Pansera, M., Owen, R., Meacham, D., & Kuh, V. L. (2020). Embedding Responsible Innovation within Synthetic Biology research and innovation: insights from a UK multi-disciplinary research centre. *Journal of Responsible Innovation*. https://doi.org/10.1080/23299460.2020.1785678

Embedding Responsible Innovation within Synthetic Biology research and innovation: insights from a UK multi-disciplinary research centre

Abstract

In the last decade the debate about the role of science and innovation in society in the fields of biosciences and biotechnologies has gradually shifted from ELSI/ELSA and ad hoc public engagement approaches to a renewed focus on the reflexive, inclusive and anticipatory governance of innovation and techno-science with an emphasis on responsibility. This paper documents and analyses this transition during the period 2014-2019 at BrisSynBio, one of the Synthetic Biology Research Centres (SBRCs) co-funded by the UK's Engineering and Physical Sciences Research Council (EPSRC) and Biotechnology and Biological Sciences Research Council (BBSRC). The case suggests that the centre has developed an approach to Responsible Innovation (RI) that includes but goes beyond public engagement to catalyse anticipation, reflexivity and deliberation in sometimes creative and innovative ways. Nevertheless, despite the efforts aimed at embedding RI in BrisSynBio, the centre has struggled to capture the impacts of RI interventions and assess how exposure to this concept is changing the way scientists routinely work. The study reveals that initiatives aimed at catalysing reflection, inclusion and anticipation do not in themselves necessarily lead straight forwardly to changes to daily practices, or to outcomes, without appropriate institutional support, openness to change and ways of capturing impact.

Keywords: responsible research and innovation; research governance; synthetic biology

Highlights

1 Introduction

The last decade has seen the progressive introduction and development of the concepts of Responsible Innovation (RI) / Responsible Research and Innovation (RRI) (see Owen and Pansera (2019a)) for a distinction between these). In the fields of biosciences and biotechnologies these have shifted the debate from ELSI/ELSA (ethical, legal and social aspects of new

technologies; (Balmer et al., 2015)) and public engagement approaches (Sykes & Macnaghten, 2013) to a renewed focus on the reflexive, inclusive and anticipatory governance of innovation (and techno-science aimed at this) with an emphasis on (co)responsibility (de Saille, 2015; Macnaghten & Chilvers, 2014; Stilgoe, Owen, & Macnaghten, 2013). One challenge in coming to grips with RI / RRI has been the different definitions and framings employed by academics and major European research funders that have built these concepts into their funding programmes. The latter include but are not limited to the European Commission's Horizon 2020 programme, the United Kingdom's Engineering and Physical Sciences Research Council (EPSRC), the Netherlands' NWO-MVI Platform and the Research Council of Norway (RCN), for example within its Digital Life programme. These funders have tended to broadly define these concepts in similar ways, as a set of practices aimed firstly at aligning scientific research and innovation to societal needs, values and challenges and secondly to anticipating/responding to the uncertainties, risks and ethical concerns new areas of science and technology (such as synthetic biology) inevitably bring. However, the kinds of specific practices they entail can vary greatly in their content, configuration and specificity.

Within Horizon 2020 for example, RRI has been translated into actions relating to a narrow set of isolated "keys" accompanied by indicators: public engagement, ethics, science education, gender equality and open access. In contrast, the EPSRC has adopted a more loosely defined 'AREA' framework: the integration and embedding of capacities for Anticipation, Reflection, Engagement and, in response to these, Action – based on dimensions described by (Stilgoe et al., 2013). This framework is similar to the Dutch NWO-MVI approach, which entails being "pro-active" and interdisciplinary, with the inclusion of valorisation panels in research projects aimed at representing stakeholder views (Swierstra, 2017). A similar approach has been adopted by the RCN in Norway that frames RRI in terms of "Look forward, Think through, Invite in and Work together" (Egeland et al, 2018). These approaches are not constrained by a set of indicators or keys (which together may result in a RRI narrative that is incoherent and apolitical e.g. (de Hoop, Pols, and Romijn 2016; Hartley et al, 2017; Owen and Pansera, 2019), allowing for (potentially) a broader and more flexible set of coherent practices. To add another layer of complexity for the practitioner, these various framings of RI/RRI are not exclusive and overlap in a number of areas (e.g. public engagement). Due to high levels of European collaboration, facilitated in large part by substantial funding from the European Union's Framework Programmes, many projects seek to combine the focus on the specific RRI keys designated by the European Commission with

broader, more reflective practices proposed within such framings as the AREA framework (e.g. the EU funded projects FoTRRIS[1] and NewHoRRIzon[2]).

Despite this interpretive flexibility and ambiguity, some general characteristics of RI/RRI approaches can nonetheless be identified. Centrally, the imperative for (better) alignment of research and innovation with societal challenges, expectations, values and needs, via: the introduction of practices and interventions that are more upstream in research and which are integrated into academic socialisation processes, (e.g. at the level of graduate and even undergraduate training (EPSRC, 2018)); consultation and deliberation with publics and civil society organisations, i.e. stakeholders; adaptive learning and knowledge co-creation/co-production. RRI and RI can thus be understood as an inclusion of new or complementary practices of (e.g. ethical) reflexivity and stakeholder inclusion, deliberation and societal legitimation in and around the visions and practice of (at least strategic, mode 2) research and innovation. This is a stark departure from the idea that market mechanisms underpinned by narrowly – constituted (and risk-based) regulation and existing codes of ethics and academic conduct in Universities are sufficient to assure the alignment of publicly and privately funded research aimed at innovation with societal needs and concerns. This shift is linked to wider concerns regarding public and civil society apprehensions about both the distribution of benefits and the potential negative externalities resulting from technological innovation (Blok & Lemmens, 2015).

There are concerns by those who frame RI/RRI as a vehicle for transformative change that narrow framings (e.g. as the EC keys) risk promoting largely 'business as usual', insufficiently challenging the legitimacy of incumbent logics and practices and inadequately questioning the politics of science and innovation governance as they currently stand (Hartley, Pearce, & Taylor, 2017a). Thus, some commentators see it as being crucial that RRI/RI remain critically reflexive and raise political questions about ST&I governance (Owen & Pansera, 2019b; van Oudheusden, 2014). Undoubtedly RI and RRI normatively question to varying degrees the discourse of innovation itself and its post WWII framing as an inherently good thing primarily perceived from an economic perspective (Blok & Lemmens, 2015). They also question the role of science, technology and innovation as a quest to deliver Eurocentric/Occidental forms of development (de Hoop et al., 2016; Pansera & Owen, 2018a) opening up spaces for other ontologies, epistemologies and value frameworks e.g. from the global South (Ludwig & Macnaghten, 2020; Macnaghten et al., 2014).

[1] http://fotrris-h2020.eu/ - Accessed April 2020
[2] https://newhorrizon.eu/ - Accessed April 2020

In many ways, given the interpretive flexibility of RI and RRI, these concepts can only be understood and made visible by exploring their meanings *in situated practice* i.e. a focus as much on the doing as on the saying. Indeed, a central challenge that has emerged in the last few years is to understand how, if at all, RI and RRI are contributing to changing and shaping institutional logics, behaviours and practices in research conducting organisations such as Universities, i.e. how RI/RRI are being *translated* into institutional practice. It remains unclear for example whether the various frameworks promoted by research funding organisations will in themselves lead to institutionalisation of RI/RRI in universities and changes to the incumbent practices that exist within them. In this paper we explore this, examining the configuration and implementation of practices within a large synthetic biology multi-disciplinary research centre housed within a UK research–intensive university that has received an explicit mandate from funding councils to implement RI at an organisational level as part of its funding agreement[3]. We consider BrisSynBio, an EPSRC and Biotechnology and Biosciences Research Council (BBSRC) funded Synthetic Biology Research Centre, based at the University of Bristol,[4] as our case study, using this to develop insights and lessons for the 'translation' of RI/RRI. The paper is structured as follows. In section 2 we introduce the institutional settings and the broader socio-political context for our case study. In section 3 we describe the research design and methods. In section 4 we present the main themes that emerge from our analysis. Finally, in section 5 we reflect on our main findings and their implications for a broader understanding of RI/RRI institutionalisation in research conducting organisations.

2 RI in the United Kingdom: the context for our case study

In the UK, RI emerged after the financial crisis of 2008, a period when there was a renewed desire for science and technology-driven innovation aimed at economic renewal, productivity and growth (a policy ambition that has continued since). The emergence of RI also came in part as a response to a number of historic and contemporary scientific controversies (such as GM and geoengineering) (Stilgoe at al, 2013; Davies and Horst 2015) and, in some fields such as synthetic biology, , in recognition of the shortcomings of previous ELSI- type approaches Balmer et al. (2015). Balmer et al. (2015, p9) argue that the ELSI approach is underpinned by an 'unbridgeable

[3] For the sake of efficiency, going forward we will use the abbreviation RI throughout as this is the term employed by the UK EPSRC and is the predominant framing in the UK. For a more detailed discussion of the evolution of these terms and how they compare see Owen and Pansera (2019a).

