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Article

Making sense of transdisciplinarity: Interpreting science policy in a biotechnology centre

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Abstract

Transdisciplinarity is a much-used concept in research policy to emphasize a need for new collaborations beyond scientific disciplines to solve societal challenges. However, how do scientists interpret transdisciplinarity and what do transdisciplinarity policies mean for their work? This paper focuses on researchers' definitions of transdisciplinarity. It is based on an empirical study of a Norwegian biotechnology centre founded to stimulate a transition in biotechnology research towards transdisciplinarity. Drawing on interpretive methods, we identify three interpretations of transdisciplinarity. In our case, the science policy idea of 'transdisciplinarity' faded away in practice in terms of collaboration with non-academic actors, but boosted the establishment of new interdisciplinary teams. By pointing to the multiplicity of ways in which policy recipients can interpret science policy, this study contributes to scholarship analysing the relation between transdisciplinarity in policy and practice.

Key words: scientific collaboration; interdisciplinarity; transdisciplinarity; research policy; biotechnology; sensemaking.

1. Introduction

Transdisciplinarity is an increasingly used concept in research policy to demand new ways of research collaboration with non-academic actors to address complex societal challenges. Since the 19th century, modern science has continuously split into many specialized disciplines and sub-disciplines. In parallel, concerns about the fragmentation of knowledge have emerged: are departmentalized knowledge regimes able to cope with big, complex, societal challenges? (Brown et al. 2010). At universities, the critique of scientific specialization has led to a variety of initiatives and approaches promoting disciplinary transgression, including the concept of transdisciplinarity. This concept calls not only for collaboration across scientific disciplines but also for joint problem-solving, including with actors outside of research communities. In this manner, social relevance and public trust are supposed to be achieved (Lieven and Maasen 2007; OECD 2020). However, definitions and theoretical emphases of 'transdisciplinarity' vary (Bernstein 2015; Jahn et al. 2012; Klein 2015; Mobjörk 2010), and the concept has proved difficult to implement (Felt et al. 2016; Schikowitz 2020; Zscheischler and Rogga 2015).

Nevertheless, research policy conceives of transdisciplinarity as a crucial tool for solving societal problems. For example, in a 2020 report, the Organization for Economic Cooperation and Development (OECD) argues that transdisciplinary research is a 'necessary complement' to traditional research practices. According to the report, solutions to complex societal challenges 'cannot be generated solely on disciplinary research', and furthermore, transdisciplinarity is needed in order to create value and to 'transform scientific insights for the good of society' (OECD 2020: 9). The OECD report is but one recent example of transdisciplinarity being mobilized in research policy to argue that increased collaboration between different actors is the solution to the many complex challenges in the world. The report promotes 'effectively implementing transdisciplinary research' (OECD 2020: 3) and draws on language emphasizing acceleration, effectiveness, and upscaling. In this context, transdisciplinarity becomes a co-production of science and relevance and is, in short, seen as a tool for accelerating the take-up of research 'for the good of society' (OECD 2020: 9). The report, however, is largely silent on how to achieve transdisciplinary research in practice. Policies on transdisciplinarity rarely provide guidance on what transdisciplinarity should mean concretely, despite it being an ambitious concept referring to problem-solving in context through a combination of research and experience-based knowledge, with interdisciplinary practices at the core of such efforts (Gibbons et al. 1994; Nowotny et al. 2001).

How then do policy recipients, such as scientists, understand and interpret transdisciplinarity? Despite considerable policy efforts, scholars question inter- and transdisciplinarity outcomes in terms of the envisioned transformation of knowledge production (Frickel et al. 2017; Weingart 1997). Previous scholarship on transformative policies has given attention, on the one hand, to policy documents and policy discourses (see, e.g. Blümel 2017; Flink and Kaldewey 2018; Borrás and Serger 2022) and, on the other hand, to research practice (Brouwer et al. 2018; Felt et al. 2016; Maasen and Lieven 2006; Morris and Rip 2006; Schikowitz 2020; Simons et al. 2020). A common finding in this scholarship

is a gap between policies and practice pointing to a need for further detailed empirical studies on transdisciplinarity. For example, Felt et al. (2016) conclude from a study of transdisciplinarity in sustainability research that although some funding schemes encourage the inclusion of non-academic actors in research, 'little is known about what this means in terms of concrete research practices and in academic environments' (734). They analysed how researchers interpret the role and relevance of societal actors in research projects and identified three categories: those that see the scientific and social arenas as 'largely separated' (745), those that consider societal actors as relevant for defining the research problem based on experience-based knowledge, and those that consider societal actors as knowledgeable agents (749). Simons et al. (2020) suggest future research to 'add comparative data on contextual understandings' (569). In a similar vein, Ramos-Vielba et al. (2018) point to a lack of understanding of the dynamics and of the heterogeneity and diversity of research cultures and scientific fields. We would like to add that only a few studies (i.e. Bos et al. 2014) looked at how policy recipients (such as scientists) interpret transdisciplinarity policies.

