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A Study of an Attempt of Transforming Biotechnology Research

Doctoral thesis

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Norwegian University of Science and Technology
Thesis for the Degree of
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Abstract

This dissertation sets out to answer the question of how disciplinary transgression in science is achieved. I study this in the context of Norwegian biotechnology, having conducted my research within a national centre for biotechnology research, the Centre for Digital Life Norway (DLN). DLN is a product of strategic efforts in the Research Council of Norway to transform Norwegian biotechnology through transdisciplinarity and therefore offers an interesting avenue to seek answers to the research question. The research in this dissertation is based mainly on ethnographic fieldwork and semi-structured interviews in DLN.

Four research papers, each of which addresses different aspects of disciplinary transgressions in DLN, form the basis of the dissertation. Paper 1 shows how scientists in a transdisciplinary research centre make sense of the research policy idea of transdisciplinarity. A key finding is that the most prevalent understanding was transdisciplinarity as collaboration between scientists within the natural sciences, that is, as corresponding to the scholarly definition of interdisciplinarity. Paper 2 follows up on this by analysing how three specific research projects do interdisciplinarity in practice. This was done by studying flows of materials and data between scientists in these research projects. Paper 3 focuses on how biotechnology scientists were socialised into an interdisciplinary mindset by place-making in a multi-sited research centre. This paper shows how initiatives and events played an important part both in place-making and socialisation. In paper 4, one such initiative is analysed: a PhD course aiming to transform early-careers' understanding of science-society relations.

The four papers are analyzed together through a theoretical framework of practice theory, combined with Knorr Cetina's notion of epistemic machineries (Knorr Cetina, 1999) to address the main research question. In the analysis, I identify a set of core and support practices that I argue are highly influential in disciplinary transgression. The scientific relay found in paper 2 is identified as a core practice, and the identified support practices are related to socialisation, affect, learning, teaching, place-making, and sensemaking. I argue that the core and support practices together constitute complex epistemic machineries of disciplinary transgressive knowledge production that are dependent on and shaped by local conditions.

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It is not uncommon to describe the PhD process as a journey. For me, it certainly does feel like an amazing journey that has led me not only to Science and Technology Studies and a range of new ideas and perspectives on science, technology, and society, but also to new countries and cities, and most importantly to a number of excellent people.

There are many I would like to acknowledge in this regard. First and foremost, I thank my supervisors. Their knowledge, ideas, feedback, and collaboration have shaped this dissertation in numerous ways and helped me complete it in a timely manner (i.e., before my contract ended!). I am grateful to my main supervisor, Heidrun Åm, not only for hiring me but also for her guidance and dedication throughout my entire PhD studies. Her sharp intellect and good ideas have greatly benefited my work and my development as a researcher. I am grateful to my co-supervisor, Knut H. Sørensen, who also invested significant time and effort in my supervision. His extensive supervisory experience, combined with his knowledge of the field and ability to find solutions to problems, have been invaluable. Moreover, I thank both my supervisors, not only for caring about my work but also about me as a person.

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The main body of this study is based on ethnographic fieldwork and interviews in the DLN, and would thus not have been possible without many persons to whom I owe great thanks for their time, perspectives, and helpful efforts. Firstly, I want to thank Berit Strand and the entire 3DLife project for the collaboration over the past few years, and for their time and efforts that have contributed considerably to my work. Secondly, I would like to acknowledge five key persons who have been of particular importance, some of whom I now also consider close friends. Due to confidentiality considerations they must remain anonymous, but I am immensely grateful to them, as they have been invaluable for my understanding, insights, and inclusion in the scientific environment. I am also grateful to my interviewees and to the project leaders who welcomed me into their project. Finally, I would like to thank the DLN scientific director, Trygve Brautaset, the old networking project and the new Operational Management Team (for their time and energy in answering all my various questions), and the Junior Resource Group for making the last part of my PhD much more fun (but seRRIously, where are the track suits?).

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Maria Bårdsen Hesjedal
February 2022

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PART I

1

Introduction

In February 2010, *Nature* published a letter from a group of 24 international scientists on the importance of funding transdisciplinary scientific collaboration: “Europe’s future hinges on funding transdisciplinary scientific collaboration. (…) we need to build a new science community that will explore common themes in natural, artificial and social systems. (…) today’s world needs sciences recast for the future” (Vasbinder et al., 2010). The scientists argued that the world needs a transformation of the current state of science to be equipped for ‘the future’. They saw disciplinarity as a barrier to understanding the complex world we live in, emphasising the need to fund transdisciplinary scientific collaboration. Vasbinder et al. (2010) are not alone in arguing for disciplinary transgression in science. Both scientists and policymakers alike argue that both science and society need more and new forms of research collaboration.

In this dissertation I explore how disciplinary transgression is achieved. The research design follows an actor-oriented approach, and with this I mean that I mainly have followed the actors involved in disciplinary transgressions in science. This approach has led me to focus on scientists’ many reasons for engaging in disciplinary transgressions in scientific research, their understandings of science policies, how they translate these into practices, their enactment of interdisciplinarity, and how exposure to different knowledges can change assumptions. The dissertation contributes to scholarship on Science and Technology Studies (STS) by providing an empirical account of how disciplinary transgression is achieved and by suggesting a new theoretical conceptualisation of disciplinary transgressive practices based on existing frameworks and practice concepts.

Many initiatives are based on the argument that more and new research collaborations are needed. In the Norwegian context, a recent case – the development of a new 'Life Science building' in Oslo – illustrates the interest in increased disciplinary transgression in science. In 2018, the Norwegian government allocated start-up funding to build a Norwegian 'Life Science building' that at 66 700 m^2 will be the largest freestanding university building in Norway and will house about 1000 employees and 1600 students. This is a huge public investment, currently estimated at 11.6 billion NOK. The rector of Oslo University (UiO) states that the aim of UiO's largest initiative ever is to "make a melting pot of professional environments to collaborate in new ways. Interplay with business, hospitals, and other actors to apply our science is a clear goal of this building and with life science in general" (Husøy, 2017, my translation). The example illustrates how disciplinary transgression often is framed and narrated by scientists and institutions. Moreover, it shows that the narrative of disciplinarity transgression is persuasive and results in enormous public investments.

The idea that merging knowledge from various specialised fields will provide new solutions sounds plausible, at least in a frame in which disciplines are considered silos that constrain collaborative flow. The need for disciplinary transgression is thus often taken for granted without further inquiry and is considered a good in itself in organisations, both as a fruitful strategy for progress and as a fruitful approach to solving problems (Frickel et al., 2017; Siedlok & Hibbert, 2014). Collaboration is thus considered valuable.

Considering the persuasive narrative of disciplinary transgression and how easily it is taken for granted, it is important to stop for a moment to ask some questions: Why is collaboration within and beyond the sciences considered so important? What are the problems such collaboration are imagined to solve? Where does the rationale behind the narrative of disciplinary transgression and collaboration come from, and why is it so persuasive? These questions give rise to inquiries regarding how these collaborations are to be achieved, where they should happen, and which actors will actually engage in disciplinary transgression in practice.

Emerging technologies such as biotechnology, nanotechnology, information technology, and cognitive science play a central role in the vision of new and increased disciplinary transgressions in science. The Norwegian Life Science building is an example of the willingness to invest in this field, and the case illustrates how such technologies are imagined to contribute importantly to Norwegian society: The minister of Education at the time described the anticipated future values from the (collaborative) life sciences as the new Norwegian oil, claiming it to be “how we will make our living after the oil runs out” (Husøy, 2017; UiO, 2017).

Research policies have been important drivers of engagement in disciplinary transgressions in the life sciences. Concepts such as multi-, inter-, and transdisciplinarity, and convergence are used to describe different kinds of transgressions. In research policy, collaboration in science is highly valued as a means for managing two interrelated matters. Firstly, it is seen as an essential component in the quest to resolve grand societal challenges (Kuhlmann & Rip, 2019; OECD, 2020; von Krogh et al., 2019). Secondly, it is seen as a crucial ingredient to facilitate research breakthroughs (OECD, 2010, 2020; Roco & Bainbridge, 2002; von Krogh et al., 2019).

According to Frickel et al. (2017, p. 7), policy discourses involve three main assumptions about interdisciplinarity. The first assumption is that interdisciplinary research leads to better knowledge than non-interdisciplinary knowledge can deliver. The second assumption is that disciplines operate as institutional silos that constrain the flow of interdisciplinary knowledge (this argument is also made by Boden et al., 2011; Evans & Marvin, 2006). The third assumption is that interdisciplinary interactions are unconstrained by disciplinary hierarchies and power asymmetries. Frickel et al. (2017) argue that each of these assumptions plays a significant role in justifying the creation of interdisciplinary knowledge, research centres, and policies. These assumptions often lack empirical evidence, despite their problematic nature (for the full argument related to each assumption, see Frickel et al., 2017, pp. 5-16).

A recent example illustrating such assumptions is the OECD (2020) “Addressing societal challenges using transdisciplinary research” report. Firstly, it assumes that solutions to complex societal challenges “cannot be generated based solely on disciplinary research” (p. 9). Secondly, it assumes that because of this it “requires a paradigm shift in research practice” (p. 9). This shift is imagined as a shift towards what the report calls transdisciplinary research.

Despite taking the need for a shift in research practice as a basic assumption, the report does not elaborate on what the perceived current problems with science and research are, beyond referring to the grand challenges and the UN sustainable development goals, taking for granted that transdisciplinary research is the best (and only) solution to address these problems. This narrative appears repeatedly throughout the report; although it is not discussed in any detail, it nevertheless guides the report recommendations and solutions. This is a recurring trait in research policy documents promoting disciplinary transgression.

In the Norwegian context, a policy brief from the Research Council of Norway is illustrative of Norwegian policies on disciplinary transgression. The policy brief, written by an international advisory board, discusses challenges the research council faces in implementing disciplinary transgression. The document frames the discourse on interdisciplinarity by first stating that interdisciplinary research is essential to solve grand societal challenges and to facilitate scientific breakthroughs in research. Then, it claims that there are "numerous barriers to conducting such research" that need to be overcome through "targeted measures in three key areas: Assessment and funding; education and careers; and leadership and cultures" (von Krogh et al., 2019, p. 1). The remainder of the document discusses these barriers and how to overcome them.

