagens significativas baseadas na investigação científica, assim como a aquisição de competências que lhes permitam tomar decisões e resolver questões sociocientíficas, elevando a auto-eficácia dos professores de ciências para se apropriarem de formas relevantes de ensinar ciências, para, a aquisição de competências para o desenvolvimento de ambientes de aprendizagem criativos. A incorporação de inovação no trabalho diário pode ser um dos principais componentes de desenvolvimento profissional dos professores.

METODOLOGIA

Com o presente estudo pretendeu-se construir conhecimento sobre: Qual o impacte de atividades IBSE integrando ferramentas da Web 2.0 no desenvolvimento de conhecimentos e competências necessários ao exercício de uma cidadania ativa, fundamentada e crítica no âmbito da investigação e inovação responsáveis em áreas científicas de ponta?

Este enunciado foi delimitado nas seguintes questões de investigação:

I. Como se poderá conjugar a reflexão sobre a investigação e inovação responsáveis com a abordagem IBSE?
II. De que forma as aplicações da Web 2.0 poderão auxiliar na concretização das diferentes fases desta abordagem?
III. Que potencialidades e dificuldades experimentam alunos e professores durante a realização destas atividades IBSE?

Estas questões operacionalizam-se nos seguintes objetivos que no seu conjunto orientam a opção metodológica do estudo:

1. Como conceber e realizar estratégias educativas de natureza investigativa (de tipo IBSE) sobre investigação e inovação responsáveis em áreas

científicas de ponta (atuais e controversas), adequadas ao programa de Ciências Naturais do 3.ºCEB e que integram aplicações da Web 2.0.

2. Identificar/descrever as potencialidades e dificuldades sentidas pelos alunos e professores durante a realização das atividades.

Através deste estudo pretende-se obter diferentes tipos de produtos, nomeadamente, estratégias didáticas destinadas à educação em ciências no 3.ºCEB e novo conhecimento relativo à conceção e à realização destas estratégias em contexto educativo.

De forma a operacionalizar este estudo, optou-se pela metodologia *Design Based Research* (DBR). Segundo Wang e Hannafin (2004) a metodologia DBR representa um novo paradigma de investigação no aprender a ensinar.

Metodologia de cariz qualitativa e quantitativa com implicações no desenvolvimento de novas teorias de ensino e aprendizagem (Dede, 2005). Combina a procura de soluções práticas para os problemas, reais, de sala de aula com a investigação para as questões de ensino e aprendizagem (Reeves, Herrington & Oliver, 2005). Permite preencher a lacuna existente entre a investigação e a prática educativa (Andriessen, 2007).

O estudo compreendeu ciclos de análise, desenvolvimento e avaliação, representado na figura 1.

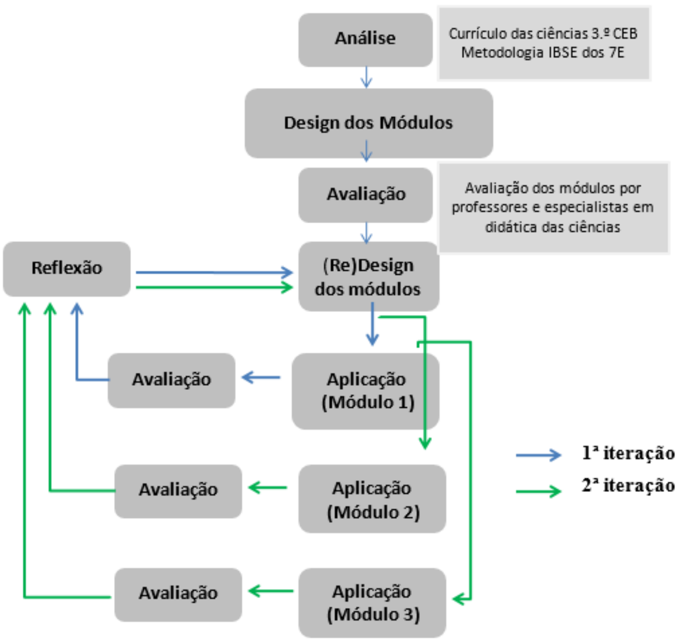

Figura 1. Ciclo do estudo.

PLANIFICAÇÃO, CONCEÇÃO E CONSTRUÇÃO DOS MÓDULOS

Os protótipos de módulos foram construídos no âmbito da formação do projeto IRRESISTIBLE, segundo a metodologia IBSE dos 7E com recurso a aplicações da Web 2.0 sobre as áreas científicas atuais e numa perspetiva de IIR. Cada módulo de ensino: (a) contextualiza o tema a ser investigado, introduzindo-o através de uma situação do dia-a-dia; (b) faz uso da metodologia IBSE com recurso a aplicações da Web 2.0, estimulando e promovendo a observação, classificação, experimentação e a explicação dos fenómenos e propriedades relevantes do tema sob investigação; (c) aborda os aspetos IIR do tema em causa: implicações sociais e ambientais, aspetos éticos, e outros; (d) inclui sugestões metodológicas para os professores acerca da implementação do módulo em sala de aula; (e) disponibiliza fontes de informação adicionais sobre a temática; e (f) permite aos alunos planear uma exposição sobre o tema investigado. Pretende-se que esta metodologia apresente o tema investigado, realçando os fenómenos e propriedades mais relevantes e abordando as implicações sociais e ambientais, numa perspetiva IIR.

A professora investigadora, no âmbito da formação do Projeto IRRESISTIBLE criou três módulos: módulo1: "Vacinar ou não Vacinar?", módulo 2: "Portugal é mais Mar?" e módulo 3: "Degelo e Erosão: Qual a relação?". Cada módulo é acompanhado pelos respetivos guiões de atividades do professor, do aluno e grelhas de avaliação para professores e alunos. As áreas científicas atuais, adequadas ao programa de ciências naturais dos 8.º e 9.º anos, subjacentes à conceção dos módulos foram os seguintes Ciência Polar, Extensão da Plataforma Continental Portuguesa para o 8.º ano e Biotecnologia e Bioética para o 9.º ano.

Os módulos foram avaliados por especialistas das áreas educativas e professores da CdA IRRESISTIBLE de ciências naturais e de biologia e geologia. Os especialistas e professores identificaram potencialidades e fragilidades dos módulos e formas de melhorar os domínios IBSE 7E, IIR e as ferramentas Web 2.0.

Os módulos foram implementados em contexto real de ensino-aprendizagem, que corresponde à experiência educativa propriamente dita. Os módulos 1 e 2 foram aplicados no 8.º ano por duas professoras, durante os 2.º e 3.º períodos letivos e o módulo 3 foi aplicado no 9.º ano, também por duas professoras, durante o 1.º e 2.º períodos letivos.

APRESENTAÇÃO E ANÁLISE DOS RESULTADOS

CONCEÇÃO E AVALIAÇÃO DOS MÓDULOS

A professora investigadora, no âmbito da formação do Projeto IRRESISTIBLE criou três módulos: módulo 1: "Vacinar ou não Vacinar?", módulo 2: "Portugal é mais Mar?" e módulo 3: "Degelo e Erosão: Qual a relação?".

Os módulos foram construídos segundo a metodologia IBSE dos 7E com recurso a aplicações da Web 2.0 sobre as áreas científicas atuais, numa perspetiva de IIR.

Pretende-se que esta metodologia apresente o tema em investigação, realçando os fenómenos e propriedades mais relevantes e abordando as implicações sociais e ambientais, numa perspetiva IIR.

Os módulos criados foram implementados em contexto real de ensino-aprendizagem. A aplicação do módulo 1 "Vacinar ou não Vacinar?" fez-se em três turmas do 9.º ano, por dois professores, durante os 1.º e 2.º períodos letivos, e permitiu identificar as possibilidades e as dificuldades da respetiva implementação em sala de aula e em relação à metodologia, bem como formas de aperfeiçoar o módulo futuramente. A identificação das possibilidades, das dificuldades e das sugestões de melhoria permitiram efetuar algumas alterações aos restantes módulos antes da sua aplicação em contexto de sala de aula.

Os módulos foram submetidos a um processo de validação por especialistas em didática das ciências e professoras da CdA IRRESISTIBLE de ciências naturais e de biologia e geologia. Os especialistas em didática das ciências (E) e os professores da CdA IRRESISTIBLE (P) identificaram potencialidades e fragilidades dos módulos e sugeriram formas de melhorar os domínios IBSE 7E, IIR e ferramentas da Web 2.0, a partir das quais foram efetuadas as correspondentes alterações.

Quadro 1

Potencialidades e fragilidades dos módulos

Potencialidades	Fragilidades
- A atualidade do tema proposto, título evoca de imediato conceitos relacionados simultaneamente com a tecnologia e a investigação que está a ser desenvolvida no projeto Portugal é mar; (P) - O módulo permite os alunos envolverem-se de modo a concretizar atividades que visam trabalhar com os 7E de forma progressiva e que pode incluir aspetos importantes com o recurso a aplicações da Web 2.0 e ainda os aspetos da IIR; (P, E) - A avaliação proposta no módulo, tanto do processo como do produto permite ao aluno ter conhecimento de si próprio a medida que vai construindo os diferentes produtos e conhecer significativamente a qualidade do que vais produzindo; (P) - A divulgação dos cartazes na escola e exposição NOSTRUM irá facilitar a partilha de todo o trabalho desenvolvido a toda a comunidade. Tornado possível a cada cidadão, refletir sobre os conteúdos, as inovações científicas e tecnológicas e construir de uma forma esclarecida uma opinião acerca da importância desta proposta entregue à ONU. (P, E) - A atualidade da temática proposta enquanto mote para uma atividade investigativa; (P) - A diversidade e interligação de temáticas, o que potencia a possibilidade de ser integrado num conjunto de outros projetos; (P) - A possibilidade de gerarem na escola uma dinâmica de atuação coletiva para um objetivo comum: a proteção de um bem essencial que é o planeta Terra enquanto território comum a todas as espécies vivas e sobre o qual temos especial responsabilidade. (P)	- Falta de clarificação das questões IIR a abordar com os alunos. (E). - As notícias escolhidas incidem sobretudo em consequências do aumento da temperatura e no contexto do território português; (P) - Ausência de um guião de exploração do vídeo e da notícia "Tempo está a esgotar-se para reduzir o aquecimento global, diz estudo da ONU"; (P) - Falta de alguma controvérsia no módulo. (E)

Os alunos do 3.º CEB, 8.º e 9.º e as professoras que aplicaram os módulos em contexto de sala de aula também avaliaram os módulos de ensino e deram algumas sugestões, a partir das quais foram efetuadas as devidas alterações.

Relativamente às modificações que as professoras introduziriam nos módulos, a professora que os experimentou no 8.º ano não sugeriu qualquer alteração. No entanto, a professora responsável pela experimentação do módulo do 9.º ano sugere textos mais curtos, salientando apenas os aspetos relevantes a serem explorados pelos alunos:

> P1:Não alteraria nada, pois no meu ver estão bastante bem encaminhados o que facilita a nossa preparação.
>
> P2: Textos mais curtos. Focando o mais importante da notícia: quem optou por não vacinar e consequências; como se fabricam e funcionam as vacinas…

Relativamente às melhorias que os alunos introduziriam na atividade, a maioria dos alunos considerou que a atividade não necessitava ser melhorada. No entanto, alguns alunos sugeriram o uso de mais ferramentas da Web 2.0, a maior partilha de opiniões com os outros grupos de trabalho, os textos informativos mais curtos, mais tempo para a realização das tarefas e, também, que a atividade deveria ter incluindo atividades experimentais.

A sequência seguinte de iterações permitiu introduzir as seguintes alterações nos módulos:

Quadro 2

Alterações introduzidas nos módulos

Módulos	Quem as propôs	Iteração	Alterações introduzidas nos módulos
Vacinar ou não Vacinar?	Professor e Especialista (CdA IRRESISTIBLE)		- Guião do aluno com instruções mais orientadas;
	Professor (CdA IRRESISTIBLE)		- Exploração em sala de aula do artigo científico;
	P2 e alunos	1.ª iteração	- Textos informativos mais curtos, focando o mais importante das notícias;
	Alunos	1.ª e 2.ª iteração	- Utilização de mais ferramentas da Web 2.0; - Partilha de ideias com os outros grupos de trabalho.
Portugal é + Mar?	Especialista (CdA IRRESISTIBLE)		-Exploração em sala de aula das questões IIR inerentes ao projeto de Alargamento da Plataforma Continental;
Degelo *versus* Erosão: Qual a relação?	Professor (CdA IRRESISTIBLE)		- Notícias que também exploram as consequências do aumento da temperatura não só para o Território Português mas também anível global - Planeta Terra; - Guiões de exploração para as notícias;
	Especialista (CdA IRRESISTIBLE)		- Exploração de alguns dados do protocolo de Quioto (de modo a acrescentar alguma controvérsia ao módulo).
	Alunos	1.ª e 2.ª iteração	- Utilização de mais ferramentas da Web 2.0; - Mais sugestões de atividades experimentais.

Esta abordagem permitiu aos alunos com maior frequência participar em discussões sobre questões éticas da ciência e da sociedade, discutir sobre problemas atuais ponderando sobre o efeito desses problemas afetam a vida da sociedade, desenvolver projetos que consideram importantes e socialmente relevantes, aprender a agir de forma socialmente responsável, desenvolver exposições científicas. Também proporcionou várias aprendizagens relativamente às 6 dimensões da IIR.

As estratégias de ensino e aprendizagem implementadas também revelaram impacte positivo no desenvolvimento profissional e na motivação dos professores, uma vez que permitiram desenvolver com maior facilidade as competências essenciais preconizadas nas orientações curriculares.

Este trabalho permitiu ao professor investigador melhorar as suas competências profissionais no domínio do conteúdo científico e prática no ensino das ciências. A formação de professores do projeto IRRESISTIBLE teve uma importância fulcral no desenvolvimento de competências no domínio do conteúdo científico, contribuindo para um maior conhecimento sobre as áreas científicas de ponta incluídas nos módulos de aprendizagem elaborados de acordo com este estudo. Contribuiu, também para um maior conhecimento didático inerente à metodologia IBSE dos 7E e uma maior integração de aplicações da Web 2.0 sobre áreas científicas de ponta numa perpetiva de IIR. Permitiu, ainda, aos professores que integravam a CdA IRRESISTIBLE se apropriarem-se de formas relevantes de ensinar ciências e de adquirir competências para o desenvolvimento de ambientes de aprendizagem inovadores e criativos.

A aplicação dos módulos na sala de aula permitiu à professora investigadora vivenciar um ambiente de grande motivação para os alunos, em que estes revelaram interesse e envolvimento nas pesquisas efetuadas. A metodologia de ensino-aprendizagem preconizada nos módulos de aprendizagem é promotora do trabalho em grupo, facilitando a compreensão da natureza colaborativa do trabalho científico, e de uma cidadania ativa e fundamentada, permitindo que o aluno se envolva numa ação coletiva fundamentada em pesquisa e investigação com a finalidade de alertar a comunidade e assim contribuir para a educação científica de outros cidadãos.

A metodologia DBR, utilizada para operacionalizar este estudo, permitiu à professora investigadora, através dos ciclos de implementação, análise e avaliação, gerar conhecimento prático sobre a intervenção, criando oportunidades de aprendizagem e de melhoria progressiva no ciclo subsequente da intervenção.

A implementação, em sala de aula dos módulos assim como a dupla função desempenhada pela professora investigadora, permitiu melhorar competências referentes à prática no ensino das ciências, à reflexão e introspeção como profissional de ensino, fatores que contribuíram para elevar a qualidade do processo ensino-aprendizagem através de melhor preparação dos alunos na aquisição das competências necessárias para os desafios do século XXI.

A melhoria qualitativa das aprendizagens e o aumento do nível de literatura científica e tecnológica dos alunos requer um ensino mais centrado no aluno. Mantendo esta finalidade em mente, é necessário que o professor adote estratégias que envolvam os alunos em atividades de investigação e pesquisa, apoiando-os na construção do seu próprio conhecimento, na colocação de questões e no planeamento e desenvolvimento de investigações científicas. Posteriormente, é necessário auxiliar os alunos a interpretar, analisar e apresentar resultados, para que estes compreendam verdadeiramente o que aprendem, ou seja, construam estruturas mentais que representam adequadamente o que aprenderam e não se limitem a memorizar conteúdos e as informações. É importante que o aluno desempenhe um papel ativo e consciente na (re)construção, ampliação e gestão do seu conhecimento.

CONSIDERAÇÕES FINAIS

Este estudo contribui para um maior conhecimento das potencialidades, compreensão e clarificação da aplicabilidade de estratégias educativas de natureza investigativa (de tipo IBSE), que integram aplicações da Web 2.0 sobre investigação e inovação responsáveis no ensino das ciências naturais, proporcionando um ensino interessante, desafiante e atualizado, conduzindo ao desenvolvimento de competências essenciais ao século XXI.

Os três módulos de aprendizagem construídos são um dos produtos deste estudo. Permitem o desenvolvimento de competências essenciais, à construção de uma literacia científica baseada em investigação e inovação responsáveis, indispensável ao exercício de uma cidadania ativa e responsável, orientada para a ação sociopolítica, no âmbito das orientações curriculares do Ensino Básico.

O envolvimento dos alunos em atividades de natureza investigativa (do tipo IBSE) e a utilização de ferramentas da Web 2.0 para o desenvolvimento de conhecimentos e competências no âmbito da IIR em áreas científicas de ponta, influencia de modo positivo a dinâmica das aulas potenciadoras de pesquisa e facilita a participação ativa, partilha de conhecimentos e colaboração entre alunos. Metodologia promotora de interação entre alunos e aluno-professor, hábitos de trabalho de grupo, discussão de ideias/opiniões, espírito crítico, capacidade de síntese e reflexão e respeito pela opinião dos outros levando os alunos à compreensão do que é a ciência numa perspetiva de investigação e inovação responsáveis.

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Interactive Exhibition on Climate Geoengineering: Empowering Future Teachers for Sociopolitical Action

ELISABETE FERNANDES LINHARES

elisabete.linhares@ese.ipsantarem.pt | Escola Superior de Educação do Instituto Politécnico de Santarém, Portugal

PEDRO REIS

preis@ie.ulisboa.pt | Instituto de Educação da Universidade de Lisboa, Portugal

ABSTRACT

The present case study, involving 19 pre-service teachers, intends to identify the potentialities and the limitations associated with the development of interactive exhibitions on socio-scientific issues as a strategy to empower future teachers for sociopolitical action. An interactive scientific exhibition developed accordingly to the IRRESISTIBLE project module "Geoengineering: Climate Control?" sought to create opportunities for students to work collaboratively, to take responsibility and to participate in activism initiatives. The results suggest positive impacts on students' scientific knowledge, exhibitions' development skills and empowerment for action. The main difficulties are focused on group work and time management. This pedagogical initiative allowed the development of competences considered important for citizens' scientific literacy and active involvement in sociopolitical action.

KEY WORDS

Interactive exhibit, IRRESISTIBLE, Activism, Teacher training.

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Exposição Interativa sobre Geoengenharia Climática: Capacitação de Futuros Professores Para a Ação Sociopolítica

Elisabete Fernandes Linhares

elisabete.linhares@ese.ipsantarem.pt | Escola Superior de Educação do Instituto Politécnico de Santarém, Portugal

Pedro Reis

preis@ie.ulisboa.pt | Instituto de Educação da Universidade de Lisboa, Portugal

RESUMO

O presente estudo de caso, envolvendo 19 estudantes da formação inicial de professores, pretende identificar as potencialidades e as limitações associadas ao desenvolvimento de exposições interativas sobre questões sociocientíficas como estratégia para capacitar as futuras professoras para a ação sociopolítica. Uma exposição científica interativa desenvolvida de acordo com o módulo "Geoengenharia: Controlo do Clima?" do projeto IRRESISTIBLE procurou criar oportunidades para as estudantes trabalharem de forma colaborativa, assumirem responsabilidades e participarem em iniciativas de ativismo. Os resultados sugerem impactos positivos no conhecimento científico, em competências para o desenvolvimento de exposições e de capacitação para ação das futuras professoras. As principais dificuldades centram-se no trabalho de grupo e na gestão do tempo. Esta iniciativa pedagógica permitiu o desenvolvimento de competências consideradas importantes para a literacia científica dos cidadãos e o envolvimento ativo em ação sociopolítica.

PALAVRAS-CHAVE

Exposição interativa, IRRESISTIBLE, Ativismo, Formação de professores.

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> Democracy is not only a political form, it is a way of life, characterized above all through the transitivity of consciousness in man's behaviour. Transitivity is neither born or developed, unless through certain conditions, when man is engaged in debate, examining his and societies problems. In which he participates.
> Freire, 1967, p. 81

INTRODUTION

In a world led by constant scientific and technological innovations, there are a number of emerging problems, at the local and global level, for which it is urgent to find sustainable and responsible solutions. To deal with these problems, it is not enough to gather scientific information and knowledge. Different points of view on the issues that are being analysed must also be considered (Colucci-Gray & Camino, 2014). As Colucci-Gray and Camino (2014) mention, humans are introducing greater and deeper transformations into natural systems, resulting in an increase in socio-scientific and socio-environmental issues. Besides natural occurring transformations, others are prompted by the network of social and ecological interrelationships, leading to unpredictable results requiring decision-making and research based accountability criteria.

In this context, interactive science exhibits, including the *Exchange* and *Empower* phases of the IRRESISTIBLE project teaching modules, are part of an approach promoting democratic participation. This is sustained by a learning path seeking to give sense to future teachers lives, relating new knowledge with real concerns. This type of interactive exhibit aims to educate future teachers, as well as visitors on social issues affecting all of us. It is also our purpose to develop the participants competence to plan concrete actions, that can contribute to protect the environment and strengthen democratic values.

The IRRESISTIBLE Project involved several European countries aiming to introduce Responsible Research and Innovation (RRI) in the different levels of basic and secondary science education, through *Inquiry Based Science Education* (IBSE). One of the expected impacts of the project, through teacher training and professional development, is contributing to society scientific literacies, responsibility, and creativity (Apotheker, Blonder, Akaygun, Reis, Kampschulte & Laherto, 2016).

By providing future teachers with this type of teaching-learning scenarios they will be better prepared to teach inquiry based science, and actively participate in solving social issues related to science, technology, and the environment, through initiatives such as interactive science exhibits. This study, intends to research the potentialities and limitations associated with the use of interactive science exhibits in the training of future teachers for sociopolitical action.

INQUIRY AND RESPONSIBLE RESEARCH AND INNOVATION

RRI plays a leading role in Europe, integrating one of the central concerns of the European Union (EU) Framework Program (Direcção-Geral da Investigação e da Inovação, 2014; Von Schomberg, 2013). In this program, investing in research is considered crucial for Europe's smart, sustainable and inclusive development (Direcção-Geral da Investigação e da Inovação, 2014, p.5). The responsible research and innovation is a transparent and interactive process, with various actors, from civil society and/or researchers, aiming for the acceptability, sustainability and social relevance of the innovation processes and its products. The purpose of its underlying principles and dimensions is to enable the scientific and technological advancement of our society to be properly incorporated (Von Schomberg, 2013), while finding solutions to a wide range of existing challenges. The European Commission (European Union, 2012) sought to answer these challenges through the creation of a society-driven research and innovation policy, and through an inclusive participatory approach for all social actors, implemented in six key elements: Involvement, Gender Equality, Science Education, Ethics, Free Access and Governance. Therefore, the IRRESISTIBLE project tried to involve teachers, students and the general public in the RRI process by raising awareness to the need for cooperation between scientific research and society, in order to promote truly responsible research and innovation (Reis & Marques, 2016a, p. 9). Each module is focused on a current and controversial science issue, promoting the participants learning about these topics, and their discussion, taking into account the six dimensions of RRI (Apotheker et al., 2016; Reis & Marques, 2016a). Each module was also developed taking into account an Inquiry Based Science Education (IBSE) approach integrating Rodger Bybee's (5E) teaching model: Engage, Explore, Explain, Elaborate and Evaluate. Another core characteristic of the project was the development of teachers and students' technological competences using digital resources. The Portuguese project team added to this model two new phases - *Exchange* and *Empower*, extending it to 7Es (Azinhaga, Marques & Reis, 2016; Reis & Marques, 2016a). The two added phases to the 5E model imply the design, implementation and evaluation of the interactive science exhibits, by the students, creating a strategy for school activism (Reis & Marques, 2016a). The construction and presentation of the exhibits create an opportunity for students to participate in collective action on the controversial issues being analysed, while also encouraging exhibit visitors to take action (Reis & Marques, 2016b).

The adoption of *Inquiry* in the IRRESISTIBLE project intended to react the recommendations of the European Commission report presented by Rocard (2007). One of the problems pointed out in this report, by the science education experts group led by

Rocard (2007), was the small number of young people interested in this area. According to Osborne and Dillon (2008), the introduction of the IBSE pedagogical model in science classes opposes this tendency allowing students to increase their interest in science. *Inquiry* is a teaching strategy that captures the spirit of science research, and the development of knowledge about the natural world, and should not be described or confused with practical activities such as hands-on (Bybee, 2006). In the published book about *Inquiry* (NRC, 2000), the National Research Council highlights some features that should be present in teaching and learning when using this pedagogical strategy. Bybee (2006), when analysing these characteristics, highlights the students as the central element of this approach, and their mental activity with a scientific orientation towards the goal of developing scientific explanations. Other features emphasized by Bybee (2006) are the relationship between the issues analysed with current scientific knowledge, and the existence of elements of rationalization and communication.

Recognizing the importance of the RRI approach and the use of *Inquiry* in the context science education, the scope of the IRRESISTIBLE project was extended, giving the opportunity to students of the Undergraduate Program in Basic Education, future teachers, to engage with the proposals of the project modules. If it is important to invest in current teacher's professional development, it is no less important to involve future teachers in training and learning experiences of this nature. This intervention can benefit students understanding, reasoning and attitudes towards the environment and a healthy life, as well as society through the dissemination of RRI principals, promoting each individual ability to make better informed choices.

ACTIVISM AND INTERACTIVE SCIENCE EXHIBITS

Interactive exhibits aim to empower future teachers for action, promoting a deeper understanding of the studied issues using *Inquiry* and RRI. This knowledge can stimulate and motivate future teachers to invest in issues that affect our society and encourage them to act (Hodson, 2003). The interactive dimension of the exhibits favour's the emergence of meaning, resulting from the interaction between the visitors and the facilitators present at the exhibit (Reis & Marques, 2016b). For Reis and Marques (2016b) the visitors' active participation is crucial for the emergence of clear conceptual knowledge built in the group. In order to promote meaningful learning, the artefact planned by the students must actively engage the visitor, prompting him to the application of new knowledge. The tasks and the reflection promoted during the exhibit are essential in the process of building knowledge and awareness. Interactivity can be promoted by using multimedia applications, by manipulating virtual objects on screens, simulating experiments, online tests with immediate *feedback*, *role-playing*, synchronous and asynchronous communications between groups, and sharing alternative points of view about a given issue. Another effective strategy to stimulate interaction is questioning. According to Marques (2016), questions raised in the beginning, middle or at the end of the exhibit/exploration of the artefact can direct the visitors' attention, raise doubts and encourage discussion.

Conducting interactive exhibits seeks to create opportunities for students to work collaboratively, take on responsibility, and participate in activities promoting change. This is a way for students to learn how to participate, by experiencing participation.

According to Hodson (2014), "to show students how to establish, support and sustain politically active communities" (p. 69). In this context, we adopted Hodson's (2003) definition of sociopolitical action as a form of participation, requiring the capacity and commitment to carry out appropriate, responsible, and affective actions regarding social, economic, environmental and ethical issues in society. Educating for sociopolitical action, as Hodson (2003) emphasizes, implies recognizing that the environment is a social construct on which we act, change and reconstruct through our actions. For this author, it is essential to empower students with scientific knowledge, in order to understand and deal with socio-scientific issues. By learning more about these issues, students will be better prepared to "to understand the underlying issues, evaluate different positions, make an informed decision on where they stand in relation to the issue, and argue their point of view" (Hodson, 2014, p. 70).