This paper contributes to better understanding the heterogeneity and diversity of scientific fields regarding the implementation of policies on transdisciplinarity by studying biotechnology research in Norway. In this manner, we contribute to scholarship analysing the relation between transdisciplinarity in policy and practice. Our approach is based on an understanding of policies and organizations that focus on meanings, assuming that meanings (that various actors ascribe to, e.g. transdisciplinarity) shape actions and institutions (Weick et al. 2005; Wagenaar 2011). Thus, we aim to provide better insight into policy recipients' various interpretations of transdisciplinarity. To explore what transdisciplinarity means, we focused on scientists' sensemaking of transdisciplinarity: how do they interpret and understand transdisciplinarity and what do transdisciplinarity policies mean for their work? With this question in mind, we studied the Centre for Digital Life Norway (DLN), a biotechnology research centre founded in 2015 by the Research Council of Norway (RCN) with the mandate to transform Norwegian biotechnology. DLN lends itself well as a case study because of the European trend in research politics to put major public investment into such synthesized centres (Vermeulen 2018; Hackett et al. 2021; Hampton and Parker 2011). It is therefore of societal relevance to analyse how such public investments in transition projects realize their ambitions. Furthermore, this case adds to existing transdisciplinarity scholarship by providing an example of a centre where transdisciplinarity is imagined as going beyond individual research projects. In DLN, transdisciplinarity is conceptualized as a cross-cutting issue: a central ingredient in all aspects of centre activity, not only within each individual research project but between projects and scientists within and outside of the centre, as well as collaboration with industry. The transdisciplinary work in DLN must thus be seen also as a meta-project: the notions of 'innovation' and 'Responsible Research and Innovation (RRI)'[1] figure no less prominently in the centre. All three concepts represent demands to accelerate the translation of scientific knowledge into products and solutions to solve social challenges. Although the concepts differ in focus, they all highlight the inclusion of non-academic actors and the production of socially useful knowledge. Therefore, we consider such policy demands as highly related.[2]

1.1 Theory: meaning in action

It is helpful to understand transdisciplinarity as a policy idea because a focus on policy ideas implies recognizing that policies may build on implicit assumptions (Åm et al. 2021) and that it is not obvious that these assumptions are backed by empirical evidence or work in different contexts. For example, research policies promoting transdisciplinarity often take for granted a deficit of social relevance and are often guided by a set of tacit underlying assumptions, for example, that inter- and transdisciplinary knowledge is better than disciplinary knowledge and that disciplines are silos constraining collaborative flow (Frickel et al. 2017).

Scholars have shown how steering towards broad and generic goals in research policy 'involves the use of "big words": encompassing concepts that are uncontested themselves, but that allow for multiple interpretations and specifications' (Bos et al. 2014: 151; Flink and Kaldewey 2018). One major criticism of transdisciplinarity has been its vague and ambiguous definitions (Jahn et al. 2012; Weingart 1997), which are open for multiple interpretations. The various definitions of the term, how it is often taken for granted, and the significant uncertainties regarding how to achieve it in practice make transdisciplinarity an interesting artefact to explore.

How do those addressed by the policies, namely scientists, decode the policy idea of 'transdisciplinarity'? We may assume that the term will convey additional meanings when the policies are implemented over time and in various organizations (Yanow 1996: 18). There are different communities of meaning in any policy situation, for example, those making the policy (e.g. OECD), those implementing it (e.g. RCN), and those affected by it (e.g. citizens, scientists, lower-level employees, and bureaucrats) (Yanow 2000: 10). Although the actors in these situations may overlap (e.g. scientists might participate in drafting policies), certain vocabularies, routines, and practices are associated with these distinct social worlds. Who we think we are shapes how we interpret (Weick et al. 2005: 416). Yanow uses the term 'interpretive communities' to describe communities that share 'thought, speech, practice, and their meanings' (Yanow 2000: 10). Due to various 'interpretive communities', policy ideas undergo changes when moving among institutions or from organizations to so-called recipients. While policies may direct attention and set agendas, they do not direct responses because corporate sensemaking is in play when responding (Weick et al. 2005: 417). Consequently, the realizations of policies on transdisciplinarity depend on 'the ways in which researchers mobilize the ideas…in their research practices' (Völker 2021: 44).

Such an interpretive approach makes the meaning of a policy an empirical question to be investigated in detail in its local context. Interpretive policy studies emphasize the importance of what '*people in the situation* find meaningful' (Yanow 2000: 4) and, thus, 'the very mundane, expert understanding of and practical reasoning about local conditions derived from lived experience' (Yanow 2000: 5). Yanow reminds the analyst that we must ask what is meaningful to policy-relevant publics. That is, what are the local conditions of scientists when it comes to interpreting transdisciplinarity and why is what meaningful for them in their context? Importantly,

'meanings' derive from actors' subjective experiences, but they are also bound to concrete situations expressing larger, sedimented meaning structures (Wagenaar 2011: 53). Examples of such larger discursive configurations are what it means to be an academic and what conditions of possibility configure scientists' epistemic living space (Felt 2009). Thus, when we explore the meanings of transdisciplinarity below, we investigate scientists' contextual understandings of what transdisciplinarity signifies for their research in the context of their work conditions in a biotechnology centre in Norway.

