Sci Eng Ethics
https://doi.org/10.1007/s11948-018-0029-1

ORIGINAL PAPER

Teaching Responsible Research and Innovation: A Phronetic Perspective

Niels Mejlgaard[1] · Malene Vinther Christensen[1] · Roger Strand[2] · Ivan Buljan[3] · Mar Carrió[4] · Marta Cayetano i Giralt[5] · Erich Griessler[6] · Alexander Lang[6] · Ana Marušić[3] · Gema Revuelta[7] · Gemma Rodríguez[4] · Núria Saladié[7] · Milena Wuketich[6]

Received: 14 October 2017 / Accepted: 30 January 2018

Abstract Across the European research area and beyond, efforts are being mobilized to align research and innovation processes and products with societal values and needs, and to create mechanisms for inclusive priority setting and knowledge production. A central concern is how to foster a culture of "Responsible Research and Innovation" (RRI) among scientists and engineers. This paper focuses on RRI teaching at higher education institutions. On the basis of interviews and reviews of academic and policy documents, it highlights the generic aspects of teaching aimed at invoking a sense of care and societal obligation, and provides a set of exemplary cases of RRI-related teaching. It argues that the Aristotelian concept of *phronesis* can capture core properties of the objectives of RRI-related teaching activities. Teaching should nurture the students' capacity in terms of practical wisdom, practical ethics, or administrative ability in order to enable them to act virtuously and

✉ Niels Mejlgaard
nm@ps.au.dk

1 Danish Centre for Studies in Research and Research Policy, Department of Political Science, Aarhus University, Bartholins Allé 7, 8000 Aarhus C, Denmark

2 Centre for the Study of the Sciences and the Humanities, University of Bergen, Parkveien 9, 5020 Bergen, Norway

3 Department of Research in Biomedicine and Health, University of Split School of Medicine, Šoltanska 2, 21000 Split, Croatia

4 Health Sciences Education Research Group, Department of Experimental and Health Sciences, Universitat Pompeu Fabra, C/Aiguader 88, 08003 Barcelona, Spain

5 Association of Catalan Public Universities (ACUP) and Global University Network for Innovation (GUNi), Carrer de la Vila, UAB Campus, Bellaterra (Cerdanyola del Vallès), 08193 Barcelona, Spain

6 Institute for Advanced Studies, Josefstädter Straße 39, 1080 Vienna, Austria

7 Studies Centre on Science, Communication and Society, Department of Experimental and Health Sciences, Universitat Pompeu Fabra, C/Aiguader 88, 08003 Barcelona, Spain

Published online: 07 February 2018

responsibly in contexts which are often characterized by uncertainty, contention, and controversy.

Keywords Responsible Research and Innovation · RRI teaching · Phronesis

Introduction

Against a backdrop of increased attention towards the importance of research and innovation for dealing with environmental degradation, climate and demographic change, terror, economic and social inequalities, ageing societies and other global challenges, the concept of Responsible Research and Innovation (RRI) has gained importance in policy. In a European context, RRI has been promoted by the European Commission in particular, and a range of research and coordination activities have been funded under an RRI label. The idea that research and innovation should take responsibilities beyond those related to internal norms and quality criteria within respective research domains is not new, but the notion of RRI is clearly shaping policy agendas in Europe, and is being picked up by research and innovation performing and funding institutions also at the level of individual countries (Mejlgaard and Griessler 2016).

A growing literature addresses RRI which seeks to understand how research and innovation can become more responsible and what responsibility in research and innovation entails. A number of definitions of RRI have become influential. The Rome Declaration considers RRI an "on-going process of aligning research and innovation to the values, needs, and expectations of society" (Italian Presidency of the Council of the European Union 2014), and the widely cited work by von Schomberg (2011, p. 11) defines RRI as "(…) 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". Stilgoe et al. (2013, p. 1570) offer a broad definition emphasizing future-orientation by arguing that "responsible innovation means taking care of the future through collective stewardship of science and innovation in the present".

These are fairly broad interpretations of responsibility that point to a variety of RRI markers or dimensions such as value alignment, inclusivity, care, and anticipation. There is no universally agreed definition, but rather a growing body of empirical and theoretical contributions that offer different kinds of interpretations (Owen et al. 2012; Burget et al. 2016; Glerup and Horst 2014; Wickson and Carew 2014; Ribeiro et al. 2016; Lindner et al. 2016; Arnaldi and Bianchi 2016). The European Commission itself employs a more instrumental concept, which focuses on six key dimensions of RRI: engagement of citizens and stakeholders, gender equality, open access, science education, ethics, and governance (European Union 2012).

As part of the growing concern for RRI, there is an interest in exploring ways in which structural changes of research performing institutions can be facilitated, and how changes in the practices of researchers and innovators might be stimulated.

Teaching activities at higher education institutions can be considered an important vehicle for cultivating RRI awareness and for fostering responsible practices in research and innovation among future (and current) scientists and professionals. In that perspective, 'mainstreaming' or 'institutionalisation' of an RRI agenda can be enhanced by dedicated teaching activities, which aim at influencing students to act responsibly in their current and future research and innovation tasks.

Hence, teaching activities explicitly addressing the RRI concept are starting to be developed in higher education institutions. These efforts are, however, faced with several challenges. First, while it is to be expected that responsibility will mean different things in different situations and across different techno-scientific areas, the lack of a universally held definition of RRI can challenge the development of courses or programmes. And second, the case that few courses apply the explicit 'RRI' terminology even if they arguable concern issues related to responsibility in research and innovation, may obstruct the potential for cross-institutional learning and inspiration when it comes to developing RRI courses, simply because it is difficult to identify the relevant courses.

The study presented here examined current and historical approaches to teaching Responsible Research and Innovation. It deliberately engaged both with examples of teaching activities that are labelled 'RRI' and other streams that are not 'denominated' RRI-activities, but target issues of relevance to responsibility in research and innovation, such as 'teaching and learning for sustainability', 'teaching research integrity', 'philosophy of science' or 'teaching contextual knowledge'. The study is part of the "Higher Education Institutions and Responsible Research and Innovation" (HEIRRI) project[1] which is aimed at investigating how RRI can be taught at universities across Europe. The intention is also to contribute to the ongoing discussions and efforts at higher education institutions in terms of integrating RRI into curricula.