Other research policy documents promoting disciplinary transgression (EC, 2014a, 2017, 2020; Eisenberg & Pellmar, 2000; RCN, 2014; Sharp et al., 2011) contain similar tendencies. These research policies demand disciplinary transgression as a measure for solving societal problems, achieving new scientific breakthroughs, overcoming disciplinary barriers, and creating (economic) value and national competitiveness. Furthermore, they create a narrative about barriers that need to be overcome as soon as possible. In this way, research policies steer funding calls and initiatives toward inter- and transdisciplinary research. As we see, the policy narrative of disciplinary transgression consists of a set of normative claims. The pressing question that arises in this context is this: What is actually happening in practice?

This leads me to the principal research question for this dissertation: how and what disciplinary transgressive practices emerge in the context of policy demands for disciplinary transgression? Scientists have many motivations for engaging in disciplinary transgression, and the choice to collaborate with others can, for example, be based on scientists' experiences of the need for disciplinary transgression for scientific breakthroughs in their specific research field, and/or they can be results of research policies demanding disciplinary transgression. This has led to other, related questions: How do scientists deal with policy demands of disciplinary transgression? How do they "do" disciplinary transgression in their everyday work-lives? What do these practices consist of? The remainder of the dissertation's chapters aim to answer these questions.

1.1 Structure of dissertation

This is a compilation dissertation, with four research papers forming the basis. These papers were all written as stand-alone papers. This dissertation ties them together by placing them in a larger context and analysing them together to answer the research questions above.

The dissertation consists of three parts. Part I includes three chapters: introduction (chapter 1), previous research (chapter 2), and methods (chapter 3). The introductory chapter, which you are currently reading, outlines the wider context for my research and shows firstly, the persuasive policy discourse of disciplinary transgression and, secondly, that both scientists and research policies consider overcoming barriers to be key in achieving disciplinary transgression. Chapter 2 shows how scholarship on disciplinary transgression has been dominated by studies focusing on overcoming barriers for disciplinary transgression. The chapter ends by situating the dissertation's focus as not on barriers but on practices in disciplinary transgression. Chapter 3 is a methods chapter, where I describe the methods and methodology of my research. This chapter gives a broader introduction of the methods used for data generation and analysis in my research than was possible in the four original papers.

Part II consists of the four research papers upon which the dissertation is based. The papers engage with four research questions related to disciplinary transgression. The first paper shows how scientists in a transdisciplinary research centre make sense of the research policy idea of transdisciplinarity. A key finding is that the most prevalent understanding was transdisciplinarity as collaboration between scientists within the natural sciences, that is, as corresponding to the scholarly definition of interdisciplinarity. The second paper then analyses how three specific research projects do interdisciplinarity in practice. We did this by studying flows of materials and data between scientists in these research projects. Paper 3 widens the scope: rather than focusing on individual research projects, it instead focuses on how biotechnology scientists were socialised into an interdisciplinary mindset by place-making in the biotechnology centre Digital Life Norway (DLN). This paper shows how initiatives and events played an important part both in place-making and socialisation. In the fourth paper, one such initiative is analysed: a PhD course aiming to transform early-careers' understanding of science-society relations. Together, the four papers show how the dynamics of disciplinary transgressions are closely interwoven with policy and its many complex translations and interpretation by scientists in practice and, furthermore, that the field of Norwegian biotechnology is a result of these many movements and relationships.

Part III consists of a cross-cutting analysis of the four papers. Chapter 4 begins with an outline of the theoretical framework and concepts I use in the analysis: practice theory and epistemic machineries. Next, I analyze the four papers together in light of the practice theory framework outlined, before ending the chapter with concluding remarks on the dissertation as a whole. References and appendices with relevant supplementary information follow chapter 4.

2

Scholarship on disciplinary transgression

Based on the research questions outlined in chapter 1, this chapter investigates previous scholarship on disciplinary transgression within the social studies of science. The chapter consists of two sections. Section 2.1 addresses the relationship between science and society. After a brief introduction to this topic, I situate studies of science-society relations within the tradition of STS before examining three concepts related to disciplinary transgression that have been influential in STS. In section 2.2 I review previous scholarship on disciplinary transgression and show how this scholarship has been dominated by a focus on overcoming barriers for disciplinary transgression. The section considers institutional barriers, proximity barriers, communication barriers, and practices.

‘Inter’-, ‘multi’-, ‘cross’-, ‘pluri’-, ‘sub’-, and ‘transdisciplinarity’, ‘convergence’, ‘problem-centred’, ‘mission oriented’, ‘integrative’, and ‘holistic’ are all terms used to describe various approaches to scientific collaboration and transgression. The difference between these is frequently discussed in scholarship on interdisciplinarity, and definitions abound (see Klein, 1990 for a thorough review and definitions). In practice, however, the terms are often used interchangeably to describe the exchange of ideas, methods, technologies, and so on between disciplines. The significant interpretative flexibility of what collaboration can and should mean in science makes for an interesting research site. At the same time, the use of different terms – or similar terms with different meanings – may also be a source of frustration and interpretive challenges for the researcher.

In this dissertation, I mainly use the term ‘disciplinary transgression’. This term covers a variety of different forms of scientific collaboration. This has been important when analysing my empirical data, as I needed a term that included the range of emic conceptualisations of disciplinary transgressions made by scientists and policies during my research. This must not be taken to mean that I do not distinguish between inter- and transdisciplinarity. I use ‘interdisciplinarity’ to describe what occurs when scientists and scholars from two or more disciplines or professional fields, engage in combining, exchanging, or integrating concepts, data, and methods. I define ‘transdisciplinarity’ as collaboration not only across scientific disciplines, but as also involving joint problem-solving with external, non-academic actors, not merely as stakeholders but as knowledge producers. The term ‘disciplinary transgression’ is broad enough to cover both inter- and transdisciplinarity research.

2.1 Science-society relations

In a historical perspective, science has often been seen as an isolated sphere that produced objective scientific knowledge that could be implemented in society (Sismondo, 2010; Skjølsvold, 2015). In this perspective, scientists discovered or uncovered scientific objective facts about the world though a scientific method that ensured reliable knowledge. This entailed a picture of society and the public as passive recipients of scientific knowledge and new technology that was “provided” to them by scientists and universities. Gibbons (1999), for example, argues that the relationship between university science and society has traditionally been based on an understanding that universities will provide research and training to society, in return for public funding and a relatively high degree of institutional autonomy. This requires a high level of legitimacy in scientific endeavours.

From the 1960s and onwards, scholars started to question the view of science as separate from the rest of society (Sismondo, 2010). During the 1990s, there was increased recognition that scientific knowledge is not intended to uncover a reality “out there”, but that knowledge is produced and constructed as a part of society and social processes: science was *in* society (Bauer, 2009). This had implications for the conceptualisation of the relationship between science and society. One implication was that scholars argued that the relationship between science and society was not characterised by trust – as the traditional view would have it – but by distrust, and that science needed to be democratised in order to (re)gain the public’s trust (Callon, 1999; Latour, 1993; Stengers, 1999).

This idea was grounded in an increased awareness over the previous several decades in which the more problematic sides of socio-scientific and technical developments were discussed. The sufferings caused by the atomic bombings after the second world war, later developments of a vast arsenal of nuclear weapons, and the effects of radiation after the disaster at the Chernobyl Nuclear Power Plant in 1986 are examples of unintended consequences of the socio-technical developments from scientific research (and implemented in society) greatly, and adversely, affecting the public. In the history of science and technology, there have been many similar examples in which new technology and products developed by engineers and scientists have been shown in retrospect to have harmful effects at great costs for citizens, for example, asbestos, the toxin DDT, and the medication DES.

These examples show the significant influences of science and technology in society, and how science, technology, and society are interwoven in practice. Furthermore, such unintended consequences provide context for understanding the controversies between groups of citizens, sciences, and governments. The protests against face masks during the COVID-19 pandemic is a recent example of such a controversy, as is resistance against vaccination programs, and the debate on climate change, in which researchers, politicians, citizens, and the media vie for a monopoly on facts.

Gibbons (1999) argues that it is widely recognised that science is transforming modern society, although it is less often appreciated that, when science is recognised as a part of society, society also has the ability to speak back to science. And, furthermore, that by speaking back to science, society is in fact also exerting a transforming force on science. There are many examples of society "speaking back" to science.

One such example is the GMO controversy, which produced a heated and long-running debate around agricultural biotechnology in the early 2000s involving a range of actors, including scientists, biotechnology companies, governments, non-governmental organisations (NGOs), farmers, and consumers (Motta, 2014). The debate zeroed in on labelling, regulation, different interests, objective knowledge, and the role of genetically modified crops (Motta, 2014). Helliwell et al. (2017) argue that opposition to GMOs (in that case from NGOs) often is based on more general skepticism concerning the framing of the problem and its solutions. The authors show how skeptical NGOs presented problem and solution framings different from those offered by the scientific community, and that they did so "as part of a broader political discussion about policy impacts within society" (p. 2093). The NGOs in this example illustrate society speaking back to science, challenging the views and knowledge of the scientific community.

Increased awareness toward science-society relations led to an increased demand for citizens to take part in and influence the directions of technoscientific developments from the 1980s and onwards (Irwin, 2006; Stengers, 1999). Controversies within biotechnology – such as the GMO debate – played an important part in driving these developments (Jasanoff, 2005). Within these discussions, both collaboration and disciplinary transgression play important roles, and have aligned with a call for 'accountability' (Nowotny, 2007) and later with practices of responsibility and care (Puig de la Bellacasa, 2017). Various governance policies, such as public engagement, upstream engagement, and ELSA/ELSI (ethical, legal, and social aspects) (Delgado & Åm, 2018; Hilgartner et al., 2017; Wynne, 2006; Åm, 2019), have all been deployed in an attempt to address these concerns. The latest of these developments in science policy requesting inclusion and involvement of citizens in the development of science and technology is Responsible Research and Innovation (RRI). RRI is a European policy concept aimed at promoting practices to help shape research and innovation to respond to society's general needs and values (Von Schomberg, 2011). RRI is often conceptualised though four dimensions: anticipation, reflection, inclusion, and responsiveness (Stilgoe et al., 2013). This approach to RRI implemented, for example, by RCN, differs from other forms of participatory governance (like its forerunner, ELSA) in that it situates responsibility not in institutions but with scientists' research practices (Åm, 2019, p. 2). By engaging in the four dimensions, scientists thus become the key actors to ensure responsible research and innovation.