2. Method

Methods for the interpretive approach outlined above are based on 'the presupposition that we live in a social world characterized by the possibilities of multiple interpretations', as 'living requires sensemaking, and sensemaking entails interpretation' (Yanow 2000: 5). The methodological question, thus, is: how best to explore the multiple meanings of transdisciplinarity?

This paper is based on a case study of the biotechnology centre DLN. Employing a method assemblage (Law 2004), the first author conducted an in-depth study at multiple sites in the centre from 2017 to 2021. The fieldwork consisted of participatory observations (of meetings, events, courses, workshops, organizing committees and groups, conferences, etc.), an ethnographic study in a laboratory in a selected research project, and two rounds of interviews. The first round of interviews encompassed twenty-two semi-structured interviews, starting with the scientists (at all career levels) from the selected laboratory study and then extending the interviews to two additional DLN research projects to gain a better understanding of questions of inter- and transdisciplinarity at several sites. From the preliminary analysis of these interviews and from an action research conference within the centre (in which both authors participated, the first as a notetaker and the second as an initiator), the multiplicity of meanings and unclarities connected to the concept 'transdisciplinarity' emerged. This was followed by a second round of interviews consisting of two focus group interviews and four semi-structured interviews (the latter representing a work around to COVID-19 pandemic restrictions that precluded further focus groups). In the second round of interviews, scientists (both senior/principal investigator level and early/mid-career) were invited to reflect on their experiences with forms of collaboration, including inter- and transdisciplinarity. This round was also part of writing DLN's transdisciplinarity strategy, which emerged as an action point from the action research conference and in which Maria B. Hesjedal became the lead author.

Focus groups are a common approach in the social sciences to generate information on collective views, as they can 'yield data on the *meanings* that lie behind…group assessments' (Bloor et al. 2001). Focus groups have also been used as a method for public engagement, e.g. to involve citizens in the deliberation of public policy issues (see, e.g. Macnaghten 2021) or to make scientists reflect on topics such as societal relevance and research integrity (see, e.g. Felt et al. 2018; Felt and Frantz 2022). The extent of the participant's knowledge and prior reflections on the topic of the focus group can differ substantially. In our case, in asking how the scientists understand transdisciplinarity in the focus group interviews, we create a space where the scientists can make sense of their research processes and enable 'the communication of and reflection on complex and rather unfamiliar issues' (Sigl et al. 2020: 1574). This process must thus also be seen as a part of the sensemaking process generating the three meanings of transdisciplinarity that we present below. In the analysis, we started from the scientists' accounts of their understandings and practices of transdisciplinarity and generated the three meanings as composites made up by our combination and integration of accounts consisting of both diversity and consistency.

In addition to the two rounds of interviews, we descriptively reviewed transdisciplinary centre initiatives, including funding calls (for cross-project collaborations), prize announcements (for the best transdisciplinary paper), conference programmes, and central documents dealing with transdisciplinarity, such as the DLN 'Digital Life – Convergence for Innovation' (RCN 2014) strategy.

We used the concept of 'transdisciplinarity' as the criterion for selecting empirical data and in interview questions to operationalize our research questions. In a way, we essentialized the concept of 'transdisciplinary' to be able to search for relevant sources. We could as well have chosen a focus on 'RRI' or 'innovation' to learn more about how scientists dealt with the demands for including other kinds of knowledge and for solving social concerns. As mentioned in the Introduction, these three concepts are highly related in their demands to accelerate the translation of scientific knowledge by including non-academic actors. Nevertheless, selection criteria are necessary to make a research project feasible, and, as we show below, we still achieved access to broader discussions of transdisciplinarity because of the concerns that interviewees raised.

Data analysis was inspired by a grounded approach (Charmaz 2006). A preliminary analysis of field notes indicated that scientists ascribed multiple meanings to transdisciplinarity. This observation was integrated in the interview guide and led the focus of analysis towards exploring the specific meanings being communicated through the scientists' accounts. By processing, reading, and re-reading transcripts and field notes while taking preliminary analytic memos on comparisons, contexts, and other ideas about the data, we also identified other areas to explore further in the interviews, for example, how the scientists saw the relations between transdisciplinarity, innovation, and RRI. In this way, the analysis process involved moving back and forth between data and analysis. In this manner, we followed a stepwise approach in which the sampling and questions were informed by 'empirical analytical reference points' (Tjora 2017) identified in earlier research steps. The interviews were analysed inductively, noting who said what and when, identifying words that seemed to carry significant meaning, noting the meanings' relationships to other ideas, and identifying conflicting interpretations (Yanow 2000: 30). Our own interpretations appear in the categories we formed by gathering different codes under one umbrella (as opposed to another), thereby deciding which characteristics interviewees' accounts, text parts, or observed practices share.

When the analysis below mainly illustrates categories with quotes from interviews, this is because interpretations of and attitudes to transdisciplinarity are most clearly expressed in interviews. At the same time, the identified meanings below

are also the result of our interpretations as analysts, in which the extended fieldwork beyond the interviews is in play. The excerpts from interviews are marked with F or I to indicate if they are from a focus group interview (F) or an individual interview (I); numbers indicate the different participating scientists. F1–F7 indicate participants from the first focus group, and F8–F13 indicate participants from the second focus group. An overview of interviewees appears in the Appendix 1.