The HEIRRI project carried out a review of the literature and consulted key educators in order to compile examples of training programs and training materials relevant to teaching RRI, and provided open access to a database of 'exemplary cases' of teaching and training activities concerned with issues of responsibility in research and innovation. The immediate results of the review were communicated in project deliverables (Mejlgaard et al. 2016a, b). This paper synthesises the findings of this exercise by arguing that the Aristotelian concept of *phronesis* can capture the core properties of the objectives of RRI teaching activities (whether or not these are labelled RRI). To illustrate the generic aspects of RRI teaching objectives and approaches, the paper provides short examples of some of the teaching activities encountered in the review, which can be helpful in demonstrating how a phronetic perspective emerges from the review materials. The authors believe that an understanding of the notion of phronesis can be informative in the continued academic and policy discussions about how to stimulate and implement RRI teaching at higher education institutions.

[1] More information on the project at http://heirri.eu/.

The following sections will describe the review approach and discuss the relevance of the concept of phronesis, after which the main characteristics of RRI teaching, conveyed by some of the examples of teaching activities that were elicited during the review, will be examined.

Review Methodology

The purpose of the review was to examine the landscape of higher education teaching activities concerned with issues of responsibility in research and innovation. These are referred to as RRI teaching activities, even though the vast majority of course descriptions, curricula, exercises, training materials and other information identified were not labelled RRI. Indeed, the overall challenge of the review was to delineate the search for teaching activities related to a complex, evolving concept such as RRI. It required sensitivity towards the lessons learned from areas such as Science and Technology Studies, Technology Assessment, Ethical, Legal, and Social Issues in Science (ELSI), History, Philosophy, and Sociology of Science, Higher Education Studies, and Science and Innovation Policy, which are areas that have been dealing with issues of responsibility in research and innovation and represent the roots of the emerging RRI concept. But importantly, teaching activities concerned with or reflecting dimensions or components most often associated with RRI—such as those mentioned above: anticipation, inclusion, reflexivity, or the specific key issues highlighted by the European Commission—also needed to be captured.

The approach was not a traditional keyword or word string based search of an, in principle, limitless universe of publications. Rather, this study took an approach that combined consultation of core sources (key educators, scholars, and RRI research communities) through interviews, workshops, and email inquiries with a review of a body of literature already identified by previous research projects as particularly important for the notion of responsibility in research and innovation. The literature review included academic papers and policy documents on RRI (labelled and non-labelled) compiled as part of the ResAGorA project (see www.res-agora.eu) and the MoRRI project (see www.technopolis-group.com/morri), altogether 334 documents, 47 of which concerned teaching in one way or another. These were deemed relevant and scrutinized further. Second, a range of documents relating to 55 specific EU-funded RRI or RRI-related projects were considered. 16 out of these provided useful information on issues of teaching RRI, and these were also analysed in detail. The 47 academic and policy documents and the 16 project-specific documents were analysed individually following uniform guidelines and reporting templates. Detailed information on the specific documents used for our analysis, guidelines and reporting templates is reported in Mejlgaard et al. (2016a), but it should be noted here that the substantial parts of the document review template concerned issues such as: RRI-labelling or not, the main responsibility dimensions addressed, and the document's relevance to RRI teaching and learning (e.g. specific didactic concepts, curricula components, training materials, exemplary teaching topics etc.). Several of the authors of this paper contributed to the document review.

Seventeen qualitative, consultative interviews with key educators, scholars, and experts in educational research with personal experience in teaching RRI related issues at higher education institutions were conducted. Informants were recruited through the members of the HEIRRI consortium who nominated potential interviewees. The interviews were explorative and structured as informal conversations on either the telephone, skype, e-mail, or face-to-face. Whenever possible, the interviews were recorded and a short summary was written for each interview. The interviews focused on the interviewees' own experiences with teaching issues of responsibility in research and innovation, their perception of benefits and barriers in relation to RRI teaching, experiences related to the conduciveness of various pedagogical approaches to teaching RRI, and their knowledge of exemplary courses, training materials, topics or other input to the study. A list of interviewees and the interview guide are reported by Mejlgaard et al. (2016a).

In addition, members of the Advisory Boards for the HEIRRI project and the virtual forum around the project were queried for sources of information on RRI teaching, invited by e-mail, as well as approached during the 1st HEIRRI conference in March, 2016. Furthermore, a broader community of scholars and practitioners were approached using different online fora and mailing lists, where it was considered likely that discussions of RRI related teachings and practices would be prevalent. Finally, the 1st HEIRRI conference was an important source of information on RRI-related teaching, and a targeted workshop was organized at the end of the conference, with the specific aim of summarizing the main messages from the conference, as well as collecting examples of specific courses and materials related to teaching RRI. Mejlgaard et al. (2016a) provides the supporting documents for these parts of the review as well.

All in all, the structured exploration of multiple sources of evidence provided a useful background for identifying core components of RRI teaching, even in a context where the notion of RRI is somewhat vague. The analyses of the range of collected evidence on RRI teaching pointed towards critical reflection as a core learning objective and deliberative and cross-disciplinary discussion supported by student-centred and problem-based pedagogical approaches as particularly useful in RRI teaching. Before turning to presenting these central findings and populating them with real cases of what could be considered exemplary RRI teaching activities, the article will discuss the concept of phronesis, which captures the essence of the findings from the review. In a sense, phronesis appears to be a red thread through a rather diverse RRI teaching landscape.

The Concept of Phronesis

In his work *the Nichomachean Ethics* Aristotle distinguishes between five intellectual virtues and capacities: *Techne* as context-dependent practical knowledge of production, such as artisanship; *Episteme* as the universal, context-independent knowledge; *Nous* as sound intuition or intellect; *Sophia* as wisdom or profound understanding; and lastly—and of special interest in this case—*Phronesis* as practical wisdom, administrative ability, or practical ethics which are interchangeable

terms (Pakaluk 2005; Natali 2014). Phronesis is often defined as the "intellectual capacity to adapt moral virtues wisely to particular (sometimes new and conflict-ridden, possibly extraordinary, and tragic) situations" (Kristjánsson 2015, p. 300). Phronesis is the ability to assess a given situation and choose the best and most efficient action to achieve the universal highest human good, *Eudaimonia*. In other words, phronesis is virtuous judgement and decision-making to secure the best not only for oneself but for one's family, friends, and fellow citizens (Natali 2014). A key concept in this regard is deliberation as it allows the agent to see what he or she should do when facing a practical problem. As Aristotle puts it, it is the mark of the prudent man or *phronimos.*

> to be able to deliberate about what is good and expedient for himself (…) about what sorts of thing conduce to the good life in general (…). It follows in the general sense also the man who is capable of deliberating has practical wisdom (Aristotle 2009, p. 126).