Although several authors defend the use of activities that promote sociopolitical action in educational contexts (Blatt, 2014; Hodson, 2003, 2014; Reis, 2014; Schusler & Krasny, 2015), its adoption by teachers is not an easy task. As illustrated by the results of the study developed by Reis (2014), with teachers from the *We Act* project community of practice (aimed at supporting teachers and students of different levels of education - from the first grade of basic education to higher education – taking informed and negotiated actions to address social and environmental issues), the adoption of practices oriented towards informed activism about socio-scientific and social-environmental issues faces several obstacles. Thus, the integration of activities that aim at sociopolitical action requires the teacher to have: knowledge about the interactions between science, technology, society and the environment; a strong belief in their educational potential to empower students as citizens; didactic knowledge to implement initiatives of this nature; willingness and ability to participate in social change (Reis, 2014). For sociopolitical action to be a reality in our classrooms, it is essential that future teachers experience it, in order to understand their potential and build knowledge about how to act in society. As advocated by Hodson (2014), action-oriented education helps students to be prepared and engage in responsible action by developing the competences, attitudes, and values necessary to control their lives. Teaching-learning situations that allow students to act (at school) considerably increases their likelihood of becoming active citizens in the present and in their adult life. For Blatt (2014), understanding current societal issues and preparing for intervention requires a different view of school's role, and of the purpose of education, moving away from standardized testing and adopting a new culture that seeks to create an "activist mentality" in students. This requires a pedagogical approach geared towards environmental action, favouring the development of youngsters' capacities to participate as scientifically literate citizens (Schusler & Krasny, 2015). Schusler and Krasny (2015) found that youngsters, between the ages of 9 and 18 (attending environmental education programs – in formal and non-formal educational contexts – in the United States), developed diverse knowledge, dispositions, and capacities related to science and civic participation, namely to understand problems, to be able to find alternative explanations and to critically debate within a community. Besides this, they also developed critical thinking, allowing them to draw their own conclusions about socio-scientific and socio-environmental issues. Another advantage related to action-oriented practices is developing the capacity to negotiate with others through democratic processes stemming from concerns centred on social, economic, environmental, moral, and ethical dimensions. According to these authors, environmental action, as a pedagogical approach, takes place in the intersection between youngster's civic engagement and *Inquiry* based science education (Figure 1).

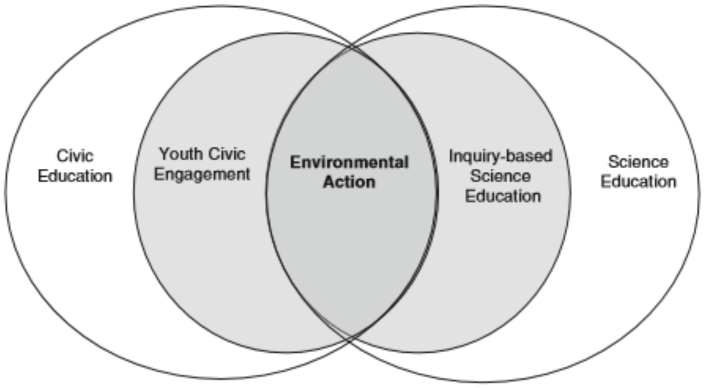

Figure 1. Representative scheme of environmental action occurring at the intersection between youngster's civic engagement and *Inquiry* based science education. Retrieved of Schusler and Krasny (2015).

The processes of doing science and engaging in participatory democracy share many characteristics, such as questioning, understanding systems, considering alternative explanations, and the need to critically discuss issues within a community. Youngsters civic engagement during public consultations and when integrating organizations, fosters their development, as well as stimulates change in society. As stated by Schusler and Krasny (2015), *Inquiry* activities allow students to describe objects, raise questions, construct and evaluate explanations, taking into account current scientific knowledge, and communicating their ideas to others. Thus, "environmental action provides context for learners to engage in scientific inquiry toward specific social purposes" (Schusler & Krasny 2015, p. 367). Students can become co-producers of scientific knowledge when engaged in a process of community action. Simovska (2008) further points out that when students have the opportunity to actively participate in improving the environment during their educational process, they become agents of their own learning and take responsibility in their lives and are able to cope with change.

ACTING IN DEMOCRATIC SOCIETIES

Action-oriented science education implies the transformation of attitudes, values, behaviours and beliefs that awaken the will, desire and ability to act (Ukpokodu, 2009). This study view of science education aims at the expansion of democracy and democratic citizenship. Democratic citizenship means that the actors are responsible and able to engage in social problems on scientific and technological issues.

In Dewey's view, school is an especially primed institution to ensure the principles of a democratic society. It is through schools that society is transformed, emphasizing its very important role in the production of social change (Dewey, 2005). This same author argues that such a function is only possible if a transformation occurs in what is the essence of the school purpose. A society with these characteristics should offer a type of education that provides individuals with personal interest in social relationships, and reasoning competences that ensure social change (Paraskeva, 2005).

Carter, Rodriguez and Jones (2014) argue that transformative learning theory provides a relevant framework for students to raise their awareness about current science issues, enabling them to take informed decisions necessary for sociopolitical action. Transformative learning requires the direct intervention of the individual, enabling him to develop the competences and dispositions for critical reflection. These premises are essential components for democratic citizenship (Mezirow, 2003). In this sense, it is a process where the acquired problematic reference frameworks (assumptions and expectations) are transformed in order to become more reflective. This change in reference frameworks guides the learners action (Mezirow, 2000).

Carter et al. (2014) identify four fundamental characteristics in the interpretation of transformative learning theory - critical reflection, disorientation and conflict, emotional self-learning and focus on action. Reflection developed in this process stems from a dilemma, or confrontation, that encourage students to identify and critically review their ideas. Beliefs, emotions, and knowledge about a particular issue are questioned. Reflection and construction of new knowledge allow for the emergence of alternative viewpoints. Thus, the authors conclude that "where personal framework, beliefs and values are changed, action and activism is much more likely" (p. 537).

For Freire (1967), education for democracy should offer the learner the necessary tools to engage in discussions about the issues affecting society. In this perspective, it is important to educate the student about existing dangers, and to enable him to intervene instead of submitting himself to other’s guidelines. It is an education for dialogue, focused on the constant critical reflection about the reality we live in, and guided towards change. This same author argues that education must lead man to engage in changing society, in his context, emphasizing the power of transformation of reality by man, which can only occur in a society where relations between subjects are not of domination. In a problematizing education, the way each actor in the educational process perceives the world around him dictates his way of acting (Freire, 1987).

METHOD

The qualitative nature of this case study means that its direct data source is the natural environment in which it takes place, during which a rich and detailed description of the context and data are obtained, in order to generate meaning (Bogdan & Biklen, 1994). Ponte (2006) characterizes a case study as a well-defined entity (in this case, a class from the 1st year of the Basic Education Degree program attending an Ecology course), which is assumed to be particularly singular, and where one tries to discover what characterizes it, as well as to understand the participants points of view. As Ponte (2006) concludes, it is hoped that the case study will contribute to a better understanding of the problems of practice, helping to understand certain aspects of everyday reality related to the training of future teachers for sociopolitical action. The purpose of this study is to identify the potentialities and limitations associated with the use of interactive science exhibits, in the training of future teachers for sociopolitical action. In order to reach this objective and to study the implications of the implementation of the "Geoengineering: Climate Control" module of the IRRESISTIBLE project, we collected data from participant interviews, a final evaluation questionnaire and participant observation. The choice for semi-structured interviews as the main technique for data collection is related to the possibility of expanding viewpoints and opinions regarding the phenomenon under study (Gray, 2012). According to Quivy and Campenhoudt (1992), its main advantages are due to the depth of the collected contributions, and the respect for the interviewees reference frameworks. The administration of a final evaluation questionnaire aimed at accessing the visitors' opinions, allowing for a considerable number of individuals to be questioned in a short time (Quivy & Campenhoudt, 1992). Participant observation sought additional information about the study for its better understanding. As Gray (2012) points out, observation allows us to go beyond people's opinions and interpretations about their own attitudes and behaviours, allowing us to evaluate their actions. This method allows the capturing of behaviours as they occur (Quivy & Campenhoudt, 1992). Observation involves a systematic look at people's actions and the recording, analysis, and interpretation of their behaviour (Gray, 2012). Observation data was recorded using field notes.

The study included 19 participants, students of initial teacher training, from a 1st year course on Ecology from the Degree in Basic Education program. The exhibition had as target audience students of the 3rd Cycle of Basic Education (a group of the 8th grade) and Secondary (a group of the 12th grade). However, the interactive exhibition was open and divulged to all citizens who had an interest in visiting it.

Data sources were submitted to content analysis complemented with a statistical analysis (Bardin, 2009). The quantitative treatment can suggest trends and descriptive information about the participants and their perceptions. The entire process of analysis sought to systematically organize the collected data in order to increase its understanding through reduction (Bogdan & Biklen, 1994).

INTERACTIVE SCIENCE EXHIBIT DEVELOPMENT PROCESS

Planning, designing and implementing an interactive science exhibit on the topic of Climate Geoengineering (CG) came about following the proposal introduced in the "Geoengineering: Climate control?" module as part of the IRRESISTIBLE project. The exploration of the module followed an *Inquiry* Based Science Education strategy (5E model) to which the *Exchange* and *Empower* phases were added. All phases were thoroughly explained to the class and, over the course of eight weeks, all work was developed around this issue, in order to arouse the interest and deepen the future teachers' knowledge. In order to achieve the proposed tasks, the class was organized into four to five-member working groups.

The didactic approach involved several stages that are schematically presented in Table 1.

Table 1
Schematic summary of the main activities developed during the module

Phases	Activities and tasks
Engage	- Identification students' prior knowledge - Analysis of cartoons, videos and newspaper articles
Explore	- Research on CG techniques through guiding questions; - Experimental activity: "Albedo and the effect of surface colour"
Explain	- Construction of a collaborative document about the studied techniques (*Popplet* and *Glogster*); - Presentation of the document and group discussion
Elaborate	- Introduction of the RRI concept; - Analysis of CG news in the world and class discussion
Exchange and *Empower*	- Planning and developing the final interactive exhibit
Evaluate	- Concept net, poster; discussion activity; evaluation of the exhibition artefacts and of the exhibition itself.

In order to recall the theme of Climate Change, a task was proposed to the students where they had to define this concept based on their previous knowledge, and then compare it with the definition used by the Intergovernmental Panel on Climate Change (IPCC). The group was also reminded to include the layers that make up the atmosphere, and to provide captions to a figure illustrating a model of the natural greenhouse effect impact, as well as other factors in the energy balance of the climate system, including the main greenhouse gases.

In the *Engage* phase, each group had the task of analysing a *cartoon*, related to the issue being studied, and interpret its message. Their ideas were later shared within the class. After this first contact with the module topic, in pairs, the students explored some resources about CG with the purpose of elaborating a concept net in *Popplet*, in order to display their initial understanding. The concept net elaborated by each pair was presented and discussed in the class. The *Explore* phase sought to deepen students' knowledge of CG, understanding that there are a number of CG strategies that are being researched. Each group, based on their research about the technologies used in one of the CG categories - removal of CO2 from the atmosphere and management of solar radiation, prepared a collaborative document in the form of a poster (built with *Glogster software*). A second stage of this phase consisted in an experimental activity for the future teachers to research the effect of surface colour in the Albedo, with the goal of restructuring the knowledge built about one of the strategies of Solar radiation management - painting the roofs white. In the *Explain* phase, the groups presented and discussed the ideas included in the *Glogster* posters and answered an online questionnaire (elaborated by each group) about the techniques that each group explored in their posters, in order to assess their learning and to evaluate the effectiveness of the presentations. Each student also had to elaborate a new concepts net about their learning until that moment. The introduction of RRI happened during the *Elaborate* phase through the reading of texts, and the discussion of the dimensions that integrate RRI using a matching activity. In order to enrich this phase, participants were also requested to research and analyse news about CG strategies that have been implemented worldwide, in order to reflect about the consequences of its use in social, environmental and ethical terms, and to understand who participates in this process. Finally, a discussion activity was carried out in the form of role-playing for a deeper understanding of the problem. Exposure to planning, designing and facilitating the exhibit still integrates the *Elaborate* phase, and corresponds to the *Exchange* and *Empower* phases. With this exhibit, the future teachers are expected to share with the community their research results, and communicate the knowledge they have built. The preparation of the exhibition took place over two weeks. During the period of planning and design, the teacher clarified doubts and guided the work of all the groups both inside and outside the class, meeting with the work groups and sending written feedback by e-mail. Through this collective action, we intend to promote the visitors' awareness regarding this issue, and simultaneously contribute to solving problems affecting our society. The last phase, *Evaluate*, was carried out during the whole module, through the evaluation of the various products and tasks completed by the future teachers. The future teachers' progress was assessed against established learning objectives, creating opportunities for to reflect about their performance (Reis & Marques, 2016a).

RESULTS AND DISCUSSION

LEARNING OUTCOMES AND ENGAGMENT IN SOLVING SOCIAL PROBLEMS OF SCIENTIFIC AND TECHNOLOGICAL NATURE

The content analysis of the interview transcripts allow to detect the following main lessons learned by the future teachers during the development of interactive science exhibits: a) deepening/consolidating knowledge (N=9); b) organizing an exhibit (N=7); c) communicating (N=3); d) explaining the problem (N=2); e) importance of collaborative work (N=2); f) adapting to the age group (N=1); and g) citizens' duty to participate (N=1) (Table 2).

Table 2
Future teacher's opinion about main lessons learned from the exhibit

Category	N	%
Deepening/consolidating knowledge	9	47,4
Organizing an exhibit	7	36,8
Communicating	3	15,8
Explaining the problem	2	10,5
Importance of collaborative work	2	10,5
Adapting to the age group	1	5,3
Citizens' duty to participate	1	5,3

Legend: N - number of future teachers who mentioned a particular category.

Many of the above-mentioned learning instances are related to active citizenship competences that the students recognize they developed. According to the respondents, the exhibit allowed them to deepen and consolidate their knowledge during the "Climate Geoengineering" module. As the future teachers are not only the exhibit facilitators, but also the ones who produce and create the visitors experience, they are encouraged to research, organize and systematize information, explaining the various CG techniques, and communicate this information in an understandable and adequate way, leading them to learn more about the issue. The knowledge developed during this process is expressed in the following excerpts:

> "*When a person is explaining something, being able to articulate some discourse, explain things and learn with them. At the same time, we end up interiorizing, this happened to me".* (T17)

> "*I got to understand more about the Geoengineering topic*". (T14)

The field notes allow to support the data obtained by the interview, evidencing the knowledge built by the future teachers, namely in terms of the advantages and disadvantages associated with CG techniques. However, they add information about the process developed, since, at an early stage, some students have shown difficulties in understanding the subject. As the tasks were being carried out, accompanied by discussion in the classroom and feedback from the teacher, the difficulties were overcome.

> "*In general, the class is able to understand the various techniques involved in the CG, identifying advantages and disadvantages. When I presented the problem that we were going to study, I found that no one had heard of this area of research. Little by little, and after doing some tasks, the groups that showed some difficulties in understanding the theme (through the work and interventions) ended up overcoming their main shortcomings*". (Field notes, April 24, 2017)

The competence to organize an exhibition was the second most mentioned category (N=7). In fact, the students were confronted with a reality unknown to the majority – organizing an exhibit, becoming aware of all the work required by such an initiative, in particular, the importance of adequate planning and time management.

> "*It's a little bit hard to organize exhibits, isn't it, once we have the objectives, we have to follow certain phases and so I think that this was the main thing I became aware of, how important it is to have everything organized, that is, to have time well distributed*". (T4)

"*All the work in the background! I had no idea that for such a small exhibit there was so much background work, from the teacher and ours!".* (T6)

Communicating was also a competence emphasized by the future teachers (N=3). Thus, if the expression of ideas was initially seen as difficult, this experience allowed to overcome it. The exhibit provided an interaction with the visitors, which ended up developing the students' communication competence, allowing them to gain confidence to express their ideas.

"*The first step is really hard, because after that it is really easy to talk with other people, and if people show interest it's very good, because we feel we are spreading a very important message!*" (T5)

"*Concerning the issue of being able to talk to… other people… unknown (…) It helped me a little bit to work on the part of… not being at ease, of feeling more restrained*". (T18)

In the process of interacting with the target audience, another lesson expressed by the future teachers was related to their ability to explain the problem (N=2) and to answer questions posed by the visitors. Notwithstanding this insecurity, the participants considered that they have overcome this limitation by explaining the problem adequately and becoming more comfortable doing so as they further interacted with the public.

"(…) initially I was very concerned, how would it be explaining to the students and making them understand, or some doubts that they might have, not being able to answer (…) the best part of the experience was this one. It was being more at ease and becoming more confident". (T16)

"*With them [visitors], we learned how to explain, and present the work*". (T19)

The science exhibit also allowed future teachers to work collaboratively (N=2), to adapt their intervention to different age groups (N=1), as well as to become aware of the duty of all citizens to participate in solving problems affecting society (N=1).

"*It's very important to work in a team*". (T2)

"*(…) we had the chance to engage with other age groups, I for example had never had the opportunity to interact with a group of much older kids*". (T13)

"*I learned that people should show more interest and should get more engaged in the issues, in society, because it is also something that affects them, that affects all of us*". (T1)

Regarding the potentialities emphasized by the future teachers, the answers were organized in the following categories: a) knowledge (N=9); b) raising interest (N=4); c) raising awareness (N=2); and d) satisfaction (N=2) (Table 3). The references related to the knowledge provided by interactive science exhibits were organized in scientific (N=8) and didactical knowledge (N=1).

Table 3
Potentialities attributed to interactive science exhibits

Category	Subcategory	N	%
Knowledge	Scientific	8	42,1
	Didactic	1	5,3
Raising interest		4	21,1
Raising awareness		2	10,5
Satisfaction		2	10,5

Legend: N - number of future teachers who mentioned a particular category.

With the exception of one respondent, for whom these experiences may encourage future teachers to adopt lecturing as a teaching strategy in their classes, the others valued the exhibits as a dynamic strategy to facilitate learning.

"*If they have a good experience with the exhibits, later and in the science domain, in this case, they will also like to be the ones making certain exhibits. If they think they will benefit from it (…) it's a good teaching tool that they can later reproduce*". (T16)

"*In an interactive exhibition (...), as I have a participative role, I end up getting better knowledge and I can put the doubts (...), and I think this is important because it is possible to consolidate the knowledge better*". (T4)

According to the future teachers, this type of initiative has another advantage, which is the fact of raising the visitors interest. Because it is able to stimulate the interaction among visitors, and between these and the artefacts, it becomes more appealing and grabs the visitors' attention.

"If it's a more monotonous thing, there's a tendency to divert attention to other things that are happening; if it's a more interactive thing, the person is more focused on what is happening at that moment in that station". (T6)

> "*An exhibit arouses interest. That is, addressing a subject that is not known, and if it is in an interactive format, if it uses multimedia or other kind of support, it ends up almost requiring the person to react to it*." (T17)

Another benefit of the exhibit is related to the awareness it raises in visitors through the shared knowledge, discussion, and reflection promoted about the addressed issue. This way, future teachers hope that their action alerted others about the issue, so that they can play an active role in addressing it, and thus introduce improvements in society.

> "*Alert someone to the problem and try to show, in this case, how harmful it is*" (T2)

> "(…) *were able to became aware and stay alert to this problem, and may in the future use some of the things they have learned*" (T4)

The future teachers also highlight the visitors' satisfaction, evidenced through their engagement in the various activities designed by the students. This students' perception is confirmed by the evaluation carried out by the visitors at the end of the exhibit, as illustrated by the data that will be presented in the section on evaluation (exhibit impact on visitors).

DESIGNING AN INTERACTIVE EXHIBIT AS A STRATEGY OF ACTIVE PARTICIPATION AND SOCIAL ACTION FOR FUTURE TEACHERS

Future teachers considered that features related to design – time management (N=7), artefact (N=7), and the exhibit itself (N=2); group work – between group members (N=6) and between groups (N=2); facilitating the exhibit – communication (N=3), group organization (N=2) and time management (N=1), are unfavourable factors to the achievement of an interactive exhibit (Table 4).

Table 4
Unfavourable factors to the achievement of an interactive exhibit

Category	**Subcategory**	**N**	**%**
Design	Time management	7	36,8
	Artefact	7	36,8
	Exhibit	2	10,5
Group Work	Between group members	6	31,6
	Between different groups	2	10,5
Facilitating	Communication	3	15,8
	Group Organization	2	10,5
	Time management	1	5,3

Legend: N - number of future teachers who mentioned a particular category.

Time management was mentioned by the students as one of their biggest challenges. They struggled to have everything ready for the exhibit set up, making them unable to include some of the things they would have liked. For some groups, this problem was also related to their lack of organization.

> "*Even in the set up. It was a lot to do! We had to assemble the exhibit, and then we wanted to do things that we didn't do because there was no time*". (T5)

> "*We left a lot of things for the last minute! Everything was a rush, some of us were organized, others weren't and we weren't together, it seems that things get more difficult*". (T11)

The artefact design was also, for some students, a difficult process requiring adjustments and input from the teacher to overcome some difficulties. Two students mentioned their lack of knowledge about the procedures to design an exhibit, as well as the complexity associated with organizing the exhibit space, and the interconnection between different sections.

> "*In the beginning, I felt I hasn't understanding anything about Kahoot! (…) But after, with the teachers help, I did it. After all it wasn't that hard to move!".* (T8)

> "(...) *it was hard to organize the space as well as to interconnect all the groups*" (T16)

Reconciling all group members availability was difficult, making group work sometimes problematic to organize. It was also difficult for different working groups to articulate and share their work with each other (as planned in the classroom) in order to achieve a more coherent and relevant final result.

> "*We would meet now and again during our free afternoons, we tried to reconcile our time with other tasks, each other's time-schedules – sometimes it was not easy*!". (T1)

> *"[Between different class groups] we have to articulate different ways of being, and effectively, when there isn't an agreement, either each person gets involved in a certain way, and there were people that got more involved and participated, while others didn't*". (T 17)

Communication was considered by three students, during the facilitating phase, as a factor that could hinder the exhibit, given some facilitators struggles to express themselves and explain the issues. Another problem identified by the students was related to the lack of organization in some groups. In a specific case, this even prevented parts of the artefact to be ready in a timely manner. For one of the participants, the lack of time to properly explore all exhibit areas was the reason for a less profound and enriching experience.

> "(…) *when presenting, which is where I struggle the most to explain the techniques and how things are organized*". (T15)

> "(…) *organization was not up to our expectations, given that at the time it was all supposed to be ready, it effectively was not*." (T4)

> "*If we had more time …maybe things could have been better explored* (…)." (T18)

The difficulties related to time management and communication were also dimensions registered in the field notes. The problems mentioned focus on the lack of groups' organization in order to finish on time the tasks and oral communication:

> "*The process developed until the final stage of exhibition's development was not easy. The class only became aware of the work to be done for the exhibition previous day of its development, despite constantly alerting and advising the working groups about the need to send me the objects built. Despite the difficulties, some groups struggled in the final phase of the work: the exhibition was completed on time and the space was pleasantly well organized. Many groups did not share with me the fears they had and their anxiety, because they had to accompany students of different levels of education, explaining the problem and interacting with them ... I only understood this at the end, when some students admitted that this dimension - communication oral - was their great fear, but they quickly overcame it*". (Field Notes, June 30, 2017)

EXHIBT IMPACT ON VISITORS

In the interview, for 16 of the 19 future teachers, the exhibit had the intended impact, two of the participants did not answer this question, and one admitted not being sure about the exhibit impact saying *"I do not know exactly what impact it had on the public that came here (...)"* (T18). However, he also acknowledges that *"it must have had some impact ..."* (T18) on the visitors, mainly because he considered the issue to be new to them.

Most future teachers (N=14) considered visitors learning as the main exhibit impact, followed by the interest it may have aroused in the target audience (N=11). Exploring the exhibit allowed visitors to understand an issue that was new to them. Their interest could be perceived through their attention and questions raised.

"*By chance, I knew two people that came to visit and asked them if they had liked it, and if they understood the topic, and they said that they did, and that they liked it a lot* (…)". (T14)

"*In general, I found that students were motivated, that they listened and participated. Teachers said the same (…) they wanted to see the procedure of the experience so that they could reproduce it, in their classes, and of course all these comments show that it had a positive impact in the students that were there* ". (T16)

The exhibit acted as a way to raise awareness in the community to the issues being presented, and through the reflection it promoted. This way, it might have helped participants (visitors and facilitators) to elaborate an opinion about the issue.

"(...) *they become more aware, and I think that they started thinking differently*". (T2)

"*It might have changed the visitor's opinions, and even the opinion of those involved!*". (T14)

The written evaluation of the exhibit allowed the collection of 33 visitors answers. In this questionnaire, the evaluated criteria focused on the Exhibit characteristics. For this purpose, a Likert scale was used with the levels "insufficient, reasonable, good and excellent". The questions sought information on the aspects that they liked the most, and least. They were also asked to include any suggestion that they might consider relevant for the improvement of this experience.

All criteria were positively assessed by the visitors, who did not select the "insufficient" level for any of the characteristics indicated in the evaluation table (Table 5).

Table 5

Visitors evaluation of the interactive science exhibit

Criteria	Insufficient	Reasonable	Good	Excellent
Educational			17 (51,5%)	16 (48,5%)
Interactive		2 (10,5%)	16 (48,5%)	15 (45,5%)
Informative		1 (3%)	8 (24,2%)	24 (72,7%)
Innovative		3 (9,1%)	14 (42,4%)	16 (48,5%)
Fun		3 (9,1%)	12 (36,4%)	18 (54,5%)
Attractive		5 (15,2%)	15 (45,5%)	13 (39,4%)
Interesting		3 (9,1%)	11 (33,3%)	19 (57,6%)
Clarifying		1 (3%)	18 (54,5%)	14 (42,4%)

FINAL REMARKS

Planning, designing and facilitating interactive science exhibits supported the future teachers development of a diverse set of skills, fundamental for changing attitudes towards issues affecting society. Lessons learned on Climate Geoengineering and Responsible Research and Innovation were essential to get to know and understand the scientific issue, in order to design a relevant and interesting exhibit. In this way, the knowledge built on the socio-scientific issue studied was fundamental to their understanding (Hodson, 2014). The purpose of the IRRESISTIBLE project was thus achieved, by verifying that whole process around the exhibit raised awareness to the issues being studied, and helped to realise that all research and innovation should be guided by responsibility principles (Reis & Marques, 2016a). Through the exhibit, the study participants had the opportunity to participate in collective community action on a controversial issue, functioning as a platform for raising awareness and providing information for the community and themselves (Reis & Marques, 2016b). Therefore, particular attention should be given to planning, designing and creating the exhibit. Artefact characteristics are emphasized by future teachers, as fundamental factors to the implementation of an exhibit, similarly to Reis and Marques (2016b). Artefacts should actively engage the visitor, stimulating reflection about the experience. Digital resources also play a key role in the design of the artefact, given that they can help to attract the visitors'attention, and provide a better visually representation of what is intended (Reis & Marques, 2016b).