[4] The Engineering and Physical Sciences Research Council (EPSRC) is the main funding body for engineering and physical sciences research in the UK, the Biotechnology and Biological Sciences Research Council is a UK Research Council and is the largest UK public funder of non-medical bioscience.

separation between what should be done in the technical sense and what should be done in the ethical sense'. In this view, social scientists and ethicists rise to the status of peripheral experts that are 'responsible for the identification and remediation of potential negative *downstream consequences* [our italics] of science'. According to Bardone & Lind (2016) ELSI in turn assumes a simplistic, linear model of innovation that is maintained and reproduced by a technocratic approach that underpins most of science governance in industrialised countries. The discourse of RI that emerged in part in reaction to these limits was based on the opposite view that reflections about values, motivations and purposes should be situated at the early stages of any scientific endeavour, and in particular those that are more strategic / innovation - oriented in nature. Furthermore, the emphasis on more inclusive governance of innovation and technoscience, particularly when publicly funded, has an important "responsibilisation" effect. By including civil society organisations, "public(s)", and other stakeholders in the governance of techno-science and innovation at earlier stages in the research and development processes, these processes can, it is hoped, be more socially robust and to a certain extent immunised against accusations of being unresponsive to societal needs and concerns. RI in other words was foreseen as having an important function in the broader democratisation and public accountability of science (van Oudheusden, 2014). RI also emerged in part as a response to the critique of the predominant triple helix/innovation systems framework that configures contemporary innovation, emphasising the importance of the purposeful combination and commodification of knowledge flows from Universities and Research and Technology Organisations, often aimed at realising economic and societal impact, for example through the commercialization of knowledge (Schot & Steinmueller, 2018).

However, RI has a controversial and paradoxical relation with the broader political context in which it emerges. On one hand it seems to play a mediating function to interrogate and reconcile the instrumental aspirations of the triple helix framework with perceived societal needs and demands, and democratic exigencies. On the other, it has the potential to transform the very foundations of the incumbent system if it is implemented in a manner that catalyses systemic change, potentially undermining the triple helix innovation systems model (and even its civil society-acknowledging "quadruple helix" successor) altogether. RI then can be a vehicle for consensus and co-construction of status quo techno-social arrangements, perhaps with some social optimisation and civil society buy-in or an engine of dissensus and disruption.

The EPSRC has been an important location for the development of the RI discourse in the UK, culminating in the articulation of the above-mentioned framework (described as the so called

'AREA' dimensions) and organisational policy in 2013 (EPSRC, 2013; Owen, 2014). This framework seeks to include but extend existing responsibility norms relating to science (such as those relating to academic conduct, research ethics and integrity) to integrate and embed capacities for anticipation, reflexivity, deliberative and inclusive engagement, and action (responsiveness) in and around the processes of scientific knowledge production, technology development and innovation as an inter- and transdisciplinary endeavour. Below we will describe some initiatives and experiments aligned to this that have been conducted at BrisSynBio since the publication of the EPSRC policy in 2013. Drawing on interviews we have conducted with scientists and staff at the centre and the University, and document reviews, we provide an analysis of the evolution of RI at BrisSynBio, set in the broader political context within which RI has become situated.

BrysSynBio[5] is a centre focused on synthetic biology. Synthetic biology is an emergent research field or umbrella term for collaboration between and across various fields (molecular biology, engineering, computer science, chemistry) (Balmer, Bulpin, & Molyneux-Hodgson, n.d.). It also has had from the outset, at least in the UK, a clear orientation towards innovation and commercialisation (Taylor & Woods, 2020). As a field it presents many interesting features through which the above mentioned framings and tensions in RI can be analysed (Schyfter & Calvert, 2015). It has, to varying degrees, also become a locus for the pioneering of new forms of public engagement (Balmer et al., 2015). There is a particular affinity between the intertwined development of Synthetic Biology, specifically the EPSRC/BBSRC funded Synthetic Biology Research Centres (of which BrisSynBio is one of six), and RI that reflects the specific history of public funding for synthetic biology in the UK. The initial funding for the Centres came from a UK treasury level programme entitled: '8 Great Technologies for Growth' (UK Gov, 2013). These were specific funding programmes aimed at areas of research and innovation where the UK was "set to be an international leader".[6] The specific allocation of research funding for synthetic biology was made in accordance with a national "synthetic biology" roadmap, first published in 2012 by the Synthetic Biology Leadership Council (EPSRC, 2012; Marris & Calvert, 2019). According to EPSRC: "The roadmap, produced by an independent panel of experts for the government's Department for Business Innovation and Skills (now the Department for Business, Energy & Industrial Strategy [BEIS]), sets out a shared vision for realising the potential of synthetic biology in the UK (EPSRC, 2012)." From this brief description, it is clear that synthetic biology research in the UK has, since the second decade of the century at least, been clearly situated in a

[5] Now part of the Bristol BioDesign Institute

[6] These "8 great technologies" included: big data and energy-efficient computing; Satellites and commercial applications of space; robotics and autonomous systems; synthetic biology; regenerative medicine; agro-science; advanced materials and nanotechnology; energy and its storage (UK Gov, 2013).

political-economic context that has been oriented not only toward scientific knowledge production but also a clear goal of commercialising this to drive economic growth within a triple-helix model of technological innovation, stressing the intertwined relations between academia, government and industry. This view is especially evident in the material produced by the Synthetic Biology Leadership Council (SBLC, 2016; Taylor and Woods, 2020).

According to Schyfter and Calvert (2015) this orientation reflects an internal debate amongst synthetic biologists in terms of their role, classified as: (i) 'epistemics' – scientists who see synthetic biology techniques as primarily being a way to generate new knowledge; (ii) 'pragmatic constructors' – those who see synthetic biology as new science to solve grand challenges or make specific products; and (iii) 'committed engineers' – those who expect that the application of engineering principles will render biology open to manipulation in a reliable and predictable manner. Arguably, synthetic biology (at least in the UK) has been significantly shaped by the latter two categories, influencing how synthetic biology has become framed in the UK and, with this, expectations of the delivery of tangible products to markets and economic growth in the short to medium term.

The concept of RI was embedded in synthetic biology policy documents in the UK from an early stage, although its inclusion and how it was framed, (e.g. around the concept of 'public acceptance') created considerable tension (see Marris and Calvert, 2019 for a view from the social scientists involved). That said, RI would come to have a significant and visible presence as 'Theme 2' of the 2012 roadmap: 'Continuing Responsible Research and Innovation' where it was stated (p. 19):

> 'Since synthetic biology is a new field, there is much uncertainty surrounding both the risks and benefits of its research and applications. […] It is essential for debates to go beyond the community of experts to open up discussions about the purpose of innovation and about uncertainties and complexities surrounding both the benefits and risks associated with particular applications. […] Integrating social sciences, humanities and arts researchers can help with understanding of, and engagement with, such issues and thus foster responsible innovation.'

The Roadmap encouraged synthetic biologists to engage with key questions emerging from an earlier public dialogue in synthetic biology published in 2010 and commissioned by the BBSRC (BBRSC, 2010, p. 12): "*What is the purpose* [of synthetic biology research]*? Why do you want to do it? What are you going to gain from it? What else is it going to do? How do you know you are right?"*. Synthetic biology and its perceived (heuristic) proximity to GM technologies had prompted concerns amongst funders about the potential public and civil society reception to and acceptance of synthetic biology. This was accentuated by a 2012 call for a moratorium on synthetic biology published in a document entitled "The Principles for the Oversight of Synthetic Biology"(FOE,

2012). This document, authored by Friends of the Earth, USA, the ETC. Group and the International Center for Technology Assessment and signed by over a hundred other civil society groups referred to synthetic biology as an "extreme form of genetic engineering, […] developing rapidly with little oversight or regulation despite carrying vast uncertainty." While this description did not fit the UK or European context, where synthetic biology broadly fell within existing European (risk based) GMO regulation (POST, 2015), there remained concerns that synthetic biology could encounter similar public opposition to that witnessed earlier in the case of GM - indeed there has since been some consumer backlash against the use of some synthetic biology products in the production of consumer products in the EU e.g. Ecover (Thomas, 2014).

The 2010 Synthetic Biology Dialogue aimed to understand stakeholder and broader public attitudes toward synthetic biology (BBSRC, 2012). It subsequently formed one input to the SynBio Roadmap and revealed a number of concerns, including those relating to potential societal impacts and the distribution of risks and benefits. There was also, broadly speaking, stakeholder agreement on the importance of more inclusive governance of science and changes to public scientific funding (and a desire to 're-imagine this'), though this point was received with some caution by representatives from the academic and research communities. Ensuing public consultations pertaining to technologies that arguably fall under the umbrella of synthetic biology (e.g. gene-editing, synthetic red blood cells) have shown similar results (Hopkins & van Mil, 2018).

The Dialogue was also an important input into the evolving concept of RI at EPSRC, informing discussions on RI within the Council and its advisory group on societal and ethical issues (see Owen 2014 for a fuller description). As a result of this growing, wider commitment to RI, and specific commitment to it within the 2012 Roadmap, RI featured within the requirements for funding of the newly funded synthetic biology research centers, of which BrisSynBio was one. BrisSynBio, as with the other centres, was then placed in an interesting, potentially conflicting position. On one hand its funding reflected a strong political mandate for synthetic biology to unreflexively and instrumentally drive economic growth within a triple-helix model of innovation, aimed at co-producing impact and economic growth with new knowledge. On the other hand, the centres were being asked to commit to RI as a process that asks for reflexivity, including on the assumptions and motivations associated with its funding. Notwithstanding this tension, RI became subsequently built directly into the assessments of proposals for funding, and then into the funding arrangements and activities of the UK SBRCs, to varying degrees and with varying levels of appetite for meaningful translation into practice from grantees. In the remainder of the article we ask what happened next, focussing on the evolution of RI and constituent practices such

as public engagement in BrisSynBio. We conclude with some reflections about the potential for 'institutionalisation' of RI practices from observations made in the case study.