To the extent that one accepts the relevance of Aristotle's analysis for life in general, one could make a reasonable claim that all five Aristotelian virtues are of importance also in the life as a scientific practitioner. Techne and nous were always appreciated, not least in laboratory science, as studied in detail in Michael Polanyi's philosophy of science. Sophia and phronesis in science have also been thematized at least since Mary Shelley's novel *Dr. Frankenstein* and later, with debates and doubts around the roles of science in the development of chemical warfare, nuclear weapons and genetic engineering. The case for phronesis seems to become stronger as scientific practices and institutions become ever more closely entangled with practices and institutions on the "outside"—in the economy and in civil society (Gibbons 1999). Indeed, most contemporary post-empiricist history, philosophy and sociology of science as well as Science and Technology Studies coincide in that they show that science always was embedded in society, and that science, technology and society are co-produced by highly interconnected practices and processes (Shapin and Schaffer 1985; Winner 1985; Latour 1987).

Still, in the commonsensical, ill-informed understandings of science that often prevail in science education, science is still often portrayed as a mere production of episteme, as theory building and hypotheses-testing in pursuit of universal knowledge. This ideal is dominant in the natural sciences but exists across scientific fields. Accordingly, even within social science one may find oneself in need of explicitly carving out room for phronesis, such as in Flyvbjerg's (2001) book "Making social science matter". Flyvbjerg advocates a phronetic social science that should investigate values and power relations instead of emulating natural science and its epistemic ideal of universal theories with which it cannot compete. He emphasizes four questions that social science should seek to answer with its research in order to be phronetic: Where are we going? Is this desirable? What should be done? Who gains and who loses? And by which mechanisms? (Flyvbjerg's 2001, p. 60).

The goal here is not to discuss understandings and purposes of "good" social science but to point out that this perspective of phronetic science can be viewed as an important part of Responsible Research and Innovation practices in the care that individual researchers perform in their daily work. In an RRI perspective, all

researchers and innovators—across scientific fields—should ask themselves the above questions not only *in* the research they do but also *about* the research they do. Ultimately, the aim is that researchers and innovators give care, in their praxis, to the needs and values of greater society, to the anticipated positive and negative consequences of their research, and thus reflect on their own work. In this sense, the Aristotelian concept of phronesis has important insights to offer in the discussion of RRI, as a practical skill that allows researchers to deliberate on and make smart decisions in their work.

Phronesis comes only with personal, practical experience. It is formed as people encounter and reflect on multiple practical issues and thus, by definition, young and inexperienced people cannot be *phronimoi* (Natali 2014). Kristjánsson (2015) describes it in the following way: "In order to take [the] step, from merely externally taught ('habituated') virtue to full virtue, one must learn to choose the right actions and emotions through phronesis-guided reflection—which eventually becomes routine, that is, one's autofocus mode" (Kristjánsson 2015, p. 303). In this sense, the administrative ability is tacit knowledge that cannot solemnly be taught with words and explanations. It must be learned by experience, by deliberating on practical problems. In an Aristotelian sense, administrative ability can be thought of as the acquired ability to navigate and deliberate about a plurality of values and normative demands. Introducing the concept of phronesis into the discussion of RRI thus highlights the importance of practical training and the conditions under which practical experience can be developed and refined.

Below, the recurring themes encountered during the review of RRI teaching are presented along with examples of inspirational practices across the world. As mentioned earlier, the specific examples presented below are extracted from a wider compilation of relevant RRI teaching cases identified during the review. In total, Mejlgaard et al. (2016a) describe 23 cases in some detail, but only a subgroup of these can be presented in this article. There will be a special focus on teaching responsible research practices as an administrative ability or practical wisdom gained through deliberation.

Teaching RRI as Practical Wisdom: Review Results

Critical Reflection as Learning Objective

Unsurprisingly, the review shows that critical reflection is of vital importance when teaching RRI or RRI related issues in higher education. This concerns the students' abilities and opportunities to critically question what it considered good research practice in their field, as well as how their scientific field, and the skills they have obtained through their education, relate to other areas of research and to society as a whole. From an Aristotelian perspective, this appears sensible. Phronesis is not a question of merely having experienced particular situations but also of engaging in deliberation and learning from them. An example of this focus is a Bachelor course on the use of camera drones in news journalism at the University of Bergen (Department of Information Science and Media Studies 2015). Students are taught to use

this novel technology responsibly; reflecting on approved journalistic practices regarding accountability and relevance while also considering potential negative effects of the technology such as safety and protection of privacy (Nyre et al. 2015).

Camera Drones in Education, University of Bergen, Norway.
The Department of Information Science and Media Studies has implemented a course on responsible use of camera drones in journalism in the bachelor programme, New Media. ViSmedia (Responsible Adoption of Visual Surveillance Technologies in the News Media), an international and interdisciplinary research project funded by the Norwegian Research Council, offers the course. The course teaches media students to use this novel technology in journalism; by programming and flying drones throughout four workshops, meanwhile taking both high quality journalism and societal responsibility into account. The course explores two essential aspects of responsibility: avoiding the potential danger of drones for the pilot as well as bystanders and the ethical requirements of journalism regarding accountability, relevance, and principles of personal protection in the news media. This means that when students use drone filming they must present a transparent operational manual with a clearly stated purpose. The course has a strong RRI basis by applying participatory learning and continued evaluation throughout the four workshops, with the stated purpose of getting students to "anticipate and systematically reflect on the implications of their innovations" (Nyre et al. 2015, p. 15).

This course requires students to deliberate and to weigh the pros and cons in each specific case where they want to use drone filming. These activities help preparing them for conducting virtuous judgement and decision making on ethical issues in their future work. It becomes clear here that the aim of RRI is not that students know that the specific concept and terminology of RRI, but that they know how to practice reflexivity: that they can interpret their context, think and act responsibly in research and innovation processes, or in other words, that they possess administrative ability.