We begin below with an analytical reading of the DLN strategy document to provide the reader with background information on which transformative role Norwegian policymakers ascribe to transdisciplinarity. Our ensuing analysis, however, is focused on scientists' interpretations of these policy demands.

2.1 Policy considerations regarding the need for disciplinary transgression in biotechnology

In 2014, the Norwegian Research Council (RCN) launched the 'Digital Life – Convergence for Innovation' (RCN 2014) initiative. The aim of the initiative was 'to create economic, societal and environmental value in Norway from biotechnological research and innovation, by encouraging transdisciplinary research' (RCN 2014: 3). The initiative led to the founding of the DLN, initially consisting of a networking project and six research projects, to create a transdisciplinary 'networked digital life community in Norway' (RCN 2014: 9). By 2022, DLN has grown to include forty different research projects and affiliated partner projects.

The policy strategy outlined in the document was based on a narrative about a need for a long-lasting transformation of biotechnology to achieve innovation and increased value creation through Norwegian biotechnology. According to the strategy, biotechnology is severely hampered by the inability to understand and control complex biological systems, and scientists are struggling to handle the large amount of data constantly being generated (RCN 2014: 7). Digitalization, in combination with the assemblage of relevant disciplines, a stronger focus on transdisciplinarity, innovation, as well as RRI should help solve the supposedly lacking transformation of biotechnology for the sake of the societal good.

Accordingly, the document promotes 'transdisciplinarity', 'innovation', and 'RRI' to facilitate the called-for major shift in Norwegian biotechnology, emphasizing the importance of collaboration with actors outside of biotechnology. The document also addresses convergence, in the sense of integrating relevant disciplines (e.g. life sciences, physics, and Information and Communication Technology) into new fields (e.g. bioinformatics, bioethics, and bioengineering) (RCN 2014: 8). RRI is presented as a cross-cutting issue and tool for making the biotechnology community 'mindful of its societal context and develop anticipatory competence regarding its impacts' and for challenging the community to think about 'our responsibilities for the future…and act upon these' (RCN 2014: 11). In addition, 'innovation' was a central element in the Digital Life initiative. Not only was the funding granted from an innovation initiative at RCN, but science innovation was also regarded as an important and necessary outcome of DLN. In sum, the initiative promotes the assumptions that steering towards transdisciplinarity, convergence, RRI, and innovation would produce better and more valuable knowledge than the disciplines could produce on their own. Solbu (2021) gives an account of how these different and potentially conflicting, policy ideas came into Norwegian biotechnology and how they were established as key political objectives for biotechnology investments.

In practice, these policy demands were established as separate focus areas in the DLN centre, and faculty were hired accordingly: one coordinator for 'innovation', one for 'RRI', one for 'data infrastructure', one for 'communication', etc. These coordinators (and their work package leaders) constituted *the networking project*, whose main task was to facilitate the daily workings of the centre and to steer DLN towards the DLN initiative's aim. The coordinators had scientific backgrounds with PhDs in life sciences, computational biotechnology, neurosciences, or philosophy/political science (RRI). Thus, the coordinator position marked a career transition from research to administration, but the coordinators were anchored in their experiences of what it means to be a scientist. Although the coordinators had weekly meetings to discuss across their areas, the division of focus areas influenced how DLN addressed related issues. For instance, when the centre organized a stakeholder workshop in the first year, this was seen as the innovation coordinator's responsibility, and the actors invited shared a market and industry orientation. A stakeholder conference organized by the RRI coordinator would have probably had a different angle. The DLN research projects were expected to engage in all focus areas and to report on the project's work in each area, thus adding to the scientists' experience that these policy demands differ.

3. Making sense of transdisciplinarity in DLN

In this paper, we explore how scientists interpret and understand transdisciplinarity and what transdisciplinarity policies mean for their work. Above, we presented the science policy's interpretation of transdisciplinarity as outlined in the strategy forming DLN's mandate. In the following, we present scientists' interpretations of transdisciplinarity. In our analysis, we identified three categories of meanings of transdisciplinarity. In this section, we present the analysis of the three meanings by focusing first on the understandings derived from the research projects, and second, on interpretations based on a review of activities in the networking project.

3.1 Meaning 1: transdisciplinarity as collaboration with other natural science disciplines

The most prominent interpretation of transdisciplinarity in DLN was to consider it as interdisciplinary collaboration within the natural science disciplines.

3.1.1 Research projects

Imagine you are a scientist applying for funding in a new prestigious research funding stream called Digital Life. The stakes are high, there is a lot of money in the research pot that you can apply for, and there are fearful rumours that all money for biotechnology funding would be channelled through this initiative in the coming years. To succeed, you must fulfil many new demands associated with confusing terms such as transdisciplinarity, convergence, RRI, and innovation. In addition, and according to the name of the centre, your project proposal needs to have a significant digital dimension. What do you do?

Confused by these terms, we found that scientists considered the interpretation of 'one natural science discipline working with more than one other natural science discipline' as the most obvious solution to the puzzle of composing a successful project proposal. For example, a biophysicist in a DLN project on biomarkers and nanosensors said:

> [w]e are quite transdisciplinary, so there are the people who are more [about] hard physics and modelling and figuring out to do the sensor bit and then make the sensor, and then I just smash some antibodies on top, and we have a third part which is the microbiologists. And then everything is supposed to work together [F9].

