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Controversies and scandals as an RRI teaching and learning tool: beyond inspiring

Ioana A. Albu [a,b], Rebecca Downs-Ford [c], Rachel Furmidge [d], Caitlin E. Jackson [d], Amy Morgan [e], Keir Nathan [a,b], Yasmine Osmani[a,b], Ayesha Patel [a,b], Catherine E. W. Pennington [f], Ryan Weller[a,b], Tom Whalley[f,g] and Alison G. Harvey [a]

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ABSTRACT

The transition from undergraduate to PhD student in STEM disciplines is a key point for introducing RRI, as we see a natural increase in responsibility and a shift to active research. In this study, one lecturer and eleven STEM PhD students reflect on our experiences of learning about RRI and explore how controversies and scandals can be used for teaching, through reflective essays and discussions of nine controversies and scandals. Thematic analysis was used to highlight key challenges in learning about RRI in our context, map the case studies against an RRI framework, and identify four ways to view RRI when learning as a PhD student in STEM: (1) starting point, (2) developing research identity, (3) communities of research and innovation, and (4) bigger picture. We suggest there are rich learning opportunities within studying such cases that go beyond the obvious 'inspiring and eliciting interest'.

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Introduction

It has been widely recognised that true uptake of Responsible Research and Innovation (RRI) involves changes to norms and philosophies (Arnaldi, Gorgoni, and Pariotti 2016; Christensen et al. 2020; Hufty 2011; Meijer et al. 2016; Zwart, Landeweerd, and van Rooij 2014). The transition from undergraduate student to PhD researcher is a key transition point where we have the opportunity to influence the philosophies and practices of future researchers. Therefore, there is value in understanding the challenges and recognising the

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approaches that can have an impact on the understanding and practice of RRI by this group.

The authors of this paper are a group of researchers, composed of one lecturer (A.G. Harvey, referred to as the lecturer-author), and eleven PhD students (referred to as the student-authors)[1], associated with the Engineering and Physical Sciences Research Council before abbreviation (EPSRC)-funded Centre for Doctoral Training (CDT) in Advanced Biomedical Materials, University of Manchester and University of Sheffield, UK. Our CDT includes a 12-week taught unit on RRI, created and delivered by the lecturer-author. Controversies and Scandals (C&Ss) form a significant component of our approach to introducing RRI.

Over the past 5 years, the lecturer-author has found some specific challenges to teaching RRI to students with STEM backgrounds that she feels reflect the larger challenges in achieving uptake of RRI by the academic scientific research community, including but not limited to: reluctance to engage with social science research, and a difficulty recognising what RRI could mean in their context. She approached the former students from the taught unit to collect their thoughts on the role of the controversies and scandals case studies in the unit. Together we (all authors) then set out to explore the research question: In the context of 1st year STEM PhD student training, what are the opportunities available in using C&Ss as a learning tool for RRI? We opted to use a collaborative autoethnography-based approach to this project to tease out some of the commonalities and differences in our experiences of learning about this topic, in order to see what could be applied more widely to teaching and learning about RRI, and in particular to recognise how C&Ss can facilitate this.

We present our work in this paper in the following structure. Firstly, we outline the background to the role of C&Ss in RRI teaching and learning (T&L) and provide the context of the taught RRI unit that forms the background to our reflections. Secondly, we outline the research strategy and methodology we have used to explore our experiences of learning through this approach. We then outline the findings of our study before discussing these through the use of two existing frameworks of motivation for learning, in particular highlighting ways to approach teaching RRI for STEM PhD students.

Scientific controversies and scandals

Whether we consider RRI under the terms of the European Commission's (EC) Horizon 2020 framework (von European Commission 2017; Schomberg 2012; Strand et al. 2015) which incorporates the 8 key themes; science education, public engagement, gender equality, open access, governance, ethics, social justice and sustainability, the UKRI's EPSRC AREA framework (Stilgoe, Owen, and Macnaghten 2013) which stands for Anticipate, Reflect, Engage and Act, or other local/disciplinary approaches (Jirotka et al. 2019; Sutcliffe 2011), a central theme to all, is the interface between science and society. The motivation for the development and use of such frameworks has been influenced by a desire to avoid 'repeating history' with regard to the more controversial aspects of science and technology:

> In the past decades, controversies in science and technology have fuelled the call for a research and innovation system that is open to public scrutiny and sensitive to public

> needs and values. These calls have been translated into a framework for responsible research and innovation (RRI). (Heltzel et al. 2022)

Within this study, we consider both controversies and scandals alongside one another, as we see both these concepts as being central to, and influencing the interface between science and society. In terms of definitions of these two concepts: 'Scandals are publicized transgression of moral or legal norms that cause public outcry' (Adut 2008), i.e. events that involve specific people and places with a specific outcome, while controversies can be described as ongoing 'debate' as a means to understand and organise our world (Raynaud 2017), that may involve consideration of specific scandals but generally involves wider consideration of an issue.

Often C&Ss are tied up together, providing a topic or space in which scientists, policy makers, the public, and other stakeholders concurrently have an interest. This interaction provides insights into the different priorities and ways of thinking. Turnhout and Gieryn (2019) highlight issues around public perceptions of scientific controversies as having three facets: 'the processes and methods surrounding the issue' (i.e. how are 'facts' proven), 'what is the social context related to the issue', and 'people choosing a "side"' (or disengaging from discussion completely), recognising, therefore, the roles of multiple actors in creating systems and practices that are acceptable and respected by all. The inevitable interaction arising between these communities can lead to changes in policies and regulations, and in approaches to communication and dissemination of information. For example, movement away from the Deficit Model of public understanding of science, which focuses on the transfer of knowledge *from* experts *to* the uneducated public, towards models of public engagement in science, where the focus is on recognising the value in diverse voices and by contrast, allowing space for dialogue and shared decision making (Nadkarni et al. 2019; Stilgoe, Lock, and Wilsdon 2014).

RRI education

RRI highlights the need for public and multistakeholder engagement, and movement of discussion around the social implications of R&I further upstream (Felt et al. 2007; Owen, Macnaghten, and Stilgoe 2012; Stilgoe, Owen, and Macnaghten 2013). This necessitates education around RRI at a variety of levels, and suitable for different actors. With C&Ss being such a central aspect of RRI, we consider here how approaches to RRI education incorporate these issues at different levels.

Literature shows that education focused on citizen awareness of RRI, as well as primary and secondary education, often focusses on Socio-Scientific Issues and Socio-Scientific Inquiry Based Learning (Bardone, Burget, and Pedaste 2023; Levinson 2018; Okada 2016; Romero-Ariza, Abril, and Quesada 2017), making use of C&Ss as a way to engage the public, and children with RRI topics. The irresistible project (http://www.irresistible-project.eu/index.php/en/ last accessed: 05/01/2024), a multi-country project funded by the European Union which aims to 'design activities that foster the involvement of students and the public in the process of [RRI]', provides resources for delivering such teaching.