Collaboration is seen as crucial for RRI, as is early and continuous engagement of all stakeholders, including civil society (EC, 2014b). There is thus overlap between RRI and disciplinarity transgression – in particular with transdisciplinarity: Both RRI and transdisciplinarity aim for a production of useful and relevant knowledge in a societal context, in addition to the concepts emphasising inclusion of non-academic actors in the scientific research process. Moreover, RRI is intended as a way to re-order science-society relations (Völker, 2021, p. 42). In this sense, RRI and transdisciplinarity are not only related but can in many regards be seen as sides of the same coin.

Science and Technology Studies (STS)

STS studies these kinds of relations between science and society. The field of STS developed in the 1960 and 1970s as result of increased interest amongst sociologists and historians of science, and engineers, about the relation between scientific knowledge, technological systems, and society (Sismondo, 2010). Broadly speaking, STS has had two main focus areas: knowledge production and technology development (Jasanoff, 2017). Whereas the first has been concerned with the processes that lead to the recognition of scientific facts, the latter has been more concerned with the relationships between society, social processes, culture, and technology (Skjølsvold, 2015). Recognising the key role of knowledge and the ideal of scientific objective facts as a basis for decisions in modern societies (Jasanoff, 2004), STS scholars have investigated the processes by which facts and knowledge are made and produced.

One example of this is the STS laboratory studies, where STS scholars studying scientists in laboratories investigated into how facts were made (Collins, 1985; Latour, 1979; Lynch, 1985). These studies rejected the assumption that a laboratory method made objective facts, showing that laboratory work is about not only representation but also intervention, "as researchers actively are engaged in manipulating their materials" (Sismondo, 2010, p. 108). The laboratory studies addressed not only philosophical questions about the production of knowledge but also questions about various scientific cultures (see, e.g., Knorr Cetina, 1981; Traweek, 1988). These studies of how scientific facts were constructed were influential in later STS developments.

STS has criticised internalist and technological determinist of science and technology explanations (e.g., the idea that technologies determine social events and change) by showing that scientific facts and technology are not the outcome of independent processes external to the wider society (Skjølsvold, 2015; see also, e.g., Winner, 1986). They are rather produced by societal actors with specific interests and are influenced by social, historical, and cultural movements (Skjølsvold, 2015, p. 21). For example, Pinch and Bijker (1987) argue that no technology or object have only one potential use; they developed this point into a framework ("Social Construction of Technology" [SCOT]) for considering the development of technologies (Pinch & Bijker, 1987). Using the example of the standard modern bicycle, they showed that the design was not a result of it being the best design, but that the design stabilised as a result of a variety of factors and negotiations. The example is also illustrative of STS scholars' attempts at opening situations, facts, or objects that are black-boxed (when something is presented as the only or best solution to a problem), showing that the end product or design was not necessarily the best or the only possible outcome (Sismondo, 2010).

A key point in STS is that neither knowledge, technology, science, nor society is created in a vacuum; they are produced in a particular place, in a socio-cultural context, and by individuals in a specific historical setting (Sismondo, 2010; Skjølsvold, 2015). In short, science, technology, and society are interwoven, or co-produced (Jasanoff, 2004). Linking this section to the previous GMO example, we can say that STS has shown that such controversies cannot be adequately addressed though science alone, and that the political issues and the values underpinning them must be acknowledged.

This dissertation is a science study, and as outlined above, STS has a tradition for studying the sciences and provides a good starting point for investigating disciplinary transgressions in science. The research in this dissertation thus builds on STS scholarship and the tradition of exploring the co-production of science, technology, and society.

Three concepts used in studies of disciplinary transgression

Within STS, there are many concepts that describe interdisciplinary practices, for example boundary objects (Star & Griesemer, 1989), interactional expertise (Collins & Evans, 2002), and trading zones (Galison, 1997, 2010). I return to these later when discussing barriers to disciplinary transgression. Here, I focus on three other key concepts, developed explicitly to study the relation between science and society that has been influential and much used within STS. These are: “mode 2 science”, “post-normal science”, and “the triple helix”. These concepts were all developed in the 1990s and have since become common references within the field. In the context of this dissertation, they are interesting not only because of their influences in STS but because they describe ways of conceptualising different kinds of disciplinary transgression. A clarification of these three concepts is in order.

In 1994, Gibbons et al. introduced the idea that knowledge production had moved from what they called a mode 1 to a mode 2 knowledge regime. This implied a change of the character of scientific knowledge production. Gibbons et al. argued that while knowledge previously had been produced within traditional disciplines at universities, there had recently been a change toward more collaborative problem-solving in science, which aimed to solve concrete practical challenges: problem-solving in the context of application.

Other contemporary ideas, such as Funtowicz's and Ravetz's more normative work on post-normal science (1993), contributed to increasing the attention toward collaboration in science. Inspired by Thomas Kuhn's (1962) descriptions of normal science, Funtowicz and Ravetz argue that traditional science could not handle the many complex challenges in a world characterised by substantial uncertainty and high risk. Thus, there was a need for a post-normal science to solve such problems. Here, collaboration across disciplinary boundaries played a key role. Furthermore, they argue for a broader inclusion of actors affected by the problems that should be solved and thus for a wider dialogue between science and society.

In *Re-thinking Science. Knowledge and the Public in an Age of Uncertainty* (2001), Nowotny, Scott, and Gibbons further argue that a transformation is occurring in the relationship of science and society. They claim that mode 2 science has developed in the context of a mode 2 society, and that

> Mode-2 society has moved beyond the categorizations of modernity into discrete domains such as politics, culture, the market – and, of course, science and society; and, consequently, that under Mode-2 conditions, science and society have become transgressive arenas, co-mingling and subject to the same co-evolutionary trends. (Nowotny et al., 2001, p. 4)

According to Nowotny et al. (2001), transdisciplinarity plays a key role in this transformation and is linked to what the authors call "socially robust knowledge". According to the authors, knowledge becomes socially robust only if it transgresses disciplinary and institutional boundaries of science. This knowledge should be based on a dialogue with actors from outside of academia as an ongoing discussion in order to democratise and make science relevant in society. Nowotny et al. used the ancient Greek public marketplace, the *agora*, as a model and metaphor for such a meeting place for dialogue between different actors. Through this more inclusive and dialogical process happening in the agora, the knowledge that is produced should become transparent and socially robust. The idea of a mode 2 knowledge production suggests that the relationships between science and society are more complex and intertwined than how science traditionally has been imagined. Moreover, the mode 2 concept highlights that science is not isolated from and unaffected by society and societal processes but is rather co-produced.

Consistent with the contemporary discourse in the 1990s on science-society relations discussed above, Etzkowitz (1993) and Etzkowitz and Leydesdorff (1995) suggest a *triple helix* model to describe a closer relationship between university, industry, and government. This model attempts to understand how research and innovation are developed in society; it suggests that university, industry, and government are increasingly interwoven and interdependent. This can be related to what has been referred to as universities' "third mission": contributing to society, which is often envisaged as contribution in the form of economic growth through a different organisation of science and scientific outcomes more consistent with what Etzkowitz (2003) refers to as entrepreneurial science.

The notions of mode 2 knowledge production, post-normal science, and the triple helix are all normative concepts (although to varying extents) that describe new conceptualisations of science-society relations. These concepts have been criticised for having a weak empirical basis for many of the arguments they present (see, e.g., Etzkowitz & Leydesdorff, 2000; Godin, 1998; and Weingart, 1997 for critical perspectives on Gibbons et al. 1994), but together they represent a key trend in how science is envisioned as increasingly intertwined with other parts of society. Moreover, they represent a normative attempt to influence policy development. This normative way of thinking, illustrated here by the three concepts, later seeped into research policy and has been influential in policy visions of research and of the organisation of research programmes toward increased disciplinary transgression (see, e.g., OECD, 2020; Roco, 2003; Roco & Bainbridge, 2002).

Despite considerable policy efforts in facilitating disciplinary transgression, scholars question the outcomes envisioned by the new way of knowledge production (Frickel et al., 2017; MacLeod et al., 2019; Weingart, 1997), some arguing that relatively little progress has been made in implementing interdisciplinarity in research (Nowotny, 2017). The question that arises is this: what happens when such normative ideas of disciplinary transgression meet practice? That is the topic for the next section.

2.2 Barriers and practices in disciplinary transgression

Ample social sciences scholarship already focuses on disciplinary transgression. This scholarship covers a variety of subtopics and describes a multitude of aspects, forms for collaboration, differences between disciplinary fields, methods, and so on. In this section I review some of this scholarship to investigate what we already know regarding the question posed at the end of the last section – what happens when normative ideas of disciplinary transgression meet practice? – and thus focus on research that studied what happens when disciplinary transgression is implemented. The section is organised into four parts, focusing on institutional barriers, barriers of proximity, communication barriers, and practices, respectively.

Institutional barriers

Making disciplinary transgression work in practice has proven challenging. Scholars have identified institutional barriers as a major challenge for disciplinary transgression (Boden & Borrego, 2011; Boden et al., 2011; Brandt et al., 2013; Weingart & Padberg, 2014). Barriers are seldom defined; rather, they are explained through description of such barriers. I understand barriers to be situations, policies, or procedures that organise and structure how things are done at an institution. These situations, policies, and procedures are often conceptualised as built-in structures that hinder scientists from working across fields.