At the Erasmus University of Rotterdam this point is clearly acknowledged. The university has gathered a range of common practical cases of questionable research practices and developed a dilemma game to spark deliberation and discussion about these issues—and how to solve them, among students and staff (van Donzel et al. 2013).

Dilemma Game: Professionalism and Integrity in Research, the Erasmus University of Rotterdam, the Netherlands.
The Erasmus University of Rotterdam has developed a dilemma game, which consist of 75 cards posing a dilemma regarding research integrity on one side and multiple potential solutions on the other. The dilemmas concern questionable research practices that are common in the research process, across scientific fields, and allows the participants of the game to incorporate their own dilemmas. Its purpose is to aid staff and students in developing their own moral compasses and find proper solutions to these issues through group discussion. Meanwhile it brings attention to The Netherlands Code of Conduct for Scientific Practice which applies to all universities in the country. The

> game includes dilemmas relevant to researchers at different positions, under different research strategies, and at different stages of the research process. An example is the following:
> My PhD research is funded by a government organization. When discussing my conclusions with the organization, it becomes clear that my conclusions are much too nuanced to make any political statements. The organization asks me to rewrite my conclusions so that they offer more clear-cut statements. Based on the data I think it is impossible to say things with such certainty. When I discuss the matter with my supervisor he tells me that I need to learn to write for my audience (…). I might need the government organization for financing future research. What do I do?[2]

The focus on deliberative discussion sets high demands for the teacher to provide a proper participatory space that accommodates non-coercive, collective deliberation and reflection as well as engaging all students, and securing good interactions among them. In the same vain, the teacher's relation to the group of students is also important. It is considered useful to aim for a non-hierarchical interaction between student and teacher where the teacher's role is primarily to facilitate or moderate the discussion, and the students themselves are the inquirers.

Over a period of 6 months, Felt et al. (2009) organized six round table discussions about ethical and social dimensions of genome research among 14 lay people and 7 genome researchers. The participants jointly identified topics to discuss in plenum within the themes: science and the media, ethics issues of genome research, and regulatory issues. The roundtables showed that people tend to assess "values" differently than "facts" in discussions. Facts are deemed superior, and arguments based on values are largely disregarded, despite being relevant in the discussion of ethics. Those who hold the "right knowledge" and can refer to the "right facts" about a discussed topic—often the scientists—have the ability to derail the debate; turning it to discuss the validity of the facts that the argument is based on instead of addressing the actual argument and the values and opinions underlying it. They can even close the discussion by "solving" an ethics problem, or reframing it in such a way that further discussion is no longer welcome. By mobilizing their professional knowledge, scientists uphold a hierarchy in the discussion, a hierarchy that is widely accepted by both scientists and laypeople, and restricts laypeople from challengenging the researchers. This can be harmful for the discussion about ethics and should be taken into account. The teacher has the important task of breaking down this hierarchy and creating a space allowing argumentation based on values. This could be achieved by applying the procedural rule of the Neo-Socratic Dialogue where the basic idea is to encourage students to work on a conceptual, ethical, or psychological problem by their own collective effort without substantial help from a teacher (Griessler and Littig 2006).

[2] The dilemma game can be found here: https://www.eur.nl/fileadmin/ASSETS/ieb/integriteit/24708_integriteitsspel_interactief_2016.pdf.

The Neo-Socratic dialogue
Teachers can use the Neo-Socratic dialogue as a method to promote ethical reflection on research and innovation processes by improving participants' rhetorical skills and their abilities to state coherent and sound arguments meanwhile listening to and respecting others. In the Neo-Socratic dialogue or group work, students start by deciding on the issue they wish to address, and the discussion then takes an outset in one of the participants' personal experiences rather than a textbook example. The teacher has a very important role as facilitator of the dialogue, making sure that the participants comply with the procedural rules of the discussion, e.g. that there is a positive atmosphere for discussion, that everyone is engaged, and that compromise and consensus is sought. In addition, the facilitator guides the students towards making their own conclusions. It is recommended to lessen the very strict procedural rules of the dialogue e.g. by allowing the teacher to provide useful background information should the discussion come to a halt. Likewise, sometimes there is great pluralism in views, and no idea in attempting to force consensus where tolerance, mutual understanding, and compromise can be sought instead. It is suggested that the dialogues are carried out with approximately 12 participants, over a maximum of 20 h, in 1.5 h session over several days (Birnbacher 1999).

Teaching Methods Should Reflect the Goal of Critical Reflection

The students' abilities to engage in critical and deliberative discussion about the governance of research and innovation—as well as the underlying values of RRI—should be a specific learning objective of courses teaching responsibility in higher education institutions. This also means that teaching methods, including pedagogical and didactic tools, course material, exercises, and examples should be in accordance with this specific goal.

In the review, problem-based learning (PBL) and inquiry-based learning (IBL) were consistently mentioned as sound pedagogical approaches to teach responsible research practices. In PBL, the teacher presents students with a contextualized scenario, which students discuss in smaller groups until they agree on a number of questions or issues they wish to investigate further. These questions are posed as open-ended and do not have a "correct" answer. Then the students individually pursue information and study this issue in great depth before returning to the group to discuss potential answers and solutions to the problems. The purpose is not the solution per se, but using the problem that the students posed as a way to increase knowledge and understanding of an issue as well as gaining and practicing skills such as teamwork, listening, deliberating, presentation, and cooperation (Wood 2003). In the same sense, IBL uses trigger material to pose a question for discussion, and as such, it is a problem-based, student-centred approach based on critical thinking, questioning, and problem solving. However, a characteristic of IBL is its focus specifically on research; aiming to give students research skills as they work with the research questions they have posed (Hutchings 2006). Also, the tutor takes a slightly different role here. While learners in the PBL approach are responsible for

finding information themselves and the tutor is primarily a facilitator of productive discussion, the tutor in IBL is both a facilitator but also a provider of knowledge (Savery 2015).

