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Pupils' Understanding about Responsible Research and Innovation

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ABSTRACT

Educating a responsible and ethically sensitive citizen is a challenging task, and pupils should be offered the opportunity to exercise these qualities such as evaluating the ethical issues of nanotechnology. In the European Union, the concept of responsible research and innovation (RRI) was developed to connect both the scientific and industrial processes and their outcomes with the values, needs and expectations of society. RRI helps teachers and pupils engage with scientists, educators, museum workers and the public in doing research and innovations as part of school projects. The aim of the study was to examine how RRI dimensions were understood by Finnish pupils grade five and seven (ages 11-12 and 13-14). The results indicate that the pupils' ideas about RRI are rather difficult to measure; there was no substantial variation in the pupils' answers to the RRI questionnaire. Because the results indicated that learning to act in a socially responsible way should not take place only inside a classroom.

Keywords: RRI, science education, environmental education

INTRODUCTION

A Need for Responsible Research and Innovation

Science and technology have an impact on almost every part of our daily lives. Despite this, there can be a degree of ambivalence about science in our wider society. Overall, Europeans are generally positive about the influence of science and technology on society (Eurobarometer, 2013), so it seems somewhat paradoxical that feeling positive about science does not depend on feeling informed or being interested in science. Modern society needs to manage many ethically challenging areas of science and innovation such as nanotechnology (Sweeney, Seal & Vaidyanathan, 2003), geoengineering (Gardiner, 2011), synthetic biology (Douglas & Stemerding, 2013) and information and communication technology (Stahl, 2011), coupled with an increasing awareness of the impacts of innovations in contemporary society. Therefore, over the last seven years, the concept of responsible research and innovation (RRI) has gained visibility and traction in the European Union (EU), and specifically in the European Commission (EC) policy context (Owen, Macnaghten & Stilgoe, 2012). RRI is an approach, which brings together potential scientific implications and societal expectations with the aim of fostering the design of inclusive and sustainable research and innovation. As a broader concept, RRI implies that societal actors such as researchers, citizens, policy makers, business and third sector organizations work together during the whole research and innovation process to connect both the process and its outcomes with the values, needs and expectations of society (Sutcliffe, 2011).

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There is also an urgent need to incorporate acceptability, sustainability and societal desirability of the innovation process and its marketable products, which is described as Responsible Research and Innovation (RRI) into science education (EU, 2017). At present, humankind must deal with many serious problems such as climate change, global food security, the acidification of the oceans and pollution caused by plastic waste and urbanization, all of which can be dealt with responsible manufacturing process. In order to think their participation worthwhile, citizens need an understanding of the research and innovation and must trust that their own voices will be heard by other parties. The objective of attempting RRI during school years is to help today's children build confidence in; to see that their opinions and concerns in the society are valued, and their actions have an impact on the decisions of manufacturers of products at school (Blonder, Zemler & Rosenfeld, 2016). RRI connects science education with other subjects such as history, health and environmental education and in the school projects pupils can, for example, study how human health problems forced manufacturers to abandon the use of asbestos. RRI helps teachers and pupils to engage many actors, such as climate scientists, and members of the public, such as parents, in research and innovation as realized in different school projects. Those projects help learners to appreciate easier online access to scientific results, the take-up of gender and ethics in the research, innovation content and process, and formal and informal science education. RRI also serve as a natural chassis to manage socially and ethically sensitive, inclusive science and environmental education at schools and the other words as Blonder, Zemler & Rosenfeld (2016) believe RRI can advance the field of social scientific issues of science education.

Different Dimensions of Responsible Research and Innovation

RRI in science and environmental education is a framework to promote learners' thinking about responsible scientific research and technological development for making sustainable products and innovation. In schools, RRI enables learners to be ready, via an understanding of engagement, gender and ethical issues, open access to data, governance and the role of science and environmental education, to obtain and evaluate relevant knowledge on the consequences of the outcomes of scientific innovation as part of the learners' own science projects, in terms of societal needs and moral values (Blonder, Zemler & Rosenfeld, 2016). For studying pupils' understanding of RRI regarding the development of science and technology advances, we need to define it more deeply. Von Schomberg (2013) describes RRI as follows:

"Responsible research and innovation is 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)."