Approaches to teaching/training around RRI at the undergraduate and postgraduate levels tend to focus on reflectivity, interaction, discussion, and debate (Konstantinidis,

Petsani, and Bamidis 2021; Limson 2021; Matolay, Toarniczky, and Gáspár 2021), often including C&Ss. Hesjedal et al. (2020) encouraged student reflection on 'their own practices, values and ontologies'. Mejlgaard et al. (2019) suggest viewing RRI education in terms of '*RRI as phronesis*' (practical wisdom) as opposed to '*knowing RRI policies*', capturing the need for RRI education to relate to the personal development of students. In a recent article, Brahic et al. (2024) highlighted that students cultural and personal backgrounds influence how they relate to RRI. In addition, as part of the Enhancing Responsible Research and Innovation through Curricula in Higher Education (EnRRIch) project (a Horizon 2020 funded project to help embed RRI in higher education curricula), Tassone et al. (2018) conclude that Higher Education approaches to RRI should consider '*education for society*', '*education with society*', and '*educating the whole person*' building skills within students to encourage inclusive and interdisciplinary working with a focus on global challenges.

RRI in a STEM PhD research setting

A shift occurs at PhD and professional level training in the sense that we need to understand what RRI means specifically in the context of our level, discipline, and sector.

Focussing specifically on PhD students (and early career researchers) in STEM disciplines, previous educational experience in 'science' is already a component of identity and with this, expectations around scientific research as 'objective knowledge'. In contrast, STEM PhD students are unlikely to have significant previous education around social science topics. The vast differences in both teaching approaches and research methodologies seen between physical sciences and social sciences at the undergraduate level can lead to a preconception of 'the other' (discipline) as less rigorous, a challenge that is recognised in literature focussing on interdisciplinary higher education approaches (Holley 2009).

Literature frequently highlights that embedding RRI in research culture requires changes to norms and philosophies (Arnaldi, Gorgoni, and Pariotti 2016; Christensen et al. 2020; Hufty 2011; Meijer et al. 2016; Zwart, Landeweerd, and van Rooij 2014). As students transition from undergraduate to Master's to PhD education there is increasing independence and development of identity as a researcher (Coffman et al. 2016; Gonzalez, Kim, and Flaster 2021; Tobbell, O'Donnell, and Zammit 2010), providing an interesting opportunity to introduce RRI.

Challenges in translation of RRI from social science into policy and now into R&I practices have included academic perceptions of RRI and the conflicting demands being placed on researchers (Åm 2019; Moher et al. 2020), as well as conflicting ideas around what 'responsibility' means (Levikov, Quacinella, and Duca 2020), and the need for 'actors to build their own concepts of RRI' (Burget, Bardone, and Pedaste 2017; Heltzel et al. 2022; Stahl et al. 2017; Strand et al. 2015; Sutcliffe 2011). These challenges can also be hard for new PhD students to grasp, who are yet to fully comprehend the context in which their research sits. While we can argue that this means they have a less pre-conceived idea of what academic research culture should be like, we must remember that they are currently navigating an existing culture and finding their place within it.

When we teach RRI therefore, we should consider who we are teaching and enable students to build a concept of RRI for their context. We need to recognise what

knowledge and skills our students bring to the classroom, what challenges they may face in engaging with this topic, and the practices already present in the communities they are joining.

Recent notable work by Stahl et al. (2023) acknowledges the variety of possible approaches to RRI training for PhD researchers (particularly within a CDT context). Their study combines reflections from a variety of RRI training approaches across the UK, including bespoke in-house courses for individual CDT programmes, and wider-reaching programmes designed for a range of disciplines, and varying in length from a 1-day workshop to a series of sessions over 7-months. Their study outlines the variety of approaches taken to in-house training which include workshops using Lego® Serious Play®, Ethical Hackathons, 'values-based planning' approaches to building trust and considering stakeholder engagement, approaches that focus on building RRI into research plans and cyclically reflecting on and building on these, as well as blended approaches to content delivery and role-play in person. Interestingly, while some of these approaches discuss the use of case studies in considering RRI, there is no specific mention of discussion around the kinds of historical controversies and scandals that appear to have played a significant role in the motivation behind the development of RRI frameworks.

Given the significance of PhD researchers in the academic research process, quality training in RRI is clearly important. However, to our knowledge, there is nothing in the literature to date that gives a direct voice to the experiences of STEM PhD students regarding learning about and incorporating RRI in their research. There is much that can be learned from this group in terms of the challenges they may face in both learning about and practicing RRI, and also in terms of the ways that RRI can be made relatable and valuable. Today PhD students are tomorrow's leaders in researcher and innovation, and so they should be included in the dialogue around the future directions of RRI approaches. This study aims to contribute to the discussion by exploring students' experiences of learning about RRI, in particular through consideration of C&Ss, in a reflective and collaborative approach.

Context of this study: C&Ss in ABM CDT RRI training

The study presented here reflects on the authors' experiences of learning (and teaching) on a 12-week taught unit on RRI within which C&Ss have been used as one aspect of teaching and learning. Here we outline the C&S aspect (only) of the original taught unit that has inspired this study.

The unit is a requirement for all enrolled students in the EPSRC-funded Centre for Doctoral Training in Advanced Biomedical Materials (ABM CDT), starting in 2019. Students join from a variety of disciplinary backgrounds within the category of STEM and are unlikely to have any social science educational background. As the unit is specifically for this CDT the class size is small (9-13 students per cohort).

As an introduction to the unit, students watch four short (9–14 min) videos detailing case studies of some well-known 'General' C&Ss (i.e. scientific C&Ss that could be considered across a variety of scientific fields, rather than discipline-specific C&Ss) from the past 100 years or so (Table 1). Within the videos, questions prompt reflection on the topic, e.g. 'what did you know about this topic previously?' and 'what were the intended

Table 1. 'General' and 'Discipline-related' C&Ss used in the taught RRI unit.

'General' Scientific Controversies/Scandals
Chlorofluorocarbons (CFCs)
Asbestos
Genetically Modified Organisms (GMOs)
Embryonic Stem Cells (ESCs)
'Discipline-related' Scientific Controversies/Scandals
Paolo Macchiarini and the tracheal transplants
Poly Implant Prostése (PIP) Breast Implants
Metal-on-Metal Hip Implants
Vaginal Mesh
HeLa Cell Lines

outcomes?'. In the first week of lectures, the class is then encouraged to discuss these case studies.

Next, small groups are asked to research a 'discipline-related' controversy/scandal from the list in Table 1 and deliver a 5–10 min presentation for the rest of the class outlining their scandal, the timeline of events, key people involved, outcomes for the people involved, and what (if anything) has changed as a result. Discussion follows each presentation.

The C&Ss are therefore used in the taught unit as an introduction to inspire interest and provide a starting point for RRI T&L. What we have seen however, is that discussion on each case has gone beyond simply inspiring interest and has helped recognise the various elements of RRI and what they might look like in different contexts. Furthermore, as the unit progresses students often refer back to these cases as different elements are discussed on a deeper level.