The narrow use of 'transdisciplinarity' in the quote of F9 illustrates how most scientists did not differentiate between different science policy concepts to describe collaboration, even ridiculing 'policy speak':

> Interviewer: Now we have talked about interdisciplinary collaborations, and in DLN it's all about transdisciplinarity. What does transdisciplinarity mean to you when you use it?
>
> F1: Isn't that maybe the wrong question? Isn't the right question what term could come next to make it even more fancy?

We see that scientists had not necessarily paid attention to that transdisciplinarity marks a shift and is distinct to, for example, interdisciplinarity, which was a term more familiar to most. In the other focus group interview, an early-career biotechnology scientist said:

> As to how we use these terms, I think we sort of just arrived at a consensus where we sort of just [mumble] disciplinarity, and sort of like ignore what comes before the disciplinary, as long as you say 'something'-disciplinarity it sort of means like not one discipline,…it's just like [cough] disciplinarity. [laughs] [F10].

Consequently, scientists interpreted the call as such that 'the fundamental thing for DLN' was that 'you shouldn't fund a purely disciplinary project' [F7]. Accordingly, the DLN call forced new interdisciplinary collaborations into being. For example, F13 told:

> DLN, for our project, was like the carrot on the stick. It brought the right research groups together, which could already have collaborated, but the DLN frame made it easier for them to join [F13].

In particular, the digital component triggered new collaborations:

> Most of the modelling happening in the project is happening because we needed a modelling component to get the grant.…it hasn't really been very well entrenched in the rest of the project.…But of course, it's still well worth it…I have noticed…that some of the questions, that those modelers ask, do make some of the experimental people go 'Huh!? That's an interesting thought!' [F10].

In this quote, F10 describes how these new interdisciplinary collaborations configured through DLN triggered some difficulties in practice, but they were also considered a worthwhile learning experience. How these *interdisciplinary* collaborations worked in practice is relevant to study further but beyond the scope of this paper.

For this paper, we would like to stress that transdisciplinarity was often interpreted as synonymous with interdisciplinarity. When the DLN call demanded transdisciplinarity, innovation, RRI, convergence, and digitalization, digitalization seemed most concrete and relatable and boosted the invitation of new project partners. In a way, this represents a more 'business as usual' approach to doing science than the transformative demands pushed for in the DLN call.

3.1.2 The networking project

The interpretation of 'transdisciplinarity' as 'interdisciplinarity' also characterized many of the DLN networking project's initiatives arranged under the heading of transdisciplinarity. In the following, we give three examples of such initiatives (open to all DLN members), including an award for best transdisciplinary publication of the year, seed funding for cross-project collaborations, and a course for early-career researchers on transdisciplinary life science.

The first of these was implemented in 2017: DLN established a prize for the best transdisciplinarity publication of the year, defining the criterion of transdisciplinarity as follows:

> The study should include both experimental measurements and computational work on a biological system, or on an engineered device developed for its integration with a biological system (DLN 2018).

In addition, the publication should emerge from DLN projects or partner projects, the connection with DLN should be clear from the affiliation or acknowledgements, and the paper should have been published, accepted, or at least submitted to an international scientific journal. Thus, the criteria describe interdisciplinary collaboration within the natural sciences, and the fact that most of the publications are intra-project interdisciplinary collaborations was reflected in who won the prize.

Secondly, DLN aims to create 'platforms for transdisciplinary workshops and meetings' (DLN 2022) and offers seed funding to encourage and facilitate cross-project collaboration to 'harvest synergies between projects and exchange of competence' (DLN 2021). Funded activities included collaborative workshops, method collaborations, and a pilot testing of antibodies with another DLN project prototype system.

Thirdly, during Spring 2020, DLN research school (DLNRS) advertised a new course to its members. 'Transdisciplinary life science—a Digital Life Norway (DLN) course' had been much discussed and long planned by the centre leadership. The intention was to develop a signature course as a cornerstone of DLN as a transdisciplinary biotechnology research centre. The first of three teaching blocks included 'the essentials on transdisciplinary group work, introduction to remote collaboration and sharing of big data, and introduction to RRI' (DLN 2020a). The second consisted of students working together in assigned groups to learn about data collection and its importance in generating new knowledge and/or innovation. All group work was linked

to modelling and/or analysis of the data. The third block included presentations of the results from all group works, as well as round-table discussions and sharing of experiences on 'transdisciplinary' group work. The course was intended and planned for early-career scientists in the natural sciences; there were no participants from other disciplines. The signature course is an interesting example of how transdisciplinarity in DLN was interpreted as collaboration between the natural science disciplines.

In sum, the networking project's transdisciplinarity efforts were based on an interpretation of transdisciplinarity as interdisciplinary collaboration within the natural science disciplines.

3.2 Meaning 2: transdisciplinarity as collaboration with disciplines far from your own

The second interpretation of transdisciplinarity was 'collaboration with disciplines far from your own', notably between the natural sciences on the one hand and the social sciences and humanities (SSH) on the other.