3 Research design and methods

3.1 Research setting

University of Bristol is a leading UK research-intensive university, being ranked within the top 50 universities in the world in the 2018 QS World University Rankings. It began as the University College Bristol, which existed from 1876 to 1909. In 2016, the University decided to embark on an ambitious process of intellectual and structural change and growth, launching a new strategic plan (UOB, 2018). Although RI/RRI is not explicitly mentioned in the strategy document, activities relating to some of the EC RRI keys (e.g. around gender equality and open access) play a prominent role in the overall discourse of the University. The University's plans for growth and change have come at a time of great volatility in the UK higher education sector, with for example extensive strike action by university staff over proposed changes to the University's pension scheme in 2018 (and again in 2020), a comprehensive review of the University sector in 2019 that includes recommendations for progressive reductions in tuition fees and most recently uncertainty caused by the CoVID 19 pandemic. This is set within an external political context that is equally volatile, e.g. relating to Brexit. In 2016 the University purchased a plot of land adjacent to some of the poorest wards in the City with the aim of building a new digitally focussed enterprise campus near the city's main railway station. This new venture provides a tangible location and opportunity it is hoped to transform the University, with a key aspiration to become a 'new civic university', underpinned by a commitment to responsible innovation (e.g. within a new Digital Futures Institute), as an anchor institution and global beacon for civic-oriented research, scholarship, education and engagement. Part of the institutional context for RI (at least in the rhetoric of the University) is therefore its situation *in a broader civic ambition* that emphasises knowledge co-creation and co-production with stakeholders, partners and communities, including those most marginalised in the city. This emerging civic mission discourse intersects very closely with RI, as well as the definition of RRI put forward by the EC.

However, RI at the University of Bristol has a history that pre-dates this emerging institutional context of the 'new civic university', both formally (i.e. labelled as RI/RRI) and through broader

"de facto rri"[7] activities, a number of which overlap closely both with the EC RRI keys and the AREA framework adopted by EPSRC. Notable amongst these is a long-standing tradition of public engagement and engaged research. The University has a substantial Public Engagement team which participates as a partner in a number of national and European public engagement and RRI-labelled projects[8]. The Public Engagement team is also a partner in BrisSynBio and has played a key role in the development and implementation of the centre's RI programme. Bristol is also home to the National Co-ordinating Centre for Public Engagement (NCCPE), which is hosted by University of Bristol and the University of the West of England (UWE), Bristol and was founded in 2008 as part of HEFCE's[9] Beacons for Public Engagement initiative. Public engagement initiatives and research are thus a relative priority for both UoB and UWE.

The overall objectives of BrisSynBio are to improve the ability to design and engineer biological systems; and to apply this knowledge in applications relevant to health and UK industry. The multidisciplinarity of the centre and the complexity of the synthetic biology field required the co-location of a multi-expertise team of researchers and support staff. The Centre also has an established network of commercial partners in e.g. biotechnology and pharmaceuticals manufacture and maintains a number of start -ups (Reinsborough, 2020). Therefore, when the Centre was established one of the main goals was to bring together academic scientists, social scientists, university administrators and industrialists to deliver an innovative research agenda. To date, this team comprises: 53 principal and associate investigators, who in turn currently lead 10 current research projects; with 21 researchers to deliver the science; and, currently, 5 industrial partners. BrisSynBio is also supported by a management team, which comprises the Director, Scientific Manager, Technical Lead, Innovations Manager, Executive Assistant and Administrator.

3.2 Data collection

We used qualitative methods since these have been widely selected for allowing the researcher to uncover and explore relationships in complex and changing social environments, adopting an interpretivist epistemological position, disclosing the influence of the social and cultural context upon the unit of analysis (Shah & Corley, 2006; Smith & Seward, 2009). The main source of data consisted of 12 audio-recorded, semi-structured interviews collected in the field between January and December 2017 and additionally the experiences and observations of those involved in delivering the RI programme within the Centre (two of whom are co-authors of this paper),

[7] Randles (2017) describes 'defacto rri' as 'what actors already do, in collective fora, in order to embed institutionalised interpretations of what it means to be responsible into the practices, processes organisational structures and outcomes of research and innovation'.
[8] More info available at: http://www.bristol.ac.uk/public-engagement/ - Accessed April 2020
[9] Higher Education Funding Council for England

supplemented by analysis of internal and external documents and reports. They further included insights from a workshop and notes from a RI retreat held in 2018 with members of the BrisSynBio Centre (including PhD students researching there). We also drew on insights from a broader national discourse analysis of RI in the UK conducted by ourselves within a large EC project (anonymised for review) to provide broader context for our case study findings. The research proposal obtained the ethical clearance by the UOB ethical committee. The interviewees were asked to sign an informed consent form with the possibility to anonymise their contribution. Despite this possibility, no participant communicated the intention to be anonymised.

The data were analysed with the aid of NVivo 9 software, which is widely used to analyse heterogeneous, qualitative datasets (Miles & Huberman, 2003), through a process of iteration, contextualised within an emerging structure of theoretical reasoning (Gioia, Corley, & Hamilton, 2012). This approach follows an inductive logic based on: (i) initial open data coding, maintaining the integrity of 1st-order (informant-centric) terms; (ii) organisation of 1st-order codes into 2nd-order (theory-centric) constructs; (iii) distillation of 2nd-order constructs into overarching aggregate dimensions; (iv) presentation of the data in a narrative fashion. In this section, personal interviews and internal documents were analysed following a 'qualitative grounded theory' approach based on the methods proposed by Gioia et al. (2012). Designed to demonstrate rigour in qualitative research, this approach is generally accepted today by an increasing community of organizations and management scholars (Gioia et al. 2012). The methodology has also been proved to be a fruitful and robust approach for the validation and building of theories (Corley & Gioia, 2011). The analysis followed two main stages: the creation of a data structure and a discussion concerning the relationships existing between the theoretical dimensions that emerged from such a structure. The pivotal step in this approach is the building of a data structure. In order to create the data structure, we started with an initial open data coding, maintaining the integrity of 1st-order (informant-centric) terms. As suggested by Miles & Huberman (2003), we performed an initial coding using a set of a priori themes: *how (R)RI is framed in the organization, perceived barriers and incentives, values and motivations to pursue (R)RI, history of (R)RI evolution, (R)RI in practice.* At a later stage, we included and/or removed other categories from the codes list that emerged from the data until we reached a manageable number of codes (typically between 20 and 30). After this first step, we performed a 2nd-order analysis based on the question: *is there some deeper structure in the 1st-order array?* In this phase we asked whether the 1st-order codes suggested concepts that might help us to describe and explain the *narrative* of the interviewees. This step provided us with a list of 2nd-order (theory-centric) themes that were finally assembled into two overarching theoretical dimensions:

1) A transition from Public Engagement to more pervasive RI practices; 2) The Impact of RI on research and researchers within BrisSynBio, which we discuss in turn in the following sections.

4. Research Findings

4.1 Theme 1: From Public Engagement to more pervasive RI practices.

4.1.1 Public engagement and engaged research culture at the University

Probably the most visible practice relating to RI within the University and BrisSynBio is the strong commitment to various forms of public and societal outreach and engagement. In our analysis, we can observe a shift from what may be described as a historical 'public understanding of science' approach (e.g. the involvement of scientists and experts in activities which are designed to inform, communicate and disseminate) to a more deliberative and dialogic approach with publics and stakeholders, increasingly grounded in the notions of *co-creation* and *co-production of knowledge*.

Public engagement and engaged research have a long history at the University. The University has an Engaged University Steering Group (EUSG), chaired by the Pro Vice-Chancellor for Research and Enterprise, which oversees the overall engagement strategy at the University, including public engagement, knowledge exchange, partnerships and engaged learning. In its latest strategy document, the EUSG declares that the University Strategy (UOB, 2011) is premised upon the idea of being a global civic university (see above). This will involve deep, ongoing and high-quality engagement between the University and its partners, stakeholders and publics.

The EUSG strategy document articulates a number of motivations for engagement. First, universities are seen as a key source of 'longitudinal knowledge', innovation and entrepreneurship. As a consequence, they are increasingly considered crucial partners for organisations (including civil society groups) interested in research, mediated through various forms of 'academic engagement' (Perkmann et al., 2013).

The University also has a centralised Public Engagement Team (UOB, 2019b), part of the Research and Enterprise Development division, and represented on the EUSG, who undertake a variety of practice–oriented activities based around five pillars: Infrastructure; Internal capacity building; Student experience; Reflection, Monitoring and Communication; Partnership culture. The team started with events like science cafes and festivals, then their strategy shifted towards a more pervasive presence across the University that includes the coordination of more targeted initiatives. In the word of the team's director:

> "We started with only simple forms of public engagement. Science cafes, science festivals in a time when it wasn't quite so common place to do that kind of activity. Now it's everywhere […] our evolution as a team has been not dissimilar to many universities in this idea of moving away from public engagement as a broadcast mechanism, as a way of informing, even sharing, or simply having a conversation with people to much more about this idea of listening and involving and including to the point of which you all may be eventually even thinking about co-producing research with public. And I think that's a really long process for most of us."