This study, therefore aims to evaluate the strengths, weaknesses, and potentially, unrecognised opportunities of this approach that could be more deliberately incorporated in RRI teaching/training for STEM PhD students. The authors have taken a reflective approach to considering the learning through the approach described here via two steps: individual reflections on the initial learning experience, and collaborative workshops to consider each of the C&S cases listed above in terms of RRI and the learning opportunities the authors can now see with hindsight (i.e. now that the student-authors have more research experience, and the lecturer-author has more experience teaching RRI).

Research strategy

When developing and teaching a unit on RRI for STEM PhD students, the lecturer-author of this paper has used C&S case studies as a T&L tool (as described in the section above: *Context of this study*). Over the past 5 years of teaching this, both she, and the students have been surprised by the richness of discussion that can arise through consideration of C&Ss, and the variety of ways in which aspects of RRI can be extracted from them. In informal discussions with former students from the unit, it has become apparent that learning around RRI has indeed continued beyond the taught unit and into the research component of the CDT programme. While we don't aim to suggest that the use of C&Ss in teaching/training around RRI is a novel idea, we were interested in exploring how the use of these has shaped our understanding

and practice of RRI over the longer term, and as a result of this, to highlight opportunities to gain a deeper level of learning through such an approach.

Recognising that the C&S cases form a significant part of the RRI unit and that the learning that takes place may go beyond our expected 'inspire and elicit interest', the authors of this study have come together to answer the following research question: 'In the context of 1st year STEM PhD student training, what are the opportunities available in using C&Ss as an RRI T&L tool?'. We aim to unpack the authors' experiences and discussions that take place (or could take place) in relation to the C&Ss used in the unit.

In setting our strategy for conducting this study, we were inspired by the concept of collaborative autoethnography: 'a group of researchers pooling their stories to find some commonalities and differences and then wrestling with these stories to discover the meanings of the stories in relation to their sociocultural contexts' (Chang, Ngunjiri, and Hernandez 2013). Given that we (both student-authors and lecturer-author) have learned about RRI as a group, it seemed logical to reflect on these experiences as a group. Furthermore, collaborative meaning-making has the potential to allow for a deeper of level exploration of experiences and connections to the wider community and literature. The iterative process of individual and group activities outlined by Chang, Ngunjiri, and Hernandez formed the basis of our approach, outlined in Table 2.

In designing the activities in Table 2 we were therefore aiming for co-creation between the lecturer-author and the student-authors. While the lecturer-author is no longer a lecturer (or PhD supervisor) for any of the student-authors, she was aware that the pre-existing dynamics could lead to imbalances within the co-creation of the study. She made efforts to diffuse these where possible, in particular by considering the balance of the perspective (student-focussed vs lecturer-focussed) throughout the study, and the balance of the workload fairly between student-authors and the lecturer-author. In terms of balancing workload and expectations for contributions by the student-authors; three workshop dates were provided with the option to attend as many as each individual was able to, submission of a reflective essay was optional, distribution of notes for coding was varied depending on time already contributed through workshop attendance and reflective essay contribution, and all student-authors were welcomed to contribute their ideas to the drafts of the manuscript. The lecturer-author took on the administrative responsibilities around progressing the project, scheduling and structuring activities, and writing the manuscript (with input). In terms of perspective given, it was felt that the discussion sessions, reflective essays and workshops grouping the outcomes were the main opportunities for student voice, whereas the lecturer-author's voice would inevitably come through from the structuring of the sessions and in the writing process. As such, the lecturer-author made conscious steps not to lead the direction of discussion in workshops but rather to focus on taking notes and observing back to the group interesting aspects that were arising.

Data collection

Data collection involved two parts. First, each author contributed a short reflective essay (500-1000 words) on their experience of learning about RRI. Then the nine C&S case studies (Table 1) were discussed over the course of three author-workshops. A discussion was loosely prompted based on the following questions:

Table 2. Student- and lecturer-author contributions to study by stage.

Aspect of study	Approach	Student-author input	Lecturer-author input
Initial project idea		• Informal discussions at CDT away day formed initial ideas.	• Proposed structure of project. • Invited all ABM CDT students to join project.
Data collection	• 3 × 3-hour workshops to discuss each of the 9 cases.	• Students attended at least 1 workshop. (Minimum of 5 student authors in each workshop) • Contribute to discussion.	• Attended all workshops. • Provided guiding questions to get discussion going. • Contributed to & took notes of discussion.
	• Option to submit reflective essay (500-1000 words)	• 9 out of 11 students submitted essays.	• Submitted essay.
Data analysis	• Coding of: - Reflective essays. - Notes from 'General' case discussions. - Notes from 'Discipline specific' case discussions.	- Each student coded 1–5 sets of notes. (depending on availability and balanced against attendance at workshops)	• Coded all notes. • Collated codes for review and discussion.
	• Grouping of codes into themes and contextualising outcomes.	• All attended at least 1 of 2 workshops to discuss the grouping of codes into broader themes.	• Facilitated discussion at both workshops to group codes. • Considered groupings in light of the research question.
Manuscript preparation		• Commented on drafts of manuscript • Added to discussion points. • Added references to literature.	• Provided skeleton of article with key points for discussion • Shared drafts for comments. • Shared final manuscript for approval pre-submission.

- What did you previously know about this C&S? (and what was the source of that knowledge?)
- What did you learn/ find interesting?
- How does this C&S link to RRI?

Different perspectives were encouraged as a way to broaden our collective understanding of what the issues arising in each case could mean. Each case was discussed in light of our previous learning experiences in relation to the cases and also in light of what we've learned since taking (or originally teaching on) the taught unit. Discussions were allowed

to continue until no one had anything further to add (approximately 30–60 min for each C&S). All three workshops were recorded for reference, and discussion notes were taken by the lecturer-author.

Data analysis

Initially, each C&S was mapped against the EC/Horizon 2020 RRI framework based on the following categories:

- *Key criteria:* Governance, Public Engagement, Gender Equality, Science Education, Open Access, Ethics, Sustainability, Social Justice
- *Stakeholders (Including but not limited to)*: Public, Patients, Industry, Research Community, Policy Makers, Education Community
- *Ethos:* Diversity and Inclusion, Openness and Transparency, Anticipation and Reflection, Responsive and Adaptive.

Thematic analysis (Braun and Clarke 2006) was then used to draw out the key themes separately for the following three sections: (1) Contributed reflections, (2) Notes from the discussions on each 'General' case, (3) Notes from the discussions on each 'Discipline-related' case.

To achieve this, the lecturer-author and at least one student-author independently coded the notes for each reflective contribution/case discussion. The codes for each section were pooled together and grouped into themes through further cyclical group discussion and reflection.

The emerging themes were used to highlight the challenges in learning about RRI as a STEM PhD student and to explore the potential opportunities in using C&Ss as a tool for RRI T&L in this context.