According to Sutcliffe (2011), RRI in science education considers the following dimensions: engagement, ethics, open access, science education, governance and gender equality. The European Commission (2014) has described these dimensions in more detail. *Engagement* implies that societal challenges should be framed by widely representative social, economic and ethical concerns. Moreover, its common principles lean on the strength of the joint participation of all societal actors — researchers, industry, policymakers and civil society. *Gender equality* addresses the fact that human resources management must be modernized and that the gender dimension should be integrated into the research and innovation content. *Science education* faces the challenge that future researchers and other societal actors need the necessary knowledge and tools to fully participate and take responsibility in the research and innovation process. *Open access* means that research and innovation must be both transparent and accessible. Free online access should be used to communicate the results of publicly funded research. *Ethics* requires that research and innovation respects fundamental rights and the highest ethical standards, ensuring the increased societal relevance and acceptability of research and innovation outcomes. Last comes *governance,* which addresses the responsibility of policymakers to prevent harmful or unethical developments in research and innovation. The latter is a fundamental basis for the development of the rest of the dimensions.

Owen, Macnaghten & Stilgoe (2012) approach RRI from three dimensions, which considerably overlap with the above-mentioned six dimensions. The first is democratic governance of the purposes of research and innovation and the orientation of making the "right impact". The second dimension is responsiveness, which emphasizes establishing different approaches to expectation, reflection and discussion in and around the integrated research and innovation in different institutes. The third is responsibility itself, in the context of research and innovation as collective activities with uncertain and unpredictable consequences. Also, according to Stilgoe, Owen & Macnaghten (2013), RRI can be seen as four dimensions: anticipation, reflexivity, inclusion and response.

Rationalization of Research

The Eurobarometer (2013) explored Europeans' views about science and engagement with science. It showed that at least half of all Europeans are interested in developments in science and technology, although only 40% say they feel informed about them. This suggests that science education, one of the RRI dimensions, is insufficient in this respect both at school and overall in the wider perspective of science communication. Many Europeans (62%) think science makes their way of life change too quickly, and 75% of Europeans agree that science and technology have provided more opportunities for future generations. Therefore, in the future, there will be many educational challenges in considering science in and for society. From the RRI point of view on open access, 79% of Europeans agree that the results of publicly funded research should be freely available online. In addition, governance was evaluated as important, because most (65%) think their government is doing too little to stimulate young people's interest in science. School education is also important in considering RRI, as 84% of Europeans think that a scientific education is important in stimulating creative thinking in young people.

Gender is currently an issue, for example, for Europe's competitive position. According to Eurobarometer (2013), 86% of Europeans think it is important that scientific research take equal account of the needs of men and women. Less than half (42%) said it is not important to respect gender equality and, as well, 50% of Europeans would ensure innovations which are better suited to both genders. However, there are still challenges, because men are more likely (64%) to be interested in and feel informed about developments in science and technology than are women (44%) (Eurobarometer, 2013). What might the percentages look like if children were asked these questions?

This sub-study is part of the Irresistible project (2017), in which we defined RRI in the same way as the EC (2012). One part of the project was to design teaching-learning sequences as a collaborative project by elementary school teachers and student teachers. Nanoscience, geoengineering and climate change were chosen as the contexts of the sessions. The possible choices were from a pool of novel developments in science, chosen by each country in the project. All topics undertaken in the project include aspects closely related to RRI, technology, and environmental education. The design task of nanoscience, climate and geoengineering was to include RRI in the classroom sessions and in pupil-curated science exhibitions, meant for sharing their project results in the schools and museums.

The learning sequences also were designed to include guided inquiry-based science education (Banchi & Bell, 2008), as there is evidence that inquiry-based teaching effectively prepares pupils for future challenges and supports a better understanding of science and of conducting science in general (Lederman, Antink & Bartos, 2014). Despite Sadler (2011) pointing out that socio-scientific issues (SSI) foster students' interest in learning science, it is still unknown how the students' argumentation and reasoning about RRI issues can be assessed in a science classroom. What RRI and inquiry-based teaching have in common is that they both reflect the actions of a researcher; inquiry is the science-specific, research-oriented context and RRI the overarching, broader societal context as it is supposed to learn students about nature of science. Blonder, Zemler & Rosenfeld (2016) pointed out that six RRI dimensions together provide an operative educational approach that is not difficult for teachers to adopt and for students to understand. Much like Nature of Science (NoS) teaching (Lederman, 2007), RRI also helps students understand how science works and helps them understand science as a key contributor in society. RRI entails a specific emphasis on the engagement of the public and of different societal actors in the processes of research and innovation, considering the responsiveness, ethical acceptability, sustainability and societal desirability of these processes. These societal concerns form a link to a different perspective — technology — alongside NoS approaches. RRI enables discussion about science and its impacts in society, but it also includes technology, which is largely lacking from NoS, in that discussion. In RRI, it becomes clear that scientific information arises from the need to create technology and that knowledge generates technology. This is important, because new technology brings with it a related responsibility and ethical considerations. Participating in the society requires the same core skills as participating in a classroom. The type of talk found in a classroom is a good indicator of the negotiation and participation skills the students come to learn. While there are different frameworks and support systems for learning to talk and think together, the main message is the same: listen to others and use their contributions, encourage others to participate, ask questions and offer ideas (Michaels, O'Connor & Resnick, 2008; Mercer et al., 2004; Wegerif et al., 2017, for details of such frameworks). The more practice there is of these fruitful discussions, the better.