IRRESISTIBLE is a research project, under the European Commission's FP7 framework, which aims to design educational activities based on IBL to spark young people's interest in and knowledge about science as well as their engagement in RRI discussions. The project consist of university partners from the Netherlands, Finland, Germany, Greece, Israel, Italy, Poland, Portugal, Romania, and Turkey. The partners have gathered a "community of learners" (schoolteachers, education experts, exhibition experts, and researchers) who have developed 17 educational modules e.g. on healthy ageing, sustainability, and nanoscience; each tested in 5–10 classes in different countries. The foundation of the modules is to use real life controversial research examples to encourage 7th to 11th graders' critical thinking and reflections (IRRESISTIBLE 2014).

> Nano in health science, IBL module developed and implemented by researchers at Bogazici University, Turkey.
> The nano in heath science module introduces pupils to the basics of nanoscience, integrating chemistry, physics, biology, and mathematics, with a specific focus on the antibacterial properties of silver nanoparticles. The module consists of nine consecutive chapters or lessons of varying length. The first chapter introduces the IBL scenario with a TV broadcast from a local TV channel reporting increases in the incidents of cross-contamination of patients and the risk to their health. It also introduces a brochure from a hospital where researchers suggest using nanosilver products such as linens, towels, and kitchenware to solve the problem. The brochure is an important "kick-starter" of the discussion and exploration amongst the pupils about the advantages and disadvantages of this technology, and it introduces terms such as nanoparticle, silver-ion technology, sterilization, and antibacterial effect, which the students will work with in subsequent chapters. According to the scenario, the hospital in questions wants to assign a committee to decide whether to apply the technology and students will identify who should be on such a committee and why. Chapter 2, 3, and 4 introduce size and scale, size-dependent properties, and instrumentation as important concepts in nanoscale science. In chapter 5, the pupils test the antibacterial effects of nanosilver particles and in chapter 6 they test the durability of this effect in a textile nano-product against washing. In the 7th chapter the student search for the uses and potential risks of other nanoparticles on which they prepare a presentation. In the 8th chapter, the students return to the initial scenario by evaluating a report on the advantages and risks of silver nanoparticles, submitted to the hospital's administration, eventually deciding whether the hospital should use or reject this technology. Lastly, the pupils develop exhibits about the subject, which are to be displayed at the school and in a science centre (Akaygun et al. 2016).

The example above is useful in showing how IBL scenarios can be used in science education to spark learning and discussions about engagement of stakeholders (who should be on the hospital board and why), governance (decisions at the

hospital), and critical reflection on potential impact—positive as well as negative—of science and innovation. Though it is developed for younger students, it can be a real inspiration to higher education institutions.

The review generally revealed the use of actual societal problems, cases, and research examples in the discussion of science as a means to solve grand societal challenges, just as there was a general focus on practical learning activities. E-learning platforms were occasionally used to support this by serving as a platform for sharing information, examples, and cases. The University of Montana has developed such a platform; an online ethics course to equip researchers and students to deal with the ethical dilemmas they may encounter in their daily work and to familiarize them with federal legislation in the area (University of Monatana 2003). E-platforms are also a practical way of allowing online discussion across geographical areas.

> Online Research Ethics Course, University of Montana, USA.
> The Online Research Ethics Course is hosted by the Practical Ethics Center at the University of Montana and is a classical Massive Open Online Course (MOOC) in responsible conduct of research. The purpose of the web-based instruction is to expose researchers and students to some of the ethical dilemmas and federal requirements they may encounter during their careers and equip them to better deal with these issues. The course consists of six sections concerning major topics in research ethics: 1) Ethical Issues in Research, 2) Interpersonal Responsibility, 3) Institutional Responsibility, 4) Professional Responsibility, 5) Animals in Research, and 6) Human Participation in Research. Each course's sections comprise identified learning objective, introduction, major issues of discussion within the field, at least one case that allows exploration of different options, external links, and lastly a self-assessment tool to test ones knowledge in the area. Each section takes approximately 30-45 min to complete without explorations, and once the section assessment has been completed, the participant can print a certificate for completion.

Engaging External Actors in RRI Teaching is Valuable

RRI can be understood as aligning research processes and expected outcomes to the needs and values of the broader society as well as being inclusive and responsive to public opinion. In order to do this, researchers must bring the public, stakeholders, businesses, civil society organizations, and scientists together in the discussion about governance of and priorities in research and innovation. In a phronetic perspective, this can be considered an important part of deliberation; taking the considerations of others into account when facing practical problems in research.

While there are many rationales for these participatory approaches, e.g. people's democratic right to voice their opinion about science or the substantive argument that it will lead to more well-adapted and performing innovations (Shelley-Egan et al. 2014), there are also practical reasons for doing so. Involving outside actors in the teaching of RRI can offer helpful cases and examples for students to work with and practical experience in cooperation with local organizations. In Japan, the 4th Science and Technology Basic Plan acknowledges the importance of public

engagement in research with a specific policy to further the relation between science and technology and society. STIPS (Program for Education and Research on Science and Technology in the Public Sphere) is an educational programme, training students to conduct public engagement activities (STIPS 2012a).

> STIPS: The Program for Education and Research on Science and Technology in the Public Sphere, Osaka University and Kyoto University, Japan.
> STIPS is a human resource, post-graduate minor, programme offered jointly by Osaka and Kyoto University. The purpose of the programme is to train students in analysing and implementing public engagement in the area of science, technology, and innovation, including the public in decision-making on science and technology, so that research takes the needs and challenges of local society into account. Through active participation, students gain both theoretical and practical skills that will enable them to "transcend the borders of their specializations, understand issues related to science, technology and society from various angles, and contribute to the process of policy making by acting as links between academia, policy, and society" (STIPS 2012a). The universities have strong ties to local government, businesses, and Non Governmental Organisations in the Kansai region and these ties are used in the programme where students gain hands-on experience in social collaboration with non-profit organizations (STIPS 2012b). STIPS is a part of the programme Science for RE-designing Science, Technology, and Innovation Policy (SciREX) established in 2012 by the Ministry of Education, Culture, Sports, Science and Technology with the specific focus on education and research in ethical, legal, and social issues (ELSI) of science and technology.

Barriers to Teaching RRI

The review identified great opportunities for teaching RRI at higher education institutions. Scholars and teachers of RRI express that students request and are highly motivated to engage in RRI teaching and that there are great benefits to reap from giving this area more attention. However, multiple barriers and counterforces hinder these initiatives.