Among the limitations pointed out by future teachers, the main problems when organizing an exhibit are related to inadequate time management of group work, that often procrastinated their tasks. Therefore, the future teachers should better organize their time, in order not to compromise the quality of their work. Consequently, the way groups are organized is crucial, since it is often difficult to articulate tasks between all group members, and between groups. One way to better support and ensure the sharing and exchange of ideas within groups could be through the inclusion of more classroom work classes during the two weeks dedicated to the design of the exhibition. This could also help groups to find solutions to the problems faced during the design of their artefacts, namely using technological tools (although most of them have been explored in classroom with the whole class). For the exhibit facilitation, it is important to provide future teachers with situations that allow the development of oral communication and interaction between different groups of visitors, in order to overcome their shyness and interaction challenges. For exhibits to be more successful, visitors must be available in order to interactively engage with the proposed artefacts, as well as include time for reflection and discussion. This experience was very restricted in the exhibit held by the future teachers, because the visiting groups had very limited time to explore the artefacts, recognizing that its purpose may have been compromised, given the more superficial and less reflected approach used. The evaluation carried out at the end of the exhibit confirms the positive impact of the future teachers on the visitors. All visitors who responded to the questionnaire (on paper) positively evaluated the initiative presented by the class, namely in the criteria related to its educational, informative, interesting and clarifying characteristics. This data illustrates how implementing interactive science exhibits, especially contributes to raise awareness and promote critical reflection.

However, this training experience turns out to be insufficient to have a more reflected and effective influence in these future teachers' practices.

Thus, teacher education has an important role to play in this area, and should provide students with more teaching-learning scenarios that provide the opportunity to develop knowledge on how to approach Responsible Research and Innovation (related to cutting-edge science and technology issues) through the construction of exhibits centred on these issues with *Inquiry* based activities (Reis & Marques, 2016b).

As discussed by Carter et al. (2014), in their study with initial teacher training students, when they are exposed to relevant issues and include critical reflection, their existing frameworks are questioned regarding their knowledge, understanding and opinions. This way, the produced confrontation encourages students to act. The development in students, future teachers, of a new awareness towards social and educational realities, based on current social issues, works as an incentive for transformation. In fact, transformative learning theory provides a powerful framework to promote students' awareness about current social and socio-environmental issues, contributing to informed decisions that lead to sociopolitical action.

Framed by the problematizing education of Freire (1987), it is concluded that the interactive exhibition had an important contribution in the formation of another view of the future teachers on the problem studied, providing them with skills to participate in changing society.

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Science Teachers as Key Actors in Responsible Research and Innovation: Evaluation of a Teacher Training Program

Marta Romero-Ariza
mromero@ujaen.es| Universidad de Jaén, Spain

Antonio Quesada
antquesa@ujaen.es| Universidad de Jaén, Spain

Ana María Abril
amabril@ujaen.es| Universidad de Jaén, Spain

ABSTRACT

This work presents the design and evaluation of a teacher professional development (TPD) program intended to promoting responsible research and innovation (RRI) through science education. The training course, builds on teachers' beliefs, provides opportunities to experience the educational potential of the innovative approach, makes explicit links to the science curriculum and supports the development of specific teaching skills necessary to enact the underpinning science education model. Additionally, we present the validation of instruments to evaluate the impact of the TPD program on teachers' beliefs. The analysis of pre-post results shows a positive evolution of participants' beliefs in line with the science education model being promoted.

KEY WORDS

Responsible Research and Innovation (RRI), Teacher Professional Development, Science Education, Questionnaire, Validation of instruments.

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Os Professores de Ciências Como Atores-chave em Investigação e Inovação Responsáveis: Avaliação de um Programa de Formação de Professores

Marta Romero-Ariza

mromero@ujaen.es| Universidad de Jaén, Espanha

Antonio Quesada

antquesa@ujaen.es| Universidad de Jaén, Espanha

Ana María Abril

amabril@ujaen.es| Universidad de Jaén, Espanha

RESUMO

Este trabalho apresenta a conceção e avaliação de um programa de desenvolvimento profissional de professores (DPP) destinado a promover a Inovação e Investigação Responsáveis (IIR) através da educação em ciências. O curso de formação baseado nas crenças dos professores proporciona oportunidades para experienciar o potencial educacional da nova abordagem, produz ligações explícitas com o currículo de ciências e fundamenta o desenvolvimento de capacidades específicas de ensino necessárias para determinar o modelo subjacente da educação em ciências. Além disso, apresentamos o modelo de validação dos instrumentos de avaliação do impacto do programa de desenvolvimento profissional nas crenças dos professores. A análise dos resultados pré-publicados mostra uma evolução positiva das crenças dos participantes em linha com o modelo da educação em ciências que está a ser utilizado.

PALAVRAS-CHAVE

Investigação e Inovação Responsáveis (IIR), Desenvolvimento Profissional dos Professores (DPP), Educação em Ciências, Questionário, Validação de Instrumentos.

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Science Teachers as Key Actors in Responsible Research and Innovation: Evaluation of a Teacher Training Program

Marta Romero-Ariza | Antonio Quesada | Ana M. Abril

INTRODUCTION AND BACKGROUND

Responsible Research and Innovation (RRI) is defined as "a process where societal actors work together, via inclusive participatory approaches, 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" (European Commission, 2015, p. 69). For effective participation in RRI, citizens need to be scientifically literate, i.e., having a critical understanding of the processes and products of science and technology and being able to deal with the associated socio-scientific issues (OECD, 2016).

In order to address the abovementioned challenges science teachers play a key role. Nevertheless, a model of science education mainly based on the explanation of scientific facts, laws and theories may not be enough to educate scientifically literate citizens (Ariza, Quesada, Abril & García, 2016). Therefore, it is necessary to support teachers in adapting their classroom practices, in order to better respond to these educational demands. But, what kinds of pedagogies support the efficient achievement of these learning outcomes? Inquiry-Based Learning (IBL), Socio-Scientific Issues (SSI), and Citizen Education (CE) are different educational approaches that have been advocated by experts and different political documents as means to address current challenges in science education (European Commission, 2007, 2015; Sadler & Dawson, 2012). The European project PARRISE (Promoting Attainment of Responsible Research and Innovation in Science Education) has successfully developed a model for science education which integrates these four components (http://www.parrise.eu). PARRISE is an international project funded within the Seven Framework Program by the European Union, which involves 18 institutions from different European countries. The main goal is to develop a research-based model for supporting teachers to promote RRI through science education. The model developed is called Socio Scientific Inquiry Based Learning (SSIBL) and has been described and discussed somewhere else (Levinson & the PARRISE consortium, 2017). Starting from an RRI context and making links to powerful socio-scientific scenarios, the SSIBL model empower teachers to work with students in the map of the controversy and in the development of democratic informed opinions, which should lead to responsible and responsive actions (Romero-Ariza, Abril & Quesada, 2017).

Supporting teachers to uptake SSIBL is a challenging endeavor, which requires adequate programs for teacher initial education and continuous professional development consistent with the methodological changes being promoted.

Taking into account the above-mention background, the objectives of the present work are:

1. To present a research-based model of teacher professional development (TPD) to promote scientific literacy and RRI though science education.
2. To discuss the process of development and validation of some instruments to measure teachers' beliefs about how science education should be taught and learnt and the science education model being promoted.
3. To evaluate the impact on teachers' beliefs of a TPD program for promoting RRI through science education.

A RESEARCH-BASED PROGRAM FOR TEACHER TRAINING

In the following we draw on the specialised literature about teacher professional development in order to determine what makes a teacher training program effective in terms of its impact on teaching practices. The main goal is to provide a research basis for the design of a program intended at equipping teachers with the knowledge, skills and dispositions necessary to promote RRI through science education.

Teacher beliefs are known to play a key role not only on teaching practices, but also on teachers' acceptability of innovation and potential change (Basturkmen, 2012; Buehl & Beck, 2015; Donnell & Gettinger, 2015; Glackin, 2016; Herrington, Bancroft, Edwards & Schairer, 2016; Hofer, 2006; Lebak, 2015; Wong & Luft, 2015).

Trying to unpack the complex relationship between beliefs, practices and change, Leback (2015) shows that initially espoused beliefs were often inconsistent with enacted practice and some beliefs emerged as more salient than others for influencing practice. The analysis indicates that change in both beliefs and practice was an interactive process mediated by collaborative and self-reflection through teachers' active participation in the process (Leback, 2015).

Along with needs to take into account teachers' previous beliefs and experiences, the review conducted by Luft and Hewson (2014) highlights other key components of effective teacher professional development. These authors emphasize the importance of providing long-term support, linking innovation with science curricula and focussing on both, science content knowledge and pedagogical content knowledge. The use of specialised techniques for teacher professional development and the promotion of specific teaching competences are also highly recommended (Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003).

Based on the above research results, we have designed a program for teacher professional development that builds on teachers' beliefs, makes explicit links to science curricula, focus both on science knowledge and pedagogical content knowledge, implements specific techniques for teacher professional development and provides multiple opportunities for communication, collaboration and reflection (Ariza, Quesada, Abril & García, 2016; Loucks-Horsley et al., 2003; Luft & Hewson, 2014; Penuel, Fishman, Yamaguchi & Gallagher, 2007).

As previously mentioned, the ultimate goal of the designed TPD program is supporting teachers in the education of future citizens able to actively participate in RRI. The program encompasses a set of successive TPD activities articulated in seven phases, which place teachers into different roles: teachers as learners, teachers as designers and teachers as reflective practitioners:

Phase 1: Building on teachers' beliefs and concerns
The main goal of this initial phase is to provide teachers with opportunities to express their beliefs on science teaching and learning. This activity promotes teachers' engagement and allows educators to identify teachers' epistemic beliefs and build on them to enhance impact on teaching practices.

Phase 2: Highlighting links with the Spanish curriculum
The initial activity to make participants' beliefs explicit is followed by an open discussion on current challenges in science education related to the promotion of students' competences, critical thinking and scientific literacy. Teachers are encouraged to identify those learning outcomes within the Spanish policy documents; afterwards, they will be given the opportunity to reflect on how the SSIBL model can assist them in bringing about these learning outcomes.

Phase 3: Experiencing the educational potential of SSIBL as learners
In this phase teachers are encouraged to inquiry on a trendy socio-scientific issue in order to make informed-decisions. In the process they will really experience the SSIBL approach as students.

Phase 4: Reflecting on students' learning through SSIBL
After experiencing SSIBL as learners, teachers are asked to reflect on what their students could learn through these kinds of activities. Additionally, they are invited to identify links between the potential learning outcomes from SSIBL activities and curricular recommendations for science education.

Phase 5: Developing specific teaching skills
The enactment of the SSIBL model requires an important change in the classroom culture. Teachers will need to successfully engage students and support them to productively inquire about relevant socio-scientific issues and promote reasoning, deliberation and informed decision-making. Thus, our program includes activities to develop specific teaching skills related to the identification and design of relevant SSI scenarios and the appropriate use of questions and assessment to support the pursued learning outcomes (Ariza et al., 2016).

Phase 6: Design of SSIBL classroom activities
This phase is intended at rooting teacher professional development into daily practice at school. For this purpose teachers are encouraged to have a look at the media and select a recent new dealing with a topic of interest to their students. The topic has to be related to current scientific advances and its implications, be controversial and provide opportunities to get a better understanding, as well as the development of informed

opinions in students. Additionally, they are asked to identify connections with the existing curriculum, define learning outcomes and reflect on how to assess the process.

Phase 7: Reflecting back on how to improve the process
The final phase has a two-fold purpose: to promote students' communication and mutual learning and to provide opportunities for reflection and improvement. In this phase teachers presents their SSIBL activities to the rest of the group, discuss challenges and reflects on how to improve them.

METHODOLOGY

The purpose of this study is to demonstrate that our course based on SSBIL increases pre-service teacher's beliefs and knowledge related to that methodology. We have used a quasi-experimental pre-test post-test research design with pre-service teachers of primary education participating in general Science Education subject where our SSIBL course was embedded. In this study, the measurements have been done using some instrument developed as a part of the research process.

INSTRUMENTS: DEVELOPMENT, REFINEMENT AND VALIDATION

This section describes the process of refinement of an instrument originally developed to measure pre-service teachers' attitudes, beliefs and knowledge towards SSIBL approaches. Some of the items of the questionnaire express traditional visions of science education in which teachers use practical work to demonstrate scientific knowledge or provide correct and precise answers to problems. Other items reflect the main principles underlying the SSIBL model. In contrast with traditional visions, the SSIBL model recognises the importance of bringing authenticity into the classroom by connecting science education with current socio-scientific and intends to promote students' active engagement in inquiry and argumentation. Special emphasis is placed on the evaluation of different ideas and perspectives as an important requirement for educating critical and responsive citizens.

The refined instrument comprises 17-items that incorporate different constructs related with traditional and advanced pedagogies, as well as with the relevance and authenticity. The revised instrument was found to exhibit adequate ranges of internal consistency and reliability. As stated for some authors, labelling of constructs is a theoretical, subjective and inductive process (Pett, Lackey et al. 2003, p. 9) and respond to previous experience and needs regarding the underlying theory. Therefore "the meaningfulness of latent factors is ultimately dependent on researcher definition" (Henson & Roberts, 2006). We thought that chosen labels of constructs in this study reflect our theoretical and conceptual intent concerning SSIBL framework.

As stated for Romine et al. (2013), some of the challenges researchers faces in using instruments to measure attitudes and beliefs in science education is that they may be too closely tied to a particular project, length instrument format, limited reporting of psychometric, instrument that cover too many construct that are not sufficiently operationalized and last but not least some concerns related to validity (Romine et al., 2013, p. 264). Although these words are associated within the STEM education, measurement of students´ attitudes it could be extended to researcher concerns along the development or application of a new instrument.

Thus, sharing these concerns, to measure pre-service teacher beliefs regarding main dimension of our SSIBL framework, we decide to face the development of a validated instrument. Once this instrument was reliable and validated we could, not just identify pre-service teacher's beliefs, but also to measure what has been the effect of a SSIBL instruction in term of positive evolution of the pre-service beliefs and gains.

In this section we will present two instruments as a part of our main research exploring pre-service teachers SSIBL beliefs. The second instrument (questionnaire B) is a shorter and improved version of the first one (questionnaire A).
Based on some main dimensions emerged form SSIBL framework (Levinson, 2017) and specialized literature on SSI and IBL we developed a series of Likert-scale statements that conformed our first version of the questionnaire (Quesada, Ariza & Abril, 2017a).

The preliminary version consisted of a total number of 60 items organized in three main sections related to Inquiry-Based Learning Socio-Scientific Issues and Evaluation. For the survey, different sections were headed as "*In an inquiry-based learning setting …*", "*When using IBL…*"; "*To use SSIBL…*", "*When using SSI…*" and "*About evaluation…*". Based on our content research criteria, we mainly articulated those statement in 5 dimensions (Quesada, Ariza & Abril, 2017b) designated as **[GI-IBL]** (general issues regarding Inquiry Based Learning), **[G-IBL-D]** (guiding inquiry-based learning and deliberation), **[MPC]** (mapping controversy), **[AUT]** (Authenticity) and **[EVA]** (evaluation). We designated them regarding some teachers´ competencies defined at SSIBL framework. After we made that set of 60 statements, we submitted the questionnaire to 2 experienced science educators and we collected their feedback. We relied on these researchers to provide feedback regarding to what extend each statement were appropriately allocated within each dimension and to what extend the items could be refined to a better understanding of the meaning and within our research context. After experts' feedback, we made some minor changes in terms of rewritten some items and/or delete others. A final revisited version included a total number of 54 items. For each statement, pre-service teachers had to indicate to what extend they agree on a four-type Likert scale ranging from score 1 as "completely disagree" to score 4 as "completely agree".

Correlation between variables suggested to perform a factorial analysis. The KMO (Kaiser-Meyer-Olkin) sampling adequacy ratio reached the value of 0.776 and Bartlett's test of sphericity χ^2 (378) was 1590.40 ($p < .001$). Through these indicators a deep analysis of anti-image matrix, deemed that the answers were related, justifying the fulfillment of this analysis (Field, 2009). We carried out a previous exploratory factor analysis which seemed to show a structure of ten factors using the *eigen value* as cut-off, and eight component using the criteria of scatterplot (extraction method and rotation: principal component analysis with Varimax). The previous Exploratory Factor Analysis (EFA) on a reduced number of X statements showed a covariance value explained of 57 % for a total number of 8 components. Loading factors of the rotated components oscillated between 0.4 and 0.7 (for our sample size these should be approximately 0.420) (Quesada et al., 2017b).

These EFA results in terms of grouping variables and factor content through strictly statistical validation analysis, made difficult to interpret and classify the items according to the original content criteria that researcher proposed. Thus, we thought that this complex correlation among variables and dimensions revealed a high intricacy to have a composite validated instrument which gathered almost all main features for SSIBL teacher's competencies, as we originally pretended. This is understandable and reasonable in view of the strong interconnections between different SSIBL pre-service teacher competencies defined. For example, "asking questions that promote research" can be related to the ability to "map the controversy" and also with the perception of "authenticity". Thus, our content analysis revealed the limitations of grouping items into component and treating items solely on statistical outcomes.

Consequently, we decided to submit the questionnaire to a deep review. We examined the component structure, loadings outcomes and Cronbach's alpha from our initial EFA on questionnaire A. Then, we took some decision to eliminate items and just select those statements that fitted some of the original scales defined by researcher and with acceptable values of reliability for a composite construct and also for subscales suggesting some component structure. Considering some literature recommendations for the minimum statements for subscales, we added some new items (Table 1). Therefore, we decide to propose a new range of the Likert scale from 1 to 7. Table 1 shows some interconnections and redefinition of scales and components comparing questionnaire A and B.

Table 1
Instrument A and Instrument B subscales comparison

Instrument A		**Instrument B**	
(GI-IBL)		Q1 (2*), Q2 (3*), Q3 (11*), Q4 (16*)	**(TRP)**
	4,6,7,9	Q5(6), Q6(9)	
(G-IBL-D)	12,**16***,17*, 21,27	Q7(19), Q8 (21), Q9 (23), Q10 (26), Q11 (N1),Q12 (N2)	**(ADP)**
(MC)	34,35,36,39*	Q13 (35), Q14 (N3)	
(AUT)	41,42,43,44	Q15(42), Q16 (43),N4 (Q17)	**(REL)**

N_x: New items
* Inverted statements
Qx: Renumbering and rewording items for instrument B. In brackets, original numbering in Instrument A

A final version for instrument B (annex I) consisted of 13 statements retained from questionnaire A. New 4 items (Q11, Q12, Q14, Q17) were redefined and incorporated in their corresponding section (N1-N4). Statements were grouped within 3 components which were named as "Traditional Pedagogy" **[TRP],** "Advanced Pedagogy" **[ADP],** and "Relevance & Authenticity" **[REL].**

After that, we piloted the questionnaire with a sample of 318 pre-service teachers enrolled at different compulsory subjects related to Science Education. For instrument B, the KMO sampling adequacy ratio reached the value of 0.887 and Barlett´s sphericity revealed a $\chi 2$ (136)=2043, p<0.001. These data estimated that the answers were substantially related, justifying the realization of an exploratory factor analysis (Table 2).

This EFA suggested that **[ADP]** could be explained through two components. Thus we have defined them as "Student Autonomy" **[STA]** and "Quality criteria for mapping controversy and deliberation" **[QMD].** We should report that some items showed cross-loading factors but with values behind 0.5. We calculated the composite and subscale reliability. Reliability for the whole instrument (all items included in the analysis, 17) revealed a Cronbach's alpha of 0.870. For the **[TRP]** was 0.721, for **[ADP]** was 0.875, presented as **[STA]** was 0.844 and **[QMC]** was 0.828; **[REL]** presented a value of 0.601. For this last component, as Cronbach's alpha in sensible to number of statements, this values could be acceptable because we only have 3 statements within it. All these Cronbach´s alpha values pointed out to a good level of reliability and item stability of the instrument.

Table 2

The rotated component matrix factor loadings for the 17-items Questionnaire B

	Component			
	1	2	3	4
Q1 (TRP)			.700	
Q2 (TRP)			.792	
Q3 (TRP)			.769	
Q4 (TRP)			.511	
Q5 (ADP)(STA)		.817		
Q6 (ADP) (STA)		.820		
Q7 (ADP) (STA)		.698		
Q8 (ADP) (QMD)	.534			
Q9 (ADP) (QMD)	.700			
Q10 (ADP) (QMD)	.598			
Q11 (ADP) (QMD)	.672			
Q12 (ADP) (QMD)	.563			
Q13 (ADP) (QMD)	.623			
Q14 (ADP) (QMD)	.543			
Q15 (REL)				.565
Q16 (REL)				.766
Q17 (REL)				.712

Extraction method: Principal component analysis:
Rotation Method: Varimax with Kaiser normalization
Rotation converged in 7 iterations. Variance explained: 59%

ANALYSIS, SAMPLE AND RESULTS

Analysis and sample

Data processing and analysis from this study were done using the SPSS statistical program for MAC V.22.0.

SSIBL modules were part of compulsory subjects related to Science Education for pre-service teachers. These subjects are part of the degree of primary education at University of Jaén. Participants were pre-service teachers (generalists) with different levels of training and multi-disciplinary backgrounds. This course was implemented along different academic years: i) 2015-2016, Cohort 1 ($N_{pre\text{-}test}$= 141 $N_{post\text{-}test}$=117, $N_{fit\ pre\text{-}post}$= 95), and Cohort 2, ($N_{pre\text{-}test}$= 107, $N_{post\text{-}test}$= 75, $N_{fitpre\text{-}post}$= 57); ii) 2016-2017, Cohort 3 ($N_{pre\text{-}test}$= 113 $N_{post\text{-}test}$= 109, $N_{fit\ pre\text{-}post}$= 98). Surveys were administrated using the google-formularies tool before and after the SSIBL course to that different cohorts of pre-service teachers. To fill questionnaires was not compulsory for pre-service teachers enrolled in the SSIBL course.

Results

Definition of subscales (using the researchers content approach) for instrument A has been quite valuable in terms of findings and results. This decision was supported for moderate Cronbach´s alfa for that subscales (0.530-0.856) (tables 3-4).

A deep analysis using those subscales an item-by-item approach for instrument A, showed that those gains and improvements had not equally been grasped within all pre-service facets regarding SSIBL.

Using this approach, main findings regarding some gains for SSIBL competences were related with different dimensions within that questionnaire such as: General Issues Regarding IBL (GI-IBL), Guiding IBL and Deliberation (G-IBL-D), Mapping Controversy (MPC) and Authenticity (AUT). As composite scale, pre-test result showed a value of 52.77 and post-test showed a value of 56.97 for cohort 1. This value meant a difference of total gain of 4.20 (this represent a gain of 6 % on the composite scale, Table 3). For cohort 2 this gain represented a 7%. Non-parametric tests revealed some significance differences ($p<0.05$) for pre and post results. In terms of size effect, we can describe it as small effect but close to medium (d: -0,99 r=-0,44; small effect $0.5<d>0.2$, medium effect $0.8<d>0.5$). What we really want to highlight is that in almost all statements, and instead, subscales and SSIBL facets, there were some pre-service teacher's gains regarding beliefs and knowledge related to SSIBL competencies.

Table 3

SSIBL pre-service teachers beliefs for pre-test and post-test Cohort 1 (instrument A)

	Pre-test Mean (SD)	**Post-test** Mean (SD)	**Cronbach´s alfa (post)**
(GI-IBL)	13,04 (1.42)	13,81 (1,73)	0.690
(G-IBL-D)	15,14 (1.74)	16,43 (1,80)	0.590
(MPC)	11,77 (1,46)	13,07 (1,44)	0.578
(AUT)	12,86 (1.46)	13,66 (1,58)	0.628
Composite Scale (GI-IBL)+(G-IBL-D)+ (MC)+(AUT)	52.77 (4.12)	56.97 (5.18)	0.851

Table 4

SSIBL pre-service teachers beliefs for pre-test and post-test Cohort 2 (instrument A)

	Pre-test Mean (SD)	**Post-test** Mean (SD)	**Cronbach´s alfa (post)**
(GI-IBL)	12.42 (1.71)	13.50 (1.68)	0.723
(G-IBL-D)	14.98 (1.91)	16.33 (1,89)	0.532
(MPC)	11.89 (1.83)	13.08 (1.77)	0.659
(AUT)	13.14 (1.84)	14.13 (1.78)	0.820
Composite Scale (GI-IBL)+(G-IBL-D)+ (MC)+(AUT)	52.43 (5.23)	57.05 (5.46)	0.856

Following a similar analysis done for cohort 1 and 2 but now using questionnaire B for cohort 3 we found that main gains took place in those statements related to an informed vision of teaching Science within our SSIBL framework, **[ADP]**. Post-test results showed gains in almost all different statements within all scales defined (Table 5). Nevertheless, gains in **[TRP]** and **[REL]** have shown that pre-service teachers did not acquire significant evolution in those dimensions. We can say that they kept their beliefs regarding some facets within this dimension. This results are aligned with research literature which reported that some teacher's beliefs are resistant to be changed**.** Regarding **[REL]** factor, pre-service teachers´ scores showed a very positive values before the SSIBL course started, which indicated a well-informed pre-service perception about of the authenticity in a Science Educational setting (mean score: 19.23 over 21 in pre-test and 19.45 over 21 in post-test, size effect 0.06 "irrelevant"). A possible explanation is that our sample is biased regarding their previous background and specific educational subjects which emphasized the pedagogical potential of authentic context. On the other hand, a result to be highlighted is the improvement of participants' beliefs and knowledge related to the **[ADP]** dimension. This dimension integrates the key features of the science education model being promoted and offers a promising result in the attempt to empower teachers as key players in the education of a society ready for RRI.

Table 5

Pre-test post-test results for Cohort 3 (instrument B used)

	Pre-test	**Post-test**	**Cronbach´s alpha pre-post**
	Mean (SD)	Mean (SD)	
(TRP) INV	8.75 (3.12)	8.37 (4.41)	0.610- 0.757
(ADP)*	56.93 (7.28)	60.98 (6.68)	0.847-0.890
(ADP)(STA)	17.37 (2.93)	18.90 (2.16)	0.804-0.779
(ADP)(QMD)	39.45 (5.07)	42.08 (4.94)	0,776-0.845
(REL)	19.23 (1.56)	19.45 (1.77)	0.423-0.689
ALL*	84.90 (7.20)	88.80 (6.27)	0.645-0.712

INV: inverted
*p<0.05

CONCLUSIONS

This work presents the research foundation of a teacher professional development program to equip teachers with the knowledge, skills, values and dispositions necessary to become key promoters of RRI through science education. Additionally, the work focussed on describing the process to design and validate some research instruments to measure teachers' beliefs related to science teaching in general and the science education, model for RRI in particular.

The process of development and validation of instruments has yielded two questionnaires. Statistics methods confirm the internal consistency of both instruments and a structure of components in line with the underpinning theoretical model. The second instruments resulted from a simplification of items and factors taking into account how the key dimensions of the model were interrelated.

The application of both instruments to different cohorts of teachers reveal a positive impact of the teacher professional development program on participant's beliefs and an evolution in line with a science education model for RRI.

This work is part of a broader one intended at getting a better understanding of how to best support teachers to promote RRI through science education. Data from the pre-post study of teachers' beliefs have been complemented with a qualitative approach including case studies and the analysis of the RRI-oriented classroom activities designed by teachers (Romero-Ariza et al., 2017).

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ANNEX I. QUESTIONNAIRE B

Instructions: *Please select to what extend do you agree with the following statements (1 completely disagree to 7 completely agree) (*)*

When using a SSIBL approach for science education***…***

Q1 …practical tasks have to be designed to demonstrate what teachers have explained before.

Q2 …tasks have to be solved by giving a precise and clear answer.

Q3 ... the teacher should finally show the correct answer.

Q4 ...the teacher has to make sure that students follow his/her explanations

Q5 ...students should be given opportunities to express and explain their own ideas.

Q6 … students should discuss and evaluate different ideas and strategies.

Q7 … after making a question, teachers have to give enough time to student for thinking and responding.

Q8 … students have to listen to, respect and evaluate different ideas.

Q9 …teachers can build on their students' explanations to respond to other students who are their schoolmates.

Q10 …students think about their own wrong ideas.

Q11…teachers support students in the development of evidence-based arguments.

Q12… different ideas are evaluated according to their potential to explain evidence.

Q13 … students are given opportunities to evaluate both scientific and moral/ethical arguments.

Q14 … teachers support students to reflect about the social, economical and ethical consequences of scientific advances.

Q15 …it is important that students choose their own topics for inquiry.

