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ORIGINAL RESEARCH PAPER

Addressing Multiple Responsibilities in the Early Stages of R&D with Provenance Assessment

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Abstract A wealth of literature and best practices on Responsible Research and Innovation (RRI) document how it can be implemented in projects. However, each project is too specific to simply replicate existing patterns. Especially in early projects with a high degree of uncertainty, where indicators and measures cannot be applied, the so-called provenance assessment as a methodological change of perspective makes it possible to assess the procedural quality of research by means of narratives. A clear picture of the challenges for European bio-economy projects is sought by mapping the broader debate on "RRI in practice" in the context of biotechnology. The SUSPHIRE project is used as a case study to show how project-specific narratives integrate and signify RRI. By unpacking various concepts of "responsibility" that are already present in the project narrative at an early stage, I will show how this assessment differs significantly from other attempts to "do RRI". It is precisely in the absence of other criteria that the assessment of provenance can bring to the fore the specific form(s) of responsibility inherent in the development of projects.

Keywords RRI · Responsibility · Narrative analysis · Process assessment · Biotechnology

The RRI Challenge in Early R&D Projects

The implementation of Responsible Research and Innovation (RRI) in practice can be a delicate task: on the one hand, there is a wealth of literature and best practices on which to draw, but on the other hand, each project is too specific to be easily replicable. In the context of scientific research and development (R&D) projects, RRI has been inherent in the structure of the European bioeconomy and its accompanying funding system [1, 2]. In part, RRI has been implemented within these structures to address a variety of issues arising from the awareness of a number of different, overlapping, yet unspecified responsibilities and the struggle to manage their interactions. Therefore, any kind of research activity under RRI conditions is inevitably engaged in, and needs to position itself within, a broader debate at the transnational policy level about the kind of inquiry to be pursued and the processes to be employed [3, 4]. Each project must position its work in the continuum between R&D and application contexts, and thus define what makes it scientifically and publicly relevant to these approaches, including in terms of relevance outside the field and to the public.

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In this respect, the commitment to RRI can be interpreted in part as a call for practical complexity management, communication, and transfer of knowledge, materials, and capacity. While these implementation issues need not be at the core of RRI, they can determine what it means for individual projects.

However, the question of implementing RRI-related activities in research programs has yet another dimension: in practice, it ranges from more or less frequent stakeholder surveys to integrated research agendas. Each of these different approaches contributes to building responsibility proposals into the process from the outset. However, any possible assessment of the form, manner and extent to which this is done seems to remain undisclosed until publication, i.e. at the end of the project, when the scientific results can be evaluated. As a result, there is a lively debate about how to get RRI right, or whether it should be discarded in favor of other approaches that may or may not share the challenge of impact assessment but, for example, provide guidance [5, 6]. Since RRI is not a fixed method or tool, these practical considerations often limit the "doing" of RRI. Therefore, the main argument against engaging in RRI is that if only there were a standard process for RRI, R&D activities would be open to scrutiny and thus transparent to different publics and stakeholders [6, 7]. As the concept of RRI is crucial to the funding system and inherently relevant to the transnational research agenda, it is inevitably included in the tasks of many projects. However, as it does not provide a framework or guideline to work with, it becomes an additional package to be dealt with, where it remains unclear how it will pay off. While it is easy to make a compelling case for why and how RRI has historically entered R&D funding [4, 6, 7], the challenge remains why projects should (still) consider engaging with it.

In this paper, I will show how RRI can be used to provide a motive for evaluating the provenance of value-related decisions in the course of a project through their traceability in non-conflicting narratives. By broadening the picture, RRI can help to ask specific transformative and somewhat preliminary questions that are, for example, inherent in early R&D trajectories. Assessing these can then help to track and understand the choices made in the early stages of a project's development. To illustrate these dynamic interdependencies, the SUSPHIRE project is presented as a paradigmatic example. SUSPHIRE is the sustainable bioproduction of pheromones for agricultural pest control and was funded under Horizon 2020, so it necessarily engaged with RRI. To show how this engagement has (co)shaped the project, I will show where RRI plays a role in the SUSPHIRE narratives. In doing so, I will discuss the varieties of responsibility involved—especially in cases like SUSPHIRE—and introduce the idea of provenance assessment as a means of fixing progress, making it transparent and evaluable. This highlights the importance of value-related decisions, which are ubiquitous in the early stages of R&D projects, but are overlooked when addressed at the ex-post stage. Therefore, in order to address these difficulties in implementing RRI in early R&D, this paper proposes a different perspective, with its own way of evaluating and "doing" RRI in European bioeconomy projects. Therefore, I briefly sketch the landscape of RRI and its challenge for early R&D projects in the European context ("RRI in early R&D in the European Context" section). In order to illustrate how RRI can (co)shape projects, I show where the engagement with responsibility through narratives plays a role in the case of SUSPHIRE ("Narratives as scientific practice" section). Next, by introducing the idea of provenance assessment, I discuss how narratives can document, make accessible, and evaluate the management of multiple responsibilities in projects ("Provenance Assessment - assessing processes as they happen" section). The core of the paper is then an exploration of the various aspects of "responsibility", drawing on an approach by a working group at TU Delft [8] ("Varieties of Responsibility in early R&D projects" section). The final section summarizes the argument and presents some practical ideas for implementing RRI in early R&D ("Conclusive Remarks" section).

RRI in Early R&D in the European Context

In the European context, a core concept of responsibility in research and innovation can be understood as value-oriented, based on specifically European values that refer to the given framework [4, 5, 9]. In this sense, RRI is inherently practice-oriented: values adhere to standards that can be evaluated through their implementation. Therefore, this paper aims to illustrate specific practices around the implementation of RRI in project trajectories as

entry points for so-called provenance assessment, using early biotechnology R&D as a proxy example for cases of high uncertainty and massive impact potential. However, there are significant differences in the formulation and visibility of these European values, the respective frameworks and their implications for RRI.