3.2.1 Research projects

In the research projects, transdisciplinarity was sometimes but not always referred to as collaboration with 'the RRI people'. RRI was mentioned in all interviews when talking about transdisciplinarity and collaboration and was presented as something new and particular to *this* centre. 'Trans' referred to the inclusion of SSH disciplines:

> 'Honestly, I don't know, but if you asked me about trans – for example, in my case, AI and responsibility and innovation – they are different things all together. Yeah. So I think in that case I would say "trans"' [F12].

This quote and the following, in which another scientist elaborates on RRI in his/her project, show how participants linked transdisciplinarity to disciplines they regarded far from their own and often to the RRI work done by SSH researchers. This theme emerged when discussing different forms of collaboration. A microbiologist explained it thus:

> [Y]ou could approach it like a Venn-diagram. 'Intra-' is where all the circles overlap, 'inter-' is where just two overlap and transdisciplinary is when you are in completely different circles. So if I'm a biologist and I'm working together with a geneticist – that's rather close, if I'm working with somebody from physics who's doing microscopy, we are still, like, on the same..., but if I then go to humanity and ask about ethics about my research, then we have transdisciplinary, because then I'm completely across the...[gestures to signal how far off s/he considered this knowledge] [F13].

This understanding of 'transdisciplinarity' corresponds to the concept of radical interdisciplinarity (see, e.g. Evans and Marvin 2006; Clarke et al. 2019). It should be noted that the DLN scientists did not only apply 'transdisciplinarity' in relation to RRI. They also gave accounts of fruitful collaborations on implants between engineers and doctors, or biologists and informaticians.

3.2.2 The networking project

This second interpretation of transdisciplinarity was also represented in the DLN networking project's initiatives and events. Some of the initiatives can be interpreted as creating arenas to meet disciplines far from your own, for example, the DLN annual conference and the DLNRS.

The DLN annual conferences, inviting all project, research school, and advisory board members, appear to have a rather conventional structure typically consisting of 2 days of invited keynote speakers, scientific presentations from the different research projects, a poster session, as well as mingling in combination with food and drinks. As DLN is a centre for biotechnology, biotechnology presentations are prominent. At the same time, the programme also included keynotes from invited speakers in the biotech industry and from SSH researchers.

Second, the DLNRS, with more than 200 PhD and postdoc members, offers 'transdisciplinary training and education for the future of biotechnology' and aims to 'help create opportunities for promoting transdisciplinary integration, building a culture for innovation, and creating a new collective team spirit among all younger scientists who are connected to the Digital Life initiative' (DLN 2020b). The research school has been an important arena for many of the members (Hesjedal 2022), also in terms of transdisciplinarity. During our interviews, the scientists frequently mentioned how interesting it was to meet others working on issues very different from their own and shared accounts of how some of these encounters resulted in scientific discussions relevant to their project. Although these were mainly collaborations within the natural sciences, there were also a few attempts to find common ground for collaborations with SSH. RRI was a recurring topic in the research school, and several members showed heightened interest in this topic.

3.3 Meaning 3: transdisciplinarity as 'something more': integration and collaboration with non-academic actors

The third interpretation of transdisciplinarity was that it referred to 'something more', which often entailed including actors from outside of academia.

3.3.1 Research projects

An early-career biotechnology scientist described his/her understanding of transdisciplinarity as follows: 'it can also be used as going beyond disciplines, so leaving academia—more like industry partners and so on' [F10]. Many scientists we interviewed were positive about including industry. Given their perception of the importance of probing the market for interest in their research and/or products, these scientists often saw industry and potentially providing something useful to the project. A neuroscience researcher stated:

> I think that, in this transdisciplinary work, there should be this user group that should be actively involved in each project, so we at least know that the work we are doing is, like, good for them or not. So, we also need to incorporate their views in the work we are doing [F3].

The quote illustrates how some of the DLN scientists thought that inclusion of both industry and user groups in scientific

collaboration was important when talking about transdisciplinarity. At the same time, some interviewees also objected to this interpretation of transdisciplinarity as industry collaboration, arguing that 'it's a misunderstanding that in order to have innovation you need to have tight connection with industry from the beginning' [F7]. These interviewees were critical to the acceleration logic underpinning the concepts of transdisciplinarity, innovation, and RRI, pointing out that high impact research derives from 'blue sky projects' and needs a longer timeline.

Although collaboration with external actors was not part of everyday research for most projects, a few discussed such exchanges. For example, at the first workshop for a DLN project on environmental toxicology, the project participants mapped institutions and companies that they might interact with the interviews were conducted when 1 year remained for the project, and although the project had initiated some contact with external actors, for example, the Norwegian Environment Agency, such interaction was still in its infancy:

> [W]e probably haven't come so far that we have done a lot of it, but this is also a bit because the data and the analysis somehow have not progressed as we had hoped. But it [collaboration with external actors] is however still in progress, also through this innovation activity…where they have started to do interviews with possible actors that may be interested in monitoring products, so we could probably have done more than we have done, but, yes, we have at least begun [I1].

In this project, the more experienced senior researchers with access to a network of potentially interested actors primarily did the transdisciplinary work. The biology professor running the project was well aware of the understanding of transdisciplinarity that corresponds to the OECD definition highlighting the need for increased collaboration between different societal actors, and s/he made efforts working towards this aim but did not get very far, and s/he was also ambivalent about—what s/he experienced as—RRI demands about this form of collaboration beyond academia being most important in transdisciplinary work.