Q16 … it is important make connections with students´ daily experiences.

Q17… students get deeply engaged in science learning when they can see the utility to what they are doing.

*Authors' notes: the questionnaire was originally developed and validated in Spanish. For the purpose of this article the statements have been translated into English, thus meanings might varied slightly. Likert *Scale numbers were explicit shown.*

Statements are distributed into three main components identified as:

- Traditional Pedagogies [TRP]: Q1-Q4
- Advanced Pedagogies [ADP]: Q5-Q14
- Relevance and Authenticity [REL]: Q15-Q17

Assessing Attitudes About Responsible Research and Innovation (RRI): The Development and Use of a Questionnaire

Ron Blonder
ron.blonder@weizmann.ac.il | Weizmann Institute of Science, Israel

Shelley Rap
shelley.rap@weizmann.ac.il | Weizmann Institute of Science, Israel

Esty Zemler
estyzemler@gmail.com | Weizmann Institute of Science, Israel

Sherman Rosenfeld
shermrosenfeld@gmail.com | Weizmann Institute of Science, Israel

Abstract

The purpose of this article is to trace the development, validation and use of a questionnaire for evaluating teacher and student attitudes regarding Responsible Research and Innovation (RRI). RRI is a framework, developed by the European Union, which provides general standards to guide the development of trust and confidence of the public regarding advances in science and technology, and the development of their participation in these advances. The article traces the development of the RRI framework and focuses on its educational component, whose goal is to sensitize teachers and students into "RRI-based thinking" about past and current scenarios regarding the development of science and technology advances. The use of the RRI questionnaire is demonstrated through the presentation of teacher and student data taken before and after the implementation of RRI-based modules, developed in the EU-funded Irresistible Project. Based on this work, we suggest that the RRI questionnaire can be used to assess the development of attitudes regarding RRI across diverse populations of teachers, students, scientists, consumers and other members of the general public.

Key Words

Responsible Research and Innovation (RRI), Socioscientific issues (SSI), Science Education, Questionnaire, High school, Teachers' Attitudes.

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Avaliação de Atitudes Sobre Inovação e Investigação Responsáveis (IIR): Desenvolvimento e Uso de um Questionário

Ron Blonder
ron.blonder@weizmann.ac.il | Weizmann Institute of Science, Israel

Shelley Rap
shelley.rap@weizmann.ac.il | Weizmann Institute of Science, Israel

Esty Zemler
estyzemler@gmail.com | Weizmann Institute of Science, Israel

Sherman Rosenfeld
shermrosenfeld@gmail.com | Weizmann Institute of Science, Israel

RESUMO

O objetivo deste artigo é delinear o desenvolvimento, validação e uso de um questionário de avaliação de atitudes de professores e alunos, relativas à Inovação e Investigação Responsáveis (IIR). O artigo descreve o enquadramento do desenvolvimento da IIR e foca-se na componente educacional, cujo objetivo é sensibilizar os professores para um "pensamento fundamentado na IIR", sobre cenários passados e presentes relativos ao desenvolvimento da ciência e aos avanços da tecnologia. O uso do questionário sobre IIR é demonstrado através da apresentação de dados sobre estudantes e professores, recolhidos antes e depois da implementação dos modelos fundamentados sobre IIR, desenvolvidos no âmbito do projeto IRRESISTIBLE, financiado pela EU. Baseados neste trabalho, sugerimos que o questionário sobre IIR pode ser usado para avaliar o desenvolvimento das atitudes face à IIR em diferentes populações de professores, estudantes, cientistas, consumidores e outros membros do público em geral.

PALAVRAS-CHAVE

Investigação e inovação responsáveis (IIR), Questões sociocientíficas (QSC), Educação em ciências, Questionário, Escola secundária, Atitudes dos professores.

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Assessing Attitudes about Responsible Research and Innovation (RRI): The Development and Use of a Questionnaire

Ron Blonder | Shelley Rap | Esty Zemler | Sherman Rosenfeld

BACKGROUND

Responsible Research and Innovation (RRI) represents a contemporary view of the connection between science and society. This concept has been developed by the European Union and is the basis of several EU projects. The goal of RRI is to create a shared understanding of the appropriate roles of those who have a stake in the products of science and technology, including governments, businesses, scientists, technologists, educators, the general public and NGOs. The hope is that through the creation of such a shared understanding, mutual trust and confidence will result, along with safe and effective systems, processes and products of innovation (Sutcliffe, 2011).

One way to understand RRI is to see it as

> a transparent, 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 and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society). (Schomberg & Von Schomberg, 2013, p. 19)

Another definition of RRI is built on six dimensions: 1. Engagement, 2. Open Access, 3. Ethics, 4. Science Education, 5. Gender Equality, and 6. Governance. These dimensions were published and recommended by the Horizon 2020 framework of the European commission (2015). More detailed description of the 6 RRI dimensions is provided in an earlier publication (Blonder, Zemler & Rosenfeld, 2016).

RRI is not only a framework to promote responsible scientific research and technological development, but it also has an educational component, whose goal with teachers and students is to develop the skills and attitudes associated with "RRI-based thinking" about past and current scenarios regarding the development of science and technology advances. When working to achieve this goal, an evaluation tool is needed to assess teacher and student attitudes relating to RRI.

GOALS

The goals of this article are to trace the development and use of a questionnaire for evaluating teacher and student attitudes regarding RRI. More specifically:

- To develop and validate a questionnaire attitudes about responsible research and innovation (RRI).
- To illustrate the use of this questionnaire within an evaluation study.

The article begins with a brief history of the development of the RRI framework, followed by a presentation of how the RRI questionnaire was developed and used, within the context of an EU-funded project called Irresistible (Irresistible, 2015). We close by exploring the possibility that the RRI questionnaire can be used to assess the development of attitudes regarding RRI across diverse populations of teachers, students, scientists, and members of the general public.

THE DEVELOPMENT OF AN EDUCATIONAL FRAMEWORK TO ASSESS ATTITUDES ABOUT RRI

RRI can be seen as a new contract between science and society, a "social innovation" which relates to the roles and responsibilities of the many stakeholders involved in the processes and products of science and technology, including scientists, technologists, businesses, governments, citizens, NGO's, teachers and students (Rip, 2014).

The roots of the educational framework for RRI can be seen in the use of socio-scientific issues (SSI) within the science curriculum. SSI was used as early as 1986 (Fleming, 1986) but its development as a recognizable framework for research and practice in science education emerged only in the late 1990's. SSI can be defined as "social dilemmas linked to science about which citizens have to make decisions" (Molinatti, Girault & Hammond, 2010, p. 513). This definition reflects the view that "all aspects of science are inseparable from the society from which they arise" (Sadler, 2004, p. 513). According to this view, it is important to recognize that there are links between science, politics and business and that there are many different actors in the scientific-technological enterprise (Simonneaux, 2014).

Therefore, it is important for teachers and students to develop "moral-ethical reasoning" so that they will be able to take into account the different points of view of different social groups when considering real-world socio-scientific issues, which by nature are controversial, preliminary and under debate (Sadler & Zeidler, 2005; Zimmerman et al., 2001). In SSI, students are encouraged to understand how different stakeholders have different perspectives, i.e., *different ways to perceive and interpret the same issue*; in this regard, it is important to distinguish perspectives from positions (where one stands on an issue) and orientations (how one approaches an issue in relation to others) (Kahn & Zeidler, 2016). SSI "entails the examination of competing claims, values, and evidence, thoughtful deliberation and negotiation, and the ability (to) navigate the concept of optimality throughout this process" (Zeidler, 2014, p. 720).

Developing this type of reasoning by teachers and students is one of the educational goals of RRI scenarios, in which teachers and students consider how different stakeholders can cooperate to produce optimal scientific and technological products. One way to evaluate RRI is to assess teacher and student attitudes regarding the above-mentioned 6-dimensions of RRI (Apotheker et al., 2016; Blonder et al., 2016). If we can produce an appropriate tool to assess attitudes relating to each of these dimensions and to the perceived responsibility of the different stakeholders, we may be able to evaluate how well teachers and students internalize the intended educational outcomes of RRI.

THE CONTEXT OF THE STUDY

In order to understand the context in which the questionnaire was developed and used, we need to understand the cultural environment in which it was developed. In the last decade, several EU-sponsored projects have been devoted to integrating RRI into science education. The general approach has been to provide relevant curricular materials to Communities of Teachers (CoLs), in order for them to engage their students in socio-scientific issues via IBSE (Inquiry-Based Science Education) strategies. For example, the "ENGAGE" project offers three kinds of materials: dilemma lessons, problem-solution lessons, and scenario-based topics (Okada, Young & Sherborne, 2015). Another example is that "PARRIS" project offers an integrated approach to Socio-Scientific Inquiry-Based Learning (SSIBL). It collects and shares existing best practices across Europe and develops learning tools, materials and in/pre-service training courses for science teachers based on the SSIBL approach. Other examples are described in Blonder, Zemler, and Rosenfeld (2016).

Next will now describe in more detail one of the EU-funded projects to integrate RRI into science education–the Irresistible project, in which the questionnaire was developed.

The Irresistible project (Irresistible , 2015) is an European project in the FP-7 framework aims to make young people more aware about RRI issues, through curricular materials (the Irresistible modules) to be used both in the classroom and in science centers. Ten European countries participated in the three years project (2014-2016). Each partner country has formed a Community of Learners (CoL). Detailed description of the Irresistible project is provided in several recent publications (Apotheker et al., 2017; Blonder et al., 2017) and in the project Website (Irresistible, 2015). Three important features of the project are described below:

CoL:

The modules were developed by a Community of Learners (CoL) composed of a research scientist, high-school science teachers, a member of the local science center and science educators. Each module was based on the research work of a research scientist at the university.

MODULE'S GOALS AND MAIN TOPICS:

The main goal of the Irresistible modules was to foster positive attitudes towards RRI by both teachers and students. Each module that was developed by the different CoLs has its own scientific topic (e.g. the main topic of the Israeli module was the development of perovskite-based photovoltaic cells (Snaith, 2013) within the context of using alternative energy). The topics of the other modules are presented in the Irresistible project website (Irresistible, 2015).

PEDAGOGICAL APPROACH:

The design of the modules was guided by two approaches: (a) the 6E inquiry model, based on Bybee, et al. (2006) and (b) an effort to bridge between formal and informal science education (Fallik, Rosenfeld & Eylon, 2013), which focused on the production of student-designed exhibits, in the tradition of interactive science exhibits.

THE STRUCTURE OF THE RRI QUESTIONNAIRE

With the above 6-dimension definition of RRI in mind (see Table 1), a RRI questionnaire for teachers and for students was developed and validated according the stages presented in Table 2. The questionnaire includes three parts:

ATTITUDES TOWARDS THE RRI DIMENSIONS

This section was included in the teachers' and students' questionnaire. It evaluated their attitudes towards the 6 different dimensions that constitute RRI. The respondents were asked to "determine the degree to which you agree with the following statements

(5 = agree a great deal, 1 = do not agree at all.)". Table 1 presents examples of items in this part according the RRI dimension.

Table 1
Sample of items for each RRI dimension in the RRI questionnaire

RRI dimension	Sample item
(1) Engagement	To decide what topics to research, scientists should consult with community representatives, such as people who work for nature conservation, human rights, and consumer rights.
(2) Open access	Scientists should spend part of their research budget to present their research online, in a free and open way.
(3) Ethics	Having high ethical standards can help ensure high quality results in science and technology.
(4) Science education	The science curriculum in schools should include topics like how science solves society's problems.
(5) Gender equality	Women and men should have equal rights and responsibilities in scientific research.
(6) Governance	The government needs to regulate scientific research institutions.

RESPONSIBILITY OF DIFFERENT STAKEHOLDERS IN THE REAL WORLD AND IN AN IDEAL WORLD

This section was given only to the teachers. It started by presenting by the following question: "The following groups can each take different degrees of responsibility for the consequences of research and innovation in society and the environment. In an *ideal world*, what degree of responsibility should each of these groups take?" They were then presented with a list of the following actors: the Government (policy planners), Academic Institutions, Scientists, Educators, Environmental Organizations, Non-profit organizations, Consumers, Businesses, the Printed and Electronic Media. The teachers were asked to rate the degree of responsibility for RRI in an ideal world (1= to a very small degree ; 5 = to a great degree).

Next they were asked to do the same in the real world: "In your country today, what degree of responsibility for RRI does each of these groups take? (1= to a very small degree ; 5 = to a great degree)".

TEACHER EXPERIENCE IN INTEGRATING SOCIAL ISSUES IN SCIENCE EDUCATION

This section was given only to the teachers. It presented the following four questions: How often have you participated in discussions in science classrooms that deal with ethical issues of science and society? (For example: "Should we pursue new nuclear technologies?" or "What are the risks and benefits of nanotechnology applications?") (1= never ; 5 = often). How often have you participated in classes or workshops that deal with ethical issues of science and society? (1= never ; 5 = often). How often have you taught ethical issues relating to science and society? (1= never ; 5 = often). Which ethical issues in science and society do you think are relevant in regard to developing new technologies for _______? (Each partner was asked to write here the name of the domain topic of the module which was taught)?

In the first three questions, the prior experience of the teachers was collected in a Likert scale (1= never ; 5 = often). These questions track the teachers' personal experiences as participants in discussions which involve SSI (socio-scientific issues) and their professional experience in conducting science lessons that integrate ethical and social aspects with science and technology. The fourth question is an open question in which the respondents are asked to suggest and write social issues that relate to the scientific topic of the module they would learn and teach.

THE DEVELOPMENT OF THE RRI QUESTIONNAIRE

The process of developing the RRI questionnaire included several stages of validation, a test of internal consistency to support its reliability, and its multicultural adaptation in the international community of the Irresistible project. The implementation process is summarized in Table 2 (on the following page), and further elaborated in the text.

STAGE 1: CREATING ITEM POOL

At the first development stage the Weizmann team created a pool of items (in Hebrew) that were based on the RRI literature and covered the 6 RRI dimensions. Forty-four items were gathered in this stage.

STAGE 2: FIRST EXPERT VALIDITY CHECK

Three experts in science education who were part of the Weizman team's CoL discussed the items' content and validated that the phrasing reflected the meaning of the RRI dimensions that each item represented. The three experts also selected 5 items for each of the 6 RRI dimensions to produce a 30-item questionnaire.

Table 2

The implementation process of the RRI questionnaire

	Stage	Description
1)	Creating item pool*	Literature review Item pool with 44 items
2)	First expert validity check*	Checking by 3 experts in science education Choosing 5 items per each RRI dimension
3)	Translation to English and inter-translator reliability	Two translations were completed and compared in order to obtain inter-translator reliability (Anastasi, 1988)
4)	Second expert validity check and multicultural adaptations	Checking by 10 experts in Science education from 10 EU countries Rephrasing the items according experts' comments
5)	Pilot international implementation	Translating to 10 languages 54 teachers in 10 countries
6)	Reliability analysis & third expert validity check*	Alpha-Cronbach internal consistency test for each dimension Re-examining the items in each RRI dimension Choosing 4 items for each dimension (based on alpha-Cronbach results)
7)	First international implementation	120 teachers 1160 students 10 different countries
8)	Reliability analysis (teachers and students separately)*	Alpha-Cronbach internal consistency test for each dimension Pearson r correlation test for each dimension Choosing 2 items for each dimension (based on correlation test) Alpha Cronbach internal consistency test for the whole questionnaire (RRI construct)
9)	Final scale*	A RRI scale consist of 12 items
10)	International implementation of the final scale	Pre-post administer of the final questionnaire Pearson r correlation test for each dimension* Alpha Cronbach internal consistency test for the RRI construct*

* These stages were conducted only for the first part of the questionnaire (attitudes towards the RRI Dimension).

STAGE 3: TRANSLATION TO ENGLISH AND INTER-TRANSLATOR RELIABILITY

Based on Anastasi (1988), the questionnaire was translated to English by two translators. Two translations were compared by the development teams and the meaning of the translated items was compared to the meaning of original items in Hebrew in order to obtain inter-translator reliability.

STAGE 4: SECOND EXPERT VALIDITY CHECK AND MULTICULTURAL ADAPTATIONS

The 30 items were sent to all the partners (10 experts in science education in ten European countries) for expert validation, and modifications were made according the comments the partners sent. For example the item: "A research director that needs 'work around the clock' should not hire women who have young children." (NEGATIVE statement regarding the gender dimension), was modified to: "A research director that needs 'work around the clock' should not hire pregnant women" according the Turkish suggestion to emphasize the dilemma. In another suggestion, the item: "A scientist should be involved in programs to make his/her research accessible to students and their teachers in the science classroom" was modified to "Scientists should be involved in programs to make their research accessible to students and their teachers in the science classroom." This change was made in response to a suggestion of the Finish team that this issue is not about just one scientist. In other items some modifications were made to keep the English simpler and to share the same meaning in the different countries. These modifications helped to clarify the meaning of the items for the international community of teachers and students.

STAGE 5: PILOT INTERNATIONAL IMPLEMENTATION

The modified version (pilot version) was sent to all partners and was translated into 10 languages. In the pilot trial, the teachers from all the CoL members in all countries (N=54) filled the questionnaire. Appendix 1 presents the pilot stage of the questionnaire.

STAGE 6: RELIABILITY ANALYSIS AND THIRD EXPERT VALIDITY CHECK

The items were again examined by three experts in science education for their valid representation of the RRI dimension and more coherent language was applied. For example, instead of using different terms to describe academic research and researchers (e.g., research institutes, universities, academic institute, and scientists), only one term was chosen (scientists), because this term is clearly understood by students and teachers who are not part of the academic culture. In addition, based on alpha-Cronbach test, items were reduced to 4 for each RRI dimension.

STAGE 7: FIRST INTERNATIONAL IMPLEMENTATION

The new version (version 1) of the questionnaire was filled-in by the teachers (N=210) and students (N=1160) in the 10 countries. Appendix 2 presents the questionnaire that was administered in this stage.

STAGE 8: RELIABILITY ANALYSIS

Alpha-Cronbach values were calculated for each of the 6 RRI dimension (teachers and students separately). We therefore decided to choose for each dimension the two items (as shown in Table 3) showing the highest significant correlation (for both students and teachers) and to proceed with a shorted questionnaire that measures the RRI construct. The alpha-Cronbach for the 12 selected items that composed the RRI construct was 0.76 for students and 0.78 for teachers.

Table 3

The selected items for each RRI dimension and their r-correlation value

RRI Dimension	Items	Teachers	Students
Engagement	5,16	0.33***	0.25***
Gender Equality	11,21	0.27***	0.24***
Science Education	9,19	0.24***	0.27***
Open Access	13,23	0.33***	0.34***
Ethics	15,17	0.32***	0.16**
Governance	14,22	0.41***	0.27***

*** p<0.0001

STAGE 9: FINAL SCALE

The final version questionnaire included three sections (1) 12 items to measure the respondents' attitudes towards the RRI construct' (2) a comparison of the respondents' perspectives regarding the responsibility for RRI of different stakeholders in the real world and in an ideal world (only teachers), and (3) measurement of the ability to find socio-scientific ethical issues related to relevant module's scientific topic (only teachers). The results presented in section 3 of this report used the final scale of the RRI questionnaire.

STAGE 10: INTERNATIONAL IMPLEMENTATION OF THE FINAL SCALE

In the last stage, the RRI questionnaire was administered in a pre-post procedure in the second round of the CoL (the second phase of the project. The alpha-Cronbach for the 12 selected items was 0.78 for students (N=3117); and 0.79 for teachers (N=224). The r-correlation between the two items that construct each RRI dimensions are presented in Table 4.

Table 4

The r-correlation value for two items represent the same RRI dimension

RRI Dimension	Students	Teachers
Engagement	0.301***	0.393***
Gender Equality	0.307***	0.253***
Science Education	0.259***	0.245***
Open Access	0.335***	0.407***
Ethics	0.257***	0.304***
Governance	0.344***	0.418***

*** $p<0.0001$

ETHICAL ISSUES

The evaluation was carried out according to the ethical issues and precautions described in the Irresistible Description of Work (Irresistible, 2015). To ensure anonymous analysis of the research data, each surveyed CoL member was represented by a personal code which cannot be tracked back to the respondents' identity but can be used to connect an individual's responses for the pre- and post-tests. According to EU regulations, participating schools, students and parents returned consent forms, also containing information about the research (Irresistible Description of Work, 2013).

USING THE RRI QUESTIONNAIRE IN EDUCATIONAL RESEARCH

The RRI questionnaire was used in ten European countries who participated in the Irresistible project. Teachers who were members in the CoL and their students who learned the Irresistible modules filled the questionnaire in a pre-post procedure. In this part we present the results gained from the Israeli teachers and students, and present them in the context of the results obtained by all the Irresistible teachers and students.

POPULATION

The numbers of teachers and students who completed the questionnaire are presented in Table 5.

Table 5
Number of teachers from the different countries who completed the questionnaire

County	**Teachers who completed the questionnaire**		**Students who completed the questionnaire**	
	Pre	Post	Pre	Post
All	216	225	3181	2332
Israel	28	28	136	78

RESULTS

The results will be presented according the 3 parts of the questionnaire: (1) attitudes towards the RRI dimensions, (2) responsibility of different stakeholders in the real world and in an ideal world, and (3) Teacher experience in integrating social issues in science education. The final scale was used in its on-line version (Each country used the translated questionnaire to its own language, see Table 2 for details).

ATTITUDES TOWARDS THE RRI DIMENSIONS

This part of the questionnaire was administered to teachers who participated in the CoL and to students who studied the Irresistible modules. Tables 6 and 7 present the results of the teachers and students respectively, both regarding the Israeli data as well as the data for the 10 partner countries in the Irresistible project.

Table 6

Pre-post average scores of teachers' attitudes towards RRI and its 6 dimensions, in Israel and in the Irresistible project (Comparison between pre and post values were calculated using two-tailed t-test)

		Engagement	Science Education	Gender Equality	Open Access	Ethics	Governance	RRI
Israel	Pre (SD)	3.232 (0.81)	4.1429 (0.678)	3.428 (0.79)	3.375 (0.845)	3.6786 (0.92)	3.1964 (0.906)	3.508 (0.556)
	Post (SD)	3.538 (1.019)	4.615 (0.454)	3.653 (0.924)	4.307 (0.617)	4.2885 (1.04)	3.9808 (0.932)	4.057 (0.633)
	t	n.s.	3.027**	n.s.	4.598***	2.279*	3.134**	3.389***
All teachers in the Irresistible project	Pre (SD)	3.8687 (0.9)	3.97 (0.803)	4.11 (0.796)	4.089 (0.813)	3.98 (0.885)	3.7189 (0.975)	3.957 (0.576)
	Post (SD)	4.2895 (0.77)	4.449 (0.587)	4.5 (0.672)	4.44 (0.603)	4.277 (0.79)	4.107 (0.89)	4.352 (0.461)
	t	5.175***	7.052***	5.429***	5.07***	3.625***	4.273***	7.926***

*p<0.05, **p<0.01, ***p<0.001

Table 7

Pre-post average scores of students' attitudes towards RRI and its 6 dimensions, in Israel and in the Irresistible project (Comparison between pre and post values were calculated using two-tailed t-test)

		Engagement	Science Education	Gender Equality	Open Access	Ethics	Governance	RRI
Israel	Pre(SD)	3.768 (0.827)	3.87 (0.89)	3.665 (1.06)	3.54 (0.95)	3.8 (0.869)	3.88 (0.85)	3.757 (0.605)
	Post(SD)	4.044 (0.73)	4.12 (0.74)	3.897 (0.97)	3.92 (0.938)	4.02 (0.973)	3.846 (1.14)	3.98 (0.564)
	t	2.448*	2.085*	n.s.	2.89**	n.s.	n.s.	2.693**
All the students in the project	Pre(SD)	3.92 (0.826)	3.746 (0.904)	3.96 (0.92)	3.68 (0.936)	3.74 (0.922)	3.63 (0.933)	3.77 (0.58)
	Post(SD)	4.01 (0.803)	3.85 (0.866)	4.17 (0.917)	3.83 (0.92)	3.84 (0.89)	3.7 (0.926)	3.908 (0.657)
	t	4.098***	4.206***	7.972***	5.569***	4.091***	2.523*	7.654***

* p<0.05; **p<0.01; ***p<0.001

The findings show that in Israel, the process of teacher professional development in the CoL led to a positive statistically significant difference between the pre- and the post-test attitudes of teachers toward RRI as a general construct and for 4 of the RRI dimensions (the dimensions of engagement and gender equality were not statistically significant), as presented in Table 6. The teachers who participated in the Israeli CoLs used the modules that were developed in the project and positively influenced the development of students' attitudes towards RRI (statistically significant for the general construct, and for all the RRI dimensions, except for gender equality, ethics and governance), as presented in Table 7.

Regarding the Irresistible project, the findings show that the process of teacher professional development in the CoLs led to a positive statistically significant difference between the pre- and the post-test attitudes of teachers toward RRI as a general construct and for each of the 6 RRI dimensions that compose it, as presented in Table 6. The teachers who participated in the Irresistible CoLs used the modules that were developed in the project and positively influenced the development of students' attitudes towards RRI (statistically significant for the general construct, and for all the RRI dimensions), as presented in Table 7.

RESPONSIBILITY OF DIFFERENT STAKEHOLDERS IN THE REAL WORLD AND IN AN IDEAL WORLD

When the Irresistible teachers were asked: "In your country today, what degree of responsibility does each specific group take (for the consequences of research and innovation in society and the environment)?" only one significant difference between the pre- and post-test was obtained regarding the degree of responsibility of the NGOs ($p<0.01$). For all the other stakeholders, no differences were found between how teachers perceived the degree responsibility in the real world between the pre- and post-test, as shown in Figure 1. The results of the Israeli teachers are presented in Figure 2. The same trend was obtained by the Israeli teachers: the only statistically significant difference was the NGOs. In both the overall Irresistible data as well as in the Israeli data, the stakeholders considered most responsible for RRI were the scientists and academic institutions, while the stakeholders least responsible for RRI were consumers and educators.

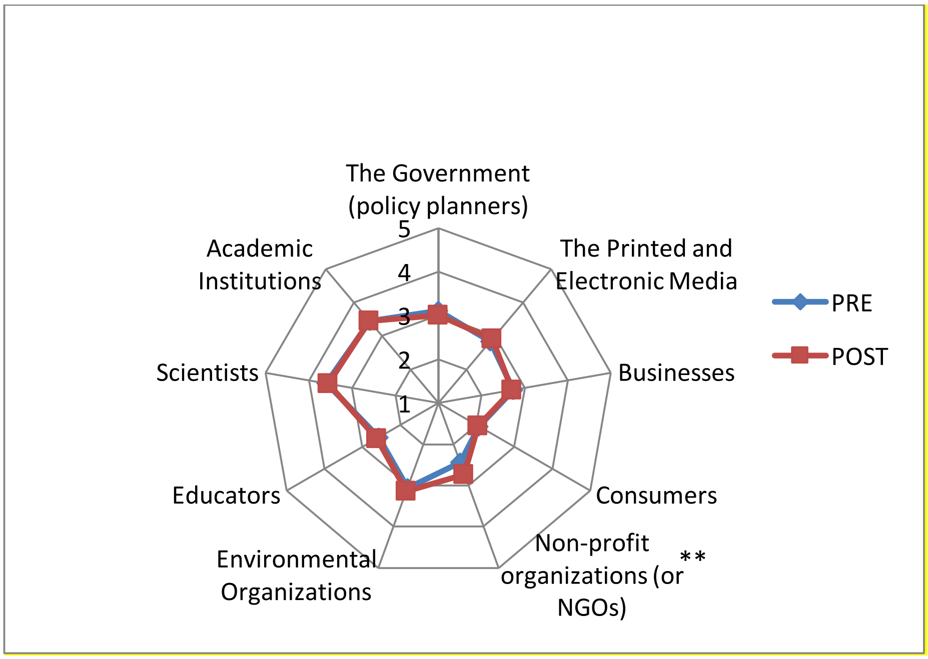

Figure 1. Teachers' perspectives regarding degree of responsibility that each of specific group takes in their country today ("the real world") in the pre- and post-test. This analysis includes all the teachers in the Irresistible project who filled in the questionnaire (N=213). ** p<0.01.