In the global bio-economic context, the European framework includes primarily political values (e.g. justice, peace, democracy, access to medicines), but also environmental, economic and social values (e.g. biodiversity, equality, high employment levels). As a result, most contemporary research projects in this field have to perform various balancing acts on their way to (funding) applications. In essence, European R&D projects serve not only scientific goals, but also broader goals and purposes, be they economic, environmental, societal, or political. Each of these evokes and provokes different responses, actions and efforts, and implies different dimensions of responsibility. These conditions could be commented on half-jokingly, as those involved are paid for the marketable product, and yet basic research works well, since this is the working basis on which to achieve them—accompanied, not surprisingly, by a specific form of handling responsibilities. The global biotechnology sector (biotech for short) is developing so rapidly that projects end up competing for funding, market share, and the advancement of technological control and knowledge, all at the same time—with different, related responsibilities. Specifically, as the scope of biotech research expands, the demands become greater. Since many biotech projects can visibly achieve their goals in terms of technical control and effectiveness, the entire sector is seen as a driver of economic growth. At the same time, it is seen as an archetype of the very idea of sustainability as it caters the European and global visions of a green new deal [10]. This has made biotech something of a "funding magnet", capable of opening up new opportunities in all areas of application.

For this and other reasons, the bio-economy is a research paradigm that has long been adopted by the European Union. Accordingly, the European version of a knowledge-based bio-economy provides a framework for research activities in the EU. This framework is binding for projects supported by EU funding programs [1]. However, the term "knowledge-based bioeconomy" is not just a descriptive label. In the framework, knowledge-based bioeconomy also functions as a guideline for research activities in the field, which has a regulatory content, as it implies a normatively oriented marketplace for projects and ideas. In this marketplace, a variety of responsibilities are at play. Adherence to them makes it possible to evaluate good and desirable new research projects that seek solutions to current supply and sustainability problems. As a result, the bio-economy in the European Union poses specific challenges for biotechnological research: in all project phases, there is a demand for processes that favor so-called biological production processes as opposed to chemical or mechanical processes in the broadest sense. In the European funding context, the Technology Readiness Level (TRL) indicates the status of the project in terms of application maturity, with low TRLs indicating early R&D and relatively basic research projects.[1] High uncertainties about processes, development and results demarcate early stages. Implicitly, the recognition of this knowledge-based bio-economy and the acceptance of its premises, rules and values is a prerequisite for obtaining EU research funding for the low TRL range, despite the fact that "production" is out of scope [11]. The fact that TRLs and other project status indicators are not addressed in RRI concepts poses an additional problem for the implementation and execution of RRI under high uncertainties and relatively exploratory trajectories.

The European Union has emphasized that RRI responds to the need for research and innovation to address societal issues and challenges, while taking into account ethical, social and environmental considerations. The aim of RRI is to ensure that research and innovation contribute to the well-being and sustainability of society and are in line with citizens' values and expectations. This includes involving stakeholders in the research and innovation

[1] The development of marketable products is the objective of high TRL projects. In these already mature trajectories, the bioeconomy framework specifically promotes techniques that possess unique plasticity and materials that offer modular functionality, such as chassis in biochemistry, biomass in the energy sector, or the use of algae and fungi in synthetic biology. How the normative paradigms of the bioeconomy play out in this part of the spectrum of possible projects is beyond the scope of this paper.

process, promoting open and transparent communication, and considering the potential impacts, risks and benefits of research and innovation. From this perspective, RRI is relevant to research because of other, external, non-scientific factors. Indeed, efforts such as RRI are becoming increasingly important as the role of research and innovation in society continues to grow [5]. As societal challenges become more complex, responsible and inclusive research and innovation processes are essential to address them effectively, efficiently and correctly [1, 4, 5]. This perspective on the implementation of RRI as a means to build public trust and support for scientific progress focuses on ensuring that societal needs and values are considered [4].

The concept of RRI in European funding programs, which goes back to the work of René von Schomberg, already includes integration and exchange. It points to a set of values for RRI, declaring "(ethical) acceptability, sustainability and societal desirability" as the yardstick for validating activities in terms of responsibility in research practice that can be taken up and that could become very instructive. In addition, RRI is about making connections and dependencies visible, which is another rather hidden hint [4]. But, instead of following up on these clues, another storylines develop: RRI has been embedded to bring the cross-cutting issues of engagement, gender, science education, ethics and open access to the fore, so that ultimately RRI will make their research process accessible, evaluable, and transparent—especially for those outside the field or project [1, 2, 12]. RRI in research practice and the related field of Responsible Innovation (RI) applied in industry understand "responsibility" partly in ex-ante terms already: To promote the alignment of processes, outcomes, and purposes with societal values and expectations, they call for early, reflective, and inclusive deliberation with and for everyone outside the respective project. The classic definition of RRI by von Schomberg or the European Commission, for example, already contains this element: RRI "allows all societal actors (researchers, citizens, policymakers, business, third sector organisations etc.) to work together during the whole research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of European society" [12]. Still, von Schomberg's work does not provide guidance on how to do that and does not specify what responsibility means to practice (e.g. "mutual responsiveness between the actors involved").[2] However, already von Schomberg's early vision of RRI, as presented, offers an idea of tools or practical instructions on how to work with it to enable practitioners to address their issues in their projects. When doing RRI with EU funding, what is the basis to rely on? Well, best use is perhaps the only standard by which current projects could be judged, if anyone has ever bothered to try. "Responsible research and innovation is an approach that anticipates and assesses potential implications and societal expectations with regard to research and innovation, with the aim to foster the design of inclusive and sustainable research and innovation" [2]. This is the definition given in the application literature for the Horizon 2020 funding program; it is as open-ended as possible and does not specify anything—especially not for implementation in practice. It does, however, suggest a certain timetable for anticipating and assessing the impacts and expectations of the R&D project in question—and this is what practitioners do as part of their projects.