'Not getting far' was a common experience among those projects trying to collaborate with external actors. F9 told:

> I think we in the beginning tried to put together like an advisory board from industry when we still thought [laughs] this might end up somewhere [someone else laughs loudly] [F9].

We see that the scientists experienced difficulties in implementing unrealistic policy demands to accelerate the translation of scientific knowledge into products and solutions to solve social challenges. Even in those projects that made significant effort in getting collaborations with non-academic actors going, the scientists found collaboration with industry challenging and difficult in practice.

3.3.2 The networking project

The DLN networking project also struggled with facilitating this wider form of collaboration, but it offered innovation workshops, the above-mentioned stakeholder conference, and courses for scientists providing contact points between biotech industry and research projects. In addition, the networking project established industry internships for early-career researchers. The accounts of the scientists who have finished their internships have been very positive in terms of individual growth and relevance for the labour market outside of academia (Juskewitz et al. 2021). Through these initiatives, DLN aimed to facilitate increased interactions with actors from outside of academia and in particular collaboration with biotechnology industry. This work was, however, not straightforward. These findings are supported by Solbu (2021) who shows that DLN coordinators in the networking project struggle with tensions between the biotechnology innovation narrative articulated in policy and how to achieve it in practice. For example, in the empirical section, he quotes a DLN coordinator reporting that most scientists think it is 'way too early to start talking to trade and industry', that few projects collaborate with industry, and that 'of the ones that do it, the industry is not a very active partner' (915).

In sum, we see that one way of making sense of transdisciplinarity was to interpret it as collaboration beyond the scientific disciplines. This interpretation often entailed tensions between who should be included and when. Furthermore, we see that scientists were ambivalent about these demands.

3.4 The 'fading away' of transdisciplinarity policies in practice

This article begins by questioning how biotechnology scientists made sense of the concept of transdisciplinarity when facing increased policy demands for transdisciplinarity. While policymakers often take the meaning of transdisciplinarity as collaboration with non-academic actors for granted and use the concept to promote increased collaboration for innovation and value creation from scientific endeavours (see, e.g. OECD 2020), they often do not go into details of how this could or should be achieved. Thus, scientists depend on translating transdisciplinarity into something that makes sense in practice in their local context. We identified three diverse meanings of transdisciplinarity in DLN: (1) transdisciplinarity as collaboration with other natural science disciplines, (2) transdisciplinarity as collaboration with scientific fields or disciplines far from your own, and (3) transdisciplinarity as 'something more' than collaboration between disciplines. These three composed meanings of transdisciplinarity must not be taken to mean that each interviewed scientist had *one* clear idea about transdisciplinarity: the scientists' accounts also revealed substantial confusion, differences, and even disagreements when it came to the concept, both in terms of defining it and regarding scepticism on how to achieve user involvement and industrial collaboration in practice.

In a way, these findings are dissatisfying: in practice, the transformative science policy idea of 'transdisciplinarity' seems to fade away. The aim of the RCN's DLN policy is to transform the Norwegian biotechnology landscape and thus also scientists' understandings and practices related to transdisciplinarity. The empirical accounts from scientists in DLN suggest that increased collaboration with non-academic actors is not happening. When looking at the three meanings of transdisciplinarity generated, we see that few scientists generate a meaning of transdisciplinarity in line with the

policy understanding of the term. Furthermore, even the scientists who do in fact categorize transdisciplinarity as 'meaning 3'—which is closest to the science policy ambitions—the interview accounts show that the scientists found it very difficult to realize this in practice in their actual research. Our empirical analysis thus supports findings in recent scholarship comparing transformative policy programmes in the Nordic countries (Borrás and Serger 2022): even though all the Nordic programmes had individual transformative elements, they only showed weak or medium links between and across constitutive layers of policy instrument design. This, in turn, created challenges for implementing the envisioned transformative research policies. Our analysis is in line with the findings of Morris and Rip (2006: 260) who argue that the life scientists in their study have 'shifted their ideas and practices sufficiently to cooperate with a more intrusive policy regime, but without stepping out of their traditional academic framework…'. They conclude that 'these actors show adaptation, but not transformation' in terms of policy demands, and our findings are similar.

Nevertheless, the point of highlighting the various interpretations is not to measure them against the scholarly definitions as 'right' or 'wrong'. Considering DLN's focus on integration of digital methods into the life sciences, we do not find the frequent interpretation of transdisciplinarity as interdisciplinarity surprising. The DLN initiative can be considered a success regarding the fostering of new interdisciplinary constellations and radical interdisciplinarity. Further research should study what kind of research practices these new constellations generate. To understand why transdisciplinarity policies may fail in terms of steering activities in intended non-academic actor collaboration, it is important for policymakers to know what these science policies mean for scientists, both in terms of the various interpretations of transdisciplinarity and in terms of these policies' effects on time resources and careers pathways. While Bos et al. (2014) found that big words such as 'sustainability' or 'valorization' can steer research silently through making collaborations obligatory, our interviewees told very ambiguous accounts of how well the collaborations, which exist on paper, work in practice. Our hope is that our findings will inform policymakers and help them see the necessity of taking the initiative for establishing mutual understanding. One challenge in this regard worth noting is that the DLN policy demands, as described in the introductory section of this paper, are in fact not clear-cut but in themselves rather indistinct. Furthermore, the different policy demands of 'transdisciplinarity', 'innovation', and 'RRI' intermingle, creating a vague demand for collaborating across disciplinary boundaries and for societal relevance. In this sense, the scientists' different interpretations of transdisciplinarity do reflect the sometimes confusing research policy landscape. Furthermore, building a mutual understanding within the DLN networking project regarding what transdisciplinarity in the centre should mean is, as we see it, a prerequisite for the support structure to guide scientists' implementation of transdisciplinarity in a direction desired by DLN.