Because of its recent emergence (EU, 2017), RRI is a rapidly evolving concept. Therefore, it is not surprising that there still are shortcomings and ambiguities as to the motivation, theoretical conceptualization and translation of RRI into practice. When one envisions a future which also includes RRI in science, environmental education and geography on a large scale, it is important to know how to develop pupils' readiness to study RRI in their classes. Not knowing how pupils understand science and its societal connections, a teacher faces a large challenge addressing these issues in class. It is known that reforms in schools are unlikely to happen if teachers are not involved from the beginning of the reform process, and teachers' attitudes towards learning innovation play a "make-or-break" role in the success of that innovation (van Driel, Beijaard, & Verloop, 2001). And these days, at least in Finland, the pupils' voice is also considered in educational reforms in tune with RRI (Finnish National Board of Education, 2014).

In this regard, RRI exhibits traits common to many innovations in their early stages; its purposes, processes and products are still shrouded in uncertainty. Nevertheless, we can identify some distinct features, locating how pupils associate RRI with their thinking in the context of science education and their construction of exhibits regarding climate change with their primary student teachers. Despite the fact that Eurobarometer (2013) does not reveal differences in the opinions related to RRI dimensions between younger (15-year-old) and older people, there is uncertainty about how children would actually answer the questions posed for RRI.

We will now study the six features of RRI highlighted by the EC, as they are most informative with respect to how our pupils think about RRI. Blonder et al. (2017) described how RRI dimensions has been used in earlier studies but there is still a lack of knowledge how pupils understand RRI according to gender, school level and science discussion. We pointed out that primary student teachers have difficulties to incorporate RRI into their inquiry-based lesson plans (Ratinen, 2016). The aim of the present study was to examine how RRI dimensions were understood by Finnish pupils.

RESEARCH QUESTION

Because there is still considerable uncertainty regarding how to incorporate RRI into science education, the present study seeks to answer the following questions:

- How do fifth and seventh grade pupils respond to claims in the six RRI dimensions ("RRI claims")?
- How do pupils' gender, school level, and science discussion activity affect their responses to the RRI claims?
- How do science discussion activity in science classrooms differ due to gender or school level?

METHODS

Solutions to the research questions were sought by further analysing questionnaire data collected during the Irresistible project in Finland. The goal of the project was to design activities that foster the involvement of students and the public in the process of RRI in the contexts of nanoscience, geoengineering, and climate change. This study, focusing on pupils' thinking and opinions expressed in the questionnaires, analysed and interconnected the data using quantitative methodology and statistical generalizations.

Participants

This data is part of a large sample collected from seven European countries, consisting only of the answers of Finnish pupils in seven Jyväskylä region schools (four elementary school classrooms in 2014, and 14 elementary and 3 lower secondary school classrooms in 2015, ages 11–12 and 13–14). The studied pupils are from the classes of a convenience sample of schoolteachers – those who responded with interest to our proposal of participating in a science education development project. The principals of the school as well as the teachers and pupils (and their parents) in each classroom received information letters about the project and gave written informed consent of their participation in the research.

In total, 276 Finnish respondents answered in Finnish the questionnaire during the project in 2014 and 2015. The sample is not representative of the entire set of classes participating in the project. Some teachers flat out refused to give the questionnaire to their students, as they felt it was too demanding for young pupils. One teacher reported having to mentor each pupil taking the questionnaire individually to ensure the pupil understood the abstract concepts and exotic terminology. In addition, 26 of the given answers were deficient, e.g. the age of the pupil was left blank, or there were no answers to the RRI claims. These 26 were not included in the final sample (250). Of the respondents, 50.8% were girls; 88% of all respondents were in the fifth grade and 12% in the seventh grade.