In addition to the implementation challenges and questions about the feasibility and effectiveness of RRI in real-world settings, the RRI debate has encountered a number of complications regarding practices: RRI promotes responsible and inclusive research, but this can conflict with the need for institutions and countries to remain competitive in the global market (balancing competitiveness and responsibility, e.g., ARRI Framework by Jack Stilgoe, Richard Owen, and Phil Macnaghten and others [13, 14]). There is no universally agreed definition of RRI, which creates confusion, leads to a wide range of different interpretations and applications of RRI, specifically in the global context (see e.g. [6, 15]). This complexity makes it difficult to measure the impact of RRI and contributes to the question of why to engage in the first place (unclear

[2] European working definition RRI: "Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (to allow a proper embedding of scientific and technological advances in our society)."[9, p.9].

definition and measurement). RRI also emphasizes the importance of involving stakeholders, including the public, in the research and innovation process. In practice, however, it is often difficult to engage and incorporate the diverse perspectives and needs of the public, demonstrating a prevailing lack of relevant forms of public engagement, e.g. in a democratic sense. Further considerations underscore this challenge: While RRI seeks to promote more or less ethical considerations in research and innovation, there are relevant concerns about defining and applying the necessary principles, especially in the context of regulation and complex systems such as new and emerging technologies and in particular AI. Finally, unresolved issues of funding and resources complete the picture: Implementing RRI may require additional resources and funding, which can be challenging for researchers and institutions, especially those with limited budgets. This is the challenge of RRI for any given project: On the one hand, there are various examples of attempts to capture RRI, many of which are cases in point for the more general RRI debate, and many seem to do well. On the other hand, many case studies fail to provide transferable patterns because they are too narrowly focused. Although many of these approaches to RRI could be applied to biotechnology projects, for example, they cannot be put into practice without considerable interpretation and adaptation. But why to take this effort of customization and adaptation and how to do it?

One common point, which I will rely on without discussion, is that ethical checks and balances are not enough in the practice of RRI. The idea of responsibility in R&D is not just a matter of ticking boxes, nor does it begin and end with the routine of grant applications. The argument is this: If one is busy implementing RRI in a project, peers and the public judge those practices and activities as long as they are minimally assessable. By engaging with the narratives that projects inevitably produce for and around their work, varieties of responsibility are communicated, and that are analyzed, discussed, and documented. This kind of accompanying assessment brings to the fore how—not why—RRI is being addressed ("done") in this particular case. What counts as "correct" in ongoing research processes is the association with the framework, i.e. the European normative bioeconomy. This is checked by "looking at" the performance of a project in terms of the RRI criteria like transparency, reflexivity and participation at the given stage.[3] These "assessments" are already in place, done while the project is ongoing and incomplete, and in their own right. The quality of RRI-related practices, e.g. in the work process, via activity reports, at networking events, is inherently judged by the system in which they operate – focusing on that with a methodological impetus like provenance assessment highlights where RRI enrichens project trajectories, this added value of good processes offers a reason for why to engage.

Narratives as Scientific Practice

The SUSPHIRE project is a paradigmatic example of a specific contemporary research strategy, as are many other projects funded, for example, under Horizon 2020 (H2020) funding: as established production routes are very costly and inefficient, more sustainable and cost-effective alternatives are sought through biotechnological methods and materials. However, the project narrative in SUSPHIRE has been carefully crafted to emphasize this in many ways. To explain the approach, one can read from the acronym what SUSPHIRE stands for, thus unraveling the plot of the R&D effort and how its parts are connected: "SUSPHIRE is the sustainable bio-production of pheromones for insect pest control in agriculture."[4] The project builds on an iGEM2014 competition entry that established the "sexy plant" narrative and demonstrated its biotechnological capabilities [16]. The "sexy plant" narrative represented the idea of tobacco plants emitting sex pheromones to attract specific pests, thus deterring them from damaging

[3] The distinction made here is between "correct" in the sense of conforming to the overall system, given norms, and legal regulations, and "good" in the sense of being lawful, responsible, responsive, and virtuous with respect to given tasks and situations. This distinction is modeled analogously to the epistemic distinction between original and copy, theory and parody, and other meaningful transformations as outlined in [27, 29]. How this contrast plays out in the evaluation of early R&D is part of "Varieties of Responsibility in early R&D projects" section of this paper.

[4] The SUSPHIRE project has been supported by the European Union's Horizon 2020 Research and Innovation program under Grant Agreement 722,361. Many project narratives can be accessed via their webpage http://www.susphire.info.