First, some informants reported a reluctance towards implementing RRI teaching activities because they are considered resource demanding and at the same time seen as peripheral to more important core subjects of a given scientific discipline. This makes RRI teaching hard to justify, even when successful. Likewise, RRI teaching is under constant threat of funding cuts or new university administration as it has low priority and is often the first thing to be cut back. Secondly, the type of teaching described as RRI teaching does not fit well into the disciplinary organized study programmes at the universities and the courses may be at odds with the accustomed way of developing programmes and organizing curricula at universities. In the same vain, interviewees note that universities are change-averse institutions, where current rewards systems and the dominant understanding of research excellence do not accommodate the transition towards a greater focus on responsibility in research and innovation. Measures of merit, performance, and success, which are implemented

throughout the university sector, nationally and locally, tend to favour traditional components of academic work such as publishing in high impact journals and patenting the results of research and innovation activities. This is not necessarily compatible with the ideas of RRI. The third issue is the case that while societies push universities to contribute more to societies, universities often focus on strengthening commercialisation, industrial relevance, and technology transfer rather than the more complex issues related to democratisation of alignment with societal values. Lastly, RRI is often perceived a mere cosmetic, "box-ticking" practice, making it difficult to implement RRI discussions and learning in higher education institutions.

In this regard, Broerse (2016) emphasizes how the development towards Responsible Research and Innovation is dependent on both a push from the bottom and from the top of the organization. In a 5-day interdisciplinary and international summer programme, University of California, Berkeley and Delft University of Technology have sought to address some of these issues by offering a space where students can discuss institutional hindrances to researching engineering ethics, and allowing them to develop research questions within this area.

> Summer programme: Global Perspectives: Engineering Ethics Across International and Academic Border, University of California, Berkeley, USA and Delft University of Technology, The Netherlands.
> In cooperation, University of California, Berkeley and Delft University of Technology, have sought to introduce research ethics at the core of curricula in engineering. They address the problem that many engineering departments tend to favour the more technical research that can be published in reputable and influential disciplinary journals. Ethical considerations are seen as detached from core engineering practices and applied ethics research is disregarded as lower-status and less important. With their programme they "set the stage for frank discussions about the practical hurdles and institutional arrangements that discourage students from taking ethics seriously" with the stated goal to show students that there is room for researching engineering ethics, without necessarily becoming independent experts in this discipline (Sunderland et al. 2014, p. 231).
> Participants include graduate engineering students from the University of California, Berkeley and philosophy of technology graduate students from Delft University of Technology. In preparation to the programme, students were assigned specific readings introducing engineering ethics. The first 2 days were then used to identify, discuss, and elaborate potential research opportunities in engineering ethics and developing researchable ethics questions and outline research papers. The third day was used to strengthening collaborative relationships with a field trip, and the fourth concerned theory and practice of collaboration across disciplines; students worked towards developing strategies and infrastructure to support collaborative efforts. The final day was used to refine research questions and plans.
> The summer programme sought to break down traditional academic and disciplinary hierarchies for instance a teacher - student division. Students were thus seen as co-inquirers and the role of the instructors was primarily supportive;

> engaging students in discussion, creating a space that allowed the students to voice their opinions, values, concerns, and interests in their own language, and suggesting literature, potential conferences and scholars who might be willing to offer feedback on their ideas.

The above is an example of how engineering is often assessed solely in terms of its epistemic value and how this can be at odds with research in engineering ethics. It is also an example of how interdisciplinarity, the cooperation between engineering students and philosophy of technology students, can remedy this. The example is thus also an encouragement for interdisciplinarity in the teaching of RRI.

On a more fundamental level, however, and teachers and promoters of RRI might do well to prepare for more than overcoming misunderstandings, nuisances and institutional noise in their work, the teaching of RRI and related concepts is also impeded by counterforces to it emerging out of the commonsensical understandings of what science is and should be. From the point of view that science merely is, or should be, devoted to the production of episteme, RRI and critical reflection can appear as worse than simply a waste of time: It may be seen as a threat to the socialization of students into the ideals of universal, value-free objectivity and the disinterestedness of science. Most interviewees in the review emphasized therefore a twofold role of critique. On one hand, as explained above, it is of crucial value to allow students to engage in critical reflection. On the other, and more fundamentally, any academically justified type of teaching into issues of RRI should be anchored into a solid knowledge base, which may be experiential and related to the accumulated phronesis of the teacher (and in that sense autodidact), but preferably should also include the episteme of history, philosophy and sociology of science, Science and Technology Studies and similar critical studies of science and its relationships with society. Without this knowledge base, RRI teaching is easily eliminated in the course of the ideological battles and institutional power games that occur if it indeed is successful and accomplishes a change in students' attitudes and behaviours.

Conclusion

RRI is an emerging principle, based on much older traditions of technology assessment, public engagement, research integrity and ethics, which focus on aligning research and innovation processes and outcomes to the values and needs of greater society. These principles lay a substantial responsibility on individual researchers and innovators to give care, in their daily work, to public values, to the anticipated positive and negative consequences of their praxis, and require them to reflect on their own work. This paper has attempted to address the question of how we prepare future researchers and professionals for this task. How do we teach current students to make decisions in potentially conflict-ridden situations and ethical dilemmas?

This review aimed to gather exemplary cases of teaching Responsible Research and Innovation practices across countries and scientific fields. This paper has elaborated on six such examples, and the common denominator for them is a strong focus on deliberative discussion and critical reflection as both learning objectives and

teaching methods. Cultivating and fostering responsible practices require a safe and open forum for active participation for all students involved, which is a demanding task for teachers and discussion moderators. This can be achieved by applying rules from, e.g. the neo-Socratic dialogue, and by maintaining a commitment to breaking down traditional hierarchies in the classroom, which is also an aim of the PBL approach, where the tutor takes a role as discussion facilitator. The examples presented in this paper are also characterized by a focus on practical and real life cases in the teaching of RRI or RRI-related issues and by problem-based and inquiry-based teaching and learning methods.