Urhahne and Wijnia's (2023) Basic Motivation Model and Eccles (2009) Motivators of Action were used as frameworks through which to consider the themes that emerged in terms of how C&Ss could be used to motivate learning around RRI, and also in terms of what is missing, thereby offering suggestions of how to link C&Ss into wider learning and training around RRI.[2]

Findings

In this section, we first consider the student-authors' reflections on their experiences of learning about RRI. While the lecturer-author also contributed a reflective essay to the study, it was felt that the student-authors' voices were more valuable in this respect. Therefore, this section focusses specifically on the student-authors' perspective.

Following this we outline the main discussion points that arose in relation to each C&S case through mapping against the key criteria, before discussing the four themes that emerged from the discussions between all authors. The themes that emerged were present across both 'general' and 'discipline-related' C&S discussions and are therefore presented to represent both categories, followed by a short discussion of the differences that were noticed between the categories.

Reflections of STEM students on experiences in learning about RRI

Through reflecting on their experiences of learning about and engaging with RRI as PhD students in STEM, the student-authors aimed to identify some of the challenges they faced which we discuss here. However, alongside the challenges, student-authors also expressed positive feelings: 'it was widely captivating and sparked my interest greatly!', and recognised value in terms of personal and professional development: 'broadened my thinking', 'starting to see ourselves differently', 'has opened a world of science beyond my individual PhD project'.

The challenges that arose could be grouped into three themes: (1) Physical vs Social sciences mindset, (2) Positionality, and (3) Concerns around implementation of RRI.

Physical vs. social sciences mindset

The newness of RRI was a persistent topic throughout the reflections in two ways. Firstly, in the sense that RRI as a concept or framework is relatively new and definitions are somewhat fluid, aligning with Heltzel et al. (2022), and Burget, Bardone, and Pedaste (2017). Secondly, the topics sitting under RRI are more closely associated with what we would perceive as social sciences.

While RRI has been around for more than a decade, none of the student-authors had heard of this framework specifically previous to their training within the CDT (despite receiving education on RRI topics under other headings). Some student-authors expressed surprise at this, and as a result, question whether RRI is widely recognised and valued within the research community.

Several student-authors identified 'norms' within STEM disciplines that centre around 'right or wrong' answers. There is a nuance and complexity to the RRI topics that can lead to more questions (rather than answers). With this student-authors sometimes felt a 'desire to solve RRI', in the way they might approach an engineering problem.

Student-authors also recognised that they may 'lack the language' of social sciences, and the skills associated with learning in this field, e.g. reflective practice, and active listening skills.

> … it was a challenge to flip from the 'science mindset' and into the RRI way of thinking. Our sessions included discussing ethical and sensitive issues, politics, and shocking science history. I found it challenging as a scientist (who is often excited about some of the technologies we discussed) to flip into a softer, empathetic, and humanities-led approach.

Underlying this was discomfort in recognising some bias they may feel towards social sciences as being 'less than' as they begin to recognise the value in other disciplines approaches. In addition, some student-authors expressed joy in this shift in thinking:

> Once I started thinking 'in RRI', it was very difficult to stop! I believe that this does make me a more intentional STEM researcher, driven by something bigger than myself and my achievements.

Positionality

All student-authors recognised the significance of their background and previous experiences in how they interact with RRI. This was expressed as a challenge in the sense that (1) from the student-authors perception: personal feelings and experiences are not often

valued within STEM disciplines (2) student-authors felt challenged to recognise their own privilege, and (3) where a student-author has a cultural background or experience that gives them a different perspective, they may feel nervous/afraid to contribute authentically. However, several student-authors also found that having a space to discuss RRI issues, where their voice was valued and listened to, was 'validating' and 'empowering'.

> Exploring themes such as 'who should benefit from research' was a great outlet for me to voice my opinions and personal experiences on the disparity between the global north and global south regarding technology advances and the subsequent trickledown effect into infrastructure, healthcare and education.

Hearing peers' different experiences and perspectives was consistently highlighted as a valuable and enlightening aspect of RRI discussions.

Concerns about the implementation of RRI

Alongside recognising the relevance of their starting positions in relation to RRI, student-authors also communicated a need to relate RRI to their individual PhD research projects. Concerns around the implementation of RRI in day-to-day life as a PhD researcher included consideration of the markers for success within a PhD, 'struggling to see the relevance of some aspects of RRI' and 'difficulty getting past seeing RRI as a tick-boxing exercise'.

As student-authors have begun to adopt an RRI mindset, however, they have also raised deeper concerns such as questioning the wider research community's attitudes towards RRI and questioning the potential/opportunity PhD students actually have to enact change within their roles.

> I did an RRI presentation to other [PhD] researchers … and I couldn't help but feel it was a topic no one was really interested in. People engaged with it and asked questions, but again I think they saw it as a box ticking exercise as part of my PhD, rather than taking much on board.

Student-authors recognised the time and money required to fully embed RRI within research and expressed concern around balancing time considering RRI issues and 'making progress' on the research. They also worry that we can 'spend time discussing issues but not actually making any tangible change' or that personal connection to a specific aspect of RRI could lead to a strong focus on that singular aspect rather than balancing the various components of RRI in consideration of our research.

Overall, the student-authors' reflections on their experiences of learning about RRI represented some barriers to learning around new skills and new knowledge needed to understand the topics being covered, concerns around balancing time and priorities, and concerns around the way RRI is perceived by the wider community. Despite these initial barriers and perhaps ongoing concerns during research, there is a general perception among this group that the benefits of learning about RRI (in particular with regard to personal and professional development) outweigh these initial barriers, and that group learning and discussion of controversial topics was a key component of this.

Exploring the use of C&S cases in RRI T&L

Within the workshops, discussion of each C&S was allowed to continue until the topic was exhausted (30–60 min). Discussion naturally covered both how the cases link to

RRI directly (e.g. through key criteria, and identification of stakeholders involved), and reflection on how we (all authors) experienced the discussion of these cases the first time around. With this was the consideration of the aspects of each case that can enrich our learning around the wider ethos of RRI.

As part of these discussions, each case was mapped against the EC/Horizon 2020 RRI key criteria. Tables 3 and 4 provide a summary of the discussion points for each 'General' and each 'Discipline-specific' case respectively.

Each C&S case was found to be linked to multiple elements of RRI, for example within the Asbestos case study, aspects of governance, sustainability, social justice, equality and stakeholder engagement were covered. Mapping each case, we see that it's likely the full set of criteria for RRI could be covered within 3–4 cases. Furthermore, considering the RRI elements in connection to a historical controversy or scandal (and with the advantage of that historical perspective specifically) we can see that often these criteria link to one another, and that these criteria can have multiple meanings in different contexts.

An aspect we noted through these discussions was that many of us had pre-conceived ideas related to the terms in the key criteria (social justice, equality, science education, research integrity, etc.), but learning about them in an RRI framework that combines them together made connections between these aspects of research and innovation, and society clearer to see. Mapping the cases against the key criteria within these workshops was therefore an interesting activity that could prove useful in teaching and learning.