food crops. Over the course of the project, the iGEM team achieved many goals toward a stabilized model plant and reliable release mechanism, and undoubtedly demonstrated that the approach is feasible. Building on this "proof of concept," SUSPHIRE's narrative continues to rely on the technical and narrative aspects achieved by the iGEM competition team.[5] Although different disciplines, scientific cultures, and methodological approaches structured their collaboration, they integrated them and produced more storylines about how premises, methods, and actions intersected and how specific goals and objectives were planned as the project evolved. Thus, we can look for many storylines in and around SUSPHIRE, such as the chemical versus bio-production storyline (in short, along the lines of "green" production of compounds, waste efficiency, least toxicity). One can also elaborate on more general pest control mechanisms in agriculture, such as specific pest control, i.e. the "save the bees" plot, or the "insect larvae as pests in agriculture" story [17]. There are debates about traditional versus industrial agriculture that SUSPHIRE links to, and one could also point to organic and sustainable agriculture with SUSPHIRE in mind. There is a different story to tell about food security, especially in light of climate change. Or you can link SUSPHIRE to the more socio-political sphere and sustainability goals. Each of these narratives is not only illustrative in its own way, but also carries an implicit, tentative burden of proof by answering different claims. The narratives can only stand up to these demands because they do not contradict each other—in time, space or content.[6] What distinguishes them is their recipient and its demands and expectations: because these narratives take up points of view that correspond to a specific question, they become responsive in themselves. As stories, they rely on the fact of a shared reality that integrates them into a larger picture. Because they are without contradiction, they are mutually reinforcing. This is partly because these stories and their retelling serve another purpose: they reveal certain socio-cultural contexts about the sphere in which they operate. They are inherently scientific, and thus confirm ideas and assumptions about science that would be very abstract and difficult to grasp without narrative. Moreover, they are not extrapolations into an uncertain future state. As narratives, they provide a glimpse of a possible future reality that is strongly connected to and responsive to the present. They are meaningful in and for the present because they convey values and emotions related to a specific, shared environment in which science seeks to help solve pressing societal problems that are shaped and governed by democratic societies.[7] In this sense, these narratives are not arbitrary stories, but established plots that promote the legitimacy of, for instance, scientific work in progress [18, 19].

Explaining complex and multifaceted research efforts with such non-contradictory narratives can show how people work in complex projects. In cases of high uncertainty and with novel technologies at play, these narratives may certainly be exaggerated or vague to some extent, but need not automatically over-promise ([20], p. 284ff). They provide much needed insight, not hard measures. In this sense, as scientists go about their daily work, they "narrate" their projects as they develop, producing artifacts of their work and the knowledge they are advancing in papers, posters, and presentations. Moreover, the polyphony of voices telling and retelling the narrative from different perspectives is a particular and unjustly neglected feature of contemporary scientific collaboration [20–23], where SUSPHIRE serves as an example: just as

[5] The status of "proof of concept" is a prerequisite within the technical conditions of R&D project management and is considered fundamental for further procedures, including funding opportunities. The specific epistemic status of this type of proof also allows for a specific form of project trajectories as epistemic scientific endeavors [21].

[6] Narrative in science must be distinguished from other types of storytelling, especially in interdisciplinary settings and at the interface of politics, science, and society. As features of collaboration, narratives are not constructed or arranged to meet requirements. They depend on and are connected to the structure, the material, and the people in a project, and they evolve or move with them, which is to use a definition of narrative that is commonly used in historical research [18, 22, 30].

[7] An argument for this pragmatic version of lifeworld-bound consequentialism, especially in the context of technology development, can be found in [31], a detailed defense of the necessity of exaggeration in scientific storytelling [20], and the need for governance of early R&D in the application area of food and agriculture [19].

practical project work is divided into packages to share workload and expertise, a diverse team of authors tells the project narrative together, with common goals and different expertise. Ideally, each project involves different researchers in "writing" these integrating storylines, for example, in proposals, agreements, and contracts—what is often overlooked is that they continue to write and rewrite them as the project unfolds. Project narratives frame the case in such a way that narratives of e.g. SUSPHRIE as stories are effective tools because listeners [20, p. 282] (or readers) become engaged and therefore easily remember the bottom line of the narratives [20, p. 4]. As a result, these narratives generate trust in complex projects and their multiple uses of technology. In this sense, these narratives are stories that are told to capture and fix conditions, dates, or other details of a shared endeavour, so as to monitor more than just eventual successful research outcomes. These kinds of narratives can serve as additional documentation of a project's evolution, and are already an integral part of repositories and hubs in many disciplines. Equally important, and often overlooked, is that narratives envision and establish connections and dependencies because the narrative style is procedural and open-ended rather than dogmatic. In this way, narratives can be subject to change over time without automatically evoking contradiction, and with the ability to trace these changes over time. The narrative style is promoting to disclosure and transparency.

It is important to note that retrospective analyses can also be resolved by evaluating narratives. However, ex-post evaluations can also be conducted using other methods or tools. As a non-immersive perspective integrated into the process, this procedure is unique. To use von Schomberg's words, the non-contradictory narratives produced indicate the acceptability, sustainability, and social desirability of an ongoing innovation process. We can evaluate the SUSPHIRE narratives as performances that point to the RRI criteria in relation to the given normative framework. They can therefore be distinguished from marketing slogans or the seductive plots of commercials and erratic stories: their specific way of engaging with responsibility makes a difference in practice and revision, and the assessment of this is an evaluation of provenance.

Provenance Assessment—Assessing Processes as they Happen[8]

To enable practitioners in early technology projects to engage with RRI, "provenance assessment" helps to evaluate the research process at a given stage and in cases where additional criteria are not available.[9] Provenance assessment can bring to the fore that RRI focuses on features of the research and innovation process as it evolves—to the extent that these features impart a certain quality to the outcome [1, 12]. By placing the process, the materials used, and the decisions made in historical perspective, the provenance of evidence and scientific work becomes assessable and helps to distinguish otherwise indiscernible commodities. In the absence of other criteria, this practice can enable discussions about the inclusivity, responsiveness, reflexivity, and prudence of those who conducted the research. In doing so, it sheds more light on what makes a project scientifically relevant in and of itself. Provenance assessment as means of documenting and making accessible the development of project trajectories follows the very practical concept of "sharing is caring," as in open access initiatives, which have already been widely applied in highly specific and data-intensive research fields such as particle physics, data mining technology, and (bio-)informatics [24].