Table 1. Constructed sum variables of RRI dimensions and their Cronbach's alphas

Sum variable	Statement	α
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. Industrialists who develop technology products, such as new cell phones and computer applications, should be invited to give lectures on their work in schools.	.163
Gender	Scientists should try to balance the number of men and women in their research teams. Women and men should have equal rights and responsibilities in scientific research.	.257
Open access	Scientists should spend part of their research budget to present their research online, in a free and open way. Scientists have an obligation to make their research findings available to everyone.	.497
Governance	The government needs to regulate scientific research institutions. One of the roles of government is to prevent harmful or unethical practices in research and innovation.	.235
Ethics	Having high ethical standards can help ensure high quality results in science and technology. Organizations which fund scientific research should consult with scientists to decide which research topics to fund. If it is clear that doing research has negative implications or risks, scientists have the duty to stop conducting this research.	.593
Science education	The science curriculum in schools should include topics like how science solves society's problems. In science classes (s c), I develop competencies that allow me to have a more active role in society. In s c, I carry out projects that I consider important and socially relevant. In s c, I learn to act in a socially responsible way. In s c, I learn about ways to influence other people's decisions about social issues related to science, technology and society. In s c, I am responsible for initiatives that allow me to influence other people's decisions about social issues related to science, technology and society.	.748

Materials and Procedures

A Google Forms-based online questionnaire used in the present study was developed, piloted and validated during the Irresistible project (Blonder et al., 2017). The online questionnaire included 17 Likert-scale statements on RRI dimensions. The respondents expressed their opinions about statements on a unipolar scale from "do not agree at all" to "agree a great deal" (the alternative opinions 2, 3 and 4 were unnamed). Sum variables were calculated for the statistical analysis (**Table 1**). It is notable that the Cronbach's alpha values are relatively small (<.6) in almost every constructed sum variable. A low alpha indicates pupils' difficulty in answering the questions consistently, unlike what was presupposed for this study. In the questionnaire, each question represents some of the RRI dimensions, within which the answers were initially expected to align as a measure of how the pupils reacted to this dimension. Here, the overarching dimensions of each RRI aspect appear as sum variables.

The sum variable of science discussion was calculated from three question statements: "In science class I discuss current problems and how they affect my life"; "In science class I am encouraged to ask questions"; and "In science class I learn to respect my colleagues' opinions." The Cronbach's alpha values are relatively small (<.68).

The classroom discussion activity variable was also a Likert scale (ranging from "never" to "often"). The new variable connected opinions 1 and 2 (named "almost never") and 4 and 5 ("quite often"). Expressed opinion 3 was given the label "once in a while". A discussion activity variable and background variables determining the school level and gender were used as dependent variables in the statistical analysis. After careful data screening, missing values were replaced by mean values before the statistical analysis.

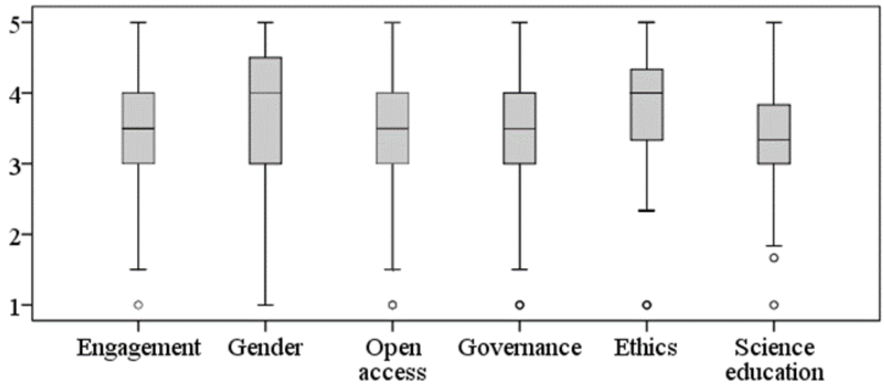

Figure 1. Box plot of RRI dimension sum variables, composed of respondents' answers to the RRI opinions questionnaire. 5 is "agree a great deal"; 1 is "do not agree". All outliers were located in the data of five respondents. (n=250)

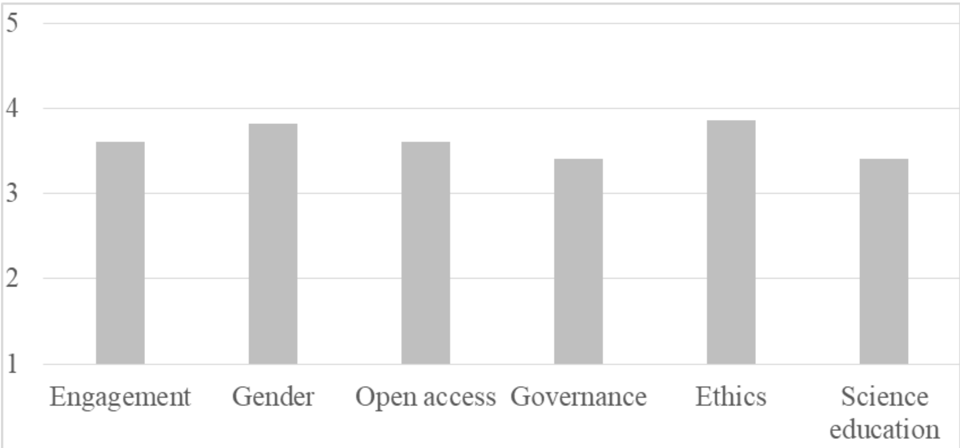

Figure 2. Mean values of RRI dimension sum variables, composed of respondents' answers to the RRI opinions questionnaire. 5 is "agree a great deal"; 1 is "do not agree". (n=250)