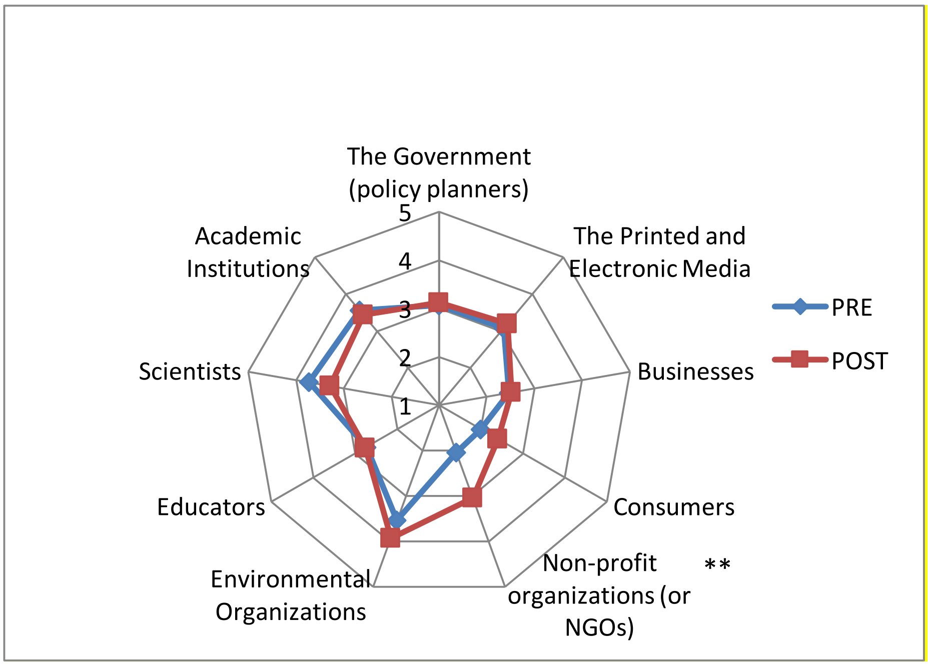

Figure 2. Israeli teachers' perspectives regarding the degree of responsibility that each of specific group takes for RRI in Israel today ("the real world") in the pre and post-test (N=25). ** p<0.01.

When the teachers were asked: "In an ideal world, what degree of responsibility should each of specific groups take for RRI (for the consequences of research and innovation in society and the environment)?" significant differences between the pre- and post-test were obtained regarding the degree of responsibility of all the presented stakeholders (p<0.001). A less significant difference was obtained regarding the government (policy makers): p<0.05. For all the other stakeholders, no differences were found between how teachers perceived the degree of different stakeholders take in the real world (in their own country) in the pre- and post-test, as shown in Figure 3. Figure 4 presents the results for the Israeli teachers. In the Israeli sample, an increase was obtained regarding the perceived responsibility of all the stake holders. However only four of them had a significant with P<0.01 (governance, educators, consumers, and NGOs). The last three stakeholders represent roles that can be taken by the teachers who are educators, consumers that can be part of NGOs.

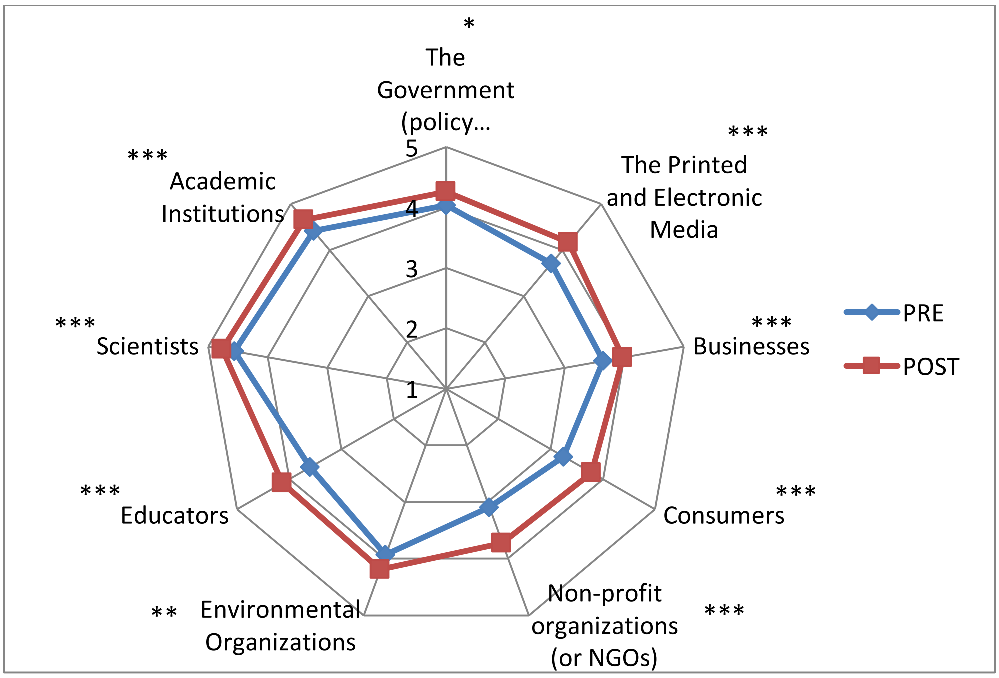

Figure 3. Teachers' perspectives regarding degree of responsibility that each of specific group takes for RRI in ideal word in the pre and post-test. This analysis includes all the teachers in the project who filled in the questionnaire (N=213).
* p<0.05; **p<0.01; ***p<0.001

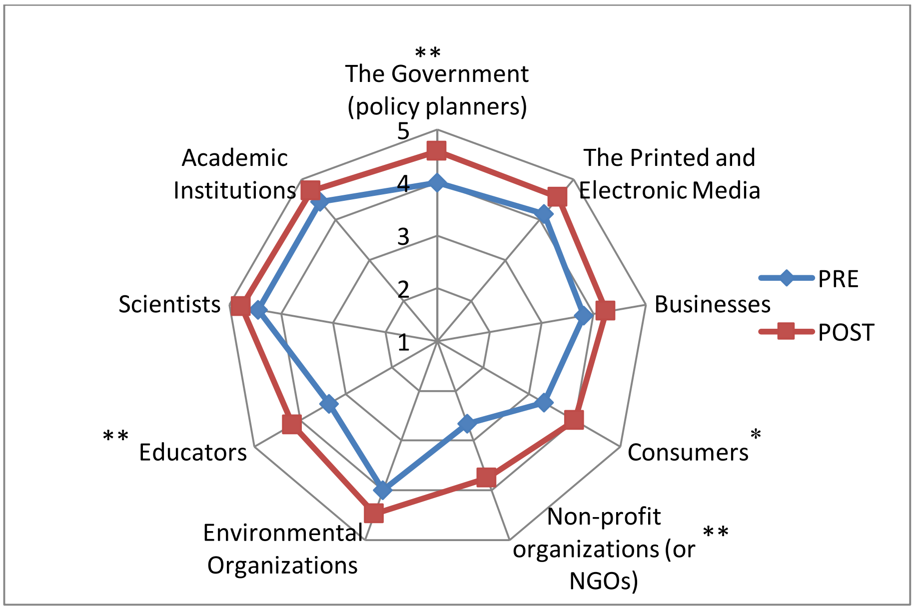

Figure 4. Israeli teachers' (N=25) perspectives regarding degree of responsibility that each of specific group takes for RRI in an ideal word in the pre and post-test. This analysis includes all the teachers in the project who filled the questionnaire.
* p<0.05; **p<0.01; ***p<0.001

It is interesting to note that the teachers' perspectives regarding stakeholders with whom they could be identified (such as educators, NGO, and consumers) received the lowest values, especially in the pre-test. However, even though teachers' perspectives regarding these stakeholders significantly improved in the posttest, they were still lower than the responsibility they assigned to the scientists and academic institutions. Teachers still perceived that the major responsibility for RRI rests with these two traditional stakeholders and much less with themselves as teachers or consumers.

TEACHER EXPERIENCE IN INTEGRATING SOCIAL ISSUES IN SCIENCE EDUCATION

The third part of the questionnaire recorded the teachers' experience in connecting social issues to scientific content. This section included four questions:

How often have you participated in discussions in science classrooms that deal with ethical issues of science and society? (For example: "Should we pursue new nuclear technologies?" or "What are the risks and benefits of nanotechnology applications?") (1= never ; 5 = often). How often have you participated in classes or workshops that deal with ethical issues of science and society? (1= never ; 5 = often). How often have you taught ethical issues relating to science and society? (1= never ; 5 = often). Which ethical issues in science and society do you think are relevant in regard to developing new technologies for? (Each partner was asked to write here the name of the domain topic of the module which was taught)? Table 8 presents the pre-post average results obtained for all the teachers who completed the questionnaire. For the first three questions, responses could be found between 1-5 in the Likert questionnaire. For the fourth question, the number of the ethical issues suggested by the teachers was counted and the average presents the average number of issues that was suggested.

Table 8

Teachers' experience with SSI issues as indicated in third part if the questionnaire and their ability to suggest ethical issue related to the scientific topic of the module in their country

Sample	Question No.	Pre (SD)	Post (SD)	P	t
All the Irresistible teachers	1	2.948 (1.209)	3.53(1.101)	5.203	P<0.001
	2	2.33(1.13)	2.968(1.09)	5.917	P<0.001
	3	2.812(1.17)	3.304(1.105)	4.473	P<0.001
	4	2.942(1.629)	3.298(1.767)	1.748	n.s.
The Israeli-Irresistible teachers	1	2.11(1.17)	3.5(1.1)	4.28	P<0.001
	2	1.57(0.98)	2.8(0.89)	4.71	P<0.001
	3	3.1(1.3)	3.4(1.06)	1.04	n.s
	4	1.87(2.667)	1.73(4.217)	2.742	P<0.01

In order to explain which ethical issues were expressed by teachers we provide some examples, taken from the Israeli sample:

> "Are the voices of everyone involved equal in the decision making regarding the innovative solar cells?"; "To what extent do the perovskite-based solar cells development take into account social and environmental damage?"; "Who will supervise the influence of perovskite-based solar cells of children health?"

Regarding the Irresistible teachers, in general, the results of part three show that they reported an increase in their experience to take part in social issues related to scientific and technological topics and to participate in workshops dealing with these socio-scientific issues (SSI). These results are reasonable since the teachers participated in their respective CoLs in which such discussions were part of the CoL activity. The teachers also reported that they tend to conduct more SSI discussions in their classes (question 3). However, when they were asked to suggest ethical issues that are relevant to the scientific topic that was part of their Irresistible module, they were able to suggest more issues but the difference between their pre and post abilities was not significant (Table 8).

Regarding the Israeli teachers, specifically, the results show that they also reported an increase in their experience to take part in social issues related to SSI issues and to participate in workshops dealing with them. However, unlike the general Irresistible teachers, the Israeli teachers showed no statistically significant difference regarding their teaching of SSI. Upon closer examination of the data, the reason for this finding seems to be that the Israeli teachers scored higher than the Irresistible teachers on both the pre-test and on the post-test for this item, but that the difference between these two scores was not statistically significant.

SUMMARY AND DISCUSSION

As mentioned above, one way to understand RRI is to see it as a framework to guide scientists and technologists, citizens and consumers, as well as other innovators and societal actors to "become responsive to each other" in terms of the ethical acceptability, sustainability and societal desirability of the marketable products of science and technology (Schomberg & Von Schomberg, 2013). Thus, the effort to implement RRI in society is a broad-ranging goal which relates to many societal groups. Some of the societal groups involved in this effort include science teachers and their students within formal and informal science education settings. In order to assist these groups in implementing RRI, the European Community has established a number of projects focusing on RRI in science education as mentioned earlier.

The educational focus on RRI in these projects has emphasized the development of various curricular interventions for teachers and their students. Our interest in developing a questionnaire to assess attitudes relating to the 6 RRI dimensions has been to provide educators with a way to evaluate how well teachers and students internalize the intended educational outcomes of RRI. Thus, such a questionnaire could provide teachers with a way to obtain feedback about the effectiveness of RRI-based curricula. It could provide science education researchers with a tool to explore various issues relating to RRI in science education.

Using a 10-stage development process, we produced a valid and reliable 3-part questionnaire to evaluate the attitudes of teachers and students regarding the RRI construct which includes 6 dimensions. We then used this questionnaire to explore various issues relating to RRI in science education, within the context of the Irresistible project. We used the questionnaire in a pre-post design with teachers and students to evaluate to what extent their attitudes were changed during the course of the project, using curricular modules produced and taught in each of the 10 countries.

There were three parts of the questionnaire that were used to explore the development of RRI attitudes in teachers and their students, before and after teaching and learning the various modules developed within the context of the Irresistible project. The first part explored the RRI attitudes of teachers and their students in the project. The results demonstrate statistically significant gains in positive attitudes regarding the RRI construct for both teachers and their students. We can therefore conclude that the process of professional development in the Communities of Learners (CoLs) in the project led to significant gains in the teachers' attitudes and that the teachers used the modules developed in the Irresistible project to positively promote students' attitudes towards the RRI construct, across all 10 partner countries. It is interesting to note that when we examine the attitudes of teachers and students regarding the RRI in one country (for example Israel) the change was not significant for all 6 RRI dimensions. The accumulation of all 10 countries provides a variety of Irresistible modules, each emphasize different RRI dimensions, and together create a significant change in the attitudes of teachers and students of the whole project regarding the RRI.

The second part of the questionnaire explored how teachers viewed the respective responsibility for RRI taken by potential stakeholders, in the *real* world as well as in an *ideal* world. While the teachers developed stronger attitudes regarding RRI during the project, their view of their degree of responsibility, as educators and consumers in the real world, remained relatively low before and after the project. At the same time, their post-test assessment of the degree of responsibility that educators *should* take for RRI in an *ideal* world increased significantly. This finding leads to the conclusion that the Irresistible project empowered teachers to begin to expand their ideal role as science teachers regarding their teaching of RRI in their classrooms. Teachers also developed higher expectations for *all* potential stakeholders to take responsibility for developing RRI in an *ideal* world—especially NGOs, consumers and educators—which leads to the conclusion that the project expanded their view of the importance of RRI and the importance of its implementation by a variety of stakeholders.

Based on the results of the third part of the questionnaire, we can conclude that the Irresistible project increased the teachers' experiences with ethical issues in science education. However, teachers' inability to significantly improve their ability to suggest multiple examples of such SSIs may be explained by the conclusion that they do not have enough experience in working with ethical issues in the classroom. Another explanation for the same data is that these findings are module-dependent, i.e., it was more difficult for teachers to think of multiple examples of ethical issues for the domain topics of some modules than for others.

One implication of the questionnaire's findings with a sample drawn from 10 countries is that the use of socio-scientific issues (SSI) in science education has not yet become mainstream in science teaching practice. Yet the findings of the study also provide a reason for optimism. Although teachers originally expressed the attitude that educators and consumers have a low responsibility for RRI, after teaching the RRI-based modules the teachers felt that educators and consumers have a much greater responsibility for RRI, in an ideal world.

This attitudinal shift—as well as the increase in positive attitudes about RRI as reported above—may mirror an epistemological shift, based on a pedagogical strategy that engages teachers and their students into a "knowledge inquiry" (Simonneaux, 2014). According to this line of thinking, epistemological stances are fostered by pedagogical strategies. For example, a "scientistic" epistemological stance, where science is understood to be essential to progress and the researcher is accepted as the essential actor, is supported by a "doctrinal" pedagogical strategy, where the teacher's authority leaves little room for interaction with the students. Alternatively, an epistemological stance of "skepticism," which understands that scientific research produces controversies and risks (as well as breakthroughs) and therefore may be guided by political and economic choices, is supported by pedagogical strategies such as "problematising" and assessing uncertainties and risks relating to complex socioscientific issues (Simonneaux, 2011, cited in Simonneaux, 2014).

More specifically, since the pedagogical approach of the Irresistible Project included these latter two pedagogical strategies, by raising questions relating to each RRI dimension (See Table 9), this approach could have fostered an epistemological stance of "skepticism," first by the participating teachers and afterwards by their students.

Table 9

Student Questions Relating to Each RRI Dimension (from Blonder et al., 2016)

RRI Dimension	Related Student Questions
Engagement	Who should be involved? Are the voices of all those involved equal in the decision-making process? What is the decision-making process? Should people who are not knowledgeable of science influence scientific decisions?
Open Access	Is it enough to publish research results in professional journals that are accessible to the scientific community? Should studies also publish possible shortcomings and risks? Should there be an obligation to publish information about patents?
Ethics	Which ethical values are essential to consider? Does adhering to ethical standards improve research or hinder it? Does the product and its development take into account social and environmental values? Is the development sustainable? Does it take into account possible effects on the future?
Science Education	What degree of commitment (if any) should the scientist have to science education? How much effort should scientists and technologists be asked to invest, in order to share their research and development with people who are not experts in these areas?
Gender Equality	What is the proper representation of men and women in R & D work? What should happen if there is no proper representation of men and women?
Governance	Who will supervise the work? What stages of research and development need to involve the supervision? What is the source of authority for this supervision? Do scientists and technologists have an obligation to report their work? What is involved in the process of supervision?

Science education needs to expose teachers and their students not only to the facts, principles and discoveries of science, but also to the challenge of how to navigate a reality in which science and technology produces consumer products, when universities and research institutes, as well as the military and commercial sponsors of research and innovation operate with vested interests (Hodson, 2011; Ziman, 1998). While these vested interests might try to promote "the cultural production of ignorance" for consumers (Proctor & Schiebinger, 2008) Clearly engaging teachers and students in actively assessing complex socioscientific issues, using something like the RRI-related questions presented in Table 9, could act to counter this possibility.

Clearly more work needs to be invested in developing and implementing curriculum that develop RRI attitudes in science classrooms, as well as in developing and using tools to evaluate these attitudes in teachers and their students. We suggest that the RRI questionnaire presented here is one such tool.

We also suggest that the RRI questionnaire can be used to assess the development of attitudes regarding RRI across other stakeholders involving RRI, such as scientists, consumers and other members of the general public.

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Appendices

APPENDIX 1: PILOT VERSION OF THE QUESTIONNAIRE

QUESTIONNAIRE TO MEASURE ATTITUDES ON RESEARCH AND INNOVATION IN TODAY'S SOCIETY

The purpose of this questionnaire is to investigate the attitudes of teachers, students and scientists, in regard to the role of academic research and innovation in today's society.

Part 1:

Instructions: Please determine the degree to which you agree with the following statements (5 = agree a great deal, 1 = do not agree at all.)

Statement	1 do not agree at all	2	3	4	5 agree a great deal
1. Scientists should be involved in public programs to make their research results accessible to students and their teachers in the science classroom.					
2. The results of scientific research should be published only in professional scientific journals.					
3. It is alright for a male researcher to prefer to hire male students, over female students, given the same qualifications.					
4. Scientists should present their research to the general public in popular lectures.					
5. Research institutes should consult with representatives of the civil community (such as non-profit organizations for nature conservation, human rights, and consumer rights) while they determine the research topics for the coming work years.					
6. Research institutions should concentrate only on doing research and do not to play an active role in promoting science learning in schools.					
7. The general community's reactions to any research topic are not relevant to a scientist in his/her choice of what research topics to investigate.					

8. It is not the role or responsibility of industrialists to think about the social implications of the products they develop.					
9. Even if scientists are not required to do so, they should to report the findings of their research to the public agencies that support their research.					
10. Industrialists who develop technology products should be invited to give lectures on their work in schools.					
11. Government, academic institutions, NGO's (non-governmental organizations) and businesses have different interests, so they cannot share common values.					
12. A research institution should make sure to balance the number of men and women it hires to work in research groups.					
13. Because the business community and the scientific research community are motivated by different interests, there is no room for cooperation between them.					
14. One of the responsibilities of a country should be to encourage young people to study science and technology in order to get them interested about work in these fields.					
15. Part of the budget of a research proposal should include the production of free and open online access to the research's publications and data.					
16. Academic research institutions need to be regulated by the policy-makers.					
17. Having high ethical standards can help ensure high quality results in science and technology.					
18. Scientists should be the only authority to determine and regulate the components of "responsible research."					
19. Funding organizations should cooperate with scientists from academic research institutions, in order to determine research topics for funding.					
20. Scientists should have a sense of social responsibility and therefore should stop conducting research when it is clear that it has negative implications for society and/or the environment.					
21. When a scientist is required to report about the details of his/her research, this negates his or her academic freedom.					
22. Science teachers should devote some of their time to teaching about the ways in which scientists and society can work together to solve society's problems.					
23. A research director that needs "work around the clock" should not hire women who have young children.					
24. Scientists should limit their lectures to other scientists who can understand what they are talking about.					
25. If a large majority of women constitutes a research group, efforts should be made to hire more men, in order to have a better balance of men and women in that group.					

26. Dealing with ethical issues is a constraint to research and innovation.					
27. In order to create a fuller representation of women with young children in research, they should be given a longer time to reach scientific excellence than their male colleagues.					
28. Government has the responsibility to prevent harmful or unethical developments in research and innovation.					
29. An academic research institution needs to make all of its research findings available to people outside of the institution.					
30. The government has no place in prioritizing topics of research in research institutions.					

Part 2:

31. The following groups can each take different degrees of responsibility for the consequences of research and innovation on society and the environment. **In an ideal world**, what degree of responsibility should each of these groups take? (5 = to a great degree, 1= to a very small degree)

	1 None	2	3	4	5 to a great degree
The Government (policy planners)					
Academic Institutions					
Scientists					
Educators					
Environmental Organizations					
Non-profit organization s					
Consumers					
Businesses					
The Printed and Electronic Media					

32. **In your country today**, what degree of responsibility does each of these groups take? (5 = to a great degree, 1= to a very small degree)

	1 to a very small degree	2	3	4	5 to a great degree
The Government (policy planners)					
Academic Institutions					

Scientists					
Educators					
Environmental Organizations					
Non-profit organization s					
Consumers					
Businesses					
The Printed and Electronic Media					

Part 3:

33. How often have you participated in discussions that deal with ethical issues of science and society? (For example: "Should we pursue new nuclear technologies?") (5 = to a great extent, 1= to a very small extent)

1 Never	2	3	4	5 often

34. How often have you participated in classes or workshops that deal with ethical issues of science and society? (5 = to a great extent, 1= to a very small extent)

1 Never	2	3	4	5 often

35. How often have you taught ethical issues of science and society? (5 = to a great extent, 1= to a very small extent)

36. Which ethical issues in science and society do you think are relevant in regard to: **Developing new technologies for solar cells** (Each Partner should write here the name of the domain topic of the CoL).

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APPENDIX 2: VERSION 1 OF THE QUESTIONNAIRE

QUESTIONNAIRE TO MEASURE ATTITUDES ON RESEARCH AND INNOVATION IN TODAY'S SOCIETY

The purpose of this questionnaire is to investigate the attitudes of teachers, students in regard to the role of academic research and innovation in today's society.

Part One

Instructions: Please determine the degree to which you agree with the 24 following statements (1- do not agree at all;   5 - agree a great deal)

1. Scientists should give lectures about their work in science classrooms.
2. Scientists should publish their research findings only for other scientists. (NEGATIVE statement)
3. It is fine if a male researcher prefers to hire male students over female students, even though both have the same qualifications. (NEGATIVE statement)
4. Scientists should present their research to the general public in popular lectures.
5. To decide what topics to research, scientists should consult with community representatives, such as people who work for nature conservation, human rights, and consumer rights.
6. Scientists should focus only on doing research and should not invest time on promoting learning in schools. (NEGATIVE statement)
7. People who create products do not need to think about the possible risks of these products. (NEGATIVE statement)
8. Scientists should report their findings to the government, even if they are not required to do so.
9. Industrialists who develop technology products, such as new cell phones and computer applications, should be invited to give lectures on their work in schools.
10. Government, businesses and non-profit organizations (or NGOs) do not share the same values, so they cannot work together. (NEGATIVE statement)
11. Scientists should try to balance the number of men and women in their research teams.

12. The scientific and business communities cannot work together because they are motivated by different interests. (NEGATIVE statement)
13. Scientists should spend part of their research budget to present their research online, in a free and open way.
14. The government needs to regulate scientific research institutions.
15. Having high ethical standards can help ensure high quality results in science and technology.
16. Organizations which fund scientific research should consult with scientists to decide which research topics to fund.
17. If it is clear that doing research has negative implications or risks, scientists have the duty to stop conducting this research.
18. When scientists are required to report about the details of their research, this negates their academic freedom. (NEGATIVE statement)
19. The science curriculum in schools should include topics like how science solves society's problems.
20. A scientist who needs people to "work around the clock" should not hire women with young children. (NEGATIVE statement)
21. Women and men should have equal rights and responsibilities in scientific research.
22. One of the roles of government is to prevent harmful or unethical practices in research and innovation.
23. Scientists have an obligation to make their research findings available to everyone.
24. The government should not determine which topics of research are more important than others. (NEGATIVE statement)

Part Two

All of the following questions should be for the Teachers Questionnaire.
* Only questions #27 and #30 should be included in the Students Questionnaire

25. The following groups can each take different degrees of responsibility for the consequences of research and innovation on society and the environment. **In an ideal world**, what degree of responsibility should each of these groups take? (1= to a very small degree ; 5 = to a great degree)

	1	2	3	4	5
The Government (policy planners)					
Academic Institutions					
Scientists					
Educators					
Environmental Organizations					
Musicians					
Non-profit organizations (or NGOs)					

Consumers					
Businesses					
The Printed and Electronic Media					

26. The following groups can each take different degrees of responsibility for the consequences of research and innovation on society and the environment.
In a real world (in your country today), what degree of responsibility each of these groups take? (1= to a very small degree ; 5 = to a great degree).

	1	2	3	4	5
The Government (policy planners)					
Academic Institutions					
Scientists					
Educators					
Environmental Organizations					
Musicians					
Non-profit organizations (or NGOs)					
Consumers					
Businesses					
The Printed and Electronic Media					

Part Three

27. How often have you participated in discussions in science classrooms that deal with ethical issues of science and society? (for example: "Should we pursue new nuclear technologies?" or "What are the risks and benefits of nanotechnology applications?") (1= never ; 5 = often)
28. How often have you participated in classes or workshops that deal with ethical issues of science and society? (1= never ; 5 = often)
29. How often have you taught ethical issues relating to science and society? (1= never ; 5 = often)
30. Which ethical issues in science and society do you think are relevant in regard to developing new technologies for solar cells?

RRI dimensions (categories in the questionnaire)

i. Statements relating to the dimension of ENGAGEMENT ("Choose together"):

5 ; 12(Negative) ; 24 (Negative) ; 16

ii. Statements relating to the dimension of GENDER EQUALITY ("Unlock the full potential"):

3(Negative) ; 11 ; 20(Negative) ; 21

iii. Statements relating to the dimension of SCIENCE EDUCATION ("Creative learning of fresh ideas"):

1 ; 19 ; 6(Negative) ; 9

iv. Statements relating to the dimension of OPEN ACCESS ("Share results to advance"):

23 ; 2(Negative) ; 4 ; 13

v. Statements relating to the dimension of ETHICS ("Do the right thing and do it right"):

10(Negative) ; 7(Negative) ; 15 ; 17

vi. Statements relating to the dimension of GOVERNANCE ("Design science for and with society"):

9 ; 14 ; 18(Negative) ; 22

APPENDIX 3: THE FINAL SCALE

QUESTIONNAIRE TO MEASURE ATTITUDES ON RESEARCH AND INNOVATION IN TODAY'S SOCIETY

The purpose of this questionnaire is to investigate the attitudes of teachers, students in regard to the role of academic research and innovation in today's society.