Beyond the key criteria

An overarching theme throughout the discussions was the different 'levels of responsibility' present. We found that, depending on the specific aspect of a C&S case being considered, the student-authors would switch between different ways of connecting with, or viewing the aspects of the C&S case and RRI. After some discussion and reflection, we have identified four categories for connecting with or viewing RRI, to which all aspects of the C&S discussions could be linked: (1) Starting Positions (connecting with public viewpoints), (2) Developing Researcher Identity, (3) Communities (of R&I), and (4) Bigger Picture. We believe therefore, that these four categories could provide 'windows' through which to view RRI that connect to one another as shown in Figure 1, and if used intentionally could form a basis for framing teaching/training around RRI.

Starting positions (connecting with public viewpoints)

Previous sources of knowledge for C&Ss for all authors, included primary and secondary education, previous higher education, and mainstream television that is both specifically focussed on information (e.g. Panorama and QI), and also that is fiction based (e.g. Grey's Anatomy). Considering these routes to knowledge and our subsequent forming of an opinion on these topics highlighted the role of science education and public engagement in concepts such as 'trust in science'.

When discussion was allowed to continue in this line there was recognition of a tendency to 'pick a side', both by us and by so-called 'anti-science' groups. Exploring this we noticed that we 'pick a side' particularly when we are 'watching' the topic from a distance. When we discuss these issues in a small group and hear someone else in our community

Table 3. Mapping the four 'General' C&S case studies against the EC/Horizon2020 RRI framework.

	Links to RRI via	
	Key Elements	Stakeholders
Case 1: CFCs	**G** Highlights need for governance of innovation. Introduces concept of governance. **PE** Communication with the public was a necessary component of responding and adapting. **SE** Most participants knew something about CFCs from high school education (UK based). **OA** Discussion around the challenges of open access with intellectual property requirements (especially when working with industry). **E** Morality related to different stakeholder perspectives and priorities. **S** Aim behind the development of CFCs for refrigeration was to move away from harmful toxic chemicals. Intended outcomes vs potential unintended negative consequences.	**Ind./ Res. Comm./ Ed. Comm./ PMs** Value of interdisciplinarity in research. Global change requires high-level policy agreements and individual responsibility. Role of Science Education in public response and change.
Case 2: Asbestos	**G** Change comes from policy. Slowness of change in this case was staggering. Discussion of the reasons for this. (e.g. consideration of global politics in this time frame, including two world wars.) **PE** Engagement between different stakeholders was required to recognise the issues in this case. **GE** It was interesting to the participants that one of the first people to raise concerns around the health issues associated with asbestos was a woman called Lucy Deane (a factory inspector who raised concerns in 1898). Raising the opportunity to discuss credit of women in science. **S** Raised questions around the routes to disposal of asbestos. Opportunity arises to consider sustainability issues in general (e.g. around disposal routes, recycling, water and land purity). **SJ** The obvious adaption to the recognition that asbestos is harmful to the health of factory workers etc is to ban its production and use. However, what are the social justice implications of making a change on this scale quickly e.g. considering the socioeconomic status of factory workers/ asbestos miners in the early twentieth century. Wider implications of change.	**Ind./ Clin./ PMs** Need for multiple stakeholders to communicate. Value of diverse viewpoints in decision making. Need for 'hard' policies.
Case 3: GMOs	**G** Key case in development of RRI. Raise awareness of milestones that led to policy decision making and difference in global responses. **PE** Importance of recognising all stakeholders with an interest/agenda related to the R&I. Recognising myths around public perceptions and understanding of science (ref). Value of two-way discussion. **SE** Topic often taught in high school. Opportunity to build on this. Need for education around critical evaluation of online material and assessment of risk. Link to current topics e.g. CRISPR. **OA** Lack of transparency contributes to controversy. Link to PE and 'trust in science'. **E** Difference in ethical viewpoints/considerations depending on application. **S** Possible opportunities with GMOs related to sustainability. SJ GMOs sold as golden ticket to 'feed the world'. Questions around the reality and motivations of these applications.	**Pub./ Ros/ Ind./ Res. Comm./ Ed. Comm./ PMs** Important to recognise and communicate with all stakeholders. Connections between SE, PE, OA.
Case 4: ESCs	**G** Timeline highlights how policy decisions come about. **PE/SE** Clarity of difference between Embryonic Stem Cells	

(*Continued*)

Table 3. Continued.

	Links to RRI via	
	Key Elements	Stakeholders
	(controversial) and other Stem Cells (not controversial) is necessary in education and communication approaches. **E** Personal and religious viewpoints strongly attached to this topic. Importance of recognising and valuing diverse viewpoints. **S** Highlight need to avoid waste in use of human (and animal) tissue in research.	**Pub./ ROs** (in particular pro-life groups)/ **Ind./ Res. Comm./ PMs/**Media Challenge with disparate agendas.
Key to abbreviations: **G** Governance **PE** Public Engagement **GE** Gender Equality **SE** Science Education **OA** Open Access **E** Ethics **S** Sustainability **SJ** Social Justice/Inclusion		**Pub.** Public **CSOs** Civil Society Organisations **Ind.** Manufacturers/ Industry/ Business **Res. Comm.** Research Community **Clin.** Clinicians/ Clinical Staff **PMs.** Policy Makers **RBs** Regulatory Bodies **Ed. Comm.** Education Communit

Key elements/ stakeholders/ ethos are only included in this table when they were explicitly linked to the case in the workshops of this study. Exclusion of a key element/ stakeholder/ ethos from this table does not mean it cannot be linked to the case.

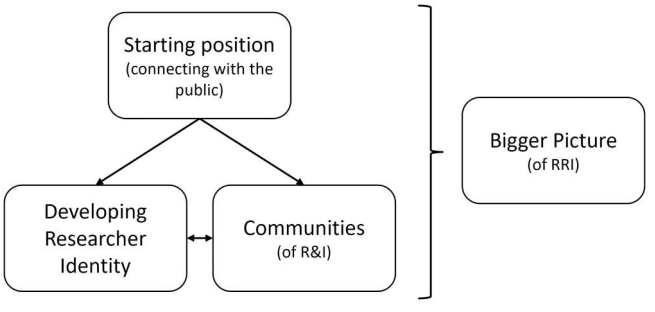

Figure 1. Four windows through which to connect with RRI as a PhD student in a STEM discipline.

(i.e. who we respect as an equal) has a different perspective, this challenges us to question our stance. We would argue from this that facilitated small group discussions of C&Ss can encourage awareness of the value of listening to diverse voices when making decisions about the future of R&I. When we consider this from the perspective of 'the public', we also recognise the value in accessible materials as an output from R&I. Not only in the sense of Open Access, but creating outputs in a language that is accessible and ensuring that we are clear by what we mean. For example, clarity around the use of embryonic stem cells vs other (non/less-controversial) stem cells.