At the heart of provenance assessment, however, is the idea that, in the absence of other criteria or standards, the quality and value of research can be judged, in this case, by the quality of the process from which it emerged. When practices or processes are indistinguishable from other research activities, for example, by "outward appearance"-that is, by looking, testing, or auditing while still in process-documenting the treatment of RRI-related values

[8] The monitoring of e.g. indicators as a way to access processes as they occur has already been proposed in the context of responsibility, management and governance [32]. In the context of technology assessment and related methods, several attempts have been made to rely on processes rather than indicators to assess complex systems, see for example [33].

[9] Provenance assessment applies to the field of research and innovation in biotech was first presented outside the SUSPHIRE project context at European Biotechnology and Society Online Seminar Series in October 2020. It has benefitted from various discussions on different occasions.

makes a difference.[10] This process assessment can then evaluate the quality of the task as "good," as opposed to the "correct" performance of the research project. This is a contextual assessment, judged in context, e.g., by adherence to transparency, reflexivity, and participation throughout the course of the project. The different ways of dealing with and managing these concepts are to some extent already recorded in the project narratives – provenance assessment build on that, and in that sense, it is nothing new or additional at all. Together with the artifacts produced, the stories told in these contexts can be evaluated and serve as indicators and provisional measures in processes.

But Provenance Assessment in the same breath, opposes a certain tradition of governing early technology and uncertainty in R&D, especially when concerning value questions. Traditionally, the issues are discussed with reference to the so-called Collingridge dilemma [25]. The Collingridge dilemma is framed around finding just the right moment for intervention in R&D, because—so the story goes—either you know too little about the outcomes of a project for a precise intervention or the project is already too far developed to intervene meaningfully at all. With the idea of provenance assessment in mind, the aim is to reframe this dilemma by first elaborating on a non-speculative way of placing things in historical and contextual perspective [22, p. 16]. As R&D activities never occur in a vacuum, individual and incremental steps can be crucial. The tracing of R&D processes is organized in such a way that the process as a chain of decisions can already be assessed to some extent via every kind of publications, project reports and milestones, but these artifacts are far from open, transparent or participatory. Just as the sharing of data, collaborative experimental practices, and concepts is an aspect of good scientific practice already, provenance assessment as an integrated idea could lead others in the same direction.

To do so, provenance assessment incorporates a specific notion of historicity. The idea of provenance assessment is derived from art research that inquiries into the provenance of an artwork—as the historical record of its ownership, but not limited to this task. Provenance research in art is a forensic method, used to diminish uncertainties concerning persecution, looted art and forgery, by keeping a record of provenance for any artwork. This record provides a variety of data and added material so that a provenance record in art research is not only a pedigree certificate but a diverse dataset open for different use cases, authors, and research agendas at different time and spaces. In a similar sense, provenance assessment accesses and documents how things came about in a project. In contrast to the almost exclusively historical orientation of art research, insight into research practices can be integrated in the process along with a project's development. Provenance assessment, therefore, assesses narrations, data, reports, and papers alike, to excavate how researchers work and decide to the best of their knowledge and ability, including, e.g. their knowledge of societal debates and moral concerns. In this regard, provenance assessment is akin to Aristotelian ethics of virtue, because it examines the qualities that characterize the research process—as opposed to a utilitarian balancing of hypothetical future benefits against hypothetical future risks and any targeted management practice.

The methodical advantage of provenance assessment is that it bypasses the lack of specific and valid information about the future state of affairs. It relies on the fact that practicing RRI is not simply about adhering to or abiding values, but about first recognizing them and then recognizing and addressing conflicts among them. These two steps are obligatory to work out practical solutions for responsibility questions when and wherever needed in "doing RRI". That is why, RRI is procedurally open and not static and cannot provide measures and guidelines [2]. With the idea of provenance assessment at play, one might still lack important information, but it is not inherently speculative about an unknown future that—according to the Collingridge dilemma—eludes predictive and technical control. Instead, provenance assessment uses the information available to judge the quality of a product's making at any stage. When integrated into scientific research, e.g. as a kind of commentary or explanation on the research process, provenance assessment can provide a tool for distinguishing what might otherwise be indistinguishable—because it

[10] For example, the products and artifacts produced by genome editing materials and techniques look and behave "just like" genetic engineering and "just like" mutagenesis. When used, examined, or disassembled, no differences can be detected, and there are no material consequences by which to evaluate them. In addition to the various possibilities offered by these bio-based production routes (e.g., producing more with less), the indistinguishability of products derived from different biotechnological processes is a long-standing issue in broader discussions, e.g., in food and agriculture or in compound industry [28, 34].

provides stories and data. Storytelling has long been a vibrant part of scientific communication, but just like RRI, there is no manual on how and why to do it right. In particular, there is no manual on how to archive the kind of non-contradictory narratives that are key to building trust in specific scientific endeavors [20, 22]. The evaluation narratives shed light on how a project team decided and worked with the obstacles and questions that arose, and on the values that accompanied them. Thus, the narrative provides not only an answer or explanation, but also a genesis of the problem and the specific actions taken to address it.[11] But how do narratives enter and develop in projects? Project members and communicators may be well aware that they need to ensure that the story they tell is appropriate for the audience, meets epistemic standards, and also makes explicit the complexity of the research they are addressing—but they do not necessarily know and anticipate every possible story that might be told, or that colleagues are already telling ([20] p. 281; [22] p. 19ff). Telling these stories means being responsive and open in communicating research activities and results - an activity that is a requirement of many project funding programs. In the EU funding context, there is a distinction between communication to peers, dissemination to the public and, more recently, the exploitation of scientific content in further directions and contexts. Narratives bridge this divide when these stories are integrated into a larger picture of what a particular research endeavor is about. They can create transparency and accountability long before more standardized mechanisms and tools can evaluate scientific results. When functional, legal, societal, political, and technical aspects take precedence, narratives are just one of many ways to evaluate. In the absence of other criteria, narratives are a promising starting point for integrated project evaluation.