The Public Engagement team now focuses on providing support and advice to academics who want to move towards more engaged forms of practice. This can mean supporting them in putting in bids for external funding, helping them get involved in external events, or helping them think about how to make their practice more meaningfully engaged, who they might engage and how. During the years, the team has secured EC funding for projects such as Synenergene (synthetic biology) and PERFORM which we describe below, as well as involvement in EPSRC grants such as SPHERE, a project in digital health with a significant public engagement component (Burrows, Meller, Craddock, Hyland, & Gooberman-Hill, 2019). These have been important locations for furthering public engagement as a key dimension of RI/ RRI within the University.

A second important point emerging from the strategy is an institutional awareness that productive knowledge is not only generated in universities, and that many societal challenges cannot be solved by academics working in isolation, a point emphasised in both the EC RRI and EPSRC RI definitions. In this sense, the strategy recognises the need for a plurality of epistemological approaches that enriches academic work and its impact. As one of our respondents stated:

> "[…] other experts exist in society. So, you know not even just with our industrial partners that exist in our communities, they exist in practice. And so by working with them we will develop better research because it is research that is informed by lots of different areas of expertise. And it also leads to better outcomes."

The interviewees suggest that the University has made some attempts to move away from traditional, unidirectional forms of science communication to more deliberative and dialogic approaches and has made attempts at fostering interdisciplinarity through its Research Institutes.

One particular (external) driver for public engagement and knowledge co-production is the changing external environment for universities, one that is moving towards greater calls for *accountability in the use of public money and demonstration of impact from this* (Hill, 2016; Watermeyer, 2016) Since 2014, the national, periodic Research Excellence Framework (REF) exercise evaluates not only the quality of university research outputs (i.e. publications) but also requires them to describe (through so called 'impact case studies') narratives of economic, social and cultural *impacts* that have arisen from research. Since impact is now evaluated though the REF exercises every 6 years,

academic career development as well as institutional incentives have responded to incorporate these new values and skill sets.

4.1.2. From public engagement to more pervasive RI practices within BrisSynBio

"For me RI is about the democratic legitimation of science"

RI Research Fellow, BrisSynBio

As noted above RI was a requirement of funding for the Synthetic Biology Research Centres and BrisSynBio embedded RI from its inception. However, the incorporation of RI into the initial funding bid was described by one of our respondents as 'not being a massive brain shift'. Not only was the centre Director supportive of public engagement approaches, but a number of the senior leadership team from biological sciences, biochemistry and social sciences had well established collaborations and associated experiences that aligned with RI and from which they could draw inspiration and motivation. At least one of the Centre Co-Investigators had undertaken clinical research involving Patient Public Involvement. Another member of the fledgling centre had received previous PhD training in a UK Centre for Doctoral Training where RI – aligned approaches had been embedded. In this sense the leadership team and at least some of the Centre academic staff were both receptive to, and had experience of, some elements of RI, notably public engagement and ethical reflection.

The incorporation of RI was driven by those charged with leading this cross - cutting theme (drawn from social sciences and philosophy (Reinsborough, 2020). As the Centre developed post funding, so did the evolution of RI, reflecting a move from an initial focus on public engagement and ELSI to a more systematic strategy to embed RI as a more expansive and broadly-configured concept into its activities and internal dialogues, in sometimes innovative and creative ways, a process which happened organically.

There remained however a strong commitment to openness and public engagement, which is clearly visible in BrisSynBio's Communication Strategy. As a central component of its RI programme, the Centre collaborates very closely with the University's Public Engagement team and has dedicated funds to finance public engagement activities focused on Synthetic Biology. These funds are available to all permanent academic staff, independently funded research fellows, Post-Doctoral Research Fellows and PhD students. Applications that target new audiences and a diverse section of the public are strongly encouraged. A particular emphasis is given to activities

that include plans for an iterative or reflexive cycle of academic-public engagement. There was considerable reflection on the configuration of such public engagement from the outset. According to the BrisSynBio Scientific Manager, the limitations associated with a "public understanding of science" approach as well as ELSI (Ethical, Legal, and Social Implications, see above) had already been discussed when the initial grant application for the centre was put together:

> "The ELSI approach has come under criticism for being too oriented toward the products of research, rather than the more encompassing processes of research and development. It has also been criticized for having too detached an approach, where social scientists are brought in at certain "gates" to assess risks, after which researchers continue their work without reflecting themselves on the broader social, ethical, environmental, etc. aspects of their work."

Another important issue that was highlighted is the potential for *tokenism* among scientists, precluding more meaningful and substantive forms of practice. In order to overcome such limitations, the Centre created a collaboration with philosophers and social scientists focused on "Fundamental problems, ethics and responsible innovation in the design and engineering of synthetic-biological systems" (BrisSynBio, 2019). This approach has some parallels with the midstream modulation work pioneered by Erik Fisher and colleagues (Fisher, Mahajan, & Mitcham, 2006) in which humanities and social science scholars are embedded in science labs to catalyse reflexivity and on the basis of this potentially modulate the direction of research. In the case of BrisSynBio, the initiative consisted of funding a resident philosopher who works alongside synthetic biology researchers at BrisSynBio to explore philosophical and ethical questions like: How does Synthetic Biology fit into the history of Science? Can life be defined? What is the relation between life and value? What is the distinction between "natural and artificial"? What is information? (BrisSynBio, 2015). This was expanded by additionally incorporating visiting philosophy PhD students.

Specifically, the RI researchers have been embedded within four groups within BrisSynBio: the Toye Lab (cultured red blood cells), the Edwards Lab (wheat genomics); the Centre for Protolife research directed by Steve Mann (Protocells), and the Biocompute lab led by Thomas Gorochowski. Within these groups a broad range of RI activities or interventions have been undertaken that include but go beyond public engagement, fostering both first and second order reflexivity (Owen and Pansera, 2019b). For example, RI activities stemming from work with the Toye lab have included reflection on the political economy of synthetic blood (Kent & Meacham, 2019) and a collaboration and artistic residency with a local artist and several subsequent exhibits (Connor, 2019), as well as numerous local and national public engagement events (e.g. Blood Culture, 2019). RI researchers in the centre have subsequently worked together with the artists-in-

residence and other scholars to publish critical analysis and reflections of these particular activities and art-science collaborations as catalysts for RI more broadly (Fannin et al 2020; Reinsborough 2020).

In addition to these four groups, which serve as specific 'case study' locations for RI, there have been more general RI initiatives across the whole centre, including RI training for doctoral students and early career researchers. These initiatives are led by two social scientists and the philosopher. The embedded philosopher also took on a leadership role with the Centre's management structure as "Deputy Director for RRI and Public Engagement."

As declared on the website, their initial intention was to embed RI/RRI across all the activities of the centre:

> "Thinking critically about the meaning of Responsible Research and Innovation, exploring what presuppositions and assumptions may go along with different renderings of the term, is part of the core mission of the Ethics and RRI cross-cutting theme of BrisSynBio. […] We will use the Centre's Fora, the website, the Ethics and RRI blog, and other tools to share and discuss our findings."

RI implementation our interviewees suggested was the result of an adaptive trial and error process developed over three years of activity. In the words of the Centre's scientific manager:

> "We really tried to develop a program for RRI practices that's meaningful and specific to us, and it is a work in progress and it's taken a really long time to get the momentum in that program, to achieve a moment in which we noticed it became fruitful. We are not only supporting some activity but we're starting to see some of the outcomes, some input [into the Centre] of these activities themselves. "

According to her, implementing RI at the core of the Centre's practices *required the creation and nurturing of a community of engaged researchers*. The Centre worked very hard to create that community, which also includes external individuals, wherein RI is a fundamental pillar and a central concern. She stressed the fact that this community building does not t happen overnight, it takes years to create a group of 36 researchers trained in and committed to RI principles. This process was certainly facilitated by the increasing interest that RI has gained across the University. Nevertheless, especially at the beginning, she noted that RI training was received with scepticism and even overt hostility in some quarters. As one staff member remembers, embedding ethics in PhD training was not a simple task:

> "I was involved in launching a training program, designing it and… […] someone in the room who I won't name said oh you mustn't do that, you must not touch that subject; it just worries people and is really bad for people. At which point I decided that I would stay on that committee until [RI] was really well embedded in training and there was no way I wasn't going to be in the meeting until the course was established and had been running for years. So, I am still on that committee, still

> running that program because I couldn't bear the thought of training at seventy-five and more PhD students in making new forms of living things and not getting ethical training right"

BrisSynBio belongs to the School of Life Sciences. The School's strategy is to begin collaborating with other schools that are interested in embedding RI in their training and practices. According to one member of staff the objective is:

> "[…] that we should be training every scientist to think of [RI] […] but we must do this in practice. It can't be just about talking and thinking, they have to be about doing research differently. […] So the ambition is to do something that's RRI in practice, that actually changes how you see things and how you make your research decisions. What research you do to some extent, whom you collaborate with... You might have broader collaborations that might think about things like environmental consequences much sooner."

Staff are working to more systematically embed RI in the new Faculty of Life Science, bringing together research and teaching activity at all scales of the life sciences: molecular, cellular, tissue, organ systems, behavioural, social and societal. The new faculty will emphasise the importance of RI,as stated in their draft vision:

> "The Faculty of Life Sciences has a unique opportunity to take a leading international role in Responsible Research and Innovation by bringing together and building upon interdisciplinary experience and expertise across the University. The afore mentioned leaves the University of Bristol unusually well placed to host major activity where innovation meets concepts of sustainability and responsibility." (internal discussion minutes collected on 11.08.2017)

In this strategy, a central role would be played by scientists and researchers who are trained in RI for its incorporation into Research-led Teaching.