According to the Kolmogorov-Smirnov test for normality, not all the sum variables were normally distributed (>.05). Distributions skewed more to the statement "agree a great deal" than "do not agree at all". Because the data was not normally distributed, dependencies and connections between the sum variables and background variables were analysed using non-parametric statistical tests. The differences in discussion activity experienced in science classrooms due to gender and school level were analysed by χ^2 tests. The Kruskall-Wallis H test was used in the analysis of differences of discussion activity between RRI dimension opinions and science discussion experiences (sum variables). The significance levels of RRI dimension opinions between pupils' gender and school level were analysed by the Mann-Whitney U test.

RESULTS

Pupils' Attitudes towards RRI Dimensions

As **Figures 1** and **2** and **Table 2** indicate, there are relatively small variations between the RRI dimensions. Descriptive statistics illustrate that pupils were in high agreement with the RRI dimension of *ethics*. Pupils mostly (78.8% agreed with the statement) emphasized scientists' responsibility to terminate their research if its outcomes are harmful and risky; 52% of them did not clearly state their opinions (middle of the scale) regarding ethical standards for enabling high quality results in science and technology. As a conclusion, the pupils agreed with the idea of ethical standards in research and its quality and risk awareness science procedures. The relatively high Cronbach's alpha (.593) indicated that pupils answered quite similarly all questions within the RRI dimension of ethics (**Table 1**).

Table 2. Descriptive statistics by gender school level and science discussion

RRI	Gender						School level						Science discussion								
	Girls			Boys			5th grade			7th grade			Almost never			Once in a while			Quite often		
	M	Mdn	SD	M	Mdn	SD	M	Mdn	SD	M	Mdn	SD	M	Mdn	SD	M	Mdn	SD	M	Mdn	SD
Engagement	3.53	3.50	.699	3.67	3.50	.797	3.63	3.50	.745	3.43	3.50	.784	3.51	3.50	.789	3.59	3.50	.699	3.81	3.50	.729
Gender	4.01	4.00	.708	3.62	4.00	.957	3.80	4.00	.872	3.95	4.00	.769	3.87	4.00	.892	3.82	4.00	.712	3.73	4.00	1.02
Open access	3.67	3.50	.793	3.55	3.50	.923	3.65	3.50	.863	3.35	3.00	.800	3.54	3.50	.910	3.66	3.50	.793	3.69	3.50	.867
Governance	3.42	3.00	.644	3.40	3.50	.775	3.40	3.50	.722	3.43	3.50	.626	3.46	3.50	.763	3.34	3.00	.571	3.42	3.50	.807
Ethics	3.92	4.00	.644	3.81	3.67	.766	3.88	4.00	.702	3.75	3.66	.747	3.96	4.00	.692	3.71	3.67	.649	3.92	4.00	.800
Science ed.	3.42	3.16	.620	3.38	3.33	.651	3.43	3.33	.635	3.24	3.16	.618	3.31	3.25	.629	3.33	3.17	.590	3.71	3.67	.636

The pupils' answers varied most (**Figure 1**) with respect to the *gender* issues, which nevertheless had the second highest mean value in a sum variable (**Figure 2**). They did not answer similarly the questions which measured opinions regarding gender issues (**Table 1**), shown by the low Cronbach's alpha level (.257). A closer look indicates that 75.6% of the pupils agreed that women and men should have equal rights and responsibilities in scientific research, but just 42.8% of them thought that scientists should try to balance the number of men and women in their research teams. The pupils thought differently about the number of men and women in research teams compared to their rights and responsibilities in scientific research.

Respondents expressed the lowest variation and median value (**Figure 1**) and lowest mean values (**Figure 2**) for the sum variable of *science education*. As **Table 1** indicates, the questionnaire also gathered pupils' opinions about the social relevance of science. The relatively high Cronbach's alpha (.748) indicates that the statements in this dimension were consistent. The pupils mostly agreed (42.2%) that in science classes, they develop competencies which will allow them to have a more active role in society. Yet only 27.2% of them agreed with the statement that they have learnt in science classes about ways to influence other people's decisions about social issues related to science, technology and society. It is interesting to know, for the curriculum development process, that pupils do not think very strongly (34.8% agreed) that the science curriculum in schools should include topics such as how science solves society's problems.