Part One

Instructions: Please determine the degree to which you agree with the 24 following statements (1- do not agree at all; 5 - agree a great deal)

1. To decide what topics to research, scientists should consult with community representatives, such as people who work for nature conservation, human rights, and consumer rights.
2. Industrialists who develop technology products, such as new cell phones and computer applications, should be invited to give lectures on their work in schools.
3. Scientists should try to balance the number of men and women in their research teams.
4. Scientists should spend part of their research budget to present their research online, in a free and open way.
5. The government needs to regulate scientific research institutions.
6. Having high ethical standards can help ensure high quality results in science and technology.
7. Organizations which fund scientific research should consult with scientists to decide which research topics to fund.
8. If it is clear that doing research has negative implications or risks, scientists have the duty to stop conducting this research.
9. The science curriculum in schools should include topics like how science solves society's problems.
10. Women and men should have equal rights and responsibilities in scientific research.
11. One of the roles of government is to prevent harmful or unethical practices in research and innovation.
12. Scientists have an obligation to make their research findings available to everyone.

13. The following groups can each take different degrees of responsibility for the consequences of research and innovation on society and the environment.
    In an ideal world, what degree of responsibility should each of these groups take? (1= to a very small degree ; 5 = to a great degree)

	1	2	3	4	5
The Government (policy planners)					
Academic Institutions					
Scientists					
Educators					
Environmental Organizations					
Musicians					
Non-profit organizations (or NGOs)					
Consumers					
Businesses					
The Printed and Electronic Media					

14. The following groups can each take different degrees of responsibility for the consequences of research and innovation on society and the environment.
    In the real world (in your country today), what degree of responsibility each of these groups take? (1= to a very small degree ; 5 = to a great degree).

	1	2	3	4	5
The Government (policy planners)					
Academic Institutions					
Scientists					
Educators					
Environmental Organizations					
Musicians					
Non-profit organizations (or NGOs)					
Consumers					
Businesses					
The Printed and Electronic Media					

15. How often have you participated in discussions in science classrooms that deal with ethical issues of science and society? (for example: "Should we pursue new nuclear technologies?" or "What are the risks and benefits of nanotechnology applications?") (1= never ; 5 = often)
16. How often have you participated in classes or workshops that deal with ethical issues of science and society? (1= never ; 5 = often)
17. How often have you taught ethical issues relating to science and society? (1= never ; 5 = often)
18. Which ethical issues in science and society do you think are relevant in regard to developing new technologies for solar cells?*

Vers des Convergences dans les Comportements Scolaires et les Representations Territoriales entre Eleves Ruraux et Urbains ?

Analyses Comparatives Rurales - Urbaines en Fin D'Ecole Primaire (France : Ardeche et Drome)

Pierre Champollion

pierre.champollion@univ-grenoble-alpes.fr | Laboratoire Éducation, Cultures, Politiques, Université de Lyon2, France

RESUME

Cette comparaison rural - urbain témoigne de la légère atténuation de la spécificité rurale qui a été observée de 2012 à 2014 à partir de la comparaison des enquêtes CM2 (fin de l'école primaire) et 5ème (collège) des deux suivis longitudinaux *OER* - *OET* sur les deux départements de l'Ardèche et de la Drôme (effectués entre 1999 et 2005, d'une part, et 2011 et 2016, d'autre part). Les toutes dernières enquêtes urbaines menées sur ces deux mêmes départements vont en effet dans le même sens que les sondages urbains antérieurs valentinois (Champollion, 2017 ; Champollion, Dos Santos & May-Carle, 2015). Y aurait-il donc à l'œuvre - portée par le développement dans tous les territoires d'internet et des réseaux sociaux ? - une tendance générale à l'homogénéisation et à l'uniformisation progressive des regards sur soi et sur l'école, ainsi que des représentations territoriales, notamment, qui traverserait tous les types de territoire, ruraux comme urbains ? Faudra-t-il dans cette perspective à terme « déconstruire » l'école rurale avec ses spécificités historiques, au-delà de la diffusion actuelle massive dans les milieux urbains, notamment dans l'éducation prioritaire, de sa « forme » la plus emblématique, la « classe à plusieurs cours » ? Sous réserve d'invalidation ultérieure par l'analyse du second suivi longitudinal *OET*, et entre autres de l'enquête 3ème en cours de saisie, les résultats des enquêtes présentées ici, tant sur le rural que sur l'urbain, semblent bien le confirmer…

MOTS CLES

Contexte territorial, Élèves ruraux, Élèves urbains, Éducation et territoire, Représentation sociale du territoire.

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Towards Convergences in School Behavior and Territorial Representations Between Rural and Urban Students?

Rural—Urban Comparative Analyzes at the End of the Primary School (France: Ardeche and Drome)

Pierre Champollion

pierre.champollion@univ-grenoble-alpes.fr | Laboratoire Éducation, Cultures, Politiques, Université de Lyon2, France

ABSTRACT

This rural—urban comparison testifies to the slight attenuation of the rural specificity that was observed from 2012 to 2014 from the comparison of the CM2 (end of primary school) surveys and 5th (secondary 1) of the two longitudinal *OER - OET* surveys on the two french départments of the Ardèche and the Drôme (1999-2005 and 2011-2016). The most recent urban surveys carried out on these two departments are in the same direction as the previous urban surveys of Valence (Champollion, 2017; Champollion, Dos Santos & May-Carle, 2015). Would there then be a general tendency—driven by the development in all territories of internet and social networks?—in the work to homogenize and gradually standardize views on oneself and on the school, as well as territorial representations, in particular, which would cross all types of territory, both rural and urban areas? Will it be necessary in this perspective to "deconstruct" the rural school and its historical specificities, beyond the current massive diffusion in urban areas, particularly in priority education, of its most emblematic "form", the "multi-grade classes "? Subject to further invalidation by the analysis of the second longitudinal *OET* follow-up, and in particular of the 3rd survey which is currently being captured, the results of the surveys presented here, both rural and urban, seem to confirm this...

KEY WORDS

Education and territory, Rural pupils, Social representation of territory, Territorial context, Urban pupils.

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Estaremos a Assistir a uma Convergência de Comportamentos Escolares e de Representações Territoriais entre os Estudantes de meios Rurais e os Estudantes de Meios Urbanos?

Análises Comparativas entre os Estudantes de Meios Rurais e de Meios Urbanos no Final do Ensino Elementar em França (França: Ardeche e Drome)

Pierre Champollion

pierre.champollion@univ-grenoble-alpes.fr | Laboratoire Éducation, Cultures, Politiques, Université de Lyon2, França

RESUMO

Esta comparação entre alunos dos meios rurais e urbanos atesta a ligeira diminuição da especificidade rural observada de 2012 a 2014 a partir da comparação dos inquéritos *CM2* (final da Escola Elementar em França, correspondente ao 5º ano do Ensino Básico em Portugal) e *5ème* do *collège* (correspondente ao 7º ano do Ensino Básico em Portugal) de dois levantamentos longitudinais efetuados pelo Observatório da escola rural (*Observatoire de l'école rurale – OER*) e pelo Observatório de educação e territórios (*Observatoire éducation et territoires – OET*), em duas divisões administrativas do território francês, Ardèche e Drôme, entre 1999 e 2005 e entre 2011 e 2016. As pesquisas mais recentes sobre territórios urbanos realizadas nestes dois locais apontam, de facto, na mesma direção que as pesquisas anteriores realizadas em Valência (Champollion, 2017; Champollion, Dos Santos & May-Carle, 2015). Haverá, então, uma tendência geral – impulsionada pelo desenvolvimento, em todos os territórios, da Internet e das redes sociais? – para homogeneizar e para uniformizar progressivamente as visões sobre si mesmo e sobre a escola, bem como as representações territoriais, em particular, que atravessariam todos os tipos de território, tanto nas áreas rurais como urbanas? Nesta perspetiva, será necessário "desconstruir" a escola rural e as suas especificidades históricas, além da sua atual difusão massiva nas áreas urbanas, particularmente no que diz respeito à questão da educação ou intervenção prioritária na sua "forma" mais emblemática, isto é, organizada por "turmas mistas"? Sujeito a uma invalidação posterior através da análise do segundo levantamento longitudinal da *OET* e, em particular, da 3ª investigação, que está atualmente em curso, os resultados dos inquéritos apresentados aqui, tanto no âmbito rural como no urbano, parecem confirmar isso...

PALAVRAS-CHAVE

Contexto territorial, Alunos de meios rurais, Alunos de meios urbanos, Educação e território, Representação social do território.

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Other articles

Vers des Convergences dans les Comportements Scolaires et les Représentations Territoriales entre Élèves Ruraux et Urbains ? Analyses Comparatives Rurales-urbaines en Fin d'École Primaire (France : Ardèche et Drôme)

Pierre Champollion

INTRODUCTION

Pour essayer de répondre à l'interrogation du titre de cet article détaillée dans la version longue de son intitulé indiquée ci-après – *Vers des convergences progressives en matière d'impact des contextes éducatifs, d'effets des représentations sociales liées aux territoires et d'auto-évaluations scolaires entre élèves ruraux et urbains... ?* – cet article s'appuiera en premier lieu sur l'analyse comparative des réponses aux mêmes questionnaires passés au début de la décennie 2010 à la fois par des élèves ruraux et urbains de CM2[1] dans les deux départements français de l'Ardèche et de la Drôme. Les données techniques de ce corpus principal sont précisées un peu plus loin (en début de partie 2).

Au-delà de l'indispensable analyse comparative issue des données précédentes, cette présentation intègrera également les conclusions de la comparaison rural-rural des enquêtes CM2 2000 et CM2 2012 conduites successivement, à douze ans d'écart, par l'*Observatoire de l'école rurale* (OER) et par l'*Observatoire éducation et territoires* (OET) qui lui a succédé[2] (Champollion, Dos Santos & May-Carle, 2015), ainsi que les résultats des comparaisons analogues résultant des investigations comparables menées au niveau 5ème de collège[3], cette fois en 2002 et en 2014 respectivement (Champollion, 2017). Ces deux comparaisons rural-rural, qui portent sur les mêmes écoles et les mêmes collèges, situés dans les deux mêmes départements et interrogés à chaque fois avec les mêmes questionnaires, permettent d'apprécier – en tendance – les évolutions en cours des représentations sociales liées à la scolarité et au territoire à l'œuvre dans l'école rurale. Il convient ici d'indiquer ici que la composition sociale de l'échantillon comparé à douze ans d'écart n'a pas été significativement modifiée même si un certain nombre de territoires ruraux – ce qui n'a été le cas qu'à la marge des territoires ruraux investigués

1 Dernière classe de l'école primaire française avant le collège, fréquentée par des élèves de 10-11 ans en moyenne.
2 L'OET a succédé en 2009 à l'OER pour tenir compte de l'élargissement aux territoires urbains des investigations initialement menées sur les seuls territoires ruraux par l'OER.
3 Il s'agit donc d'élèves de 12-13 ans en moyenne fréquentant le collège ou secondaire 1.

dans les deux départements concernés – ont récemment accueilli des publics urbains défavorisés, notamment en raison de décisions judiciaires.

La caractérisation des élèves de l'école rurale actuelle a été donc conduite via deux angles d'attaque complémentaires : d'une part, et essentiellement, par la comparaison directe entre élèves ruraux et urbains du même niveau – CM2 – afin de saisir les points de différence et de convergence actuels qui est l'objet principal de cet article ; d'autre part, également, par la comparaison d'élèves de deux niveaux – CM2 et 5ème de collège – de deux populations rurales de même extraction territoriale à douze ans d'écart pour repérer les éventuelles évolutions en cours au sein de la ruralité. Cette dernière caractérisation de la scolarité rurale actuelle, qui ne fait pas appel à une comparaison directe rural-urbain, ne sera donc que rappelée rapidement ici à la fin de la partie 1 consacrée à l'état de l'art.

PROBLEMATIQUE ET ETAT DE L'ART

CADRE CONCEPTUEL

L'école, rurale notamment, a toujours entretenu des rapports multiples et complexes, plus ou moins étroits, avec le territoire dans lequel elle inscrivait son action d'éducation et de formation, d'où étaient du reste majoritairement issus ses élèves. Il suffirait, s'il en était besoin pour s'en convaincre, de se souvenir par exemple des nombreuses caractéristiques scolaires qui ont été développées par l'école pour s'adapter aux contextes ruraux et montagnards. Aucune dimension de la scolarisation ne peut en effet s'affranchir complètement du contexte territorial dans lequel s'inscrit l'action de l'école : formes et organisations scolaires, apprentissages, performances, projets et orientations des élèves, didactique et pédagogie des enseignements, etc. sont tous concernés, plus ou moins selon les territoires, plus ou moins selon les systèmes éducatifs, bien sûr. Sur un plan plus théorique, la problématique « école et territoire », fondée sur l'étude des rapports complexes qui se nouent entre école et territoire, ne s'est véritablement construite au sein des sciences de l'éducation qu'à l'orée des années 1980. Mais la notion de « contexte », ici territorial, bien que non seulement utile, mais encore indispensable aux sciences humaines et sociales, reste aujourd'hui encore paradoxalement négligée (Arrighi, 2004 ; Lahire, 2012).

La première dimension contextuelle-spatiale – du territoire fut – évidemment – mise au jour en géographie. Elle a servi dès la fin des années 1950-1960[4] de premier cadre à un certain nombre de monographies et d'analyses éducatives contextualisées successives (Gumuchian & Mériaudeau, 1980 ; Moracchini, 1992). A partir des années 1960-1970, la dimension proprement sociologique des contextes éducatifs émergea, notamment, après que la revue *Population* eut porté à la connaissance du grand public les disparités « fantastiques » existant entre les élèves selon l'appartenance socio-

4 En se poursuivant ultérieurement bien sûr...

professionnelle des familles. Le social s'est alors vite imposé comme le plus important facteur contextuel influençant la réussite scolaire dans son ensemble (Bourdieu & Passeron, 1964, 1970). Après les années 1980, enfin, a été entreprise l'étude de la dimension politique des contextes éducatifs, c'est-à-dire d'abord des politiques territorialisées d'éducation et les politiques d'aménagement du territoire éducatif (Charlot, 1994 ; Derouet, 1992). Ces premières analyses des politiques éducatives territorialisées ont été rapidement accompagnées par l'étude de la dimension éducative « institutionnelle » qui, en cette matière contextuelle, repose principalement sur la caractérisation des « effet-maître », « effet-classe », « effet-établissement » et, éventuellement, « effet-circonscription » (Bressoux, 1994) dont les impacts sur la réussite scolaire ont été successivement identifiées et mesurés.

Ainsi, même si l'idée [même] que la localisation est importante [pour percevoir des processus éducatifs invisibles autrement, par exemple] a été en effet rarement théorisée [par le recherche en éducation], la plupart des études sur l'efficacité de l'école sont encore aujourd'hui trop souvent réalisées sans tenir compte du contexte local. Néanmoins, malgré ce contexte peu favorable, il a pu être progressivement établi dans les années 2000 que le territoire était susceptible « ès qualité », non seulement de peser de l'« extérieur » sur les différentes dimensions du scolaire, mais encore d'être et /ou de se vouloir un « acteur » éducatif de plein exercice (Champollion & Barthes, 2014). Le territoire peut même aller jusqu'à influer sur les trajectoires scolaires de façon globale, systémique, comme c'est le cas dans certains territoires ruraux montagnards français qui ont été plus particulièrement observés sous ces angles. Mais est-ce bien le territoire global, tous « versants » confondus, qui impacte l'école, ou bien n'est-ce pas en premier lieu son volet « symbolique » [5] , c'est-à-dire la territorialité (Sack, 1986) qui, inconsciemment, façonne les parcours (Champollion, 2013) ?

La territorialité correspond essentiellement à la dimension « symbolique » générale du territoire (Aldhuy, 2008 ; Caillouette, Dallaire, Boyer & Garon, 2007 ; Debarbieux, 2008 ; Ferrié, 1995 ; Le Berre, 1992) qu'avait introduite à la fin des années 1990, en parlant de territoires « rêvés » ou « symboliques » à côtés des territoires « prescrits » et « vécus », le sociologue Bernard Lahire dans son séminaire lyonnais. Le territoire, vu sous cet angle, correspond de facto à une « territorialité activée » (Vanier, 2009). Si comparaison ne vaut – évidemment ! – pas raison, la territorialité, concept proche de la « prégnance symbolique des espaces » (Parazelli, 2002), véritable « représentation symbolique des lieux » (Vanier, 2009), portée par une « conscience collective » (Caillouette et al., 2007), « construite et partagée » par tous ses acteurs (Aldhuy, 2008), est ainsi potentiellement grosse de significations susceptibles d'alimenter identifications voire, bien sûr, de contre-identifications dans certains cas. Elle pourrait bien être en quelque sorte au territoire ce que la compétence est à la performance en linguistique ou bien ce qu'est la personnalité au comportement en psychologie. La territorialité renvoie à un véritable « habitus » territorial.

Jusqu'aux débuts des années 1980, l'école rurale et montagnarde, pour s'en tenir à elle, n'était donc pas vraiment scientifiquement connue… et encore moins socialement reconnue ! Elle faisait surtout l'objet de stigmatisations venues de tous bords, y compris de l'Education Nationale. Les rapports successifs de l'Inspection Générale en font foi (Alpe & Fauguet, 2008) ! Il a fallu les travaux convergents de la *Direction de*

5 Y compris intériorisé (Merton, 1949).

l'évaluation et de la prospective (DEP / Davaillon & Oeuvrard, 1998) et de l'*Institut de recherche en éducation* (IREDU / Duru-Bellat & Mingat, 1988) pour se rendre compte que l'école rurale et montagnarde française n'était pas uniquement le parent pauvre éducatif que tout le monde ou presque croyait. Pour autant, il a encore fallu une bonne dizaine d'années pour construire l'objet « école rurale et montagnarde » dans toute sa complexité, hors de toute stigmatisation, nostalgie et, finalement, stéréotype.

RESULTATS ANTERIEURS ET QUESTIONNEMENTS ACTUELS

Une dizaine années après la mise en évidence des premiers éléments de spécification et de caractérisation de l'école rurale et montagnarde[6], au début des années 2000, l'*OET* a – déjà ! – dû commencer à revoir sa copie. Les spécificités de cette école, observées dans le cadre du second suivi longitudinal rural, ont ainsi été progressivement minorées, enquête après enquête, parfois de façon importante, parfois de manière légère, suivant les items considérés. L'enquête CM2 effectuée en 2011-2012 avait montré que certaines spécificités commençaient à s'éroder. L'enquête 5ème qui l'a suivie a confirmé ces premières tendances. Bien sûr, il faudra attendre, d'une part, les analyses de l'enquête 3ème du second suivi longitudinal rural *OET* – comparaisons avec les enquêtes du même niveau du premier suivi longitudinal incluses – et, d'autre part, la poursuite et l'élargissement des enquêtes urbaines pour assurer robustesse et précision à cette érosion – aujourd'hui débutante – et bâtir une nouvelle caractérisation de l'école rurale.

La comparaison des résultats entre les enquêtes rurales CM2 2000 et 2012 indiquent en effet assez clairement que, en termes de goût pour l'école, d'auto-estimation du niveau scolaire et d'ambition scolaire, notamment, la spécificité rurale s'estompe quelque peu. La tendance à l'homogénéisation s'exprime encore plus fortement chez les parents… Il en va de même – mais beaucoup moins nettement – des « représentations sociales » (Abric, 2011) respectives de la ville pour les ruraux et de la campagne pour les urbains qui, si elles restent encore significativement différenciées, ne sont cependant plus aussi marquées qu'antérieurement (Champollion, Dos Santos & May-Carle, 2015). Au niveau 5ème, on peut légitimement apercevoir en 2014 la confirmation, mais sans plus pour l'instant, de la légère atténuation de la spécificité rurale constatée en 2000 au seul niveau CM2. Entre les enquêtes 5ème *OER* 2002 et 5ème *OET* 2014, en effet, il est déjà possible d'effectuer les cinq observations suivantes qui témoignent de la poursuite des tendances précédentes (qui demanderont donc à être confirmées ultérieurement aux niveaux 3ème et 2nde) :

- Moindre répulsion pour la ville et, corrélativement, moindre attrait de la campagne (élèves).
- Légère amélioration de son opinion sur sa scolarité (élèves et parents).
- Davantage d'ambition scolaire (parents surtout).
- Davantage de pratiques culturelles au collège (cinéma surtout).
- Davantage de voyages à l'étranger (surtout organisés par le collège).

6 Pour en savoir plus, voir le site web de l'OET (http://observatoire-education-territoires.com/), les six tomes de l'Enseignement en milieu rural et montagnard publiés entre 2001 et 2014 aux Presses universitaires franc-comtoises et le volume 3 issue 2 2015 de *Sisyphus* intitulé *Territorial specificities of teaching and learning*.

Pourrait-on pour autant aller jusqu'à parler d'une disparition progressive programmée de la réalité scolaire rurale historique…? Sans doute pas, ou du moins pas encore. Il paraît en effet être trop tôt pour pouvoir l'affirmer péremptoirement et sans précaution (Alpe, Barthes & Champollion, 2016).

Les seules – et uniques ! – comparaisons rural / urbain effectuées par l'*OER* avant 2012 portaient exclusivement sur l'enquête 3ème 2004 du suivi longitudinal rural initial *OER* à laquelle avait été agrégée à l'époque un petit « bout » d'enquête 3ème urbaine (Alpe & Fauguet, 2006). Elles ne permettent donc pas vraiment d'alimenter point par point, aux mêmes âges, les comparaisons avec les premières données du second suivi longitudinal rural *OET* et les nouvelles données urbaines Drôme-Ardèche collectées qui, elles, portent sur le seul niveau CM2. En effet, non seulement le niveau scolaire et l'âge des élèves n'est pas le même, mais les investigations successives de l'*OER* ont montré qu'un certain nombre de spécificités rurales (« goût pour la scolarité », « ancrage territorial local », « répulsion pour les territoires éloignés » ou « pour les villes de grande taille », etc.) avaient nettement tendance à décroître à mesure que les élèves grandissaient … Pour autant, la conclusion générale des deux auteurs précités, relative essentiellement à la perception des lieux, plus ou moins attractifs et répulsifs, en 2004 par les élèves ruraux, d'une part, et urbains, d'autre part, n'est pas sans intérêt pour les comparaisons rural / urbain actuelles : « elle montre le poids important des stéréotypes » dans le cadre duquel « la stigmatisation fonctionne dans les deux sens : aussi bien ruraux qu'urbains, les élèves [de 3ème] intègrent une vision péjorative de leur propre milieu, mais ils n'en caricaturent pas moins l'autre milieu » (p. 60) …

Les investigations « exploratoires »[7] urbaines menées en 2014 au niveau CM2 dans la seule ville de Valence semble aujourd'hui confirmer ces évolutions, qui restent pour l'instant modérées (Champollion, Dos Santos & May-Carle, 2015). Mais qu'en est-t-il vraiment et précisément ? Et que nous disent les enquêtes urbaines complémentaires développées en 2015 sur l'Ardèche et la Drôme ? C'est ce que nous allons voir plus loin, dans la partie 3, à partir de l'analyse de la comparaison des nouvelles données urbaines récoltées et des données rurales comparables CM2 disponibles, après la présentation des corpus et méthodologies des enquêtes supports de cet article.

CORPUS ET METHODOLOGIES

CORPUS

Le corpus principal analysé provient de deux séries d'enquêtes conduites – essentiellement via questionnaires – principalement par deux membres de l'*OET*, Pierre Couderc, PEMF privadois pour le département de l'Ardèche et Thierry May-Carle, PEMF valentinois et docteur en sciences de l'éducation pour le département de la Drôme. Il s'agit plus précisément, d'une part, des parties ardéchoise et drômoise de l'enquête CM2 2012 du second panel rural de l'*OET*, qui touche 524 élèves de CM2 ruraux des deux

7 Que nous qualifions volontiers d'« exploratoires » parce qu'elles ont été menées avec un corpus à l'effectif insuffisant (classes de CM2 de deux écoles) pour légitimer des analyses inférentielles.

départements et, d'autre part, des deux échantillons urbains CM2 de 2014 et 2015 de l'*OET*, qui concerne 163 élèves des villes de Privas (centre-ville), de Romans et de Valence (centre-ville de ces deux mêmes départements de l'Ardèche et de la Drôme. La caractérisation rapide des deux échantillons étudiés, présentée immédiatement après dans le tableau ci-dessous (figure 1), permet tout de suite de se rendre compte que c'est le taux d'élèves d'âge « normal », donc consécutivement le taux d'élèves « en retard », qui diffère le plus, id est ici plus que significativement (passant du simple au double !), entre les deux séries d'enquêtes. Le deuxième élément, qui différencie beaucoup moins que le premier (5 points d'écart) mais qui va le même sens, les deux échantillons relève de l'origine socio-culturelle des familles : il s'agit du plus haut diplôme détenu par les mères d'élèves [8]. Cet élément, qui généralement pèse par exemple en faveur de l'ambition scolaire, renforce la force de la moindre ambition scolaire existant encore entre l'école rurale et l'école urbaine.

	Rural	Urbain
Effectif global	524	163
Répartition filles / garçons	48% / 52%	48% / 52%
Mère diplômée du supérieur (bac et au-delà)	36,2%	31,8%
Elèves nés en France	83%	86%
Elèves d'âge normal	88%	41%
Elèves ayant un an d'avance	9%	6%
Au moins un déménagement à l'intérieur du 07-26	40%	54%

Figure 1. Eléments de caractérisation des deux échantillons comparés. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

Au-delà de ces sept éléments ponctuels quantifiés dans la figure 1, ce qui caractérise de façon transversale les deux échantillons de ce corpus principal, rural et urbain, relève selon nous de la territorialité, cette dimension symbolique du territoire, qui rappelons-le est un concept proche de la « prégnance symbolique des espaces » (Parazelli, 2002). L'échantillon rural Ardèche-Drôme s'appuie largement sur l'espace rural isolé et, en Ardèche plus particulièrement, sur la zone de moyenne montagne[9], dans lesquels les difficultés intériorisées et/ou ressenties de mobilité et le fort ancrage territorial nourrissent largement aujourd'hui encore les représentations sociales liées aux

8 Cet élément, à lui seul, explique près de 80% de la variance totale des effets sur l'école des variables sociales entre crochets [professions et catégories socio-professionnelles (PCS) et diplômes des mères et pères] (Champollion, 2013).

9 Point moyen de la commune situé au-dessus de 700m d'altitude, mais au-dessous de 1.600m, altitude où commence la haute montagne.

territoires[10]. L'échantillon urbain renvoient, lui, à des villes « petites » et « moyennes » (Valence et Romans) dans lesquelles les « zones urbaines sensibles » (ZUS)[11], fortement communautarisées, qui alimentent les « réseaux d'éducation prioritaires » (REP)[12], à la fois de taille modeste et strictement localisées, n'envahissent pas toutes leurs territorialités respectives.