This paper has proposed that the concept of phronesis may be helpful in capturing the sense of care that is implicit in the notion of RRI. Phronesis is an Aristotelian concept of practical wisdom, practical ethics, or administrative ability; the capacity to understand the context, assess a given situation and weigh ones options towards the decision best for oneself and for society as a whole. This term offers a theoretical basis (cf. Tassone et al. 2017) for discussion on how to teach responsible research practices primarily as a practical skill where deliberation on real life issues are rehearsed, preparing one for the later encounters with such problems. It also points to the need for opportunities to practice moral deliberation, in terms of time and institutional endorsement. Building upon Hannah Arendt's analyses of the emergence of totalitarianism and the banality of evil, Kjølberg and Strand (2011) advocated responsibility in the sense of increased awareness of moral choices and of defending a place for "thinking", for inner moral dialogue with oneself.

Neither in Aristotle's nor in Arendt's philosophy, however, does the emphasis on individual virtue and inner moral dialogue preclude social commitment and interaction. On the contrary, Arendt emphasizes how the inner moral dialogue should be connected to *praxis,* to social life and interaction with fellow citizens. Indeed, one may in this way discover how the various dimensions of RRI—ranging from the individual virtues and capacities to recognize moral situations and act morally, to the social and political practices of public engagement initiatives or actions for equity and justice—can be seen to connect in a meaningful whole. Within Science and Technology Studies there are parallel debates on the relationship between the episteme it produces as an academic research discipline and the political responsibilities facing its practitioners. Also in these debates, Aristotelian concepts of virtue have been found valuable. Notably, Puig de la Bellacasa (2011) argues in favour of the concept of *care* and of treating the substantive issues of research and innovation (or technoscience, in her verbiage) as matters of care. Within the debates of "post-normal science", Funtowicz and Strand (2011) argued for a concept of responsibility more akin to that of *commitment,* warning that the emphasis on "responsibility" as normally understood may imbue a false sense of control. What has hopefully been shown in this paper, is not only how the challenges and practices of teaching RRI can illustrate the theoretical debates in what arguably is the epistemic knowledge base of RRI, but how they also can contribute to them as well as being highly important in their own right. Hopefully, the examples and analyses presented here are inspirational and can serve as a starting point for discussion and implementing more RRI-related teaching activities at higher education institutions as well as deepening the academic research debates on the need for phronesis, reflection, commitment,

care and virtue when facing the challenges of twenty-first century science in society. There are few other objectives that seem to be more needed.

Acknowledgements The work reported in this paper was performed in the context of the "Higher Education Institutions and Responsible Research and Innovation" (HEIRRI) project, which has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 666004. The authors wish to acknowledge the valuable advice offered by two anonymous reviewers.

References

Akaygun, S., Adadan, E., Sanyal, A., & Açikel, B. (2016). *Nano and health: Teacher notes*. Retrieved from http://www.irresistible-project.eu/index.php/en/resources/teaching-modules. Accessed 1 Sept 2017.

Aristotle. (2009). *The Nicomachean ethics* (D. Ross, Trans., revised with an introduction and notes by Lesley Brown). Oxford: OUP. ProQuest Ebook Central.

Arnaldi, S., & Bianchi, L. (2016). *Responsibility in science and technology: Elements of a social theory*. Berlin: Springer.

Birnbacher, D. (1999). The socratic method in teaching medical ethics: Potentials and limitations. *Medicine, Health Care and Philosophy, 2,* 219–224.

Broerse, J. (2016). Integrating RRI in universities: Training future students in transdisciplinary research. In *Keynote session at the 1st HEIRRI conference "Teaching Responsible Research and Innovation at University"*, Barcelona, Spain.

Burget, M., Bardone, E., & Pedaste, M. (2016). Definitions and conceptual dimensions of Responsible Research and Innovation: A literature review. *Science and Engineering Ethics, 23*(1), 1–19.

Department of Information Science and Media Studies. (2015). *ViSmedia—Visual surveillance technologies and journalism*. Retrieved from http://www.uib.no/en/infomedia/94035/vismedia-%E2%80%93-visual-surveillance-technologies-and-journalism. Accessed 1 Sept 2017.

European Union. (2012). *Responsible Research and Innovation: Europe's ability to respond to societal challenges.* Retrieved from https://ec.europa.eu/research/swafs/pdf/pub_public_engagement/responsible-research-and-innovation-leaflet_en.pdf. Accessed 1 Sept 2017.

Felt, U., Fochler, M., Müller, A., & Strassnic, M. (2009). Unruly ethics: On the difficulties of a bottom-up approach to ethics in the field of genomics. *Public Understanding of Science, 18*(3), 354–371.

Flyvbjerg, B. (2001). *Making social science matter: Why social inquiry fails and how it can succeed again*. Cambridge: Cambridge University Press.

Funtowicz, S., & Strand, R. (2011). Change and commitment: Beyond risk and responsibility. *Journal of Risk Research, 14,* 995–1003.

Gibbons, M. (1999). Science's new social contract with society. *Nature, 402,* C81–C84.

Glerup, C., & Horst, M. (2014). Mapping 'social responsibility' in science. *Journal of Responsible Innovation, 1*(1), 31–50.

Griessler, E., & Littig, B. (2006). Neosokratische Dialoge zu ethischen Fragen der Xenotransplantation. Ein Beitrag zur Bearbeitung ethischer Probleme in partizipativer Technikfolgenabschätzung. In E. Buchinger & U. Felt (Eds.), *Technik- und Wissenschaftssoziologie in Österreich. Stand und Perspektiven. Österreichische Zeitschrift für Soziologie. Sonderheft* (pp. 131–157). Wiesbaden: VS Verlag.

Hutchings, B. (2006). *Principles of enquiry-based learning*. The University of Manchester, Centre for Excellence in Enquiry-Based Learning. Retrieved from http://www.ceebl.manchester.ac.uk/resources/papers/ceeblgr002.pdf. Accessed 1 Sept 2017.

IRRESISTIBLE. (2014). *The project bringing Responsible Research and Innovation into the classroom.* A brief overview of the project. Retrieved from http://www.irresistible-project.eu/images/irr-mat/IRRESISTIBLE_folder_EN_02-2014.pdf. Accessed 1 Sept 2017.

Italian Presidency of the Council of the European Union. (2014). *Rome declaration on Responsible Research and Innovation in Europe*. Retrieved from https://ec.europa.eu/research/swafs/pdf/rome_declaration_RRI_final_21_November.pdf. Accessed 1 Sept 2017.