BrisSynBio has over time developed a two-pronged strategy. One is a 'top down' approach that consists of *cultivating a culture of RI throughout the Centre*. The objective is that everybody in the Centre should be familiar with RI principles, that everybody understands how RI is made meaningful in the context of the work they are conducting and in the broader context of the University. For this purpose, once a month they invite external speakers to discuss a variety of topics, some of which include those related to RI. They are committed to inviting at least 4 RI specialists per year. The purpose of this training is clearly expressed by the resident philosopher:

> "it's a sort of careful balance between cultivating independent scientists with really a love of science in a sort of pure sense, but also cultivating scientists as citizens. You wouldn't go and do a degree in governance in a totally disengaged fashion. It's almost non-sensical to do that. And similarly, perhaps it's non-sensical to study a discipline like engineering or biology let alone bio-technology in a fashion that presents it as disengaged from society."

The second kind of action reflects a more targeted, micro-level approach consisting of the case studies (see above) and more focused projects addressing RI dimensions. One example is the EU FP7 funded 'mutual learning action plan' project Synenergene ("Synenergene," 2016). This is an

initiative designed to contribute to RI in synthetic biology by establishing an open dialogue between stakeholders concerning potential benefits and risks of synthetic biology research, and by exploring possibilities for collaborative shaping of such research on the basis of public participation. Synenergene proved to be fundamentally transformative in terms of how RI is perceived and practiced in BrisSynBio as a *creative endeavour,* often through interaction with artists. The project looked at innovative and creative ways for scientists to engage with publics. One of these was a novel interaction established between BrisSynBio researchers, the Public Engagement team and a theatre collective called Kilter based in the nearby city of Bath (Reinsborough, 2020). The result, a play called 'Invincible' (Kilter, 2017)[10], puts the audience at the heart of some of the contemporary moral dilemmas presented by the development of Synthetic Biology (Kilter, 2017). The researchers were asked to look ten years into the future and imagine how the technology they are developing could affect the daily lives of ordinary people. The play was staged in small-group promenade format in the pressure-cooker environment of a residential apartment. Throughout the play, BrisSynBio researchers sat in and followed the action and, at the end of each performance, debated with the audience and the actors the dilemmas revealed within it. Not only has 'Invincible' showcased an innovative way to engage with publics, it also offered a creative space for the researchers (and time) to reflect deeply about their values, purposes and impact of their research projects. In the word of one of the researchers involved:

> "[…] there was this idea of the scene being set ten years in the future when certain things had happened, which obviously haven't happened yet, but potentially could have based on research that was going on in Bristol. […] it was good because it got the researchers to actually think beyond their little project of 'I have got to do these chores after I go and use the microscope and measure these cells'… to actually thinking wow, holy crap yeah… actually if this goes towards it could have big implications. In this case they went for a therapy where they design these molecules with an adaptive biological mechanism that could release drugs at certain times and control someone's mood […] Actually controlling someone's mood, that's really dangerous […] In the play the scientists said that depression is a problem, we want to solve it but through the act, we actually realise that… yeah it is a problem, but you can't just manipulate someone's mood... That's manipulating someone's emotions... It was just through that dialogue that you saw a lot of people opening up and realising things they potentially hadn't realised before."

In other words, what started as a public engagement initiative, evolved to become a more nuanced *participatory, reflexive exercise* (Reinsborough,2020) in which a reflexive *process* of co-devising and exchange (between artists and scientists over a period of 18 months) was as important as the final *product* (i.e. the performances as a moments of provocation through public engagement). In the words of the Centre's manager:

[10] www.youtube.com/watch?v=71K6h3wg1i8 – Accessed May 2019

> "We saw [Synenergene] as a Public Engagement activity. What we haven't anticipated was that the 18-month process that it took to develop the play would be this extremely powerful tool for reflection for the scientists and the actors. Actually, it was transformative to all the people involved in that piece of art. We were surprised about how empowering and meaningful this has been for all the people involved."

> "what we are doing now is somewhat different insofar as we are trying to implement RRI as a form of culture, as a set of practices, meanings, habits, and activities within the centre." (Resident Philosopher)

This arts- based approach proved to be influential in terms the Centre's future RI – related activities (Reinsborough, 2020; Fannin, 2020) as well as those in the wider University. Learning from this experience (and being inspired by it) , the Public Engagement team at the University for example have since explored how artist-led processes might be used to foster RI with scientists in fields such as quantum engineering and virtual reality. The team has also worked with BrisSynBio and artists collective ONCE (Once 2017) to develop a residential arts-based workshop for synthetic biology researchers. In September 2018, 19 synthetic biologists, artists, humanities researchers, and social scientists gathered at a retreat centre in rural Herefordshire to reflect on RI in the practice of synthetic biology through artist-led explorations. Following the workshop, the group have begun to self-organise, sharing reading, events and new ideas related to RI and meeting to reflect on how the ideas they explored together are surfacing in their day-to-day practice.

The Centre also encourages and promotes participation in a number of activities to explore different dimensions of RI that are especially aimed at junior staff members. Some of the BrisSynBio early career researchers, for example, participated in the activities promoted by the H2020 EU project PERFORM ("Perform," 2017), run by the Public Engagement team, which had the objective to encourage early career researchers to critically consider RI in scientific practices and develop skills to communicate this thinking to secondary school students. Researchers participated in a bespoke training programme covering key aspects of RRI, philosophy of science, science communication and performance. This programme was designed as a collaboration between the Public Engagement team, and University of Bristol's Centre for Science and Philosophy, involving a range of academics and practitioners from across the University and city, from philosophers of science to stand-up comedians. Alongside training, they had the opportunity to put their skills into practice by participating in workshops in secondary schools in Bristol. These workshops were led by an external consultant and focused around the school students working with the researchers to develop their own science performances about the social and ethical dimensions of science, to perform to their peers and the public.

These concrete RI - related practices reflect a policy of *formal and informal encouragement* rather than *coercion*. The RI approach has consisted of a mix of activities that have either been a requirement for all staff (e.g. the Invincible project described above) or which have been regularly offered to all but are voluntary. Even so our respondents stressed the approach is one in which RI is not forced onto people. In the Centre Manager's words:

> "We don't force people to use RRI. We have 21 projects we fund. We don't force any project to use RRI, but we encourage them to work in a way that shares information and expertise and also makes them reflect about RRI. We don't force anyone to work with anyone. But we make everything available to everyone. We make sure that when we organize something, an event or conference, our core scientific competencies as well as RRI is well represented and balanced. RRI has the same 'airtime' as anything else."

As one Senior researcher told us, they prefer this 'soft way'. Instead of trying to convince or force researchers to engage in RI activities, they prefer informal conversations in which reflexivity, inclusion of different perspectives, responsiveness – all dimensions of RI – are framed in a positive, appealing and often creative way that invites them to bring new perspectives on their work. In his words:

> "Communication effort to kind of emphasise why RRI is important. We have been quite instrumental in giving a few talks here and there… just a 10 minute talk but passionately showing why RRI is important and giving kind of personal examples of 'if you don't engage with the public or people about the implications of what you are doing then you can have issues in the future'. I think it is important obviously because the sorts of things we are developing now in 5-10 years' time could have global impact on the world and I think if we don't consider that then it can cause a lot of problems".

According to the interviewees, a more assertive strategy to 'impose' RI would have been met with hostility among scientists. Indeed, the interviewees told us that resistance to RI can be still perceived at different career levels. For example:

> "We noticed that there is an apparent difference between researchers at different levels of their careers. For older scientists RRI and SynBio is very new, so they have difficulties. For younger ones it is not a big thing to say I'm doing RRI, for them is obvious that they need to deal with RRI."

One of the reasons stated for this difference is that RI is embedded in the EPSRC and BBSRC Synthetic Biology Centre for Doctoral (PhD) Training (SynBioCDT), of which Bristol is a partner alongside Oxford and Warwick Universities. RI researchers from BrisSynBio (and academics working on RI from beyond the centre) participate in the training at the SynBioCDT, with a weeklong course on RI early in the programme of study. As a result, there is a feeling that in the case of SynBio, RI is embedded right from the beginning of the PhD journey. The narrative acknowledges that there were huge backlashes to GM, in part because the pioneers in this field failed to engage sufficiently in any meaningful debate with the public about issues of concern to

them. Most of the interviewees think that the field is special in that respect, and they had an opportunity to do it right from the very beginning. In the words of the Centre Manager:

> "In Synbio there are pockets of practitioners in which RRI far exceeded initial expectations. I like to think that BrisSynBio is one of those."

A potential shortcoming of the approach, however, is that it is a self-selecting subgroup of synthetic biologists who are most active in the RI programme, and it is within this self-selecting group that some soft impacts can be observed. The self-selecting aspect of the RI programme has also to an extent meant that the RI theme and the innovation/commercialisation theme have kept some distance from one another, though there is participation from the RI researchers in the yearly "4-Day MBA" programme for biotech start-ups. Outside this core group of RI-active/engaged researchers the take up and soft-impact has been found to be rather minimal.