The organisation of universities into disciplines is one example of an institutional barrier, and this organisation is frequently seen as the main obstacle to disciplinary transgression (Boden & Borrego, 2011; Evans & Marvin, 2006; Frickel et al., 2017). This perspective depicts disciplines as closed silos that need to be transgressed in order to achieve collaboration (Barry & Born, 2013; Centellas et al., 2014; Rhoten & Pfirman, 2007). Boden et al. (2011) argue that institutional structures and policies "often stand as barriers to interdisciplinary research and education efforts" and refer to administrative concerns over the use of budgeted monies, difficulties evaluating interdisciplinary work, and the additional time it takes to integrate different perspectives in research, pointing to the career risks arising from such barriers. Scholars have shown that this rhetoric is persuasive in policy circles, despite few empirical studies demonstrating that disciplines are in fact silos constraining the flow of knowledge (Centellas et al., 2014; Frickel et al., 2017; Rhoten & Pfirman, 2007).

Other scholars emphasise limited resources and lack of funding for interdisciplinary research as institutional barriers for disciplinary transgression, in addition to lengthy start-up times, differences in departmental policies and procedures, and dissimilar academic cultures, for example, related to differences in methodologies and interdisciplinary norms (Boden & Borrego, 2011; Morse et al., 2007). Assessment regimes and the evaluation of inter- and transdisciplinary research are also considered to be institutional and structural barriers to disciplinary transgression. These include challenges with peer-review processes (Holbrook, 2017; Huutoniemi & Ràfols, 2017), performance indicators (Marres & de Rijcke, 2020; Müller, 2017), career systems (Felt et al., 2013, 2016; Hackett & Rhoten, 2009; Müller & Kenney, 2014; Schönbauer, 2020; Turner et al., 2015), and publication regimes (Müller, 2014, 2017; Sigl et al., 2020).

Scholars have also shown the pragmatic aspect of disciplinary transgressive practices. For example, Lamont (2009) argues that scientists are guided by pragmatic concerns. In his analysis of panelists' evaluation of research proposals, Lamont shows how, despite their evaluations being shaped by their respective disciplinary evaluative cultures (and by formal criteria), the panelists often give preference to the evaluation criteria valued in the applicant's discipline rather than in their own discipline. He uses the term 'cognitive contextualization' (p. 58) to describe this practice, arguing that the interdisciplinary character of the evaluation process "affects disciplinary arguments and shapes how panelists go about convincing one another of a proposal's merits (or lack thereof)" (p. 58). Thus, assessment and evaluation of research are often influenced by academic culture but not necessarily a barrier for interdisciplinary research.

Knorr Cetina (1981, 1999) describes different academic cultures using the concept epistemic culture, emphasising that disciplines may have very different orientations to their objects, social units of knowledge production, and patterns of interaction. She compares high-energy physics and molecular biology, arguing that knowledge production in high-energy physics is categorised by large groups that function as organisms for studying objects that are invisible without equipment and data simulation. In contrast, molecular biologists study observable objects in small-scale laboratories, and Knorr Cetina emphasizes that researchers' bodily skills are important for the research in a different way than for high-energy physicists. Such differences in epistemic cultures are often considered as hindering disciplinary transgressions because they are interwoven in the peer review processes, careers systems, and publication regimes mentioned above.

Consequently, disciplinary transgressive practices challenge metric-based academic assessments, such as performance indicators, and STS scholarship has emphasised indicators as an institutional barrier to interdisciplinary (de Rijcke et al., 2019; Lamont et al., 2006; Marres & de Rijcke, 2020; Ràfols, 2019). Interdisciplinary research is often evaluated less positively than disciplinary research in peer-review panels, and it has been argued that "performance indicators such as journal impact factors exemplify and consolidate this bias against interdisciplinary research, insofar as core disciplinary journals tend to perform better according to this popular metric" (Marres & de Rijcke, 2020, p. 1043). Scholars from the social studies of science have therefore called for increased attention to non-quantitative aspects of evaluation (as opposed to the prevailing metrics system), some proposing new typologies and qualitative indicators of research evaluation (Huutoniemi et al., 2010).

Despite challenges in assessing disciplinary transgression, peer review remains the principal tool for decisions regarding publication, promotion, tenure, and grant proposals, and for evaluating scientists, research groups, departments, and universities (Holbrook, 2017). This creates tension with the many demands for disciplinary transgression at universities and research institutions in recent decades because, in disciplinary practices, it becomes less clear who the 'peers' are. The lack of relevant evaluative criteria for inter- and transdisciplinarity – approaches that are recognised as necessarily tailored, flexible, and evolving – is thus considered a substantial barrier (Carew & Wickson, 2010).

Other institutional barriers for achieving disciplinary transgression described in the scholarship are related to career systems and to challenges developing an interdisciplinary career. Scholars especially emphasise this challenge for early-career researchers without a permanent and secure position in academia (Hein et al., 2018; Klein, 1990; Rhoten & Parker, 2004). Palmer (2001) shows how some senior scientists are hesitant to recommend an interdisciplinary career for early-career researchers who were planning to work within university structures, because being "too interdisciplinary" will lessen their chances of landing permanent positions, since the relevant hiring criteria are based mainly on disciplinary competences and skills. These findings suggest that engaging in interdisciplinary research often makes it difficult to build a scientific career. This forces researchers to constantly balance between disciplinary and interdisciplinary work in order to build a carrier in academia.

Proximity barriers

Another major area of research related to challenges for achieving disciplinary transgression is scholarship on cognitive and geographical distance as barriers to collaboration (Rekers & Hansen, 2015). Both cognitive and geographical barriers relate to proximity (epistemic and physical, respectively), and for simplicity I therefore collect them here as proximity barriers. I first describe cognitive/epistemic proximity.

MacLeod (2018) argues that institutional obstacles, such as those described above, make up only one possible dimension of what makes interdisciplinarity difficult, and that too little attention has been given to the cognitive difficulties of interdisciplinarity. Cognitive or epistemic barriers to interdisciplinarity refer to

> the more intellectual and technical cognitive, conceptual and methodological challenges researchers face coordinating and integrating background concepts, methods, epistemic standards, and technologies of their respective scientific domains—particularly in the context of collaboration—in order to achieve some benefit for solving specific problems or sets of problems. (MacLeod, 2018, p. 698)

Examples of cognitive challenges are the opacity of disciplinary practices to outsiders, conflicting epistemic values, and substantial conceptual and methodological divides (MacLeod, 2018; MacLeod & Nagatsu, 2018). Cognitive challenges in disciplinary transgression arise, for example, in collaborations between systems biologists with quantitative backgrounds and molecular biologists whose main skill is experimental manipulation (MacLeod, 2018, p. 706). Due to systems biologists' limited experience and training in biology and molecular biologists' limited training in mathematics and modelling, disciplinary transgression has proved challenging (Calvert & Fujimura, 2011; MacLeod, 2018). Nersessian (2019) emphasises the importance of cognitive flexibility and epistemic awareness to make interdisciplinarity work. She refers to cognitive flexibility as "the ability to see or understand a problem from different perspectives", and epistemic awareness as "the ability to reflect both on the epistemic dimensions of one's own discipline and research practices and on those of the collaborators" (p. 573).

A more direct focus on epistemic barriers appears in Palmer's (2001) empirical study of scientists in an interdisciplinary research centre. She shows that epistemic proximity is key when collaborating, and that epistemic distance can be a barrier even when physical proximity is not. Palmer emphasises different "styles of thought" (Fleck, 1927) and how during their education scientists learn a specific way of thinking. Similar findings appear in the descriptions of high-energy physicists by Traweek (1988), where challenges of epistemic proximity are apparent even for scientists within the same discipline.

That these epistemic barriers present considerable challenges within disciplinary transgression is perhaps not surprising, as such collaborations often involve a plurality of different styles of thought, to use Fleck's concept. These different styles of thought also include different epistemological aims. Calvert and Fujimura (2011) show, in examining the field of systems biology, that such differences in aims are often "the result of differences in disciplinary training, because scientists coming from different disciplines have different ideas about the aims of their research" (p. 156). Calvert and Fujimura argue that systems biology "needs to embrace epistemic pluralism if it is to successfully pursue its interdisciplinary agenda" (p. 156). In the context of doing disciplinary transgression in practice, we thus find a tension between the advantages of such pluralism and the epistemic barrier they often involve.

The second strand of scholarship on proximity barriers emphasises the importance of interactions through face-to-face encounters and meetings at the same geographical place for achieving disciplinary transgression in science (Allen & Henn, 2007; Cummings & Kiesler, 2005; Freeman, 2008; Hampton & Parker, 2011; Schönbauer, 2017; Vermeulen, 2018; Vermeulen & Bain, 2014). One key argument is that the physical proximity of scientists, such as scientists gathered at the same place or building, may compensate for epistemic distance between scientists from different disciplines (see, e.g., Boschma, 2005; Hansen, 2014 for the same argument in the private sector). In this vein, Rekers and Hansen (2015) argue that geographical proximity must be considered in order to overcome barriers of epistemic distance.

One example that illustrates the importance of proximity for disciplinary transgression is in Allen and Henn's study on walking distances and the communication frequency of collaborating engineers and scientists (2007). They developed the 'Allen curve', which shows that the probability of communication declines with distance – arguing that "a mere 50 meters' separation between people essentially results in the end of regular communication" (p. 63).

Policy makers and institutions are driven by the narrative of proximity-for-collaboration. This is evident in Palmer (2001), where the interdisciplinary research centre she studies was founded based on the assumption that creating "a place unrestricted by departmental barriers" (Palmer, 2001, p. 4) will reduce barriers between different disciplines. Institutions and policymakers have frequently deployed the strategy of co-locating scientists in research centres in order to facilitate interdisciplinarity in research (Hackett et al., 2021; Padberg, 2014; Vermeulen, 2018). For example, Vermeulen (2018, p. 1776) argues that co-locating scientists in research centres has been an important element in the institutionalisation of systems biology, and shows that the ideas behind these policies are circulating around the world:

> Through extensive lobbying of scientists and the creation of many science policy documents promoting systems biology, funding has been made available to establish integrative centres which bring together wet and dry biology in architecture that stimulates collaboration. This institutionalisation of systems biology followed the example of first institutes in Tokyo and Seattle and has been made possible by the development of science policy for systems biology in various countries (Vermeulen, 2018, p. 1776).

The Norwegian Life Science building described in chapter 1 is another result of this narrative. The question is whether geographical proximity does in fact create epistemic proximity.