A côté de cette comparaison principale rural-urbain CM2, détaillée dans le corps de la présentation en partie 3, ont été convoquées, d'une part, l'analyse des évolutions 2000-2012 des spécificités éducatives rurales repérées au niveau CM2 et, d'autre part, l'analyse des évolutions 2002-2014 des spécificités éducatives rurales repérées au niveau 5ème présentées en fin de partie 1. Rappelons que ces deux dernières analyses comparatives au sein de la ruralité française utilisent les données ardéchoises et drômoises issues des deux suivis longitudinaux ruraux *OER* 1999-2005 de 2.394 élèves de CM2, issus de l'*espace à dominante rurale* (Champsaur, 1998) de six départements du sud-est de la France (Alpes de haute Provence, Ain, Ardèche, Drôme, Haute-Loire, Haute-Saône), et *OET* 2011-2016 de 1.208 élèves de CM2, issus eux aussi de l'*espace à dominante rurale* de trois départements du sud-est de la France (Alpes de haute Provence, Ardèche et Drôme), qui présentent tous les deux une répartition équilibrée entre *rural isolé*, *rural sous faible influence urbaine* et *pôles ruraux*. Les élèves, parents et enseignants de ces deux suivis longitudinaux effectués à douze ans d'écart ont été interrogés à quatre reprises pour le premier cité (CM2, 5ème, 3ème et 2nde) et à trois reprises pour le second cité (CM2, 5ème et 3ème). Cette segmentation de l'espace rural[13] s'appuie sur le découpage établi conjointement en 1996 par l'*Institut national de la statistique et des études économiques* (INSEE) et par l'*Institut national de la recherche agronomique* (INRA) qui se fonde essentiellement sur l'analyse des déplacements quotidiens domicile - travail (Champsaur, 1998). Dans ce cadre, l'*espace à dominante rurale* est réparti en trois grands secteurs[14] :

- L'*espace rural sous faible influence urbaine* (RSFIU) dans lequel entre 20% et 40% des habitants vont travailler en ville.
- Les *pôles ruraux* (PR) dans lesquels au moins 50% des habitants travaillent sur place (auxquels ont été associés le sous-espace rural connexe de la *périphérie des pôles ruraux*).
- Le *rural isolé* (RI), défini lui négativement, qui rassemble le reste de l'*espace à dominante rurale*.

METHODOLOGIES

Les comparaisons développées ci-après s'appuient dans cette présentation essentiellement sur quatre bilans ou tris à plat des deux enquêtes CM2 et deux enquêtes 5ème, complétés par la vérification de la significativité de tous les écarts constatés, opérée

10 Pour plus de précisions, voir notamment B. Debarbieux, 2008 et Champollion, 2017.
11 Zonage issu de la « Politique de la ville » conduite en France.
12 Les REP rassemblent des écoles et des établissements secondaires, pas forcément contigus, dans lesquels les voyants sociaux (taux de familles monoparentales, par exemple) et scolaires (taux de redoublement, par exemple) sont au rouge.
13 Défini négativement : est réputé rural ce qui n'est pas urbain !
14 Il existe, au sein de cette segmentation, un quatrième sous-espace, le rural sous forte influence urbaine qui n'est pas utilisé dans ces enquêtes.

au moyen d'intervalles de confiance. La significativité statistique des différences de fréquences observées – notée DS ou DNS[15] – a toujours été calculée au seuil de .05. Les données quantitatives collectées présentées et analysées ici feront ultérieurement, comme les précédentes données de l'*OER* et de l'*OET*, l'objet de traitements statistiques plus élaborés du type analyses factorielles des correspondances, ainsi que de recueils de données qualitatives d'approfondissement complémentaires par entretiens semi-directifs, afin de mieux comprendre l'entrelacs des interactions – attraction et répulsion – qui rassemble et divise les différentes variables actives repérées et mobilisées, tant qualitatives codées que quantitatives.

Les questionnaires « élèves » ruraux et urbains *OER* et *OET* CM2 et 5ème utilisés, essentiellement fermés, sauf pour quelques items type liste des métiers envisagés, sont tous de structure et de durée de passation similaires. Les items communs utilisés dans les questionnaires des différentes enquêtes, tant rurales qu'urbaines, sont évidemment tous identiques. Quelques rares items supplémentaires ont été rajoutés dans les questionnaires les plus récents pour tenir compte de l'évolution du questionnement. Les consignes de passation ont été les mêmes partout. Les questionnaires ruraux et urbains ont été fait passer par les enseignants des classes de CM2 concernées et, pour les données 5ème, par les Conseillers principaux d'éducation (CPE) dans les collèges, sans aucune intervention de leur part évidemment. Le temps de passation d'un questionnaire « élève » n'excédait pas 45 minutes. Les questionnaires « parents » ruraux et urbains ont été distribués et récupérés sous la responsabilité des directeurs d'école primaire, ou des principaux de collège, suivant les cas. Tous les questionnaires utilisés sont visibles sur le site web de l'*OET*[16].

RESULTATS ET ANALYSES

CONTEXTES (CULTURELS ET FAMILIAUX)

Différents éléments de contexte culturels et familiaux sont susceptibles de peser sur la scolarité et l'orientation des élèves. A côté des pratiques culturelles mises en œuvre tant à l'initiative des familles que de l'école – nous les présenterons un peu plus loin – nous en avons retenus principalement deux qui sont étroitement liés à la mobilité potentielle des élèves qui interviennent, on l'avait repéré dans le premier suivi longitudinal rural *OER* mis en œuvre de 1999 à 2007, dans la construction et la réalisation des projets d'orientation des élèves. Il s'agit des déménagements antérieurs à la première saisie des enquêtes, soit donc ici avant le CM2, et des « grands » voyages, c'est-à-dire des voyages de plusieurs jours effectués soit dans le cadre de la famille, soit dans celui de l'école.

15 DS, différence significative, et DNS, différence non significative (à .05 ici).
16 http://observatoire-education-territoires.com/

Ces deux éléments, qui sont susceptibles d'expliquer pour partie, et de façon potentielle évidemment, la dimension « mobilité » requise pour élaborer et ultérieurement – aux deux niveaux successifs de la 3ème de collège et de la 2nde générale et technologique de lycée – mettre en œuvre les choix d'orientation, c'est-à-dire les déménagements antérieurs (figures 2 et 3) et les grands voyages effectués tant avec la famille qu'avec l'école, ne varient pas de façon significativement différente d'un échantillon à l'autre, qu'il s'agisse de déménagements fréquents (« plus de deux fois ») ou inexistants (« jamais »). Les seuls écarts significatifs constatés, qui sont tous deux « au bénéfice » des élèves ruraux, concernent les grands voyages effectués avec l'école dans une autre région que la région actuelle d'habitation (figure 5) – faut-il voir ici la volonté de l'école et des collectivités territoriales de tutelle, habituelle en milieux réputés ruraux et montagnards isolés, de compenser l'isolement ressenti et l'enclavement réel des écoles, des enseignants et, donc, surtout des élèves concernés (Champollion, 2003) ? – et les grands voyages effectués dans un autre pays avec la famille – qui seraient trop chers et/ou trop compliqués à organiser par l'école pour jouer ici le même rôle compensateur que les grands voyages effectués dans une autre région française (figure 6).

- Déménagements antérieurs

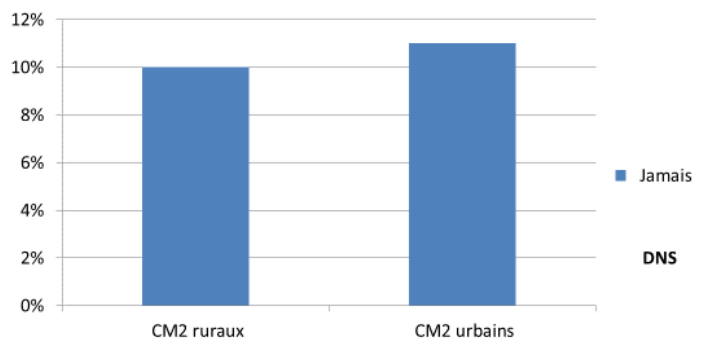

Figure 2. Déménagements antérieurs : jamais. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

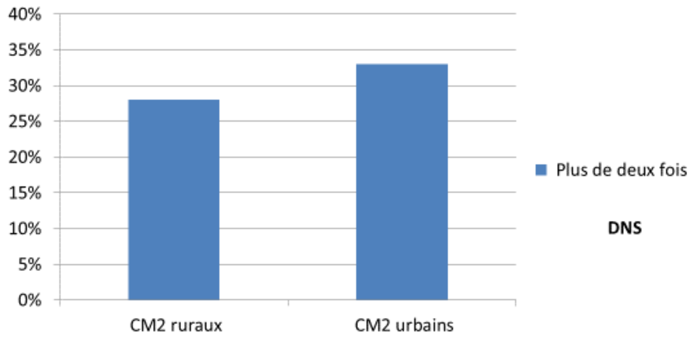

Figure 3. Déménagements antérieurs : plus de deux fois. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

- « Grands » voyages (de plusieurs jours)

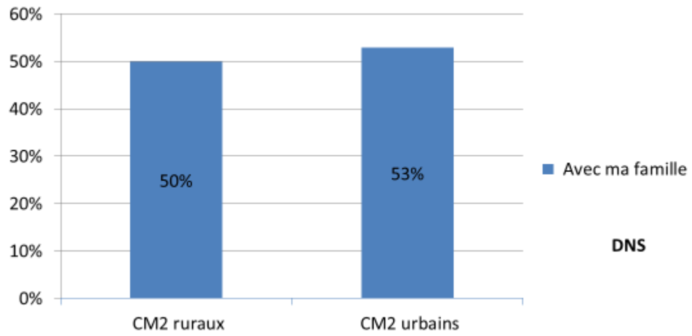

Figure 4. Grands voyages dans une autre région française dans le cadre de la famille. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

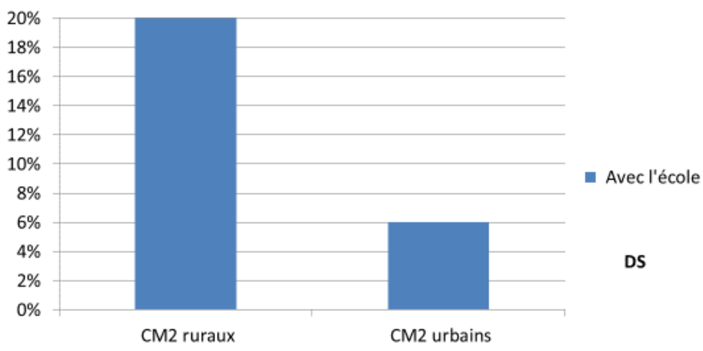

Figure 5. Grands voyages dans une autre région française dans le cadre de l'école. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

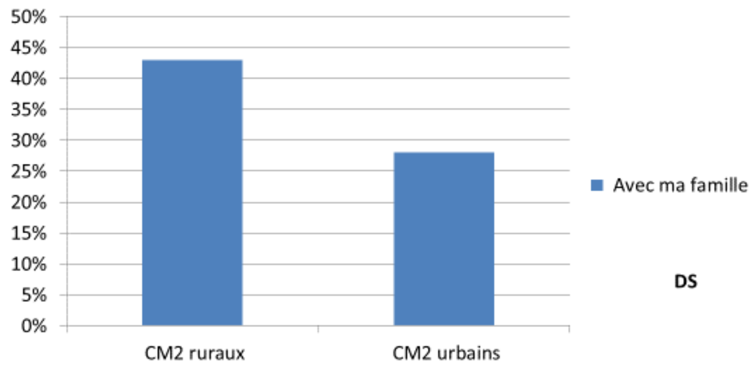

Figure 6. Grands voyages dans un autre pays dans le cadre de la famille. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

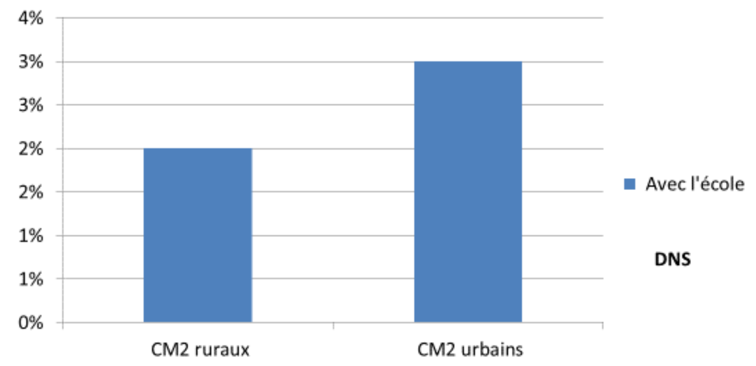

Figure 7. Grands voyages dans un autre pays dans le cadre de l'école. Source : enquêtes Observatoire éducation et territoires rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

Pratiques culturelles

Si les familles rurales continuent de contribuer à l'ouverture culturelle de leurs enfants – à la hauteur de ce que font les familles urbaines – il faut noter le décrochage de l'école rurale qui, elle, n'assure plus d'action culturelle compensatrice (en direction des sorties scolaires au musée et, surtout, des sorties scolaires au cinéma, au théâtre et au concert) (figure 8). Faut-il y déceler l'effet des difficultés actuelles de financement de l'école en milieu rural que connaîtraient les collectivités territoriales de tutelle qui, en se recentrant sur les équipements, transports et activités pédagogiques indispensables et/ou obligatoires, délaisseraient les activités pédagogiques d'ouverture culturelle ?

	Elèves ruraux	Elèves urbains	Significativité .05
Cinéma avec famille	71%	65%	DS
Théâtre avec famille	25%	28%	DNS
Concert avec famille	14%	13%	DNS
Musée avec famille	37,5%	35%	DNS
Cinéma avec école	44%	66%	DS
Théâtre avec école	29%	44%	DS
Concert avec école	2%	17%	DS
Musée avec école	29%	31%	DNS

Figure 8. Exemples de pratiques culturelles (éducatives). Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

En guise de synthèse partielle des résultats présentés dans cette sous-partie 3.1, on peut d'abord dire que, sur le plan de la fréquence des déménagements, les pratiques rurales ne se distinguent pas significativement des pratiques urbaines. Ensuite, qu'au niveau des voyages, les tendances observées ne sont pas non plus suffisamment claires ni univoques pour être vraiment significatives. Et enfin, qu'en dehors du cinéma, du théâtre et du concert, classique ici, organisés par l'école – dont l'éloignement des équipements culturels et mêmes des simples salles et, par conséquent, le coût du déplacement sont susceptibles d'expliquer les différences significatives constatées – il n'y a toujours pas ou peu d'écart entre le rural et l'urbain en matière de pratiques culturelles (testées bien sûr) … Ce qui pourrait, peut-être, également – avec la diminution déjà évoquée des financements des collectivités territoriales compétentes – expliquer que l'école rurale organise aujourd'hui moins de pratiques compensatrices qu'elle ne le faisait hier…

REPRESENTATIONS SOCIALES TERRITORIALES (DES TERRITOIRES ENVIRONNANTS ET DES TERRITOIRES LOINTAINS)

Attractivité et répulsivité des différentes représentations archétypiques du territoire

Si, en cette matière, les spécificités rurales ont quelque peu décliné entre les enquêtes 2000 et 2012 comme on l'a globalement vu plus haut, elles n'ont pas disparu pour autant.

Que ce soit pour la « campagne », la « petite ville » ou la « grande ville », les différences entre élèves ruraux et urbains restent souvent importantes et, partant, généralement significatives, ainsi qu'en attestent clairement les trois « balances »[17] entre les lieux souhaités et les lieux non souhaités qui suivent (figures 9, 10 et 11). Bien sûr, la campagne n'est plus vraiment plébiscitée par les élèves ruraux (recul de 12 points de sa « côte d'amour » entre 2000 et 2012), mais elle n'est pas pour autant massivement rejetée par ceux-ci comme elle l'est par les élèves urbains (figure 9). Quant à la « petite » et à la « grande » ville, elles ne font plus comme par le passé majoritairement « peur » aux élèves ruraux, ce qui était surtout le cas de la « grande » ville. Cette dernière ne les attire cependant toujours pas autant que les élèves urbains (figure 11).

- Campagne

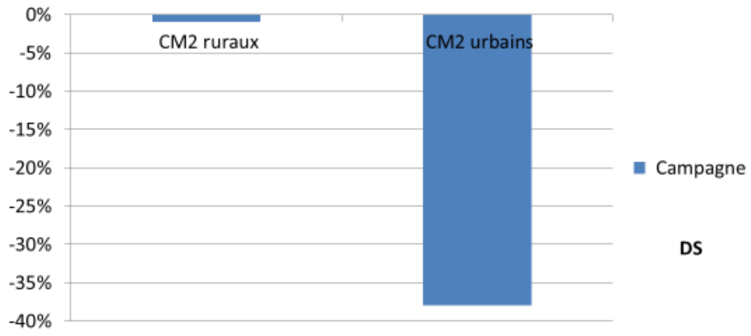

Figure 9. Balance des lieux souhaités-non souhaités : campagne. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

- Petite ville

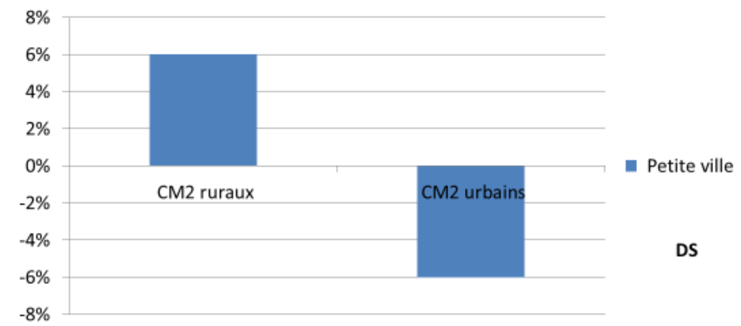

Figure 10. Balance des lieux souhaités-non souhaités : petite ville. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

17 Lieux souhaités moins lieux non souhaités.

- Grande ville

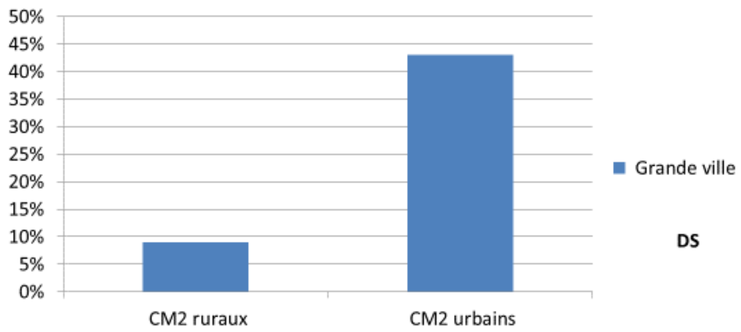

Figure 11. Balance des lieux souhaités-non souhaités : grande ville. Source : enquêtes Observatoire éducation et territoires rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

Attractivité-répulsivité des territoires en fonction de leur éloignement de l'habitat actuel

Par rapport à l'enquête 2000 comparable, la région d'habitation actuelle ne fait plus rêver en 2012 les élèves ruraux suivis. Aujourd'hui, il faut bien constater qu'il n'y a plus de différence significative, sur ce point, entre élèves ruraux et urbains (figure 12). Les deux autres items testés – « autre région » et « pays étranger » – même s'ils témoignent eux aussi d'une diminution de la spécificité rurale antérieure entre 2000 et 2012, ils n'en restent pas moins cependant encore aujourd'hui significativement différents entre élèves ruraux et urbains (figures 13 et 14).

- Ma région d'habitation

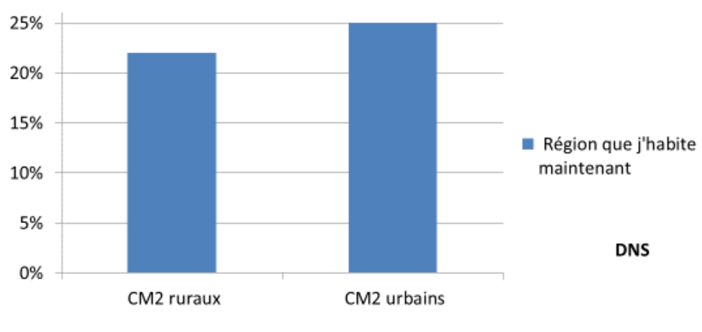

Figure 12. Balance des lieux souhaités-non souhaités : région que j'habite actuellement. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

- Autre région

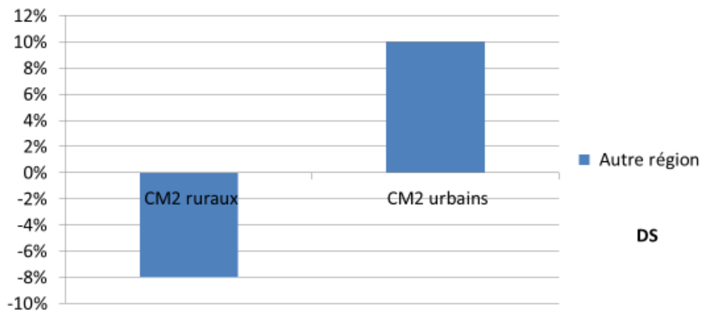

Figure 13. Balance des lieux souhaités-non souhaités : autre région. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

- Pays étranger

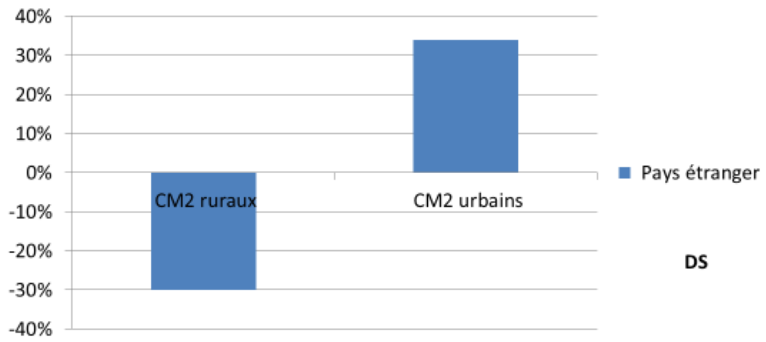

Figure 14. Balance des lieux souhaités-non souhaités : pays étranger. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

Quand on fait la synthèse des résultats présentés dans cette sous-partie 3.2, les deux constats principaux suivants apparaissent en première ligne :

- Si l'atténuation de la spécificité rurale en matière d'attractivité et de répulsivité des différents types de territoire établie par la comparaison au niveau CM2 entre les deux suivis longitudinaux ruraux 2000 - 2005 et 2012 - 2017 se confirme – sans cependant s'annuler – la différenciation rurale-urbaine en cette matière reste encore fortement marquée, aussi intensément en tous cas qu'elle apparaissait dans les sondages exploratoires drômois précédents (Champollion, Dos Santos & May-Carle, 2015).
- Les représentations sociales caricaturales des différents types de territoire, frisant souvent les stéréotypes, elles, n'ont pas été véritablement supprimées.

COMPORTEMENTS PERCUS, PERFORMANCES ESTIMEES-PROJETEES ET PROJETS D'ORIENTATION-INSERTION

Tout ce qui est analysé dans cette sous-sous-partie en matière de scolarité ne concerne que des estimations actuelles et projetées de performances et de trajectoires scolaires. Toutes les comparaisons entre les projections effectuées en termes de résultats scolaires et les réalités constatées du déroulement de la scolarité, comme entre les projets d'orientation et les orientations réalisées, ne sont pas ici possibles dans la double mesure où les élèves de CM2 urbains questionnés ne sont pas nominalement suivis au-delà de ce niveau et où les données relatives aux élèves ruraux du 2nd suivi longitudinal OET exploitées dans ce cadre sont, de ce fait, limitées au niveau CM2.

- Goût pour l'école (élèves)

Si la différence entre les élèves ruraux et urbains est bien légèrement significative, le sens de la différence a été apparemment inversé (figure 15)! En effet, dans les sondages exploratoires urbains drômois antérieurs, c'étaient plutôt les élèves ruraux de CM2 ardéchois et drômois qui disaient, de façon statistiquement presque significative, aimer légèrement plus que leurs homologues urbains valentinois leur école ! Par rapport à l'enquête CM2 de 2000, il faut noter ici que le goût pour l'école des élèves ruraux recule de près de 14 points.

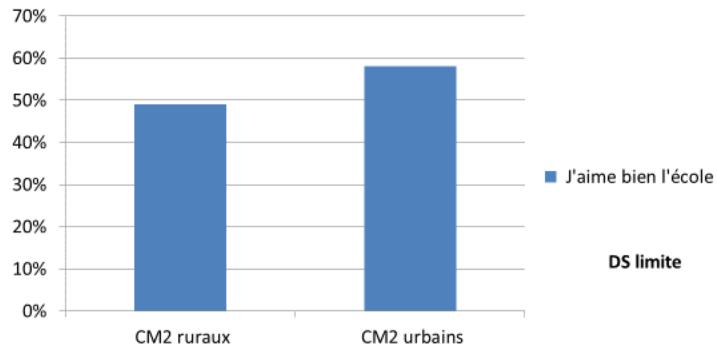

Figure 15. J'aime bien l'école (élèves). Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

- Auto-estimation du niveau scolaire actuel

La sous-estimation de leur niveau scolaire par les élèves, qui était caractéristique de l'élève-moyen dans le rural en 2000, devient moins importante (recul de 13 points) aujourd'hui. L'auto-estimation de son niveau scolaire[18] dans le milieu rural, elle, se rapproche ainsi, au point même de la dépasser très légèrement, de ce qui se passe en moyenne dans le milieu urbain (figure 16). Ici aussi, le sens de la différence s'inverse ! Il en va presque de même de l'évolution de l'estimation des résultats de leurs enfants par les parents ruraux, qui se rapproche elle aussi – sans la dépasser toutefois – de ce qui se passe chez les parents urbains pour cet item particulier (figure 16). Mais, dans tous les cas, les différences entre les ruraux et les urbains, quelles qu'en soient les sens, ne sont ici que faiblement significatives (figures 16 et 17).

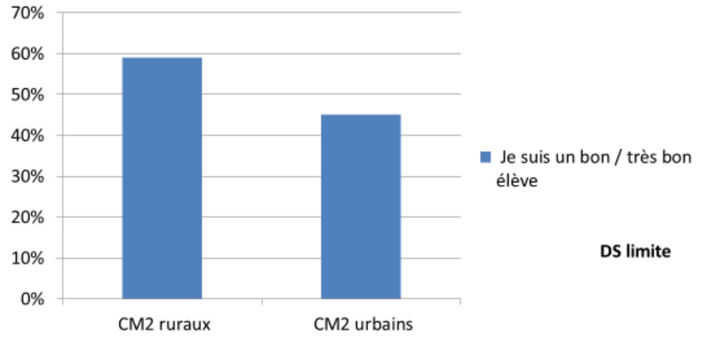

Figure 16. Auto-estimation de leur niveau scolaire actuel par les élèves : je suis un(e) bon(ne) / très bon(ne) élève. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

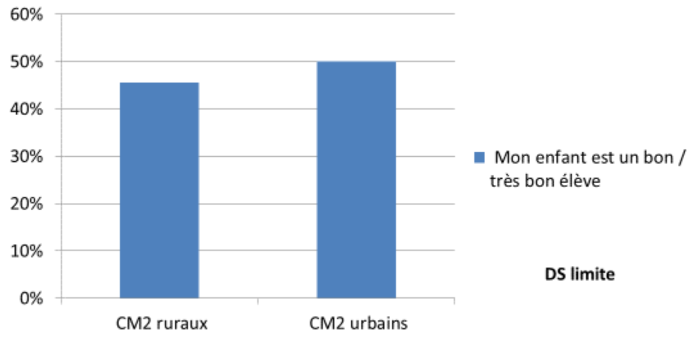

Figure 17. Estimation du niveau scolaire actuel de leurs enfants par les parents : mon enfant est un(e) bon(ne) / très bon(ne) élève. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

18 Il ne s'agit bien sûr pas ici d'une évaluation scolaire effectuée par les enseignants ou par l'administration des performances scolaires des élèves.

- Déroulement projeté de la prochaine année scolaire

Elèves et parents ruraux continuent d'appréhender négativement, significativement plus que leurs homologues urbains, la prochaine année scolaire (mais seulement la prochaine année scolaire). Cette appréhension de la « proche » réussite ultérieure[19] - négative ici - qui était déjà un des traits saillants de la spécificité de l'école rurale a même tendance à croître légèrement chez les élèves ruraux par rapport à l'enquête rurale 2000 (5 points) (figures 18 et 19).