Variations within the dimensions of *open access* and *governance* were very similar (**Figure 1**). However, as **Figure 2** indicates, the pupils more often agreed with open and free data than with governmental regulation of science. A more detailed analysis reveals that 57.2% of pupils thought that scientists have an obligation to make their research findings available to everyone, but only 28.8% of them agreed on the governmental need to regulate scientific research institutions. But when they were asked about the government's role in preventing harmful or unethical research and innovation, half (50%) expressed their great agreement with the statement. Thus, the Cronbach's alpha (.235) of governance is relatively low (**Table 1**).

The lowest Cronbach's alpha (.163) belongs to the sum variable *engagement* (**Table 1**). It seems evident that the pupils did not view the engagement statements in the questionnaire in the same way. In particular, the question of scientists' consultation with community representatives, such as people who work for nature conservation, human rights and consumer rights, was the question where 59.6% of respondents did not express great agreement. In the other question, 63.2% of pupils would invite industrialists such as new cell phone and computer application manufacturers to give lectures in schools on their work. As a conclusion, the pupils did not evaluate scientist consultation as very important for the development community, but they would invite the developers of technology products as visitors in schools to give lectures.

Figure 3 shows the overall pattern of pupils' expressed opinions regarding the RRI dimensions. Interestingly, it is evident that the more pupils discuss in science class (How often have you participated in discussion…), the more they agree with the questions in the sum variable of *science education*. According to the survey, Finnish girls and boys in the fifth and seventh grades seem to believe very similarly about the *governance* of research and innovation.

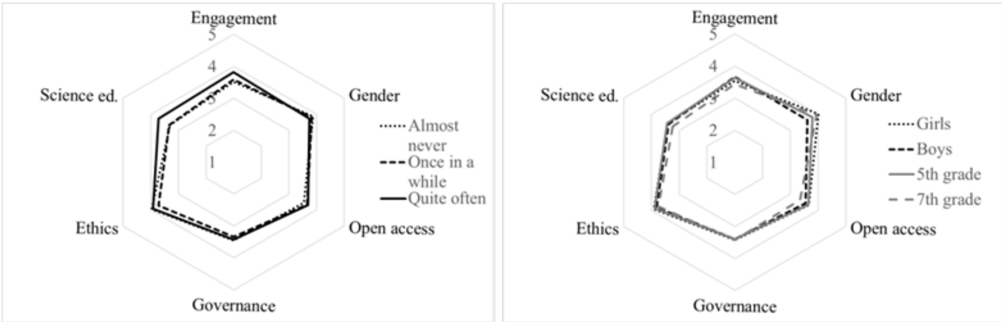

Figure 3. Mean values of agreement with RRI dimensions of pupils with different science discussion activity (left) and gender and school level (right). Dimensions represent the sum variables of respondents' answers to the questionnaire. (n=250)

Table 3. Statistical dependencies of RRI dimensions by gender, school level and science class discussion (almost never, once in a while, quite often) (n=250)

RRI	By gender			School level			Science discussion		
	U	*p*	*r*	*U*	*p*	*r*	χ^2	*p*	*r*
Engagement	6909	<.107	.10	2789	<.160	.09	4.735	<.094	.02
Gender	6109	<.002**	.19	3085	<.554	.04	.906	<.636	.00
Open access	7474	<.548	.04	2523	<.033**	.13	1.412	<.494	.01
Governance	7654	<.775	.02	3158	<.690	.03	2.187	<.335	.01
Ethics	7342	<.407	.05	2861	<.232	.08	9.642	<.008**	.04
Science ed.	7683	<.822	.01	2762	<.145	.09	12.857	<.002**	.05

Inspired by **Figure 3**, the statistically significance differences of RRI dimensions studied regarding the pupils' self-evaluated science discussion activity, their gender and school level will be presented next.

Variation of Opinions with Respect to Gender, School Level and Science Class Discussion Frequency

Tables 2 and **3** illustrate how opinions about the RRI dimensions varied with respect to gender, school level and science class discussion. Girls agreed statistically more often (U=6109, p<.002) than boys with the statement that the numbers of men and women should be equal in research teams. Closer analysis reveals that girls (*M*=4.56) more often "agreed a great deal" than boys (*M*=4.02) with the idea that women and men should have equal rights and responsibilities in scientific research. The other RRI dimensions did not differ between genders (**Table 3**). On the level of singular question data, girls (*M*=4.30) more often than boys (*M*=3.90) said that if it is clear that doing research has negative implications or risks, scientists have the duty to stop conducting this research.