In sum, scholarship on geographic proximity and disciplinary transgression has shown that geographical proximity of scientists is important but that it in itself is insufficient to facilitate disciplinary transgression. This topic is investigated further in the third research paper in part II of this dissertation.

Communication barriers

Another strand of scholarship emphasises communication between scientists with different disciplinarity backgrounds as an important barrier for disciplinary transgression. Communication barriers are related to epistemic distance, as communication challenges often result from misunderstandings grounded in different disciplinary backgrounds. Scholars have argued that communicative and epistemic challenges in inter- and transdisciplinary research can be an important reason why traffic of knowledge across disciplinarity borders often is challenging in practice (Bucciarelli, 1994; Collins & Evans, 2002; Galison, 1997, 2010; Klein, 2010; Star & Griesemer, 1989; Strathern, 2004). These scholars have focused on how such barriers can be overcome. Much of this scholarship describes different forms of traffic of knowledge, materials, and persons across disciplines. Here I briefly explain four concepts that have been influential in STS scholarship on disciplinary transgression: boundary objects, standardised packages, trading zones, and interactional expertise.

Star and Griesemer (1989) propose the concept of ‘boundary objects’ to describe how information is used in different ways in different communities, and how they “have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation” (p. 393).

Fujimura (1992, p. 169) uses the concept of ‘standardized packages’, which consist of “a scientific theory and a standardized set of technologies which is adopted by many members of multiple social worlds”. Drawing on Star and Griesemer (1989), she argues that a standardised package is a grey box that combines several boundary objects. Standardised packages can serve as interfaces for disciplinary transgression by allowing researchers to interpret theory and methods to fit their separate concerns under the same rubric.

Yet another take on interfaces of social interactions can be found in (Galison, 1997, 2010), where he proposes the metaphor of a ‘trading zone’ to describe how different cultures are able to exchange goods despite differences in language and culture. He explains how physicists from different paradigms collaborated with one another and with engineers to develop particle detectors and radars. Using the trading zone metaphor, Galison identified the development of interlanguages such as jargon, pidgin, and creole as systems of discourse for scientists. Key in developing a ‘creole’ (a common language) for well-functioning interactions is an agent who facilitates the trade, one who is familiar with both of the involved parties and who has developed interactional expertise. Interactional expertise is acquired through learning about other disciplines, enabling communication using acquired linguistic resources (Collins & Evans, 2002). Other ways of overcoming communication challenges are through boundary crossing (Klein, 1996), as well as through establishing scientific commons (Strathern, 2004).

To summarize, this scholarship shows that communication across borders is often seen as challenging in practice, but it also shows that disciplinary transgression is possible to achieve. The studies noted above provide examples of how such barriers of communication are overcome by those involved in various kinds of disciplinary transgression, for example, through metaphors describing how disciplinary transgression is achieved in various situations.

The scholarship outlined above shows that researchers studying disciplinary transgression have for the last 40 years specifically emphasised theoretical work to conceptualise and understand disciplinary transgression (MacLeod et al., 2019).

To summarise, previous scholarship on disciplinary transgression has focused on challenges and barriers for achieving inter- and transdisciplinarity, and on the strategies for overcoming them. Identifying barriers is certainly an important contribution to the understanding of disciplinary transgression. As we have seen in the scholarship outlined above, there is, however, also a need for more empirical knowledge on scientific practices that actually achieve disciplinary transgression in science. I turn to earlier research on this question in the next section.

2.3 Achieving disciplinary transgression

As outlined above, much of the existing scholarship on disciplinary transgressive practices identifies inter- or transdisciplinary tensions and challenges. We now turn to scholarship that focuses on how disciplinary transgressive practices are achieved. The previous section already contained some examples of this through the concepts of boundary objects (Star & Griesemer, 1989), standardised packages (Fujimura, 1992), trading zones (Galison, 1997, 2010), and interactional expertise (Collins & Evans, 2002).

In scholarship on how disciplinary transgressive practices are achieved, a common approach is to identify or describe scientists' strategies or coping mechanisms for inherent tensions related to working in inter- or transdisciplinary projects. (Felt et al., 2016; MacLeod & Nagatsu, 2018; Schikowitz, 2020; Woiwode & Froese, 2021).

There are many examples of this: Woiwode and Froese (2021) identify four strategies for how scholars in interdisciplinary research centres cope with monodisciplinary demands that often favour monodisciplinary research over interdisciplinary research: disciplinary innovation, strategic compliance, niche-seeking, and field creation. MacLeod and Nagatsu (2018) identify four integrative modeling strategies as responses to cognitive constraints in interdisciplinary work. Schikowitz (2020) argues that collective coping strategies are needed for dealing with tensions between different kinds of relevance in transdisciplinary research projects, but that such collective strategies were limited to modelling. Centellas et al. (2014) use the concept of calibration to describe a strategy that makes interdisciplinary collaboration without consensus possible, as it allows for management and socialisation of group members without undermining pre-existing disciplinary identities. Felt et al. (2016) show how researchers developed different strategies to address tensions between the valuing of collaboration with non-academic actors versus the values of scientific output, depending on their "career stage, their concrete institutional embedding and the predominant values there, and the role that the transdisciplinary project played in their overall research portfolio" (p. 753).

A body of literature discusses practices of disciplinary transgression in the context of specific research projects aiming to implement inter- or transdisciplinarity. Much of this scholarship focuses on synthesis or integration and how it is achieved (Bucciarelli, 1994; Defila & Di Giulio, 2015; Nersessian, 2019; Siedlok & Hibbert, 2014; Simon & Schiemer, 2015). In studies of disciplinary transgression – and, in particular, in the context of collaboration with or within the natural sciences – modelling is often seen as an important strategy of synthesis (Defila & Di Giulio, 2015; Nersessian, 2019; Schikowitz, 2020). For example, in her study of a transdisciplinary sustainable research program, Judith Igelsböck (2016) shows how projects use computer modelling and simulation to bring together knowledge. She understands computer simulation and modelling as "integration machines" and shows their performative dimensions (e.g., in their inclusion or exclusion of different kinds of knowledge, how they relate to responsibility, and in [re]producing roles and identities in the relationship between science and society). Modelling is thus one example of what disciplinary transgression can look like in practice.

Studies of specific research projects aiming to implement disciplinary transgression have provided important contributions to understanding practices in disciplinary transgression. Schikowitz (2020, p. 4) argues, however, that many of these studies "neglect the process of how researchers make sense of [relevance criteria] and how they translate them into practice”. I would argue that this also is the case for many studies of disciplinary transgression. I thus focus on more recent studies from STS perspectives that ask what knowledge and experiences are important for researchers in projects aiming for disciplinarity transgression (Barry & Born, 2013; Felt et al., 2013, 2016; Hackett & Rhoten, 2009; Schikowitz, 2020; Turner et al., 2015; Vermeulen, 2009, 2013). Felt et al. (2016) is an example of such a study.

In their study of transdisciplinary sustainability research in practice, Felt et al. (2016) identify three ideal models of science-society relations at work: the linear translation model, the delimited neutral arena model, and the temporary shared epistemic arena model. In the first model, “scientific and societal arenas are conceptualized as largely separated and situated at two ends of a spectrum of knowledge arenas that range from the production of knowledge to the consumption/application of knowledge” (p. 745). In the second model, the research arena is also delimited from the problem-related societal arena. In this model, the societal actors are regarded as strongly related to the problem to be solved, and are regarded as holding a degree of experience-based knowledge relevant to the problem. In the third model, the research arena is “functionally delimited but partly overlapping with the problem-related arena when addressing the tasks of producing, reflecting, and integrating knowledge” (p. 749). In this model, societal actors are conceptualised as knowledgeable agents. By investigating moments and practices of (dis-)entanglement, Felt et al. show what is needed for a transdisciplinary approach to knowledge production to be successfully practised. Felt et al. (2016, p. 734) conclude that, although there are funding schemes that 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’.

In this dissertation, I build on scholarship that focuses on the scientific practices of disciplinary transgression. I argue that decades of discussions of barriers and challenges show that making interdisciplinarity work in practice is the crux, and that doability (Fujimura, 1987), and knowledge of how the actual scientific practices work, are keys in understanding the mechanisms of disciplinary transgression. Consequently, I am mainly interested in *how* collaboration in science happens, rather than in only why this is challenging. By identifying various practices and showing some specific actions that result from interdisciplinary processes, as well as showing scientists’ motivations for disciplinary transgression, their understandings and sensemaking of research policies, and how additional knowledge may change underlying assumptions, my dissertation contributes to the scholarship on disciplinary transgression by illustrating what inter- and transdisciplinarity can be in practice.

The next chapter presents and discusses the methods and methodology for this research. Studying how disciplinary transgressive practices unfold in practice raises interesting methodological questions. In a special issue on interdisciplinary practices (2019), MacLeod et al. advocate a much more concerted effort to empirically observe, document, and analyze interdisciplinary practices, asking what various methodological perspectives have to offer and contribute to our understanding of interdisciplinarity, as well as to our evaluations and expectations of it (see also Nersessian, 2019, in the same issue). In the following, I present my methods and analytical strategies used for studying how disciplinary transgression in science is achieved.

3

Methods and methodology

3.1 Introduction: Studying disciplinary transgression in Norwegian biotechnology

This chapter describes the research methods used for data generation and offers some methodological reflections on the research analysis. All four research papers in this dissertation have their own methods section explaining the most important methodological choices taken in each of these studies. The limited space for methodological discussions in research articles, however, is not well-suited for deeper reflections about the research process. In this chapter, I provide reflections that encompass the entire research process, in addition to delving more deeply into data generation processes and the data analysis employed. The chapter opens with reflections on the advantages and disadvantages of ethnography and interviews, respectively, before outlining the processes of data generation and data analysis. The chapter closes with methodological reflections on the affective challenges of doing fieldwork.

Three methods were used to generate the research data for this dissertation. The main part of my research consists of ethnographic fieldwork through participant observation at various sites connected to the Centre for Digital Life Norway (DLN) and its activities from 2017 to 2021. Secondly, I conducted 26 semi-structured interviews with scientists in DLN, and two focus group interviews. Thirdly, I performed a document analysis of key policy documents connected to DLN, RCN and to disciplinary transgression in science, and content analysis of the DLN website.