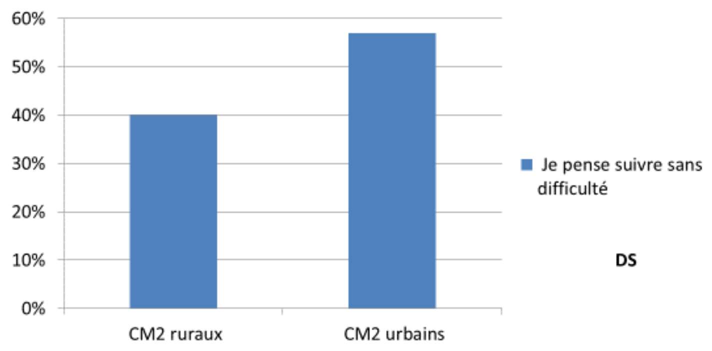

Figure 18. Déroulement projeté de la prochaine année (élèves) : je pense suivre sans difficulté. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

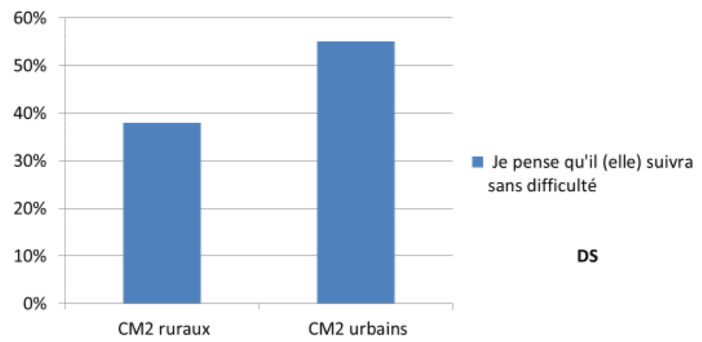

Figure 19. Déroulement projeté de la prochaine année scolaire (parents) : je pense qu'il (elle) suivra sans difficulté. Source enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

19 Qui renvoie au « niveau d'expectation », corollaire « attendu » du niveau d'aspiration », de la réussite scolaire.

- Age de fin d'études actuellement envisagé (élèves)

On observe ici toujours une différence – très légèrement – significative entre les élèves ruraux et les élèves urbains, même si le taux d'élèves ruraux envisageant de poursuivre jusqu'à vingt ans leurs études progresse d'une dizaine de points (figure 20). Elle se situe dans le droit fil de la crainte des ruraux vis-à-vis de l'avenir scolaire. Mais il n'est pas certain que, pour des enfants d'une dizaine d'années, l'item soit totalement pertinent[20]… Les projections dans l'avenir, à cet âge-là, ont en effet du mal à passer le cap de l'année…

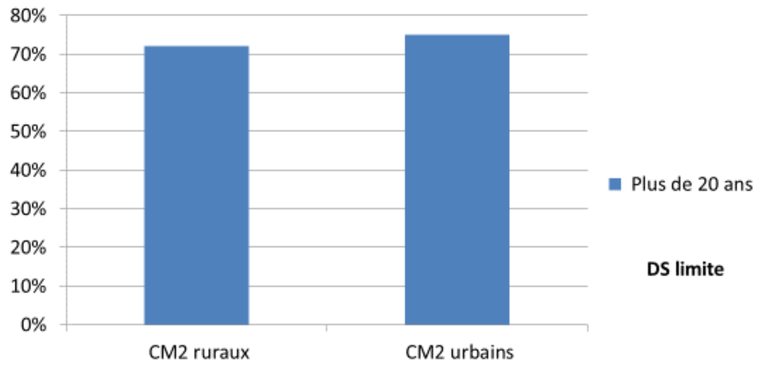

Figure 20. Age de fin d'études actuellement envisagé par les élèves : plus de 20 ans. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

- Niveau final d'études actuellement envisagées pour leurs enfants (parents)

Pour les parents, en revanche, les réserves précédentes émises par les élèves n'ont évidemment plus cours. Les différences observées entre le rural et l'urbain, qui n'ont ici guère évolué, restent significatives, même si elles ont diminué (figure 21). Elles renvoient évidemment à la « modestie » rurale habituelle – décroissante cependant aujourd'hui – des aspirations scolaires qui se traduisent par des projets d'études plutôt courts, ce qui a déjà été maintes fois constaté par le passé (Arrighi, 2004 ; Champollion, 2013 ; Grelet, 2004).

20 Cet item devrait - a minima - être libellé différemment…

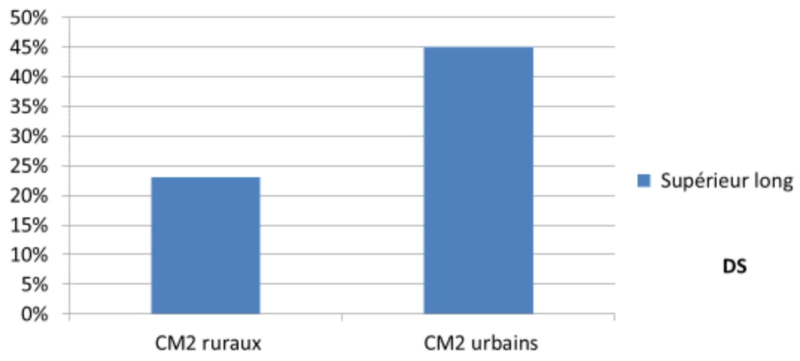

Figure 21. Niveau final d'études actuellement envisagées (parents) : enseignement supérieur long. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

- Métiers souhaités-rêvés

Les élèves ruraux et les élèves urbains souhaitent – quand ils « rêvent », id est quand ils ne se censurent pas – exercer dans le futur les mêmes métiers : sur les dix premiers métiers souhaités cités par les élèves ruraux, huit sont également cités par les élèves urbains (figure 22). Seuls changent – un peu – les rangs de citation. Au-delà de ce futur epartagé, on peut remarquer que – en dehors du métier de professeur que les élèves connaissent tous – la majorité des métiers cités, dans les deux cas, correspondent aux stéréotypes de l'âge (chanteur, coiffeur, footballeur, policier, pompier, vétérinaire, etc.) : l'effet de génération passe ici devant l'effet de territoire. Plus dans le détail, si l'on observe le premier métier cité par les élèves ruraux - vétérinaire[21] – on s'aperçoit qu'il est également cité par les élèves urbains, même si son rang - 4ème – n'est plus le même (figure 23). De la même manière, le premier métier cité par les élèves urbains – footballeur – n'est pas cité à la même hauteur par les élèves ruraux : la différence ici est un peu plus significative, notamment en termes de fréquence absolue, même si le rang - 5ème - est proche (figure 24). Sans doute faut-il y voir le poids médiatique de la « culture foot » urbaine… et la proximité des stades !

21 Ce qui ne constitue pas vraiment une surprise : au-delà du stéréotype de l'âge joue ici le poids de la territorialité rurale dont la composante agricole, même si le taux d'agriculteurs a fortement chuté, imprègne encore largement les esprits.

Métiers	Elèves ruraux	Elèves urbains
Acteur	Rang 8	Rang 7
Chanteur	Rang 10	Rang 6
Coiffeur	Rang 4	Rang 7
Cuisinier	Rang 2	/
Footballeur	Rang 5	Rang 1
Médecin	Rang 8	Rang 2
Policier	Rang 3	Rang 3
Pompier	Rang 7	/
Professeur	Rang 5	Rang 4
Vétérinaire	Rang 1	Rang 4

Figure 22. Métiers souhaités-rêvés : rangs urbains des dix 1[ers] vœux ruraux. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

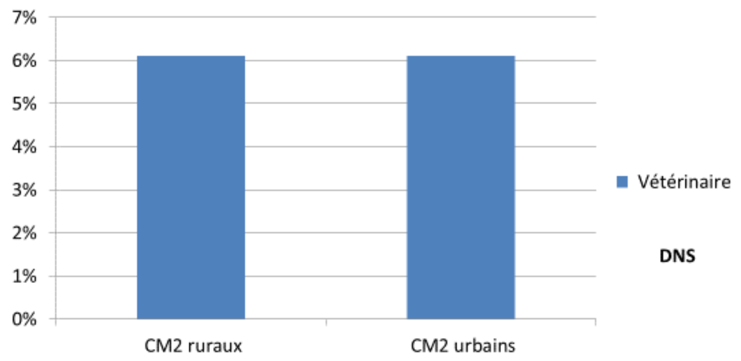

Figure 23. Métiers souhaités-rêvés : vétérinaire (1[er] vœu des élèves ruraux). Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

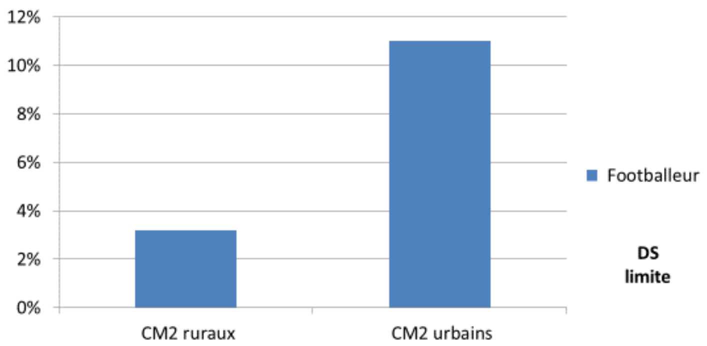

Figure 24. Métiers souhaités-rêvés : footballeur (1[er] vœu des élèves urbains). Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

- Métiers envisagés réalistes

La différence rural-urbain s'accroît quelque peu lorsqu'on regarde les choix des dix premiers métiers « réalistes » que les élèves, au-delà de leurs « rêves », s'attendent à exercer (figure 25). Certes, huit sur dix sont encore communs aux deux listes, mais les rangs dans les deux listes sont cette fois-ci nettement plus contrastés que dans la figure 22. Et, en dehors toujours du métier – bien connu de tous les élèves – de professeur, les métiers cités en tête par les élèves ruraux correspondent fréquemment à des métiers – très souvent modestes – bien présents en milieu rural, comme assistant maternel, cuisinier, coiffeur, etc. (figure 25).

Métiers	Elèves ruraux	Elèves urbains
Acteur	Rang 9	/
Assistant maternel	Rang 5	/
Coiffeur	Rang 2	Rang 8
Cuisinier	Rang 1	Rang 5
Footballeur	Rang 8	Rang 2
Médecin	Rang 7	Rang 1
Policier	Rang 10	Rang 6
Pompier	Rang 6	Rang 4
Professeur	Rang 4	Rang 2
Vétérinaire	Rang 3	Rang 7

Figure 25. Métiers réalistes envisagés : rangs urbains des dix 1ers vœux ruraux. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

De manière synthétique, cette sous-partie 3.3 montre qu'en dehors du goût pour l'école et de l'estimation de leur niveau chez les élèves, où les résultats s'inversent par rapport aux précédentes enquêtes, on peut constater que la différenciation rural / urbain – confirmation donc des sondages urbains valentinois – relative aux estimations projetées du niveau scolaire, de la durée des études et du type d'études, se maintient aussi bien chez les élèves que chez leurs parents. Sur le plan des projets ou plutôt des souhaits d'insertion, il convient de noter ici qu'en matière de métiers « rêvés », les stéréotypes liés à l'âge, au-delà de quelques légères variations liées aux différences de territorialité, sont un peu plus prégnants chez les élèves urbains que chez les élèves ruraux, tandis qu'en matière de métiers envisagés, les élèves ruraux apparaissent beaucoup plus « réalistes » … et plus modestes que leurs homologues urbains.

SYNTHESE GENERALE ET PREMIERES HYPOTHESES EXPLICATIVES

SYNTHESE GENERALE

Lorsqu'on dresse le bilan quantitatif global de la petite trentaine d'items [22] du questionnement CM2 effectué qui ont été analysés de façon comparative (figure 26), on observe au premier abord que près du tiers ne présentent plus de différences significatives en fonction de l'origine territoriale des élèves scolarisés. Sur les deux tiers restants, qui témoignent encore de différences significatives entre les deux échantillons, on remarque que ces écarts sont pour l'essentiel moins importants que par le passé. Il y a donc bien eu, depuis une dizaine d'années, atténuation de la spécificité rurale, qui avait été constatée antérieurement au plan éducatif, comme on l'a vu.

Sur le plan qualitatif, on remarque que les « poches de résistance » rurales correspondent à deux grands champs : d'une part, la projection dans l'avenir scolaire, que les élèves ruraux et leurs parents ne voient toujours pas d'un œil très assuré ni très optimiste, en comparaison avec leurs homologues urbains ; d'autre part, les représentations des lieux portées et construites par les élèves ruraux qui, si elles ont bien évolué dans le sens d'une atténuation du rejet de la ville et de l'étranger, marquent encore une différence significative avec les représentations correspondantes issues des élèves urbains.

Bien sûr, il est nécessaire de rappeler ici deux limites de ces recherches. D'abord, les enquêtes urbaines effectuées devront être encore élargies en termes de taille d'échantillon. Ensuite, il n'est évidemment pas possible d'en généraliser les résultats à toute la France, par exemple, à partir de ce qui est constaté sur l'Ardèche et la Drôme. Les enquêtes sur ces deux départements ont évidemment des caractéristiques contextuelles particulières, tant au plan rural qu'au plan urbain, qui ne les rendent pas a priori représentatifs de l'ensemble du territoire national. En revanche, les résultats obtenus - intéressants bien sûr - pour les zones investiguées, permettront sans doute de formuler et de tester des hypothèses mieux ciblées et, plus largement, d'élaborer des questions de recherche plus claires et mieux posées…

22 29 exactement.

(effectifs > 100 / 0,1 < fréquences < 0,9 / .05)

Nombre d'items entre parenthèses	DS	DNS	Balance DS - DNS
Goût pour l'école (1)	1	0	+ 1
Scolarité estimée et projetée (6)	6	0	+ 6
Métiers rêvés-souhaités (2)	1	1	0
Déménagements antérieurs (2)	0	2	- 2
Grands voyages (4)	2	2	0
Lieux attractifs et répulsifs (6)	6	0	+ 6
Pratiques culturelles (8)	4	4	0
Totaux (29)	20	9	+ 11

Figure 26. Bilan général des écarts observés. Source : enquêtes *Observatoire éducation et territoires* rurales 2012 et urbaines 2014-2015 Ardèche et Drôme.

PREMIERES HYPOTHESES EXPLICATIVES

Les différentes études conduites jusqu'ici dans la France rurale et montagnarde ont montré que, si les utilisations pédagogiques des technologies de l'information et de la communication (TIC)[23], déclinées au sein de l'Education nationale en technologies de l'information et de la communication pour l'enseignement (TICE) et en technologies usuelles de l'information et de la communication (TUIC), y sont aujourd'hui largement développées, y compris dans les zones les plus reculées qui ont souvent été équipées de façon volontariste pour « compenser » leur isolement supposé, celles-ci n'ont pas – encore ? – permis d'améliorer significativement les résultats scolaires dans lesdits territoires ruraux et montagnards (Alpe & Fauguet, 2008 ; Carulla, 2013).

Pour autant, il nous semble bien aujourd'hui que le développement rapide de la pénétration de l'internet dans les territoires ruraux, et notamment du haut débit, n'est pas étranger aux récentes évolutions présentées plus haut que nous avons constatées chez les élèves ruraux et montagnards en matière de représentations sociales et de comportements scolaires. D'une façon indirecte, cet essor rapide de l'internet dans tout le territoire national rend en effet aujourd'hui possible la généralisation effective, au sein de tous les territoires ruraux, de pratiques socio-culturelles plus homogènes qu'hier liées aux réseaux sociaux[24], qui se sont d'abord développées dans les territoires urbains qui ont été les premiers équipés (en fibre optique et téléphonie mobile notamment).

Ces pratiques, en « renversant » le sens de l'analyse sociologique traditionnelle (Mercklé, 2011), c'est-à-dire en ne regroupant plus les populations étudiées en

23 ICT en Anglais.

24 Cf. travaux du projet de recherche piloté par l'université de Rennes sur les inégalités éducatives (INéDUC 2012-2015) : "Inégalités éducatives et construction des parcours des 11-15 ans dans leurs espaces de vie".

catégories sociales ou professionnelles définies a priori (mais plutôt en considérant la population scolaire de manière indistincte, sans les classer autrement que par tranches d'âge), sont évidemment susceptibles de faciliter l'homogénéisation sur un territoire, ici national, des comportements et des représentations. Le contexte, pourrait-on rappeler, n'est pas une réalité extérieure à l'élément que l'on cherche à comprendre (Lahire, 2012) : élèves ruraux et urbains, au travers de leurs interactions et de leurs co-constructions au sein des réseaux sociaux qui les inclut en même temps qu'ils les développent, peuvent potentiellement, construire progressivement les représentations sociales qui transcenderont peut-être demain les territoires dont ils sont respectivement issus. Cette hypothèse, issue notamment des réflexions et des travaux antérieurs sur l'école rurale et montagnarde, devra bien sûr être validée – ou invalidée – par des investigations scientifiques ultérieures.

CONCLUSIONS PROVISOIRES ET PISTES DE RECHERCHE

La légère atténuation de la spécificité rurale observée à partir de la comparaison des enquêtes CM2 et 5ème des deux suivis longitudinaux *OER-OET* sur les deux départements de l'Ardèche et de la Drôme se voit donc clairement confirmée, même si les variables étudiées ne sont pas toutes touchées, ni également concernées, par les toutes dernières enquêtes urbaines menées sur ces deux mêmes départements. Ces premières évolutions observées vont elles-mêmes dans le même sens que les sondages urbains exploratoires antérieurs valentinois (Champollion, 2017 ; Champollion, Dos Santos & May-Carle, 2015). Y aurait-il donc à l'œuvre, liées à la pénétration d'internet dans les zones rurales et montagnardes, y compris les plus reculées, et consécutivement à la rapide montée en puissance des réseaux sociaux dans l'ensemble des territoires ruraux et montagnards, une tendance générale à l'homogénéisation et à l'uniformisation progressive des regards sur soi et sur l'école, ainsi que des représentations territoriales, qui traverserait tous les types de territoire ?

Faudra-t-il à terme, dans cette perspective si elle se confirme définitivement, « déconstruire » l'objet école rurale, au-delà de la diffusion actuelle massive dans les milieux urbains, notamment dans l'éducation prioritaire, de sa « forme » la plus emblématique, la « classe à plusieurs cours » ? Sous réserve d'invalidation ultérieure par le second suivi longitudinal *OET*, et notamment par l'enquête 3ème en cours de saisie, les résultats des enquêtes présentées, tant sur le rural que sur l'urbain, semblent déjà le confirmer… Les inégalités d'éducation et d'orientation d'origine territoriale repérées et constatées qui, rappelons-le, jouent de façon non univoque, tantôt positivement (éducation) et tantôt négativement (orientation), disparaîtront-elles à terme complètement ? Se conformeront-elles dans cette perspective aux pratiques et performances socialement les « meilleures » ?

Nous pensons – enfin – que les quelques pistes de recherche plus spécifiques inventoriées ci-dessous sont susceptibles d'éclairer plus avant, ainsi que de préciser plus nettement, les premières observations générales effectuées présentées plus haut :

- Elargir davantage le panel urbain observé pour le rendre totalement comparable, en termes d'ordre de grandeur des effectifs observés, au panel rural.
- Différencier plus nettement les différents panels analysés : urbain en REP et urbain hors REP, d'une part, et rural-montagne en types de ruralités et de massifs, d'autre part.
- Caractériser plus finement, avant comparaisons, les différentes territorialités urbaines investiguées.
- Tester, à partir d'un questionnement spécifique, les premières hypothèses globales explicatives émises - impact potentiel des réseaux sociaux sur les représentations sociales et les comportements scolaires - toutes choses étant égales par ailleurs, puis les affiner par des entretiens qualitatifs ciblés.
- Comparer rural et urbain en matière d'orientation (aux niveaux de la fin du collège, du début du lycée et de la fin du lycée), tant en termes de projets qu'en termes de réalisations.
- Comparer les devenirs respectifs des élèves ruraux et urbains en matière d'insertion professionnelle.

La problématique « éducation et territoires », qui gagnerait sans doute à la fois en précision et en amplitude à être qualifiée de problématique « éducation, territorialités et territoires » [25], ne laissera sûrement pas de s'affiner ni de s'approfondir à mesure que ces pistes de recherches, parmi d'autres, seront mises en œuvre. Les notions de permanences et de renouvellements de la relation complexe qu'entretiennent depuis toujours éducation et territoires, qui ont été repérés, présentés et analysés dans cet ouvrage, ne peuvent qu'en bénéficier… Le terrain n'est en effet jamais sans rien faire aux concepts (Le Marec, 2001). C'est ce cadre conceptuel global qui permettra à la comparaison rural - urbain, qui fait l'objet du présent article, de se développer dans toute sa complexité.

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25 Comme dans le séminaire international éponyme actuellement - 2015-2018 - développé au sein de l'axe 2 du laboratoire lyonnais Education, Cultures, Politiques (ECP).

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NOTES ON CONTRIBUTORS

ANA MARÍA ABRIL GALLEGO got her PhD in Molecular Biology at the Autonomous University of Madrid in 2000. She started as a science education lecturer in 2001 and since then she has published articles, and supervised PhD in the Didactics of Genetics with an emphasis of the potential of cinema as a vehicle for promoting RRI and socio-societal issues in secondary education. Furthermore, she has been involved in the European projects PRIMAS, COMPASS, mascil, PARRISE, IncluSMe and MasDiV as well as in several national research projects.

RON BLONDER is a professor of science education in the Department of Science Teaching, Weizmann Institute of Science. The goal of Prof. Blonder's research group is to bring the chemistry of tomorrow into the high school chemistry lessons of today. Her research addresses three issues: nano-scale science and technology education; science teachers' self-efficacy; and, chemistry teachers' professional development. Her efforts to enhance chemistry teachers' professional development has reached a large number of chemistry teachers via the National Chemistry Teachers' Center, the Rothschild-Weizmann program, the Israeli Chemical Society, and EU-projects. Prof. Blonder is married with four children. Professional site: http://www.weizmann.ac.il/st/blonder/

PIERRE CHAMPOLLION est actuellement chercheur titulaire au laboratoire Éducation, Cultures, Politiques (ECP) des universités de Lyon2-Saint-Etienne et chercheur associé au laboratoire Espaces et Sociétés de l'université de Caen (ESO-Caen). Préside depuis 2009 l'Observatoire éducation et territoire (OET), groupe de recherche pluridisciplinaire (sciences de l'éducation, sociologie et géographie). Ses recherches générales portent notamment, au sein de la thématique générale "éducation, territorialités et territoires", sur le segment "orientation et territorialités". Elles ciblent plus particulièrement les inégalités territoriales de scolarisation, d'éducation, d'orientation et de formation, plus particulièrement dans les milieux ruraux et de moyenne montagne, ainsi que, comparativement, dans les milieux urbains.

CARLA PACIFICO DIAS é professora de Ciências Naturais e de Biologia e Geologia no Externato Cooperativo da Benedita. Licenciou-se em Biologia e Geologia (ensino de) na Universidade de Aveiro. Mestrado e Doutoramento em Didática das Ciências pelo Instituto de Educação da Universidade de Lisboa.

HELEN HASSLÖF is senior lecturer in science education at the Faculty of Education and Society at Malmö University. Her research interests focus on complexity and the purpose of education in natural science, environmental and sustainability education. Previously working on environmental and nature conservation issues within the government's public investigation, outdoor pedagogics and ecological research. Helen has also been working with a couple of interregional EU-funded project, concerning sustainability education, integration and teacher development programs.

ELISABETE FERNANDES LINHARES is an Assistant Professor at Escola Superior de Educação do Instituto Politécnico de Santarém. Coordinator of the Master Degree for the 1st and 2nd Cycles of Basic Education. Associated member of the Unit of Research and Development in Education and Training at Instituto de Educação da Universidade de Lisboa and Member of the Research Unit from the Instituto Politécnico de Santarém, Portugal.

MATS LUNDSTRÖM has a PhD in education. He works as a senior lecturer in science education at the Faculty of Education and Society at Malmö University. His research mainly focus on scientific literacy and how scientific knowledge is used or not used in different situations, for instance concerning health. Lundström has also published research about examiners' assessment practice. He has participated in two EU-funded projects, (SAILS and PARRISE).

ANTONIO QUESADA studied Chemical Sciences at the University of Jaen (Spain), where he obtained his Ph.D. in June 2003. He worked at this University from 1998 to 2005 in the Organic Chemistry Department. He joined the Department of Science Education as lecturer and researcher in April 2005. During this period, he has actively engaged in different national and international European projects related to Science Education such COMPASS, PRIMAS, MASCIL, PARRISE; MASDIV and INCLUSME among others. His main areas of interest and research are focus on initial teacher education, continuing professional development of teachers, Inquiry-based Science Education, ICT and Science Education, among others.

SHELLEY RAP is a post doc fellow at the department of Science Teaching at Weizmann Institute of Science (Israel). Her research focuses on novel ways to use social media for advancing chemistry education at secondary school level. Dr. Rap holds MSc degree in chemistry from Bar Ilan University (Israel). In addition, she has an experience as a chemistry teacher, including preparing high school students to the matriculation exams.

PEDRO REIS is an Associate Professor and Vice Director of the Instituto de Educação da Universidade de Lisboa where he coordinates the Doctoral Program in Science Didactics.

MARTA ROMERO-ARIZA is a lecturer and researcher at the Department of Didactics of Sciences in the University of Jaén especially interested in how to enhance science learning through the use of innovative approaches and technological resources. Her lines of work include science teacher initial education and professional development with a special focus on inquiry-based science education, nature of science and socio-scientific issues. She has been actively engaged in several international projects such as EANCYT, COMPASS, PRIMAS and MASCIL. Currently she is the leader of the Spanish team in the European projects PARRISE, IncluSMe and MasDiV.

SHERMAN ROSENFELD received his Ph.D from UC Berkeley and worked as a science educator at the Weizmann Institute of Science for over 3 decades. His research interests include bridging the gap between formal and informal science education, computer simulations in science education, and whole-school change. For over 20 years, he spearheaded an effort in to introduce Project-Based Learning (PBL) into science and technology classrooms (K-12) throughout Israel. This effort has spread to all disciplines. He currently is the PBL academic advisor for the Amal School Network and an instructional designer at the Center for Educational Technology in Ramat Aviv.

JESPER SJÖSTRÖM is associate professor in educational sciences at the Department of Science-Environment-Society at Malmö University. Prior to joining Malmö University in 2007 he was a post-doc researcher at the Research Policy Institute, Lund University. His current research focuses on science education for critical citizenship and sustainability. He is, among other things, interested in praxis implications of different visions of scientific literacy and especially in the relationships between *Bildung*-view, knowledge in and about science-technology-society-environment-health (STSEH), and *Didaktik*.

ANAT YARDEN is Head of the Department of Science Teaching at the Weizmann Institute of Science, and Head of the Biology Group at this Department. The primary theme in all of her academic activities has been the attempt to adapt practices employed by scientists, to the processes by which students and teachers accumulate and advance their knowledge within the discipline of biology. Towards this end, her group pioneered the adaption of primary scientific literature for the teaching and learning of biology in high schools.

ERAN ZAFRANI is a PhD. student at the Department of Science Teaching at the Weizmann Institute of Science. His M.Sc. thesis dealt with social and cultural aspects of science learning and teaching. Specifically, he examined the the ways in which high-school students participate in a socioscientific project using identity research as an analytic lens.

ESTY ZEMLER received a BA in Biology, an MA in Public Policy (both from Tel Aviv University) and an MA in Chemistry Teaching (from the Weizmann Institute of Science). A veteran high school chemistry teacher, she also has worked as the Director of Strategic Planning for a local municipality and as a staff member for Israel's State Comptroller's Office. In the chemistry classroom, Ms. Zemler enjoys teaching with socio-scientific issues that develop student thinking about ethics and public policy. In the EU-funded IRRESISTIBLE Project, she participated in the Weizmann team develop curricular units based on RRI (Responsible Research and Innovation).

SUBMISSION GUIDELINES

PUBLICATION FREQUENCY

The Journal is published every four months: February, June and October.

Each number will focus on a specific theme. Along with the articles, the journal will include other research materials such as case-study reports, experiences and inquiries, conceptual and methodological discussions, on-going research papers and book reviews.

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