All of us found that where a C&S case had some connection to our own lives, we felt a more personal connection, and therefore felt more inclined to engage in discussion. We often found that 'General' C&S cases could be linked to more current issues, e.g. links between Asbestos and current issues with Reinforced Autoclaved Aerated Concrete (RAAC) (https://www.rics.org/news-insights/current-topics-campaigns/raac-advice-and-faqs last accessed: 23/01/2024) in UK schools, and that this allowed us to compare and contrast regulations over time or in different contexts.

Table 4. Mapping the five 'Discipline-related' C&S case studies against the EC/Horizon2020 RRI framework.

	Links to RRI via	
	Key Elements	Stakeholders
Case 5: Paolo Macchiarini Scandal	**G** Raises questions around the 'grey areas' of research and innovation. How was this able to happen? Gaps in 'hard' regulations. Therefore, the need for RRI (or similar) approaches. **E** Role of individual researchers in ethics and research integrity. Recognition of challenges in this. Opens pathways for discussion of how to deal with misconduct. **SJ** Recognising vulnerable groups and considering power dynamics in research.	**Patients/ Res. Comm./ Clin./ RBs** All these stakeholders will have been involved in some way in this case. Therefore raises questions of where responsibility lies. Highlights the need for individual responsibility (including at PhD researcher level).
Case 6: PIP breast implants	**G** Highlights need to understand Medical Device Regulations and Quality Control processes. **GE** Recognising the possibility that this case can be minimised or dismissed due to the 'cosmetic' application. Awareness of our personal biases. **E** Link to Research Integrity and personal responsibility in the work place/ research environment. **S** Hypothetical consideration: changing materials in a product for sustainability purposes could have unintended consequences on performance.	**Patients/ Clin./ Medical Insurance/ Health Services/ Ind.**
Case 7: Metal-on-Metal hip implants	**G** Highlights the importance of finer details of medical device regulations. **PE** The role of media in communication with the public. Discussion around care in communication. **S** When considering changes in choice of materials for a sustainability advantage we need to ensure that there are no unintended consequences (such as those seen in this case).	**Patients/ Clin./ Medical Insurance/ Health Services/ Ind./ Media** Prompts a look at the public and patient communication approach taken. Where does responsibility lie for patient care in this case? National differences due to health care services and accessibility.
Case 8: Vaginal meshes	**G** Raises questions around how this was able to 'fall through the gaps' in regulatory compliance. **PE** Interesting to look at how communication around this issue has been handled (especially global differences in approach). **GE** Link to gender equality issues in healthcare. **SE** Role of education in providing patients with understanding of materials used in medicine. **OA** Differences between material that is openly available and material that is accessible. **E/ SJ** Questions around who this medical device was available to in the first place, and how follow up care is now being handled (global/sociocultural differences)	**Patients/ Women's Health Groups/ Clin./ Ind./ Media** Different communication approaches. Communication as care for patients vs 'media hype'.
Case 9: HeLa cell lines	**G** Timelines showing how policy changes come about. **PE/ SE** Understanding of what we mean when we talk about a 'cell line'. Story now in the public domain, therefore need to ensure	**Minoritised Communities/ CSOs/ Clin./ Ind./ Res. Comm.** Stakeholders in two distinct categories: (1) the original case of HeLa cell lines (e.g. family and surrounding controversy) and (2) Stakeholders

(*Continued*)

Table 4. Continued.

	Links to RRI via	
	Key Elements	Stakeholders
	accessible language. **OA** Open Access initiatives prevent researchers hiding approaches behind a paywall for only the research community (and norms therein) to critique them. Makes us more accountable for our research processes. **SJ/ E** Norms at the time allowed for the tissue to be taken from a patient without their consent. Significant changes in practice since then (links also to Alderhey scandal in UK). Space to question our current 'norms'. Discussion around difference of treatment for minoritised communities. Questions around definitions of 'products' of research.	involved in anticipating future issues in this area/ involved in decision making.
Key to abbreviations: **G** Governance **PE** Public Engagement **GE** Gender Equality **SE** Science Education **OA** Open Access **E** Ethics **S** Sustainability **SJ** Social Justice/Inclusion		**Pub.** Public **CSOs** Civil Society Organisations **Ind.** Manufacturers/ Industry/ Business **Res. Comm.** Research Community **Clin.** Clinicians/ Clinical Staff **PMs.** Policy Makers **RBs** Regulatory Bodies **Ed. Comm.** Education Community

Key elements/ stakeholders/ ethos are only included in this table when they were explicitly linked to the case in the workshops of this study. Exclusion of a key element/ stakeholder/ ethos from this table does not mean it cannot be linked to the case.

Considering our sources of previous knowledge provides a starting point for our position in relation to RRI. As one student said, 'you can't help but get excited [when discussing these C&Ss]'. And in doing this we allow students to begin connecting with the social science mindset from the viewpoint of themselves as members of the public where they may hold less rigidly to physical science concepts of knowledge.

Essentially, when we view the C&S cases through this window, we are encouraged to consider diverse viewpoints that may differ from our own, and often connect the purpose of RRI to our individual values based on our upbringing or communities we are part of outside of research.

Developing researcher identity

Moving into PhD research involves an increase in independence and responsibility as a researcher. At this point in their careers, students may be absorbing more information from their mentors, and peers, about what it means to be a researcher. A key component of the discussions therefore involved relating aspects raised to the roles of researchers in R&I.

Consideration of the original motivations behind C&Ss and the controversial outcomes can highlight frustration at the difficulty in anticipating outcomes. This provides an obvious opportunity to discuss the Collingridge Dilemma (Collingridge 1982). Further to this, discussion leads to the difference between malice, ignorance, and

lack of consideration, and subsequently, questions of how students want to be, as researchers.

Discussion of each case allowed us to link to the key elements associated with RRI (see Table 2 and Table 3). This is a helpful exercise for appreciating the role of each aspect of RRI within R&I and recognising where we have skills and knowledge gaps. Often this leads us to recognising the role of regulations and policies and therefore underpins the need to get training in relevant areas (e.g. human and animal tissue regulations) and to follow institutional policies (e.g. around good research practice). However, the discussions of C&Ss also lead us beyond the hard law regulations into the areas of good research practice that aren't strictly regulated (i.e. the space where RRI sits). One student-author recognised this as the 'Swiss cheese' of regulation.

Connecting to the C&S cases through the idea of developing research identity is part of these discussions that allows us to begin recognising what skills we need to develop to be 'responsible researchers', and how these may change over time. It may be helpful within this area to provide space for articulation of concerns around the 'costs' associated with doing RRI and to acknowledge and discuss what different levels of implementing RRI within research might look like.

Communities (of R&I)

As researchers, we sit within existing R&I communities. This was particularly recognised, within the 'Discipline-related' cases where questions were raised around how these C&Ss were able to happen, considering the number of people associated with the work (e.g. Paolo Macchiarini case).