As noted in chapter 1, the research design followed an actor-oriented approach in answering the overall research question. This means that I have been interested in actors' practices and meaning construction, and that I have chosen to devote attention to the actors' movements, activities, and sensemaking in their local context rather than focusing on the system itself. I have focused on what the actors – mainly scientists within Norwegian biotechnology research – do in practice, how they construct their research practices, and what happens in their social interactions with one another. I have thus observed scientists' actions and interactions and compared these with the scientists' own perspectives and sensemaking of what they do, how they do it, and why they do it. This was then seen in the context of the current policy landscape aimed at shaping and steering research toward increased collaboration. When following the actors, I also paid attention to the non-human actors, such as machines, materials, and places, and to the relationships and networks between these and the human actors (inspired by, e.g., Latour, 2004).

The main method for data generation has been ethnography. Ethnography is a systematic approach in the social sciences that aims to explore what people think, and it investigates the cultural meanings they use daily.[1] Ethnography leads the researcher into "those separate realities which others have learned and which they use to make sense of their worlds" (Spradley, 1980, p. vii). Investigating disciplinary transgression and, more specifically, practices related to disciplinary transgression in scientific research, could be approached in various ways, and alternative methodological approaches each have their advantages and limitations. The question is then this: what insights can different methodological perspectives generate in the context of disciplinary transgression? (MacLeod et al., 2019).

An ethnographic approach to science "is particularly apt for in-depth exploration of embodied skills and step-by-step reconstructions of knowledge generation" (MacLeod et al., 2019, p. 547). Furthermore, scholarship has shown that it is well-suited to explore the tacit and embodied sites of knowledge, that is, the experience-based knowledge individuals acquire from performing an activity that is difficult to explain in words (Polanyi, 1966; Spradley, 1980). Furthermore, ethnographers have the advantage of

[1] I follow Spradley (1980, p. 6) in defining *culture* as "the acquired knowledge people use to interpret experience and generate behaviour."

directly observing a variety of interactions, and Lamont and Swidler (2014, p. 159) argue that “for the study of interactional dynamics in natural settings ethnography is superior to interviews”. Finally, I considered ethnography as a relevant method for investigation because following actors over time yields access to narratives other than merely coherent narratives; that is, it opens for seeing the narratives of “contradiction and unpredictability that real lives normally encompass” (Lamont & Swidler, 2014, p. 163).

Doing ethnography had many advantages for investigating the research question of how disciplinary transgression is achieved. I supplemented the ethnographic fieldwork with interviews and document analysis to gain additional understanding of how scientists related to disciplinary transgression in their work.

Within STS, the traditional anthropological fieldwork has been important for developing the field and has specifically played a major role in STS research on science and scientific practices (Knorr Cetina, 1981; Latour & Woolgar, 1979; Rabinow & Bennett, 2012; Traweek, 1988). These studies have inspired a variety of ways of doing and conceptualising ethnography within STS. Examples are shadowing (Czarniawska, 2014), participant comprehension (Collins, 2019), and co-presence (Beaulieu, 2010). All of these are ethnographic approaches that have challenged both the idea of a long-term fieldwork and, furthermore, the idea that fieldwork must be tied to a physical place where researchers do ethnography. The fieldwork in this dissertation was inspired by these approaches in my study of disciplinary transgressions in Norwegian biotechnology.

3.2 Research site: Centre for Digital Life Norway

This dissertation is based on research done in, and in the context of, the DLN, a national centre for biotechnology research that was established in 2015 as part of a strategic effort from the Research Council of Norway (RCN) to develop Norwegian biotechnology. DLN was part of the Digital Life initiative (DL) (RCN, 2014), which was itself part of the larger BIOTEK2021 research programme. BIOTEK2021 had a distinct innovation-oriented profile, and its objective was to generate biotechnology “that contributes to innovation and subsequent value creation in order to solve societal challenges in a responsible manner” (RCN, 2014, p. 5).

The aim of the DL initiative was consistent with the goals of BIOTEK2021: ‘to create economic, societal and environmental value in Norway from biotechnological research and innovation by encouraging transdisciplinary research" (RCN, 2014, p. 3). DLN was seen as crucial in creating a transdisciplinary networked biotechnology community and was conceptualised as "a national 'lighthouse', guiding the way in transforming biotechnology research and innovation in Norway" (RCN, 2014, p. 10). Transdisciplinarity, innovation¸ digitalisation, and responsible research and innovation (RRI) were cross-cutting issues in the centre and were seen as contributing to this transformation. Transdisciplinarity was seen as the key approach for achieving the aim of value creation and transforming biotechnology. Figure 1 illustrates how DLN was conceptualised in the strategy document.

DLN began with six funded research projects in 2015 but gradually expanded through new funding calls for projects over the next years. In 2021, the centre consisted of a national networking project to organise the day-to-day task of the centre, 17 directly funded research projects and 18 associated research projects, as well as a research school and a strategic innovation project. In total, more than 500 million NOK in public funding was invested in DLN.

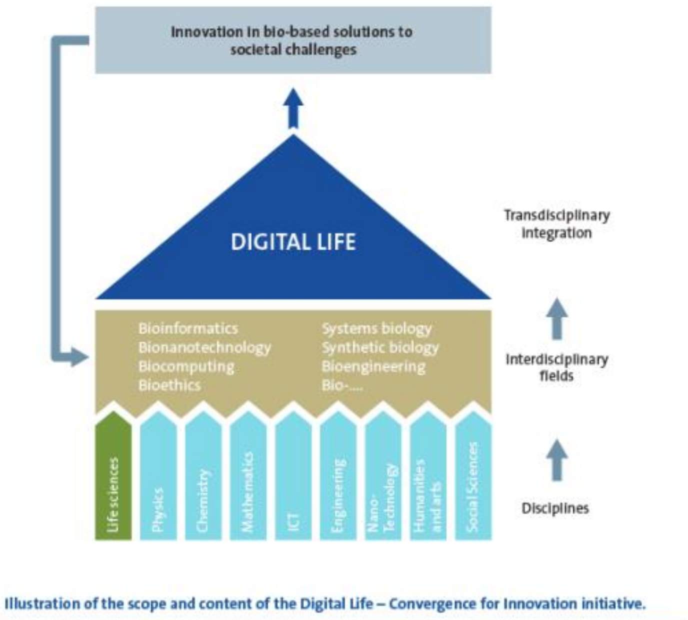

Figure 1: Illustration of the Digital Life initiative (RCN, 2014, p. 8)

DLN was organised as multi-sited centre. This means that, rather than the members working in one building, the networking project and research projects were located at universities around Norway. One result of this was that the networking project organised initiatives and events around the country. Consequently, like the DLN structure, my research was also multi-sited (see, e.g., Falzon, 2009; Marcus, 1995). I thus travelled around Norway to participate in various events and to meet with scientists and research projects located in other cities.

3.3 Data generation

Fieldwork

I began the ethnographic research in a specific DLN research project that aimed to develop novel strategies for microtissue engineering in 3D. There, I did ethnography in the laboratory at the department of biotechnology at the university where this project was located. In addition to helping and observing in the lab, I attended meetings, workshops, and other activities, taking extensive field notes in the office I shared with five early-career researchers in biotechnology. I was linked to this project through a 20% position in a work package related to RRI. This had implications for the fieldwork and thus for the research process.

According to Spradley, communicating the goal of our research is often "a process of unfolding" (1980, p. 22), rather than something the researcher declares to your research subjects (and perhaps also to yourself) once and for all. Because you seldom know what is important for the persons you study, it is difficult to know in advance, when you are still in the field, how to best present your research. Because of my link to RRI in the project, the topic of RRI always came up in my early interactions – either the scientists or I mentioned it. After some weeks at the department, I realised that the term 'RRI' was something of a conversation-ender: as soon as it came up, the conversation quickly stopped or made an abrupt turn. Some scientists I talked to became bored and restless, soon changing the topic or going somewhere else. Others became unsure and hesitant, afraid of saying something wrong or being misunderstood, and others had very strong opinions, either praising RRI or declaring it irrelevant (often on the grounds that they felt that the ethical practices it included was something they already did). Still others expressed boredom and disinterest in the topic altogether. In this way, I felt that the term ‘RRI’ narrowed down my ethnographic data.

During the initial round of fieldwork at the biology department, I therefore decided to extend and alter my focus from calling it ‘RRI’ to renewing the focus on inter- and transdisciplinarity. This change made sense on many levels. Firstly, the decision was a result of my ethnographic observations and field notes, suggesting that RRI and collaboration was closely connected. Secondly, it helped me sort out my challenging dual role: doing RRI in the project while studying it. When I started to present my research, saying that I researched inter- and transdisciplinarity, scientists responded very differently compared to when I (or others) said that I researched RRI. In my experience, the scientists I talked to then spoke more freely around topics related to their everyday research practices, also those connected to RRI. RRI was — unlike inter- and transdisciplinarity — perceived by many as yet another top-down research policy buzzword that implied that scientists are not sufficiently responsible in their practices. I found that approaching scientists’ practices by talking about collaboration was more fruitful than approaching it using the term ‘RRI’. As collaboration is a key aspect of RRI and can also in some ways be considered a specification of RRI, this shift also made sense on a conceptual level. The shift in my research toward disciplinary transgressions was communicated to the project leader and project group both at project meetings when I presented my work and in informal conversations.

After the ethnographic study, I continued my empirical exploration by conducting interviews in this and two other DLN projects (described in the next section). I return to this when discussing the interviews more in detail, but the choice of doing interviews was originally based on the need to talk to scientists in the first project that I did not meet during my ethnographic work. Conducting interviews was thus a way of gaining access to other scientists their perspectives and of generating data for comparing the DLN projects. In parallel and in the period after conducting interviews, I followed the movements in DLN related to disciplinary transgression by participating in conferences, meetings, workshops, centre evaluations, and courses. I also took part in organising the second annual research school conference and a DLN walkshop (for an explanation, see Wickson et al., 2015).