As it is a common scientific practice to publish raw data from measurements, calculations, and experiments in hubs and repositories, it could be good science to publish annotations on decisions made, discussions had, processes pursued, dead ends discovered and failures made in order to inform the work of others. In research funding, this attempt bridges the distinction between dissemination (as engaging with peers) and communication (any activity that engages with the publics) in terms of interaction, answerability, and responsibility. As one approach among others that can fulfill RRI requirements, provenance assessment is, so to speak, transverse to this separation: valuing the process and its outcome at once combines dissemination and communication elements, considering any narrative constructed and the story told. Contrary to standard scientific practice, engaging in provenance assessment might encourage publishing more than just the linear narrative of what eventually led to a breakthrough—fostering the scientific endeavor altogether.[12]

Varieties of Responsibility in Early R&D Projects

Responsibility as a specific responsiveness and answerability of a project to publics via narratives is only one facet that can be put to the fore by applying provenance assessment. But, as mentioned at the beginning of this paper, responsibility takes on different meanings in different contexts. Depending on the context, legal issues, monetization, communicative capacities, and other factors may appear prominently when talking about responsibility. In R&D activities, many of these aspects concerning responsibility intersect, sometimes interdependently, sometimes different ones at different stages. While the general approaches to RRI give little insight on how to proceed, many methods of integrated research activities have developed their own standards. The meta-responsibility framework by a workgroup at TU Delft is one of many approaches in collaborative research that seeks to visualize this complexity of issues at play in the first place [8]. As a framework for managing the varieties of responsibility in corporate R&D with Responsible Innovation (RI) rather than RRI at play, the TU Delft researchers have built on their empirical research in biotechnology. Initially focusing on companies as industrial actors that engage with RI criteria in their R&D accounts, they elaborated

[11] See, for example, [22] for a detailed argument about coherence and why narratives are essential for interdisciplinary understanding of research processes, especially over time.

[12] At first glance, the indistinguishability of products and materials is a technical, legal, and ethical issue—not an epistemological one. This paper outlines how provenance assessment as a tool can step in and fill certain gaps. But the very idea of provenance assessment implies further commitments and can be associated with a shift in the evaluation of the research system [11, 35–37]. It also needs to overcome more theoretical obstacles, including the issue of "distinguishing the indiscernible", which is beyond the scope of this paper.

a framework of so-called meta-responsibility based on data gathered from semi-structured interviews. To systemize their findings, they incorporate a framework by Luigi Pellizzoni, who originally focuses on aspects of responsibility in environmental governance. Pellizzoni therefore itemized the concept of responsibility into four elements: liability, accountability, responsiveness, and care [26]. The working group from TU Delft transferred Pellizzonis methodological work to their findings to point out the varieties of responsibility at play in their data of biotech projects. They then establish how a framework of meta-responsibility can become operationalized in corporate R&D projects. As the meta-responsibility framework remains descriptive and open to further interpretation, this paper builds on TU Delft's empirically based visualization to go beyond its original scope. By showing where aspects of provenance and narrative are already at play in the mapping exercise, the following discussion highlights how value-based RRI practice becomes an evaluation in its own right.

Mapping Responsibilities: The Meta-Responsibility Framework for Corporate R&D

The point of departure of the TU Delft paper is how to justify actions in early R&D. Especially in the light of the high level of uncertainty that characterizes projects at low TRLs, project-specific decisions can be severe to the entire endeavor—despite the best of knowledge accessible when taken. To assess that, the TU Delft team slightly re-conceptualized Pellizzoni's work to make it more descriptive and assistive in their RI context: Pellizzoni's original responsibility elements are arranged in a square, divided by two axes based on facets inherent to the items displayed. The TU Delft version sticks with the graphical arrangement but adjusts the implications and the labeling to their scope and interest. They relabel one facet as "justification", reaching from assertive to receptive. The term "justification" in the re-conceptualized version stands for "how an actor reasons his or her behaviour" [8, p. 3]. In order to determine how the uncertainty about the outcome in R&D can be addressed, the TU Delft researchers apply a conditional dichotomy, going beyond Pellizzoni: "assertive justification" stands for the state of knowing what is right or wrong in a context and knowing how to act accordingly. At the other end of the scale, it is less clear what action is supposed to be right or wrong. "Receptive justification" therefore shows a more general awareness of uncertainties at play but no action-guiding knowledge of how to cope and proceed.

A second facet of the TU Delft version, called "imputation", is labeling the possibility of tracing an action back to its agent as the causal factor. A backward-looking mindset can accompany imputation. According to the TU Delft Group, a prospective aspiration drives a forward-looking mindset to improve the current state of affairs and, failing this, to try better next time. The expectation of a retrospective attribution and evaluation of the action drives the backward-looking mindset ([8], p. 4f). It remains open whether the attribution of responsibility under these facets needs to be 1. explicit, 2. voluntarily taken (in the moral sense of making oneself accountable for) or 3. assigned to someone. Whether these judgments on appropriateness are 4. first person-issues merely or would need 5. be validated by a second person, most probably 6. regarding a third instance (norm, standard, etc.) is not discussed. Insofar, the framework remains open on what the evaluation eventually would imply or entail- blame or punishment concerning social, professional, or ethical conditions? Anyhow, the responsibility items in the framework developed are arranged in a matrix according to these facets. In this so-called meta-responsibility framework liability, accountability, responsiveness, and care are displayed, so that liability is backward-looking/assertive, accountability is backward-looking/receptive, responsiveness is forward-looking/receptive, and care is forward-looking/assertive. This graphic representation makes it possible to show different moments of tension inherent in the concept of responsibility. Labeling these "dynamics", the framework developed by the TU Delft group illustrates the multi-field aspect involved in addressing responsibility. Where distinct features intertwine and conflict depending on context arises, this kind of conception helps emphasize the issues at hand. So, from the interviews conducted, the researchers sketched where their elements of responsibility conflicted in their cases at hand ([8], p. 9ff). They then establish how a framework of meta-responsibility can become operationalized in the workflows of corporate R&D.[13]

[13] While the analogy with the STIR approach by Eric Fisher [23] or probably with the variety of balanced scorecards working in strategic management is easily made, the meta-responsibility framework is not related to these methods in the paper cited [8] and goes beyond the scope of this paper.