Within these discussions, there was a keen awareness of the difference between research culture in academia and industry, and the ways that RRI might be seen in these communities.

Under academia, discussions around research integrity and how to handle potential misconduct can be a valuable part of RRI T&L for PhD researchers. We also discussed academic publishing in terms of publication of failures, and retractions.

In terms of industry, the 'Discipline-related' C&S showed the importance of awareness of discipline-related regulations, following these authentically, listening when concerns are raised, and communicating issues in a sensible way. Concerns were raised about whistleblowing/ needing to 'tow the company line'. Indeed, student-authors felt more comfortable questioning the validity of research in an academic setting than in industry. However, in both settings, students question the reality of presenting RRI considerations in a way that will be taken seriously.

Viewing C&Ss through the perspective of the communities of research and innovation we sit in can begin to provide more context to what RRI looks like within our disciplines. This can be helpful when thinking about 'anticipating' in terms of RRI, and in considering who stakeholders might be in our disciplines, it can also open discussion around the norms and culture of the disciplines within which we are working.

Bigger picture (of R&I)

The 'General' cases in particular helped to draw a picture of the goals, and original motivations of RRI.

A strong feature of this theme was 'change', including consideration of the speed (or slowness) of change that came about as a result of C&Ss, and factors involved in change, including historical context. We also discussed some challenges in making change, for example, banning asbestos manufacture overnight would have resulted in the loss of jobs for many workers, or if the desired change involves the banning of a product already in use, then an alternative will be needed.

Central to 'change' were questions of who makes decisions, and who is involved in the discussions around these. And where issues are global/international (often the case with C&Ss) questions arose around global differences in approach both from sustainability and social justice perspectives.

Questions around responsibility highlighted a distinction of levels e.g. from laboratory to institutional to national/global. RRI considerations differ significantly at each level, as previously discussed by Shelley-Egan, Bowman, and Robinson (2018). An intended strength behind RRI is that it should underpin approaches taken at all levels. For PhD researchers, it is arguably beneficial to separate the Bigger Picture aspects from our current roles, while also considering that our involvement with RRI might change through the course of our future careers.

There are aspects of RRI that need to be covered to understand the overall goal and motivations behind the frameworks. However, sometimes these can feel far removed from us as individuals, and in particular early career, researchers. It can be helpful to separate out discussion on the bigger picture goals of RRI from discussion on smaller scale actions we can take.

'General' vs. 'Discipline-related' C&Ss

Common themes emerged across both 'General' and 'Discipline-related' C&Ss, however, slight differences in focus were observed.

Within the 'General' cases we saw more focus on 'change', and a clear distinction between the different levels of responsibility. For example, within these cases, we often see connections to the concept of governance, and global inequalities. Table 3 provides a summary of how we linked these cases to the key criteria of RRI, points that could be used as discussion prompts in a classroom setting. As individuals, we tended to feel further separated from these cases, but they provided a picture of the motivations behind RRI and some of the bigger structures that are in place around regulation.

'Discipline-related' cases allowed more consideration of RRI in our context, relating specifically to 'our projects' and highlighting the importance of the skills and knowledge associated with RRI. For example, the Metal-on-Metal hip implants, PIP breast implants, and vaginal mesh scandals highlight, in different ways, the roles of medical device regulations and how to adapt and respond responsibly to issues that arise. These C&Ss also highlighted more succinctly the roles of various stakeholders, including ourselves. For example, the Paolo Macchiarini case in particular raised questions about the responsibilities of individual researchers in a lab as part of a bigger team. Table 4 summarises the links between the discipline-related cases and the key criteria for addressing RRI, again providing prompts for classroom discussions.

Students communicated that when a case was directly related in some way to their own project it helped them understand what kinds of questions to consider, and there

was a suggestion that directing students to identify a C&S relevant to their own study and learn about that would give more personal motivation towards these activities.

Interestingly, the discipline-related cases often raised the topic of sustainability as a key issue. There was recognition for the need to be more sustainable in our approaches to research and innovation, and that this could involve day-to-day lab practices and/or consideration of using more sustainable materials within our research and innovation, or even more specifically, aiming your research to answer a sustainability issue. This is perhaps more relevant to our discipline specifically as we sit within the field of materials science. However, alongside this was a discussion around the risk of being so focussed on improving the sustainability aspects of a technology that one could inadvertently introduce unintended consequences.

Discussion

Challenges in learning about RRI as a STEM PhD student and motivations for learning

Through consideration of individual reflections, we identified three challenges experienced when learning about RRI: challenges that come with accepting/adopting a social sciences mindset, recognising our positionality in relation to RRI and the associated topics and issues, and concerns around the practical implementation of RRI within our research. Within these challenges, we saw a strong aspect of identity, values and perceived cost of engaging with RRI coming through.

The role of self, situation and goals and the balance of these against the perceived cost of action have been repeatedly shown as key factors in various theories of motivation including Heckhausen and Heckhausen (2018), Urhahne and Wijnia (2023), and Eccles (2009).

In a recent article, Urhahne and Wijnia (2023) build upon Heckhausen and Heckhausen's action model (2018) in light of six cornerstone theories of motivation (expectancy-value theories, social cognitive theory, self-determination theory, interest theory, achievement goal theory, and attribution theory) to create a 'Basic Motivational Model' that addresses the main criteria to consider in academic motivation. The resulting model highlights the importance of self in motivation, particularly in relation to situation (i.e. the social constructs, and community-based values we perceive), goals that need to be generated and actions that can be specified in relation to a goal, and finally outcomes and consequences of action.

Eccles (2009) outlines a model for motivation specifically centred around the combination of personal and collective identities. Eccles argues that identity is based on two sets of perceptions, firstly those related to our skills, personal characteristics and competencies and secondly those related to our values, individually or as a part of a community. Their model proposes that the combination of these factors inform our expectations for success associated with an activity (such as engaging with learning on RRI, or incorporating RRI aspects into our research), and the importance we attach to such an activity. Furthermore, we assign a weighting to the benefits of activities depending on the interest it holds to us, and the potential for it to fulfil (or partly fulfil) personal goals aligned with our values. Ultimately, the weighting needs to be balanced against the perceived cost to

ourselves of taking part. A key feature of Eccles argument is that values and motivation not only need to align to our individual values and competencies but also to the perceived value within our communities.

Combining the key aspects of these two theories with the challenges we have identified in learning about RRI as a PhD student in a STEM discipline, we could argue that teaching/training first year PhD students in RRI requires; connection between self and RRI, connection to personal values and community values, generation of a goal (such as becoming a responsible researcher and innovator), identification of achievable actions to reach this goal, identification of skills that need to be developed (and support to develop these), and perceived cost needs to be balanced against the benefits.

Facilitated discussion of controversies and scandals using the four windows: an approach to teaching RRI

Reflecting on our experiences as a group through learning about RRI we would suggest that there is a strong benefit to learning in a small group, through facilitated discussion, over an extended period of time, allowing for the building of a community of learners.