The Mann-Whitney U-test indicates the difference between the fifth and seventh graders' evaluations in the RRI dimension of *open access* (U=2523, *p*<.033) (**Table 3**). It shows that younger pupils thought more often than older ones that scientists should spend part of their research budget to present their research online, in a free and open manner. Similarly, fifth graders more often said that scientists have an obligation to make their research findings available to everyone. More detailed analysis revealed that fifth graders (*M*=3.41) were more willing that scientists should consult with community representatives, such as people who work for nature conservation, human rights and consumer rights in their school than were seventh graders (*M*=3.01). And, maybe surprisingly, fifth graders (*M*=3.31) more often than seventh graders (*M*=3.00) thought that the science curriculum in schools should include topics like how science solves society's problems.

According to the Kruskall-Wallis test, the amount of science discussion in science class affects pupils' opinions in the RRI dimensions of *ethics* (χ^2=9.642, *p*<.008) and *science education* (χ^2=12.857, *p*<.002). Closer analysis revealed that pupils who felt that they took part more in discussion in the classroom also expressed a greater agreement with the RRI dimension of *science education*. To them, school science also includes the societal aspects of science. Yet despite their statistical significance, these results are still difficult to explain. If a respondent participated *almost never* or *often* in the classroom discussion, (s)he agreed a great deal with the RRI with respect to *ethical dimensions*. But if a participant responded that (s)he *once in a while* (middle of the Likert scale) participated in ethical discussion, ethical dimension questions were also evaluated at the

Table 4. Responses for how often girls and boys have participated in discussion in science classrooms which deal with ethical issues of science and society (n=250)

	Almost never	Once in a while	Quite often	Total
Girls	52	49	26	127
Boys	56	40	27	123
Total	108	89	53	250

χ^2=1.013(2) p<0.602

Table 5. Responses for how often pupils in elementary and secondary science classrooms have participated in discussions which deal with ethical issues of science and society (n=250)

	Almost never	Once in a while	Quite often	Total
5th grade	93	80	47	220
7th grade	15	9	6	30
Total	108	89	53	250

χ^2=0.668(2) p<0.709

low end of the scale. As **Tables 4** and **5** show, ranked by gender and school level, there is no statistical difference in science discussion participation. However, girls (*M*=3.50) felt more encouraged to ask questions in science class than boys (*M*=3.10), and fifth graders (*M*=3.72) discussed more about current problems in science class than did seventh graders (*M*=3.37).

DISCUSSION

It is clear that the concept of RRI contains ideas similar to Nature of Science teaching and learning and Science in Society (Blonder, Zemler & Rosenfeld, 2016). RRI emphasizes the knowledge relative to technology, for example nanotechnology for product manufacturing. RRI refers to the comprehensive approach of proceeding in research and innovation in ways which allow all stakeholders to be involved in the processes of research and innovation (Jacob, 2013). From this perspective, they are willing to use these considerations for the design and development of new school science and environmental projects. Blonder et al. (2017) described how RRI dimensions on this study was developed and operationalized in the questionnaire. Based on their study the RRI questionnaire used in this study to assess the development of attitudes regarding RRI across pupils. However, as the results of the present study indicate, there will be many challenges in how we measure pupils' understanding and the incorporation of RRI into learners' thinking. The six RRI dimensions have also faced some critique. Ruggiu (2015) argued that RRI entails two viewpoints contradicting each other, which can also make it difficult to understand. One interpretation of RRI emphasises the socioempirical process in which societal actors become mutually responsive through a democratic process, whereas the other interpretation sees that RRI is based on normative values set by the EU.

How do Fifth- and Seventh-grader Pupils Respond to Claims in the Six RRI Dimensions

RRI seems to be a difficult concept for pupils — or the questionnaire we asked them to fill out was too demanding. The pupils answered all the RRI dimensions' topics in much the same way, and only within the gender issue was there a noticeable variation in their answers. The greatly varying Cronbach's alphas represent the low consistency of the pupils' answers inside the RRI dimensions of engagement, gender and governance.

How do Pupils' Gender, School Level and Science Discussion Activity Affect their RRI Opinions?

Based on the results of the present study, girls agreed statistically significantly more than boys with statements belonging to the RRI dimension of gender. This shows that the girls were more sensitive to statements about their representation in science and science teams; already the fifth-grade girls seemed to be aware of the issue of women being underrepresented in fields of science. The remaining dimensions' statements were evaluated similarly by both genders.