In the last quarter of 2020, I did participatory observation in the Networking Project, the leadership group of DLN, working on a report on transdisciplinarity. During these three months, I conducted several informal interviews with the DLN leader and others in the networking project and attended weekly group meetings and discussions on the everyday organisation of the centre. This fieldwork provided insights into the organisation's priorities and decision-making. This allowed me to extend my attention and focus of investigation gradually from a specific research project focus to looking at the centre and its activities as a whole. All participant observation was documented by fieldnotes (see Emerson et al., 2011) generally written the same day or the day following fieldwork. For more intense periods of fieldwork (e.g., during the walkshop), for practical reasons I took only brief notes during the activity and then wrote more detailed notes and reflections after the event.

When following the movements in DLN, I started out using the snowball method to reach scientists. This entails that each new person you get to know leads you to others, hence you gradually pick up momentum and extend your perspectives and network as the "snowball" rolls. After doing the interviews, and thereby being in contact with many scientists at universities around Norway, these contacts further introduced me to new environments and perspectives.

A challenge of doing ethnography in this way is that the researcher is in danger of meeting mostly persons similar to themselves. In my case, this would be early-career researchers, specifically PhD students belonging to the same age group and life situation. I met this challenge by participating not only in social events but also in fora with explicit scientific focus, such as courses, seminars, and workshops. Doing interviews was also a way of meeting this challenge. This helped me to also come in contact with scientists who were not as talkative or outgoing as the persons I first got to know during my fieldwork – persons I might not have met by adhering just to the snowball method.

The persons I encountered in the field can be divided into three groups: key actors, closer actors, and distant actors. The latter consisted of scientists I met at various DLN events or talked to once or twice during my research. This group should not be dismissed, although I spent little time with them. Various encounters with persons in this group resulted in valuable information about the field, such as common topics and widespread narratives and beliefs in the community. The closer actors consisted of scientists and employees in DLN with whom I spoke regularly during my research. This group consisted of PhDs, postdocs, researchers, professors, lab technicians, and administrative employees in DLN of various genders and nationalities. Five key actors were of particular importance during my research. They were active in assisting me with information about things that happened, with access and invitation to social and scientific settings, with putting me in contact with other relevant persons, and with explaining practical and scientific issues. Two of the five were important gatekeepers within DLN; towards the end of my PhD, I could also discuss my research findings and gain useful feedback from these two.

Interviews

In total, I conducted 26 semi-structured interviews and two focus group interviews with scientists of diverse disciplinary backgrounds and positions, including PhD students, postdocs, lab technicians, associate professors, and full professors (see details in table 1). Interviews are another way of gaining access to others' observations: their experiences, perspectives, reflections, and what they think and feel regarding events (Weiss, 1994). Furthermore, interviews often result in access to what respondents themselves think is important for the interviewer to know or that they think the interviewer wants to know, which is more difficult to obtain from shorter fieldwork (as compared with the ideal of the long-term anthropological fieldwork).

The interviews can be divided into two phases: firstly, 22 interviews held in the three individual DLN research projects during 2018-2019; secondly, two focus group interviews and four individual interviews conducted in 2020. The first and second phases of interviews were based on different sets of interview questions, although all focused on disciplinary transgression.[2] The questions in the first phase of interviews (which were all individual semi-structured interviews) were designed primarily to investigate how the scientists related to one another within the research project and beyond: how often and how they were in contact with other group members, how they transferred information within the project, if they had experienced any situations of misunderstandings related to working together, and so on. In addition, these interviews included some questions about RRI, specifically asking for the scientists' understandings of RRI and if/how they

[2] See appendices for the specific interview guides.

addressed RRI in the project and in their everyday work and in external actor collaborations.

Table 1: Overview of interviews and interview participants

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

	Medical doctor	PhD
	Cardiology	Postdoc
	Innovation	Postdoc
	Biology	Professor
Focus group interview 2 (face-to-face)	Cybernetics	PhD
	Biophysics	Researcher
	Biotechnology	PhD
	Biotechnology	PhD
	Medical Technology	Postdoc
	Microbiology	PhD
Individual interview (face-to-face)	Biology	Professor
Individual interview (face-to-face)	Systems Biology	Researcher
Individual interview (face-to-face)	Organic chemistry	Researcher
Individual interview (digital)	Physics/Biology	Researcher

Conducting interviews was motivated by the prospect of gaining a more systematic overview of the tissue-engineering research project with insights from the various scientists in the project. The scientists in this project were not co-located, which meant that since I was placed at the biotechnology department, my understanding of the project was biased toward the understanding of the scientists working in that department. In this phase of the research, I extended my scope to other research projects in order to have a basis for comparison. This led to interviews in two additional DLN projects and to a total of 22 interviews in these projects. The three research projects (henceforth called A, B, and C) were located in different cities and researched different things: project A conducted neurology research, investigating the mechanisms underlying brain diseases; project B was the tissue engineering project already mentioned; project C was an environmental toxicology project using Atlantic cod to monitor the environment in Norwegian fjords and to assess the risk during release of potential pollutants. These projects are described more in detail in the second research paper in part II of the dissertation.

Kristensen and Ravn (2015) remind us that the recruitment process significantly influences research results, and they argue that reflections on recruitment are often understated in research projects. In my case, the recruitment of projects A and C was based on the projects’ engagement and interest in disciplinary transgression. The recruitment process was guided by participant observation at various DLN events that made me aware of these projects. Moreover, I used the personal contacts that I had established with scientists in these projects during my fieldwork to gain access to the projects. The project managers were of particular importance for access.

My interviews in the three DLN research projects followed the same form and structure, ranging from 40 to 75 minutes, most lasting approximately 1 hour. For the interviews to be comparable, I followed a common structure for each interview, which I then made more specific with individualised follow-up questions. Although the interviews were similar, the experience of interviewing differed. This was mainly the result of my varying familiarity with the projects before the interviews.

In project B, I interviewed scientists I knew very well, having both been a member of the project for close to a year, and having done participant observation before conducting interviews. I was quite familiar with project C, as I had met several of the project members more than once at various events in DLN and had been doing approximately two weeks of ethnographic observations in the group before I conducted the interviews. I was not as familiar with project A, and I had spoken with the project leader only once before I conducted interviews in that project.

Hence, the background information I had before doing the interviews varied. One result of this was that the interviews in project B and C yielded richer data, and I found it easier to ask specific follow-up questions that related to specific practices in the project. Another result was that I felt more confident in my early processing and interpretation of the data from project B and C compared to project A. I compensated for this by planning to return for follow-up interviews during April and May 2020. Unfortunately, the outbreak of the COVID-19 pandemic prevented these from proceeding as planned. I compensated by instead rescheduling the interviews digitally to ask follow-up questions.

The second phase of interviews was informed by the first round, building on my experiences of which questions had worked (in the sense of yielding rich data and allowing the scientists to talk freely about specific topics) and addressed gaps in the material, for example, the relation to similar topics (e.g., RRI and innovation). The second phase also addressed broader topics related to disciplinary transgression, such as organisation (e.g., "to make scientific collaborations work, how should they be organised?") and funding ("what kind of project support or funding is suitable for making science collaborations work?").

The second phase was planned as focus group interviews, and the interview guide thus adjusted to allow for discussion amongst the scientists by asking direct but open questions regarding disciplinary transgression. Due to COVID-19 restrictions, two of the focus groups were cancelled, and four individual semi-structured individual interviews were held with scientists who had planned on participating in the (now-cancelled) focus groups. Three of these interviews were held face-to-face, and one digitally. I did these interviews as part of a three-month position in DLN where I was hired to lead the work with a white paper on transdisciplinarity in DLN (see Hesjedal & Strand, 2021).

All interviews in this phase lasted between 60 and 90 minutes. The first focus group was made up by seven scientists (three professors, three postdocs and one PhD student), three men and four women. The second focus group consisted of six scientists (one researcher, one postdoc, and four PhD students), four men and two women. The remaining four interviews were with two professors, one researcher, and one postdoc; three men and one woman.

Documents

In addition to data generation through ethnographic fieldwork and interviews, I generated data from written documents. Firstly, I used the DLN website actively for collecting information on events, initiatives, and funding calls, as well as information on how DLN presented itself to the public. Secondly, I selected three policy documents for study. These were "Digital Life – Convergence for Innovation" (RCN, 2014), an RCN policy brief titled "Interdisciplinary research: constructing a level playing field" (von Krogh et al., 2019), and the OECD "Addressing societal challenges using transdisciplinary research" (2020) document. These documents were chosen because they explicitly targeted disciplinary transgression and provided insights into different conceptualisations of inter- and transdisciplinarity. The documents increased my understanding of the policy landscape of disciplinarity transgression and provided a comparison to the DLN scientists' scientific practices.

I see the use of different sources in my dissertation as a method assemblage (Law, 2004). Law sees assemblage as a "process of bundling, of assembling, or better of recursive self-assembling in which the elements put together are not fixed in shape, do not belong to a larger pre-given list but are constructed at least in part as they are entangled together" (p. 42), and method assemblage as "the enactment or crafting of a bundle of ramifying relations that generates presence, manifest absence and Otherness" (p. 42). MacLeod et al. (2019) argue that since different methods mobilizes different relevancies, the use of different methods stimulates further investigation, and that, by consequence, "a richer understanding of interdisciplinary practice is engendered." (p. 548).

3.4 Data analysis

The research in this dissertation adheres to a grounded approach to research design and data generation (Charmaz, 2006). The data analysis is, however, mainly approached abductively (Reichertz, 2007; Tavory & Timmermans, 2014). Taking an abductive approach means that the analyst engages in recursive movements, that is, she continually goes back and forth between the empirical data and existing research and theories. In this process, the analyst refines research objectives, analytical focus, and analytical categories (Tavory & Timmermans, 2014). This means that analyzing data requires that we "pitch our observations in relation to other potential cases, both within and outside of our field. As these potential cases are then checked against other experiences, we amend them and generalise anew, thereby creating more potential, ad infinitum" (Tavory & Timmermans, 2014, p. 4). The abductive approach resembles what Tjora (2017) calls stepwise-deductive induction (SDI). This method is based on an inductive principle, where the analyst moves from raw data to concepts or theories through incremental deductive feedback loops (p. 17).