Kjølberg, K. L., & Strand, R. (2011). Conversations about responsible nanoresearch. *Nanoethics, 5,* 99–113.

Kristjánsson, K. (2015). Phronesis as an ideal in professional medical ethics: Some preliminary positionings and problematics. *Theoretical Medicine and Bioethics, 36,* 299–320.

Latour, B. (1987). *Science in action: How to follow scientists and engineers through society*. Milton Keynes: Open University Press.

Lindner, R., Kuhlmann, S., & Walhout, B. (2016). Developing an orientating framework for strategic reflection: The Res-AGorA responsibility navigator. *Technikfolgenabschätzung: Theorie und Praxis, 25*(2), 66–71.

Mejlgaard, N., Buljan, I., Elías, N. S., Cayetano i Giralt, M., Griessler, E., Hansen, L. S., Lang, A., Marušić, A., Revuelta de la Poza, G., Strand, R., & Wuketich, M. (2016a). *Stock taking/inventorying (WP2): Deliverable 2.2 state of the art review*. Retrieved from http://www.guninetwork.org/files/images/imce/heirri_wp2_d2.2.pdf. Accessed 1 Sept 2017.

Mejlgaard, N., Buljan, I., Saladié, N., Altenhofer, M., Cayetano, M., Gmelch, N., Griessler, E., Gylstroff, S., Lang, A., Marušić, A., Revuelta, G., Strand. R., & Wuketich, M. (2016b). *Stock taking/inventorying (WP2): Deliverable 2.3 HEIRRI database*. Retrieved from http://www.guninetwork.org/files/images/imce/heirri_wp2_d2.3.pdf. Accessed 1 Sept 2017.

Mejlgaard, N., & Griessler, E. (2016). Monitoring RRI in Europe: Approach and key observations. In R. Lindner, S. Kuhlmann, S. Randles, B. Bedsted, G. Gorgoni, E. Griessler, A. Loconto & N. Mejlgaard (Eds.), *Navigating towards shared responsibility in research and innovation: Approach, process and results of the Res-AGorA project* (pp. 115–120). Karlsruhe: Fraunhofer ISI.

Natali, C. (2014). The book on wisdom. In R. Polansky (Ed.), *The Cambridge companion to Aristotle's Nicomachean ethics* (pp. 180–202). Cambridge: Cambridge University Press.

Nyre, L., Gynnild, A., & Guribye, F. (2015). Drones in education: Teaching students to make responsible journalism with new technology. Retrieved from https://issuu.com/heirriproject/docs/smart_drones_for_journalism._teachi. Accessed 1 Sept 2017.

Owen, R., Macnaghten, P., & Stilgoe, J. (2012). Responsible Research and Innovation: From science in society to science for society, with society. *Science and Public Policy, 39,* 751–760.

Pakaluk, M. (2005). *Aristotle's Nichomachean ethics: An introduction*. Cambridge: Cambridge University Press.

Puig de la Bellacasa, M. (2011). Matters of care in technoscience: Assembling neglected things. *Social Studies of Science, 41,* 85–106.

Ribeiro, B. E., Smith, R. D. J., & Millar, K. (2016). A mobilising concept? Unpacking academic representations of Responsible Research and Innovation. *Science and Engineering Ethics, 23,* 81–103.

Savery, J. R. (2015). Overview of problem-based learning: Definitions and distinctions. In A. Walker, H. Leary, C. E. Hmelo-Silver, & P. E. Ertmers (Eds.), *Essential readings in problem-based learning*. West Lafayette: Purdue University Press.

Shapin, S., & Schaffer, S. (1985). *Leviathan and the air-pump: Hobbes, Boyle, and the experimental life*. New Jersey: Princeton University Press.

Shelley-Egan, C., Wright, D., Benčin, R., Riha, J. S., Strle, G., Ovadia, D., Cañedo, A. P., Angeli, C., & Sotiriou, M. (2014). *SATORI deliverable D2.1—Report (handbook) of participatory processes*. Retrieved from http://satoriproject.eu/media/D2.1_Report-handbook-of-participatory-processes_FINAL1.pdf. Accessed 1 Sept 2017.

Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. *Research Policy, 42*(9), 1570.

STIPS. (2012a). *STIPS: Program for education and research on science and technology in public sphere*. Retrieved form http://stips.jp/english/. Accessed 1 Sept 2017.

STIPS. (2012b). *Science and technology in public sphere*. Retrieved from http://www.stips.kyoto-u.ac.jp/stips_e. Accessed 1 Sept 2017.

Sunderland, M. E., Taebi, B., Carson, C., & Kastenberg, W. (2014). Teaching global perspectives: Engineering ethics across international and academic borders. *Journal of Responsible Innovation, 1*(2), 228–239.

Tassone, V. C., O'Mahony, C., McKenna, E., Eppink, H. J., & Wals, A. E. J. (2017). (Re-)designing higher education curricula in times of systemic dysfunction: A Responsible Research and Innovation perspective. *Higher Education*. https://doi.org/10.1007/s10734-017-0211-4. **(online first)**.

University of Monatana. (2003). *Online research ethics course.* Retrieved from https://ori.hhs.gov/education/products/montana_round1/research_ethics.html#brief. Accessed 1 Sept 2017.

van Donzel, M., Dijkstra, G., & Wynstra, F. (2013). Fostering professionalism and integrity in research: Final report of the taskforce scientific integrity. Retrieved from https://www.eur.nl/fileadmin/ASSETS/ieb/integriteit/Taskforce_Scientific_Integrity_EUR.pdf. Accessed 1 Sept 2017.

von Schomberg, R. (2011). Research and innovation in the information and communication technologies and security technologies fields. In R. von Schomberg (Ed.), *A report from the European commission services*. Luxembourg: Publications Office of the European Union, European Union.
Wickson, F., & Carew, A. L. (2014). Quality criteria and indicators for Responsible Research and Innovation: Learning from transdisciplinarity. *Journal of Responsible Innovation, 1,* 254–273.
Winner, L. (1985). Do artifacts have politics? In D. Mackenzie & J. Wajcman (Eds.), *The social shaping of technology*. Milton Keynes: Open University Press.
Wood, D. F. (2003). Problem based learning. *British Medical Journal, 326,* 328–330.