Handling Responsibilities: Integrating Provenance Assessment in Early R&D

While the TU Delft group is developing a contextual management tool for archiving RI, this paper proposes to revisit the value and responsibility issues in a context-sensitive way—turning their meta-case study into a more general argument on how responsibility can be addressed and managed, e.g. with provenance assessment. The dynamics mapped by the TU Delft group through the meta-responsibility approach highlight areas of potential conflict that could arise in a variety of trajectories. A key premise underlying the unpacking of the responsibilities at play in early R&D, e.g. outlined above with the TU Delft paper, is that some challenges are inherent to any early stage project, biotech or not, with or without RRI: some relevant conflicts need to be resolved early on, some decisions need to be made under uncertainty in order to start and then complete a project successfully. It is no secret that responsibility is a central theme in these activities—but how to manage it can be challenging. For biotech R&D, such as the cases at issue in this argument, the balancing challenge is paramount: What is in RRI for the project, given that things are already challenging in many ways? Does RRI make things easier and smoother? Does it help researchers achieve the broader goals of a project, such as communication and dissemination? The answer has to be both no and yes: No, it does not make things smoother, especially not without contextualization and not directly. RRI does not guarantee desirable outcomes, nor does it set thresholds or limits. Unfortunately, it is not necessarily the case that the outcomes of RRI-guided research are different from those that, for example, neglect ethical and public welfare concerns. Conflicts and uncertainties are inherent in projects at a very general level, and, as noted at the beginning of this paper, RRI itself does not provide this kind of normative framework on which to base decisions (see discussion of RRI challenges in chapter 2).

So why bother with RRI at all? The answer here uses a specific scientific attitude and notions of awareness and willingness as inherent in the normative structure of the European idea of what RRI entails. The illustration follows the empirically based meta-responsibility framework developed at TU Delft: Clearly, the addition of RRI criteria is in a sense nothing more than a broadening of the research horizon, which could, but must not, be a central feature of what can be labelled an ethos of science. The practical relevance of this ethos has long been debated and is beyond the scope of this paper. But a very practical, crucial, and therefore highly relevant point of RRI in projects is that RRI makes a difference in that it can help researchers to recognize conflicts, especially those related to values. In fact, it is only when conflicts are identified that they can be addressed and ways of resolving or managing them can be identified—ideally the sooner the better. With the elements of the meta-responsibility framework at hand as an empirically based aid, engaging with RRI means guiding the interpretation of the allocation of competence and responsibility in a given context. By interpreting the Pellizzioni framework to make it more applicable, the TU Delft group made the project's questions different and more transparent, allowing discussion and thus making the tool itself trustworthy. These procedures of use and reuse, transformation and translation of ideas are inherent to the way scientists work: they take the ideas of others, transform and enrich them, thus validating the previous steps. Equally important, the illustrative power of TU Delft's approach clarifies the fit and direction of the response (response-ability) in the sense that they have segmented the thick concept of responsibility into manageable parts.[14] Because responsibility is a dense and conflicted concept in terms of management, communication, and epistemology, deconstructing multiple responsibilities can be a method that allows for discussion. Similarly, rearranging facets of responsibility in terms of their implications in practice allows us to see connections that are otherwise hidden. The notion of responsibility in R&D is, in fact, about how to comply with norms and requirements from different schedules. It means being able to justify actions taken, not taken, or not even considered. In a broader sense, assessing responsibility in these cases means anticipating the burden of being a

[14] A thick concept is a term that is a normative construct, descriptive and at the same time evaluative, e.g. virtues like kindness. The notion of thick ethical concepts was originally introduced by Bernard Williams in 1985. It has received attention in various fields of academic philosophical research.

cause somewhere in a context as part of a project development, and probably being held accountable for it later. Certainly, taking responsibility in R&D, e.g. by engaging in RRI, directly emphasizes the expectation and willingness to be (held) accountable in the context.

By documenting and reflecting on processes and developments as they occur, provenance assessment can help to identify and then manage even subtle interdependencies, which can make the last part of responsibility manageable. In this sense, conducting a provenance assessment is an interactive exercise in deliberating what the "correct," meaning responsive and virtuous, and "overall desirable" project outcome would be. By making values and conflicts explicit, knowledge claims can be made concrete, proofs of concept can be discussed, and candidate responses can be evaluated in light of RRI criteria. Provenance assessment is thus an integrative approach that builds on the specific conditions and historicity of materials and practices in R&D activities.[15] As a process, it can help manage the unique characteristics of early R&D efforts, regardless of industry or discipline. Again, this is nothing new: in fact, any tool that can scrutinize complex dependencies can enable assessment of specific RRI issues at stake, e.g. by assigning them to a distinct meaning of responsibility in context—provenance assessment is the attempt to value historicity and more tentative shifts along a project development. But provenance assessment can also support reflection on the diversity of responsibility in and around a project. For example, one can address foreseeable conflicts at an early stage. In the early stages of research and development, the RRI criteria of transparency, reflexivity, and participation are key to bringing the unique elements of responsibility back together in work practice.