Pupils in the fifth grade thought statistically significantly more than seventh graders that there should be open access to data and that research findings should be available to everyone. There is similarities between Blonder et al. (2017) study (mean value 3.68) and this study but there is no study how pupils really understand what open access is. School level did not affect the other dimensions of RRI. Is the atmosphere different in the fifth-grade classroom, where they typically study all school subjects with the same schoolteacher, than in the seventh grade, where students change from one subject-specific classroom to another, lesson by lesson? We wonder if we are seeing here an effect on the students' comfort level of the breaching of subject-specific topics with insights from out-of-school contexts or social awareness. However, open access is probably difficult concept for young students and there is a need to develop a new methodology such as participatory study gather how they really, for example, utilize data in their environmental projects.

Somewhat surprisingly, how much the pupils felt they participated in discussion in the classroom had a statistically significant effect on two dimensions — science education and ethics. In the sum variable of science education, the result is clear. The more ethical discussion there was in a classroom, the greater agreement the pupils expressed with science education questions. The idea that promoting quality group discussions connects to enhanced science learning altogether (Mercer et al., 2004) also seems to be valid in our data. In the present study, there were no differences in discussion activity due to gender or school level.

On the effect of pupils' participation in ethical discussions in the classroom on their agreement with the ethical dimension of RRI, we cannot say much. The results were not in linear correlation with the frequency of discussions in the class. A possible interpretation for this is that superficial, inconsistent attempts at incorporating ethical discussions in the class may dishearten students with respect to the ethics of science or technology, more than either refraining from discussion altogether or providing consistent opportunities to discuss ethics. The questionnaire data shed no light on the topics or the experienced quality of the discussions, and the origin of this correlation remains unclear.

CONCLUSION AND DISCUSSION

The results of this study show that RRI is a difficult concept for pupils. However, it also offers many opportunities, such as discussion about ethical issues toward a new innovation or making exhibits as a learning tool for science educators, teachers, students and society (Bayram, 2015; Apotheker et al., 2017). In particular, the RRI dimensions such as engagement, gender and governance proved to be difficult to measure with just a few questions. Because the pupils did not answer consistently (low Cronbach's alphas) in the aforementioned dimensions' statements, the statements used should be conceptualized and reworded very carefully. This study revealed that questions which are commensurate with each other in adults' thinking may not be so in children's thinking (**Table 1**). The results is different than in Blonder et al. (2017). The questionnaire we used in this study was not properly validated for use with young learners just beginning to conceptualize RRI. Unfortunately, we cannot extrapolate that pupils might be too young to appreciate RRI concepts and therefore further study is needed.

Due to the emerging influence and the novelty of RRI as an educational objective, discussing its connections to more mature concepts (such as NoS) and trends in science and environmental education (such as climate change education) will facilitate teachers in implementing it in their classrooms. Because of the complexity of RRI, it is helpful to spell out connections with pedagogical themes with which the teachers or curriculum developers are already familiar.

During the Irresistible project, we discussed examples of how RRI could be integrated into sustainable education. The aim was to describe a pedagogically meaningful approach, content-wise, in which the RRI ideas would thrive. Potential approaches validated in the project were, for example, inquiry-based learning, where students constructed exhibits related to climate change, or debates and role-playing exercises, where the class acted as a mini-society. Based on the experiences of the Irresistible project, even if RRI is a difficult concept for learners to internalize, it is possible to incorporate it into teacher education when student teachers, teachers, scientific researchers, science educators and science exhibition experts together develop novel approaches for RRI teaching and learning.

We still need evidence and a better understanding of the potential implications of RRI in teaching and research on science and education. Pupils' opinions on gender issues, for example, are relevant. In this study girls were more sensitive to statements about their representation in science and science teams and if they feel that teaching is not gender-equitable, the teacher must change the teaching. Do students hesitate in choosing a career path when they cannot find a relatable role model? The teacher can now pay extra attention to this, knowing that young girls already have ideas about women's lower representation in science.

The present study indicated that discussion in the classroom relates to pupils' ideas with respect to RRI. According to Ratinen (2013), it is beneficial for learning when teachers create environments where students actively take part, discuss, judge, argue and evaluate. Dialogic discussion in the classroom probably helps to build a working understanding of RRI while learning about environmental challenges such as climate change (Ratinen et al., 2016) or scientific phenomena but there is still a need for new research. Dialogic discussion can also improve pupil learning motivation, because the pupil feels that her/his views are relevant.

In particular, we worry about meeting the needs for the engagement dimension. Notice that a scientist's visit to the classroom did not receive unanimous approval among pupils in this study. We need to find ways to ease the students' path into these activities, which are quite demanding even for many adults. We know that learning outside of school improves learning motivation (Braund & Reiss, 2006), but do the students initially feel that they cannot talk to scientists or industry representatives, for example?

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