Another important point that emerges from the interviews, as has been documented by Glerup et al. (2017), is the difficulty of 'selling' RI to researchers who are already pressured (time, resources) to get funding, complete PhDs, publish and undertake administrative work. As a result of these constraints, priorities and existing responsibilities, merely creating spaces for RI - related discussion and activities, whilst important, is not sufficient, particularly for those researchers who do not perceive a direct tangible value in engaging in RI activities. In this sense, the interviewees suggested that having both time and clear and concrete examples of RI practices that have contributed tangibly to high quality research is crucial to attract as yet non-engaged researchers. A collection of examples, easy to replicate, combined with a strategy of incentives, possibly integrated in the UK wide periodic Research Excellence Framework evaluation, could possibly lead to a deeper institutionalization of RI practices.

4.2. Theme 2: The Impact of RI on Research and Researchers in BrisSynBio

The experience of BrisSynBio demonstrates how exposing researchers involved in cutting edge scientific research to RI presented in innovative and creative ways can have a productive and even transformative effect on the way scientists perceive their role in terms of science and society. What initially started as a traditional public engagement exercise has become, at least for some members of the Centre's staff, a more systematically embedded practice of anticipation, reflection and deliberation concerning the purposes and potential impacts of their research. However, despite this, evidence of *the impact of RI activities* on the direction and trajectories of synthetic biology research undertaken in the centre remains elusive. For example, the Centre Manager noted that:

> "We struggle to measure the change in the scientists, we need very clear examples of how such a practice changed the practices of our scientists. I'm struggling to understand why we struggle to find those examples!"

One possible reason is the *tacit, cognitive, and intangible nature* of the changes that occur at the individual level when researchers are offered the possibility to engage with RI, (e.g. through deliberating with the public, or reflecting about the purposes of and motivations for their work). The feedback provided by the researchers suggests these are usually hard to measure (and hard to directly relate to choices, decisions and outcomes). As the director of the centre stated:

> "We get very qualitative feedback such as: this made me think deeply about the direction of my research, now I'd always embed RRI from now. We'll think about RRI for my new research projects."

Upstream "responsibilisation" seems devoid of a clear and systematically embedded institutional approach to capturing downstream (or midstream) outcomes in this respect, outcomes that are indicative of a transformative impact. According to one of the scientists interviewed, it is possible however to find some concrete examples:

> "There is a difference in terms of what people think is acceptable […] in terms of my research one of the things I have become more interested in through [RI] is ways of removing the 'biology from synthetic biology'. What I mean by that is not necessarily using a biological substrate as a starting point but removing some of the core functionality that we perceive is what makes life important. So, the ability to self-replicate. We can remove that capability from a cell but still make use of the biochemistry. From general discussions down the bars and other places, [I realised] people are a lot more comfortable with things that can't be released and [which do not] self-propagate in the environment. This seems to be their big concern […] so in terms of my research I have now started to look more into what we call in vitro systems, it is not a natural system, but it is one that we might start with living cells but then effectively remove their ability to actually reproduce. They are not really cells anymore but then we can still exploit lot of the chemistry that they perform."

Despite some largely anecdotal evidence of the impact of RI exposure on researchers in terms of changed attitudes and outlook, the effectiveness of RI interventions in re-shaping institutional practices or bringing about structural change remains elusive and unclear. The tension noted above between reflexive RI practices and institutional structures firmly embedded in the triple-helix model with commercialisation and economic growth as primary drivers (alongside excellent science) seemingly remains in place. What is clear, however, according to one senior academic is that *lack* of RI training can have important implications. This might for example potentially undermine some researchers' self-confidence in application-oriented science:

> "I think if you don't train them, some of them are too frightened to go near anything that might have consequences of any kind. So, they stay as far away from consequences as possible and do fundamental research because they're afraid of having consequences on anything, which is terrible."

On the other hand, a lack of training could she suggests play to a division of labour agenda in which personal accountability is discounted:

> "[they] think it is not their problem. Consequences aren't their problem. I would do what I like, somebody else worries about the consequences. When I was trained, we were told it wasn't our problem. We were told ethics committees would work it out, but of course they can't because they don't understand what's going on and even if they do understand, it takes ages to work it out. It would be much, much better if the people actually doing the research, did that thinking, because they are much closer to the process, they can be much more responsive."

In conclusion, our analysis of the BrisSynBio research centre demonstrates the overt intention to employ, at the heart of the centre's RI strategy and practices, a range of co-productive, creative and embedded practices based around public engagement but extending this to include and embed other core RI principles such as ethical reflexivity and anticipation. The institutionalisation of such RI practices has without doubt met with some success, but it has also not been uniform across the Centre. Likewise, the impact from these RI practices on the research at the Centre remains poorly captured, it appears to be elusive and difficult to measure. It is worth noting that impact and responsiveness has also been a criticism of historic public engagement practices and not just RI e.g. Sykes and Macnaghten, 2013).

5. Discussion and Conclusions

In this paper we sought to describe and interrogate the translation of responsible (research and) innovation into organisational practices within a synthetic biology research centre located within a university setting. Our analysis first highlights the importance of external policy drivers (e.g. the 2012 UK National Synthetic Biology Roadmap) as significant legitimators of and catalysts for RI institutionalization. Directly linked to initial funding arrangements of the Synthetic Biology Research Centres, of which BrisSynBio was one, this ensured RI was substantively included during initial bid development for the Centre. This development built on existing academic collaborations and experiences with RI related dimensions (notably ethical reflection and public engagement) (Reinsborough, 2020) and ensured RI was integrated at a very early stage of new institution formation (e.g. here the Centre), with a clear external mandate for its inclusion from the outset. However, the RI requirement was not prescriptive in terms of a detailed approach, allowing flexibility. In the case of BrisSynBio this allowed space for the development of an approach that has been characterised by its adaptive, flexible and creative nature, allowing the Centre to 'feel its way' through trial and error whilst pioneering new ways of doing RI e.g. through partnership with the creative arts. These have certainly had tangible, positive influences on at least some of the

researchers, even if the impacts on their research are less easy to measure and have not been systematically captured.

Pansera and Owen (2018b) have described significant barriers to RI institutionalisation in universities, relating in part to resistance related to incumbent institutional logics (Shields & Watermeyer, 2020), disciplinary norms and incentive and reward structures. As a result, they report RI institutionalisation to date as being patchy and often limited in reach and scope, with potential for this to be symbolic rather than substantive in nature (Bercovitz & Feldman, 2008; Hartley, Pearce, & Taylor, 2017b). Taylor and Woods (2020) for example report how senior scientists working in synthetic biology tend to normalise RI to existing norms and practices as these relate to laboratory health, safety and risk assessment and regulations. Whilst RI institutionalisation within BrisSynBio has not been uniform, our analysis suggests on the whole it has been more substantive. Why this is the case we suggest reflects a) the initial requirement from funders to include RI in funding bids, serving as an important source of RI *legitimation* (Deephouse & Suchman, 2008); b) *institutional entrepreneurship and leadership* (Hardy and Maguire, 2008) at various levels, including senior academic members of the Centre who were pre-disposed to RI and committed to implementing it in a substantive way (Reinsborough, 2020). Bercovitz and Feldman (2008) have shown that whilst responses to the introduction of new practices (here RI) will reflect researchers values, imprinting and socialisation (e.g. their academic and professional training and the norms associated with these) behaviours can be significantly modified by the local (i.e. micro-organisational) context in which that individual subsequently finds themselves. These authors draw attention to the importance of both local leadership and peer influences in this regard; c) persistent 'institutional work' (Lawrence & Sudderby, 2006), including an approach combining more formal, required elements with voluntary offerings that aimed to encourage and invite, sometimes in creative and innovative ways.

Our analysis of RI at BrisSynBio also illustrates a discourse that builds on existing 'de facto' practices of responsible research (Lindner et al., 2016) at the University (notably the strong basis in public engagement) which have evolved over time as these have been embedded in the Centre. The lessons learned from our case study can be summarised in three main points.

The first point relates to how RI was initially framed around important existing constructs, notably public engagement and ethical reflection, which served as foundations and antecedents for RI, but which in turn evolved and broadened in concept and practice over time within the Centre. Broadly, there has been a clear interest toward RI within the UK SynBio community for some years, in part stimulated by the SynBio 2010 public dialogue exercise which served as an important input into

the 2012 Roadmap in which RI played a prominent part. It is also in part motivated by previous experiences with GMO (and indeed nanotechnology, synthetic biology within BrisSynBio incorporating both GM and Nano technology). This backdrop is complemented by an existing, strong institutional commitment to and resources for public engagement and, more in general, as suggested by Balmer et al. (2016) a move towards post-ELSI forms of interdisciplinary collaborations between the natural and social sciences.

The engagement strategies implemented have varied from recognisable public engagement initiatives (e.g. science festivals, science café, public dialogues etc.) to more creative and interactive formats (e.g. the "Invincible" theatre production in collaboration with the Synenergene Project, or the BrisSynBio Artistic/RRI residencies),(see Reinsborough (2020), Fannin et al (2020) for more details). These latter examples reflect an evolution of the strategic approach, with the desire to embed methods rooted in reflexivity, co-creation and co-production that are directly connected with the EPSRC RI Framework dimensions of 'Inclusion', 'Anticipation'; and 'Reflexivity' (see also Stilgoe et al, 2013). In this sense RI has offered space for new forms of practice, for reframing, re-configuration and innovation within the existing set of public engagement practices.