The use of provenance assessment can unravel dense concepts and, at the same time, help to identify value conflicts in responsibility. In short, provenance assessment can help strengthen the social, public, and ethical robustness of a product by carefully examining the trustworthiness of the R&D process. At the same time, it helps build a robust, open, engaging, and scientifically straightforward collaborative work environment-by appealing to different ways of taking responsibility as a project.

Building on this, the TU Delft researchers identify important dynamics between the elements of responsibility they have defined, drawing on their empirical research. These dynamics show where the values attached to the varieties of responsibility at stake conflict, as they touch on different elements into which the concept has been divided: One of their dynamics arises between the elements called "accountability" and "responsiveness." They consider both to be "receptive" in character: accountability is the backward-looking facet of responsibility, aware of uncertainties that are retrospectively evaluated and attributed; they classify responsiveness as forward-looking, so that it seeks to handle things to the best of its ability. According to TU Delft, the potential conflict between these different concepts can be formulated as follows: "How to strike a balance between risk-taking and precaution in early R&D, given the uncertainty about outcomes and impacts?" [8, p.9] Unique values can come into play when discussing this kind of dynamic. The consideration of responsibility in early-stage R&D points to the fact that, even in the absence of other criteria for research outcomes, researchers still need to make considered decisions to balance, for example, risk and precaution. Great care must be taken in emphasizing and then weighing values against each other.[16] Thus, this one dynamic alone emphasizes various conflicting values. These ethical or individual values, whether economic, ecological, social, or political, must be reconciled with the more general goals and purposes of the project. If nothing else, additional dependencies bring their own values and criteria which must be considered early in the decision-making process. Provenance assessment can help monitor these processes throughout the project lifecycle.

[15] For why materials matter in research see e.g. [38], on why practice-material interdependence is relevant in R&D specifically see [39].

[16] An example of the variety of values at play in decision-making concerning technologies has been elaborated by Batya Friedman and colleagues under the label of "value sensitive design" (VSD). The primary values they discuss are privacy, trust, security, safety, community, freedom from bias, autonomy, identity, ownership, freedom of expression, dignity, calmness, compassion, respect, peace, sustainability, and healing [40].

Undoubtedly, it is a guideline that is needed to put RRI into practice, and while relevant, it is not necessarily a definition. Provenance assessment can be institutionalized as processes that frame the activities of RRI and its value-based practices. The range of activities that promote transparency, reflexivity and participation in a project define RRI in this sense. These activities can be brought together in the practice of provenance assessment. To draw on the work of Sonck et al. again, another dynamic they reconstruct arises between the aspects of "care" and "responsiveness". They ascribe both aspects of responsibility to the imputation of "forward-looking", i.e. trying to improve current situations because they are motivated by the anticipation of future states of affairs. The central difference between care and responsiveness assumed here is that care is assertive (quite sure of what is right and wrong), while responsiveness is receptive (uncertain but aware) in character. The TU Delft researchers summarize this second dynamic as follows: "How to be sure that R&D projects do the right thing, given the novelty of technologies, products and industrial sector?" (Ibid.). Of course, assurance, like any other epistemic virtue, can be multifaceted, depending on the values and criteria attached to it in the specific project in question. As noted above, a tool for assessing the idea of RRI can guide discussions about how to incorporate conflicting issues into the broader project trajectory while decisions are still possible. While the Tu Delft group introduces new management tools, the provenance assessment builds on existing patterns and practices: Whenever these dynamics are answered by a story, e.g. of the project at hand, they convey trustworthiness and legitimacy that can be assessed, revised, and judged.

Conclusive Remarks

In summary, provenance assessment can be used as a tool to emphasize that RRI focuses primarily on characteristics of the research and innovation process that give a certain quality to the outcome, especially with the high uncertainties of low-TRL projects by so-called provenance assessment. In practicing RRI, ethical checks and balances are not enough. Before that, practicing RRI is not simply about adhering to or upholding values, but about first recognizing them and then recognizing conflicts among them. These two steps of awareness and practice are essential for developing practical solutions for RRI when and where they are needed. The narratives produced by a project are a source for assessing how relevant activities are pursued by applying RRI ideals in practice. By placing processes, materials used, and decisions made in historical perspective, provenance assessment helps to distinguish otherwise indiscernible commodities. It is a tool for identifying conflicts inherent in any project, regardless of size, maturity, or goal. In particular, it enables individuals and teams to address value and balance challenges and conflicts as or before they become critically intertwined with other parts of the project work. In the absence of other criteria, provenance assessment allows for discussions that consider the inclusivity, responsiveness, reflexivity, and prudence of those who motivated and conducted the research. In this sense, a provenance assessment practice can be added to any responsibility framework, not just in early R&D. It could also enable a new way of theorizing about the concept of responsibility in science as a whole. By challenging narrow and uncritical conceptions of innovation, monitoring RRI-related practices will provide a more informed research agenda to improve future research [12].

Meanwhile, provenance assessment can help move RRI from the very abstract to the more applicable by following four steps: 1. anticipating how research and innovation might lead to value conflicts, e.g. regarding responsibility, 2. elaborating together about how to integrate a value orientation into the research process (as many assessment methods emphasize), 3. including not only a range of values but also a range of stakeholders and publics in your thinking (e.g. citizen participation, citizen science, hackathons), and 4. demonstrating responsiveness by explicitly not dismissing seemingly "irrational" or uninformed concerns. None of these points are new to practitioners or theorists of responsibility in science and research stewardship [7, 15, 19, 27, 28]. What is new, however, is the shift in focus to the historicity of products, materials, and processes in the productive spirit of making them public, accessible, and intelligible.

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