From our perspective, there is an opportunity within the consideration and discussion of C&S cases, both general scientific cases and more discipline-specific cases, to aid in the understanding of what RRI is. Mapping a C&S case against the RRI criteria is helpful for determining the varied meanings of the terms that arise in relation to RRI, for determining links between the different criteria and exploring how they interface, and for linking to further teaching or training in relation to RRI topics or relevant skills development.

We found that our discussions of the C&Ss would naturally shift to different perspectives and different ways to consider RRI depending on the aspect being considered. We've reflected on this and identified four windows through which we do this, which can help to connect with RRI and build our understanding of what it is, what it means to us as researchers, and what is means to us as individuals. We suggest that deliberately viewing RRI through these windows can be beneficial for learning, and that this can begin by viewing the C&Ss in this way.

Considering C&Ss through the window of our starting positions we can connect with each other, and with different viewpoints on a personal level helping us to recognise our starting position. PhD students are moving from that starting position into developing research identity and being part of R&I communities, where they will need to understand how to enact RRI connecting with the concerns around implementing RRI. The bigger picture of RRI provides prompts for recognising the social justice and governance aspects of R&I and the potential roles that scientists can play in these processes.

The discussion points outlined in Tables 2 and 3 could provide starting points for others aiming to facilitate or deepen the discussion on the 9 cases used in this study. From a teaching and learning perspective, the lecturer-author would urge others to be aware of the potentially personal connections students may make with these topics. The richness of discussion comes from the vulnerability within the group, but this needs to be handled with care. There is benefit in holding such discussions over an extended period of time to build the sense of trust between students (and between students and lecturer).

Guidelines around principled spaces are a great place to start with this, (https://barcworkshop.org/resources/principled-space/ last accessed: 17/01/2024) moving away from the idea of 'safe spaces' (which can never be guaranteed in reality) to the idea of spaces where values are recognised, articulated and agreed on to create a space where respect and safety are prioritised. Alongside this, an awareness of Tuckman and Jensen's (1977) stages of small group development can help with recognising when 'storming' may occur and therefore when extra facilitator guidance may be helpful. A teaching approach that diffuses the teacher-student power imbalance such as leaning toward the critical pedagogy approaches of bell hooks (1994) and Friere (1972), situating learning as '*with* not *for*', can help with setting the tone for connecting learning with personal values. Indeed, critical pedagogy aligns well with the underlying ethos of RRI and could form a topic for discussion in the RRI classroom.

Limitations of study and positionality of authors

The lecturer-author was responsible for creating and delivering the RRI unit outlined in this study. The eleven student-authors are PhD students currently enrolled in or recently graduated from the ABM CDT. All student-authors have completed the RRI unit described in this study within the past 2–5 years and had little to no previous knowledge of the specific term 'RRI'. In addition, while the lecturer-author was aware of the disparate elements of RRI previously, she has also been learning about RRI as a concept through the creation and delivery of this unit. As such, we have developed a shared understanding of RRI within the context of being PhD students in the field of Advanced Biomedical Materials Science, with each cohort influencing the teaching received by the subsequent cohorts. While we recognize that it would be valuable to engage with students (and academics) in a wider range of STEM disciplines and/or who have developed an understanding of RRI separately from our own, we have aimed here to provide an insight into how C&Ss have shaped (and continue to shape) *our* understanding and practice of RRI within this context as a case study.

We recognize that the lecturer-author's experiences of research and perceptions of RRI, will have influenced the training and collective understanding of RRI within this group, in particular as a woman in STEM, which has been shown to influence how RRI is perceived and practiced (Buhrer and Wroblewski 2019; Levikov, Quacinella, and Duca 2020). Indeed, all authors of this study feel our personal upbringings, experiences (particularly with regard to protected characteristics), religious beliefs, and political viewpoints have significantly shaped our perceptions of the case studies discussed in the workshops. We feel the diversity of the religious and cultural backgrounds of group has strengthened the results presented. However, we also recognize that there will be many more viewpoints that have not been represented. In particular, we note the largely Western/Global-North viewpoint of the authors.

In addition to the above, we are aware that the student-authors of this study are self-selected due to interest in, and willingness to engage with RRI. It would be valuable to engage with a wider range of students and particularly to gain insight into issues such as 'resistance' and 'reluctance' around RRI. From an ethical standpoint, conscious steps were taken to focus on our own perceptions and experiences rather than those of, or involving, other students or colleagues.

Conclusions

The transition from undergraduate/Master's student to PhD student is an interesting point to consider and introduce RRI training and indeed is now a required component of many PhD training programmes. This study looks at our experiences as a group of PhD students and a lecturer in STEM, using C&Ss as a tool for learning about and engaging with RRI.

Student-authors' reflections on coming from a STEM background and first engaging with RRI highlighted the challenges around the language and mindset behind RRI, recognising their personal values and beliefs around topics and perhaps having these challenged, and at the same time, trying to understand how to actually 'do' RRI within our research projects. Positive aspects of RRI training were recognised in both feelings experienced in learning and through connections to personal and professional growth, demonstrating a willingness to engage with and adopt an RRI mindset. However, concerns around the cost of engaging with RRI and the wider research community attitudes towards RRI were present.

Through group discussion on 9 C&Ss (4 'general' and 5 'discipline-related' cases) we (all authors) found links to aspects of RRI that could provide useful discussion prompts, and we also found that we could separate out four windows through which to consider C&Ss as a way to assist engagement and learning about RRI: (1) Starting positions, (2) Building Researcher Identity, (3) Communities (of R&I), and (4) Bigger Picture (of RRI).

We feel these 'windows' aid in situating ourselves in relation to RRI, allowing us to connect RRI with our personal values and also to connect RRI with our individual research projects and career aims. Seeing RRI issues through these windows helps us recognise where we need to focus on understanding the goals and where we need to focus on the actions that are required by us.

C&Ss are valuable at providing this situating of the self within RRI as a member of the public, and as an emerging researcher (both individually and as part of a community), aiding in the recognition of the goals of RRI, and the value of the various aspects, as well as guiding the identification of skills and knowledge gaps. Some further exploration beyond C&Ss would be needed to then build the identified skills and knowledge. Small group facilitated learning over an extended period has been seen as beneficial to the student-authors of this study.

As a final conclusion, based on our experiences of learning about RRI, and furthermore through the collation of our thoughts within this study, we would suggest that facilitated small group discussion of C&S cases can be beneficial for understanding RRI and that viewing these through the four windows identified in this study can provide a framework for connecting with RRI as a researcher, and go some way towards supporting students through the challenges associated with learning about and engaging with RRI.

Notes

1. Where the term 'authors' is used, we are referring to the entire author group, including both the lecturer-author and the student-authors.
2. The 'Basic Motivation Model', and 'Motivators of Action' are two recognised theories of motivation that consider the role of self, situation, goals and cost of action, providing two frameworks for consideration of the motivation for learning about RRI.

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