Where RI has been experimented in this way there has been evidence of innovative and creative thinking aiming to include but also move beyond quite narrow and existing responsibility framings e.g. those associated with research integrity or *ad hoc* public engagement exercises (e.g. Hartley et al, 2017; Goos and Lindner 2015). This evolution at BrisSynBio from science communication to public engagement to RI arguably reflects broader historic and ongoing developments in the UK, albeit to varying degrees. Innovation in RI at BrisSynBio is consistent with a broader evolution of the concept of Public Engagement over the last few decades, from one-way, deficit models of science communication focussed on 'the public understanding of science' aimed at securing legitimacy to a more deliberative and dialogic process, with resourcing of 'Beacons' and 'Catalysts' for public engagement in the UK, and the establishment of a National Co-Ordinating Centre for Public Engagement (based in Bristol).

However, public engagement in the UK has not been without its criticisms, (notably around responsiveness and outcomes (Sykes & Macnaghten, 2013)). Our respondents themselves noted for example that whilst creative encounters such as 'Invincible' were extremely valuable, the extent to which they have been able to reach and involve communities beyond the 'usual constituencies' of predominantly white middle class publics is questionable. Despite the effort to engage with a wider public, our informants are still struggling to engage with communities and sectors that are under-represented in the City region e.g. people below the poverty threshold; black and minority

/ ethnic communities etc. – a challenge shared across the university sector. In this sense our study appears to show that, despite evolution, RI has inherited similar problems of reach and responsiveness historically levelled at public engagement. The BrisSynBio RI team is trying to address this, working to set up social labs and reverse science cafes that have reach outside the traditional geographic and demographic scope of many public engagement activities and working with schools as a key partner in reaching these communities.

Notwithstanding this, we have seen evidence of clear attempts to challenge (and change) practices, addressing known barriers to RI that include disciplinary norms, incentive structures, institutional logics, lack of resources, leadership and agency (Owen & Pansera, 2019a; 2019b). A key insight from this case study is that for RI to overcome these barriers and succeed it must be enacted as a *creative process* that *invites, creates space and adds value in a flexible way*, rather than being perceived as a process of strict ethical oversight and a coercive, bureaucratic burden.

This emphasis on creativity, innovation, adaptive learning and adding value is then the second learning point from the case study. We found that in BrisSynBio, RI has been characterised by a willingness for experimentation, creating spaces for imagination where people can contribute and create rather than simply receive and be taught (important though training and RI pedagogy is).

Finally, despite the efforts in promoting and embedding RI in BrisSynBio, the Centre has struggled to assess how exposure is changing the way scientists routinely work and equally struggled to capture the impacts of RI interventions (e.g. in terms of how research agendas are set or research and innovation trajectories are modulated). We see clear evidence of reflexivity and inclusive deliberation, and an influence of interventions on the researchers. In this sense there has been a measure of responsiveness, however intangible and perhaps fleeting. But it is evident that reflection, inclusion and anticipation do not in themselves necessarily lead straight forwardly to changes to daily practices or to outcomes, in particular without appropriate institutional support, openness to change and ways of capturing impact. The impact on daily routines, practices and outcomes within the Centre remains elusive and as yet unquantified. Measuring responsiveness, impact and outcomes remains an area for significant development in this respect. Furthermore, it is important to say that most of the interviewees sampled, who are also key individuals within the centre, appeared to have strong personal interest and enthusiasm in RI practices, and this may not be representative of all individuals in the Centre, or indeed across other synthetic biology centres: we recommend studying how RI practices have been experimented with in other SynBio centres in this respect.

Nevertheless, overall it seems reasonable to conclude that RI in this case study has been substantive, evolving as an approach that includes but goes beyond public engagement to catalyse (to varying degrees) anticipation, reflexivity and deliberation in sometimes creative and innovative ways. These are three of the four core dimensions of RI described by Stilgoe et al (2013). However, the extent to which deliberation is truly inclusive, and the extent to which there has been responsiveness (in particular in relation to the impact on research agendas and trajectories) remains unclear, noting that Stilgoe et al (2013) emphasise RI as an approach that integrates and embeds all four dimensions in and around the processes of innovation and scientific knowledge production aimed at this.

Acknowledgments

This work was in part undertaken within the RRI-Practice project, funded by the European Union's Horizon 2020 Research and Innovation Programme, grant no. 709637

References

Balmer, A. S., Bulpin, K., & Molyneux-Hodgson, S. (n.d.). *Synthetic biology : a sociology of changing practices*.

Balmer, A. S., Calvert, J., Marris, C., Molyneux-Hodgson, S., Frow, E., Kearnes, M., … Martin, P. (2015). Taking roles in interdisciplinary collaborations: reflections on working in post-ELSI spaces in the UK synthetic biology community. *Science & Technology Studies*, *28*(3), 3–25. Retrieved from https://sciencetechnologystudies.journal.fi/article/view/55340

Balmer, A. S., Calvert, J., Marris, C., Molyneux-Hodgson, S., Frow, E., Kearnes, M., … Martin, P. (2016). Five rules of thumb for post-ELSI interdisciplinary collaborations. *Journal of Responsible Innovation*, *3*(1), 73–80. https://doi.org/10.1080/23299460.2016.1177867

Bardone, E., & Lind, M. (2016). Towards a phronetic space for responsible research (and innovation). *Life Sciences, Society and Policy*, *12*(1), 5. https://doi.org/10.1186/s40504-016-0040-8

BBRSC. (2010). *Synthetic Biology Dialogue*. Retrieved from https://bbsrc.ukri.org/documents/1006-synthetic-biology-dialogue-pdf/

BBSRC. (2012). Synthetic biology dialogue.

Bercovitz, J., & Feldman, M. (2008). Academic entrepreneurs: Organizational change at the individual level. *Organization Science*, *19*(1), 69–89. https://doi.org/10.1287/orsc.1070.0295

Blok, V., & Lemmens, P. (2015). The Emerging Concept of Responsible Innovation. Three Reasons Why It Is Questionable and Calls for a Radical Transformation of the Concept of Innovation. In *Responsible Innovation 2* (pp. 19–35). https://doi.org/10.1007/978-3-319-17308-5_2

Blood Culture. (2019). Blood Culture. Retrieved March 1, 2019, from https://www.blood-culture.com/credits.html

BrisSynBio. (2015). What is RRI? Retrieved March 1, 2019, from BrisSynBio website: http://www.bristol.ac.uk/brissynbio/about-brissynbio/ethics-and-responsible-research-and-innovation/what_is_rri/

BrisSynBio. (2019). BrisSynBio. Retrieved March 1, 2019, from University of Bristol website: http://www.bristol.ac.uk/brissynbio/about-brissynbio/ethics-and-responsible-research-and-innovation/t3_1/

Burrows, A., Meller, B., Craddock, I., Hyland, F., & Gooberman-Hill, R. (2019). User involvement in digital health: Working together to design smart home health technology. *Health Expectations*, *22*(1), 65–73. https://doi.org/10.1111/hex.12831

Connor, K. (2019). Katy Connor Blog. Retrieved September 20, 2006, from https://katyconnor.wordpress.com/

Corley, K. G., & Gioia, D. A. (2011). Building Theory about Theory Building: What Constitutes a Theoretical Contribution? *Academy of Management Review*, *36*(1), 12–32. Retrieved from http://amr.aom.org/content/36/1/12.full

Davies, S., & Horst, M. (2015). Responsible innovation in the US, UK and Denmark: Governance Landscapes. In J. van den H. Bert-Jaap Koops, Ilse Oosterlaken, Henny Romijn, Tsjalling Swierstra (Ed.), *Responsible Innovation 2: Concepts, Approaches, and Applications* (pp. 37–56). https://doi.org/10.1007/978-3-319-17308-5

de Hoop, E., Pols, A., & Romijn, H. (2016). Limits to responsible innovation. *Journal of Responsible Innovation*, *0*(0), 1–25. https://doi.org/10.1080/23299460.2016.1231396

de Saille, S. (2015). Innovating innovation policy: the emergence of 'Responsible Research and Innovation.' *Journal of Responsible Innovation*, *2*(2), 152–168. https://doi.org/10.1080/23299460.2015.1045280

Deephouse, D. L., & Suchman, M. (2008). Legitimacy in organizational institutionalism. In R. Greenwood, C. Oliver, K. Sahlin, & R. Suddaby (Eds.), *The Sage handbook of organizational institutionalism* (Vol. 49, p. 77). London: SAGE Publications.

Egeland, C., Maximova-Mentzoni, T., Hanssen, A. B., & Forsberg, E.-M. (2018). *RRI-Practice National Case Study Report Norway*. Retrieved from https://www.rri-practice.eu/wp-content/uploads/2018/09/RRI-Practice_National_Case_Study_Report_NORWAY.pdf

EPSRC. (2012). Synthetic biology roadmap. Retrieved September 20, 2001, from EPSRC website: https://epsrc.ukri.org/newsevents/news/syntheticbiologyroadmap/

EPSRC. (2013). Framework for Responsible Innovation. Retrieved March 1, 2019, from Framework for Responsible Innovation website: https://epsrc.ukri.org/research/framework/

EPSRC. (2018). Centre For Doctoral Training.

Fannin, M., Connor, K., Roden, D., Meacham, D. (2020) BrisSynBio Art-Science Dossier. *NanoEthics: Studies on New and Emerging Technologies*

Fisher, E., Mahajan, R. L., & Mitcham, C. (2006). Midstream Modulation of Technology: Governance From Within. *Bulletin of Science, Technology & Society*, *26*(6), 485 – 496.