Our analysis adds comparative, empirical data to studies on transdisciplinarity. A specificity of all projects in DLN is that they have a low technology readiness level. Scientists consider it difficult to engage non-academic actors in basic life science projects. It is interesting that the DLN initiative provides a transdisciplinary support structure in the form of the networking project going beyond individual research projects, but in contrast to, for example, sustainability research initiatives (Felt et al. 2016) or clinical practitioners (Simons et al. 2020), this cannot outweigh the prevailing basic science orientation in DLN. Compared with Felt et al.'s three categories of science–society relations, we see that the three meanings in our study share some similarities related to the role and inclusion of non-academic actors in research, as well as some differences. Some of our scientists' accounts suggest that societal actors are regarded as knowledgeable agents important for addressing the research question (e.g. F3), in line with Felt et al. (2016) second and third categories. That being said, scientists could understand 'transdisciplinarity' as 'inclusion of other actors' (Meaning 3) without agreeing to this or without feeling a need to include non-academic actors in the research process (e.g. I1's ambivalence about collaboration beyond academia being the most important part of transdisciplinary research).

In contrast to the participants in Thompson et al.'s (2017) study, who described a process characterized by benefits, challenges, integration, and dialogue, none of the scientists in our study voiced the view that transdisciplinarity should 'integrate diverse people from all communities affected by the problems' (34). Furthermore, the scientists in our study did not use the word dialogue but talked about the importance of good communication.

Much of previous research on transdisciplinarity is done on or in the context of applied sustainability or environmental science (e.g. Felt et al. 2016; Thompson et al. 2017; Schikowitz 2020; Borrás and Serger 2022). Our study of the DLN initiative differs from these in that transdisciplinarity in DLN was linked to further developing basic research in life sciences towards value creation. Fulfilling the centre's vague and ambitious aims is a challenging task. Public policy needs better awareness of this diversity and heterogeneity of science—maybe basic research does not lend itself well for solving complex societal challenges, and policy demands need better targeting.

Finally, the perceived need for new collaborations to achieve scientific breakthroughs was a recurring narrative, not only in the research policy but also among scientists themselves. Although the interviews showed differing understandings of transdisciplinarity, we showed that they also revealed substantial confusion when it came to the concept. Common for all interviews, however, was a clear narrative of transdisciplinarity being about collaboration and that this was perceived as something positive and good for science. This paper shows that the interpretation and sensemaking of policy concepts are complex and nuanced and that the recipients' interpretations are not always in line with the intended policy. While previous scholarship on transformative policies focused more on the policy documents and/or policy discourses themselves, the interpretation of policy recipients so far has been given less attention. Our study, where we consider the multiplicity of ways in which researchers interpret transdisciplinarity is, therefore, a valuable contribution to this scholarship.

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Notes

1. RRI is a policy concept aiming to promote practices that help shape research and innovation to respond to society's general needs and values (Von Schomberg 2011). In Europe, RRI is often framed using either four dimensions (Stilgoe et al. 2013) or six policy keys (https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation).
2. This must not be taken to mean that we necessarily agree with the RCN's policy demands and implementations in DLN. We rather take a critical analytical stance on these policy demands and the concept of transdisciplinarity in order to investigate what it means in practice for the policy recipients, that is, the scientists in DLN.

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Appendix 1.
Overview of interviews and interview participants

	Disciplinary background	Position
Phase I: 2018/2019		
Project A	Biology/physiology	Associate professor
Individual face-to-face interviews	Physics	Professor
	Mathematics	Postdoc
	Physics	PhD
	Cell biology	PhD
	Neuroscience	PhD
Project B	Biotechnology	Professor
Individual face-to-face interviews	Bioengineer	Lab technician
	Biotechnology	Postdoc
	Cell biology	Researcher
	Bioengineer	Lab technician
	Biomedicine	Researcher
	Chemistry	PhD
Project C	Environmental toxicology	Postdoc
Individual face-to-face interviews and one digital interview	Biology/toxicology	Professor
	Toxicology	PhD
	Biology	PhD
	Bioinformatics	PhD
	Bioinformatics	Professor
	Mathematics	Professor
	Mathematics	PhD
	Mathematics	PhD
Phase II: 2020		
Focus group interview 1	Molecular biology	Professor
(face-to-face)	Cell biology	Postdoc
	Neuroscience	Researcher
	Medical doctor	PhD
	Cardiology	Postdoc