FOE. (2012). Principles for the oversight of synthetic biology. Retrieved September 20, 2001, from http://www.synbioproject.org/site/assets/files/1270/principles_for_the_oversight_of_synthetic_biology.pdf

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2012). Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology. *Organizational Research Methods*, *16*(1), 15–31. https://doi.org/10.1177/1094428112452151

Glerup, C., Davies, S. R., & Horst, M. (2017). 'Nothing really responsible goes on here': scientists' experience and practice of responsibility. *Journal of Responsible Innovation*, *4*(3), 319–336. https://doi.org/10.1080/23299460.2017.1378462

Goos, K., & Lindner, R. (2015). *Institutionalising RRI – The Case of a Large Research Organisation. RES-*

AGorA case study by Fraunhofer ISI. Retrieved from https://www.res-agora.eu/assets/Institutionalising-RRI_FhG_20150325-formatiert.pdf

Hartley, S., Pearce, W., & Taylor, A. (2017a). Against the tide of depoliticisation: The politics of research governance. *Policy & Politics*, *45*(3), 361–377. https://doi.org/10.1332/030557316X14681503832036

Hartley, S., Pearce, W., & Taylor, A. (2017b). Against the tide of depoliticisation: The politics of research governance. *Policy & Politics*, *45*(3), 361–377. https://doi.org/10.1332/030557316X14681503832036

Hill, S. (2016). Assessing (For) impact: Future assessment of the societal impact of research. *Palgrave Communications*, *2*(1), 1–7. https://doi.org/10.1057/palcomms.2016.73

Hopkins, H., & van Mil, A. (2018). Human genome editing: Where to draw the line? Follow-up study to the genetic technologies public dialogue.

Kent, J., & Meacham, D. (2019). 'Synthetic Blood': Entangling Politics and Biology. *Body & Society*, *25*(2), 28–55. https://doi.org/10.1177/1357034X18822076

Kilter. (2017). *Invincible*. Retrieved from https://www.youtube.com/watch?v=71K6h3wg1i8

Lawrence, T. ., & Sudderby, R. (2006). Insitutions and Institutional Work. In S. R. Clegg, C. Hardy, T. B. Lawrence, & W. R. Nord (Eds.), *Sage Handbook of Organization Studies* (pp. p215-254). London: SAGE Publications.

Lindner, R., Kuhlmann, S., Randles, S., Bedsted, B., Gorgoni, G., Griessler, E., … Mejlgaard, N. (Eds.). (2016). *Navigating Towards Shared Responsibility in Research and Innovation. Approach, Process and Results of the Res-AGorA Project*. Retrieved from https://ris.utwente.nl/ws/portalfiles/portal/5572411/RES_AGorA_ebook.pdf

Ludwig, D., & Macnaghten, P. (2020). Traditional ecological knowledge in innovation governance: a framework for responsible and just innovation. *Journal of Responsible Innovation*, *7*(1), 26–44. https://doi.org/10.1080/23299460.2019.1676686

Macnaghten, P., & Chilvers, J. (2014). The Future of Science Governance: Publics, Policies, Practices. *Environment and Planning C: Government and Policy*, *32*(3), 530–548. https://doi.org/10.1068/c1245j

Macnaghten, P., Owen, R., Stilgoe, J., Wynne, B., Azevedo, A., de Campos, A., … Velho, L. (2014).

Responsible innovation across borders: tensions, paradoxes and possibilities. *Journal of Responsible Innovation*, *1*(2), 191–199. https://doi.org/10.1080/23299460.2014.922249

Marris, C., & Calvert, J. (2019). Science and Technology Studies in Policy: The UK Synthetic Biology Roadmap. *Science, Technology, & Human Values*, 016224391982810. https://doi.org/10.1177/0162243919828107

Miles, M. B., & Huberman, A. M. (2003). *Qualitative data analysis : an expanded sourcebook* (Second Ed.). Thousand Oaks, CA: Sage Publications.

Owen, R. (2014). The UK Engineering and Physical Sciences Research Council's commitment to a framework for responsible innovation. *Journal of Responsible Innovation*, *1*(1), 113–117. https://doi.org/10.1080/23299460.2014.882065

Owen, R., & Pansera, M. (2019a). Responsible Innovation: Process and Politics. In R. von Schomberg (Ed.), *International Handbook on Responsible Innovation*. Cheltenham, UK: Edward Elgar Publishing.

Owen, R., & Pansera, M. (2019b). Responsible Innovation and Responsible Research and Innovation. In W. C. Dagmar Simon, Stefan Kuhlmann, Julia Stamm (Ed.), *Handbook on Science and Public Policy*. Cheltenham: Edward Elgar Publishing.

Pansera, M., & Owen, R. (2018a). Framing inclusive innovation within the discourse of development: Insights from case studies in India. *Research Policy*, *47*(1), 23–34. https://doi.org/10.1016/j.respol.2017.09.007

Pansera, M., & Owen, R. (2018b). *RRI-practice UK National Report*. Retrieved from https://www.rri-practice.eu/wp-content/uploads/2019/06/RRI-Practice_National_Case_Study_Report_UNITED-KINGDOM.pdf

Perform. (2017). Retrieved March 1, 2019, from http://www.perform-research.eu/

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., … Sobrero, M. (2013). Academic engagement and commercialisation: A review of the literature on university-industry relations. *Research Policy*, *42*(2), 423–442. https://doi.org/10.1016/j.respol.2012.09.007

POST. (2015). *Regulation of Synthetic Biology*. Retrieved from https://researchbriefings.parliament.uk/ResearchBriefing/Summary/POST-PN-

0497#fullreport

Randles, S. (2017). *Deepening "Deep Institutionalisation": Elaborating a Concept and Developing a Typology to Analyse and Contrast the Institutionalisation of De-facto responsible research and innovation - EU JERRI project deliverable 1.2*. Retrieved from https://www.jerri-project.eu/jerri-wAssets/docs/deliverables/wp-1/JERRI_Deliverable_D1_2_Deepening-Deep-Institutionalisation.pdf

Reinsborough, M. (2020). Art-Science collaboration in an EPSRC/BBSRC-funded synthetic biology UK research centre. *NanoEthics: Studies on New and Emerging Technologies*

SBLC. (2016). *Biodesign for Bioeconomy. UK Syntethitic Biology Strategic plan 2016*. Retrieved from https://static1.squarespace.com/static/54a6bdb7e4b08424e69c93a1/t/589619873e00be743c62a76e/1486231951837/BioDesign+for+the+Bioeconomy+2016+-+DIGITAL.pdf

Schot, J., & Steinmueller, W. E. (2018). Three frames for innovation policy: R&D, systems of innovation and transformative change. *Research Policy*, *47*(9), 1554–1567. https://doi.org/10.1016/J.RESPOL.2018.08.011

Schyfter, P., & Calvert, J. (2015). Intentions, Expectations and Institutions: Engineering the Future of Synthetic Biology in the USA and the UK. *Science as Culture*, *24*(4), 359–383. https://doi.org/10.1080/09505431.2015.1037827

Shah, S. K., & Corley, K. G. (2006). Building Better Theory by Bridging the Quantitative – Qualitative Divide. *Journal of Management Studies*, *43*(8), 1821–1835.

Shields, R., & Watermeyer, R. (2020). Competing institutional logics in universities in the United Kingdom: schism in the church of reason. *Studies in Higher Education*, *45*(1), 3–17. https://doi.org/10.1080/03075079.2018.1504910

Smith, M. L., & Seward, C. (2009). The Relational Ontology of Amartya Sen's Capability Approach: Incorporating Social and Individual Causes. *Journal of Human Development and Capabilities*, *10*(2), 213–235.

Stilgoe, J., Owen, R., & Macnaghten, P. (2013). A Framework for Responsible Innovation. *Research Policy*, *42*(9), 1568–1580. https://doi.org/10.1016/j.respol.2013.05.008

Swierstra, T. (2017). Economic, Technological, and Socio-Epistemological Drivers of Behind RRI. In L. Asveld et al (Ed.), *Responsible Innovation 3*. Dordrecht: springer.

Sykes, K., & Macnaghten, P. (2013). Responsible Innovation – Opening up dialogue and debate. In M. Owen, R., Bessant, J., Heintz (Ed.), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society.* (pp. 85–107). London: Wiley.

Synenergene. (2016).

Taylor, K., & Woods, S. (2020). Reflections on the practice of Responsible (Research and) Innovation in synthetic biology. *New Genetics and Society*, *0*(0), 1–21. https://doi.org/10.1080/14636778.2019.1709431

Thomas, J. (2014). Ecover pioneers "synthetic biology" in consumer products.

UK Gov. (2013). Eight great technologies infographics. Retrieved from https://www.gov.uk/government/publications/eight-great-technologies-infographics

UOB. (2011). Engaged University Strategy.

UOB. (2018). University Strategy.

van Oudheusden, M. (2014). Where are the politics in responsible innovation? European governance, technology assessments, and beyond. *Journal of Responsible Innovation*, *1*(1), 67–86. https://doi.org/10.1080/23299460.2014.882097

Watermeyer, R. (2016). Impact in the REF: issues and obstacles. *Studies in Higher Education*, *41*(2), 199–214. https://doi.org/10.1080/03075079.2014.915303