The fieldnotes were analyzed though three steps. First, they were re-read several times during and after the data generation phase to avoid biased memories and "the imposition of preconceived ideas on observations" (Tavory & Timmermans, 2014, p. 54). In this process of (re)reading, I emphasised some observations, situations, and topics as a way of coding the data, and I created empirical-analytical reference (EAR) points (Tjora, 2017, p. 204). EAR points are empirical sections (e.g., observed situations or interview sequences) "that can arise early in research projects and that indicate a possible development of analytical concepts" (p. 257, my translation). When writing fieldnotes, I always left one blank page for each page written, in order to have room for further notes and reflections – both empirical and theoretical – about the situations later. These pages were important for the first step of analysis, as they guided the next step.

Secondly, the fieldnotes were written up as texts summarising reflections and empirical examples of emerging topics, drawing on both descriptions and reflections of situations. These topics were identified by noting reoccurring situations and topics of conversations in the fieldnotes (see Spradley, 1980). Examples of such reoccurring topics are struggles with understanding RRI (e.g., expressed through direct questions about RRI or expressions of annoyance with the concept), challenges with disciplinary transgression (e.g., how to bridge disciplinary gaps between biologists and bioinformaticians), or affective aspects of disciplinary transgression (e.g., expressed through notions of fun, observed interactions and emerging friendships between scientists, affective reasoning for motivation for participation in events, and expressions of irritation, annoyance, and boredom).

Thirdly, I theorised through invoking sensitising concepts, that is, concepts that give the analyst "a general sense of reference and guidance in approaching empirical instances", suggesting directions instead of providing prescriptions of what to see (Blumer, 1954, p. 7). Examples of such sensitising concepts from my analysis included espoused theory and theory-in-use, convergence, inter/transdisciplinarity, interactional expertise, co-production, standardised packages, boundary objects, socialisation, and epistemic space. The use of various sensitising concepts allowed me to shed light on different aspects of my empirical material and vice versa. To avoid the trap of "becoming overly fond of these preliminary analytics" (Clarke et al., 2017, p. 122), and to resist premature analytic closure, I did not take the sensitising concepts as endpoints but continued to analyze the data to develop other analytical and theoretical points. In this third step, I wrote texts in which I related sensitising concepts to the empirical data and used the concept to guide the reading of both fieldnotes and interviews. Some of these analytical processes were then developed further in the research papers (such as espoused theory/theory in use in paper 4, and the development knowledge transfer and flows in paper 2), usually a decision taken based on the richness of the data, relations to existing scholarship, personal interest, and discussions during supervision meetings.

Turning now to the interviews, these were transcribed, printed in hard copy, and in the first instance analyzed similarly to the fieldnotes, that is, by identifying recurring topics, and situations emphasised by the scientists as a way of coding the data. After this step, the interviews from the first phase were analyzed by open coding and memo writing (see Holton, 2010) in the coding program NVivo. I mainly used NVivo to explore and identify interesting relevant themes in the data by generating broad codes targeting the interviewees' statements, opinions, and arguments. I coded for organisational or intellectual challenges and barriers, interdisciplinary interactions, conflicts within the research group, and conflicts with the home university, with DLN, or with RCN. I used memos — that is, "theoretical notes about the data and the conceptual connections between categories" (Holton, 2010, p. 32) — to develop ideas that emerged from the data material, and to guide my next steps in further data generation and analysis. For example, the idea of affects and emotions came initially from a memo I had written when analyzing fieldnotes that described an encounter between two scientists at a conference dinner. This memo guided the further data generation, coding, and analysis, and led me to investigate affective aspects further in the interviews. Memo writing also led me to investigate existing scholarship on affect and emotions, before returning into the field. This resembles Clarke et al.'s (2017) description of memos as the researcher's conversation with and about the data. In the next step, the codes were grouped thematically in categories to form a preliminary structure for the analysis (see Tjora, 2017). As advocated by Tjora (2017, p. 207), this was done by collecting codes with thematic links into groups and by excluding codes I considered irrelevant. The categories were stabilised by more focused coding to saturate the category theoretically (Holton, 2010). The categories were central for what was developed as topics in the research papers and were used as a basis for asking "what is this an instance of?" (Tjora, 2017, p. 211), that is, as an abductive approach for finding more general labels and concepts for the situation or phenomenon.

The interview data were also used for theoretical sampling and re-examination of topics identified in analysis of fieldnotes. Theoretical sampling is a method used in grounded theory to seek additional data based on concepts developed from previous data analysis (see, e.g., Charmaz, 2014). For example, when I had identified affective aspects in the fieldnotes, I did theoretical sampling in the interviews, and coded for situations of emotion, scientists' affective expressions when talking about people or situations, also noticing when emotion and affect were not expressed. In analyzing the interviews, I also used sensitising concepts to move from empirical data to theories, as described in the fieldnotes analysis.

The interviews from the second phase were analyzed in much the same manner as in the first phase, but without the use of NVivo. The analysis of all interviews thus followed the same pattern, and one example of how this was done appears in table 2. The coding of the second phase of interviews was also discussed in a data interpretation group consisting of colleagues at my department (mainly PhD students), held 1-2 times every month, where one participant at a time brought excerpts from their data to discuss and analyze together.

Table 2: Example of open coding of interview data.

Content	**Codes**	**Category**
Honestly, I don't know, but if you asked me about trans- – for example, in my case, AI and responsibility and innovation [RI] – they are different things all together. Yeah. So I think in that case I would say trans. But for instance, among us in the data sciences, maybe we'll have different aspects of it, then we maybe say interdisciplinary, maybe it's the same data science, but very broad. So maybe trans- is when you go completely out of your comfort zone, so they know that you don't have knowledge, but with inter-, you probably have knowledge but maybe not in your core area. Kind of, yeah. I'm just guessing – it could be so just from the basic trans and inter. I could be wrong.	*Proximity to other fields *Different things and aspects *Out of comfort zone *Not having core area knowledge *Guessing/uncertainty regarding inter/transdisciplinary terms *Sensemaking	Transdisciplinarity as collaboration with disciplines far from your own.

In addition to the analysis of fieldnotes and interviews, I analyzed data collected from written sources: the DLN website and three policy documents. These documents were analyzed by content analysis. The DLN website was, for example, analyzed by content analysis, identifying DLN activities done under the heading of transdisciplinarity to complement the ethnographic and interview data. Central to the reading of the policy documents was the idea that documents reflect beliefs about scientists' practices, even though these beliefs may not be explicitly stated, and that documents thus construct meaning also by what is implicitly left out of the text (Law, 2004). When analyzing these documents, the focus was to understand the main priority of the initiatives or approaches they described, main normative underpinnings for these priorities and initiatives, and the type of data used to underpin them. Of these three, the DLN strategy document (RCN, 2014) became the most important, as it was key to understanding the policy background for the Digital Life initiative. The analysis of this strategy was guided by questions such as "why do Norwegian biotechnology need a transformation?", "what does this transformation entail?", "who are the actors that will drive this transformation?", and "how is disciplinary transgression conceptualised?"

I consider my participation in a variety of DLN arenas an advantage for my analysis, as it provided me with data from different perspectives on disciplinary transgression in DLN – not only at the research or policy level, but also at the levels between, where scientists and DLN operated. Together they covered different levels of the centre – the individual experiences of scientists, the research projects, the project-transcending work in the Networking Project, and the policy strategy behind the Digital Life initiative – creating an assemblage of the disciplinary transgression efforts DLN engaged in and the wider context.

3.5 Emotions and affects in research: Final reflections

The role of emotions and affects in science has recently been given more attention within STS, with studies highlighting how these always are at play in science. We return to this topic in the third research paper, and investigating affective aspects in disciplinary transgressive practices have allowed me to reflect about the roles of emotions and affects in the research process.

Researchers' own feelings and relations to the persons they study are seldom discussed (notable exceptions are some detailed fieldwork accounts from anthropologists). The researcher's affective dimensions and relation to participants always matter in qualitative research and should be reflected upon – especially in the context of ethnographic fieldwork, where the boundaries between "study subjects" and friends, fieldwork and non-fieldwork oftentimes become blurry. Affects and emotions were not only important for choices taken regarding science collaborations by the scientists in my research, as described in paper 3. They undoubtedly also influenced my own decisions during fieldwork.

Parker and Hackett (2014, pp. 558-559) remind us of the intricate ways emotions and affects influence the qualitative researcher in her research:

> Finally, *feelings about participants* matter. Fieldworkers are expected to become emotionally involved in their subject, though the degree to which such involvement is expected varies. Feelings about study subjects—note the clean, emotionless, objective ring to that term—shape the conduct and findings of field research. Feelings of sexual attraction, anger, boredom or moral judgment determine in part how one apportions their attention to different aspects of the field site. In many cases there is also a strong need to suppress and manage the expression of such deep emotional experiences, requiring significant psychic energy.

This quotation resonates well with my own experiences researching disciplinary transgression in DLN. Managing the emotional and affective aspects of participant observation requires reflection and attention throughout the research process. The longer you stay in the field, and the closer the ties you create with the persons there, the more difficult it often becomes to maintain balance between your research interests and your relations to your study participants. Engaging in your research field in this manner raises some challenges that often are less visible when doing, for example, interviews, as the interview situation often is much more clarified than the presence of a participant observer in the field over time.

Since emotion and affects are often considered to be private, supported by how traditional methods elide the fact that private feelings shape our behaviour in research to create a "platina of objectivity" (Parker & Hackett, 2014, p. 557), it is not evident what is relevant for the researcher to address in a discussion on methodology. There are many examples of situations that influence the researcher and her choices in the field that are rarely openly discussed: What happens when the researcher become close friends with the persons she studies during the research process? What happens when a cultural difference makes it difficult for a participant to accept the researcher (or vice versa)? What happens when research participants develop romantic feelings for the researcher (or vice versa)? What happens when the researcher has a fallout with a gatekeeper or key person? What happens when a serious personality conflict develops between the researcher and a participant? These are just a few examples of such situations.

Parker and Hackett (2014, p. 557) suggest "being as honest as possible about one's own feelings and biases" as the way to address how emotions and affects influence the research process. In my experience, this means that you as a researcher must confront the persons in your study (and yourself) with sometimes uncomfortable truths, for example to keep reminding participants who have become friends about your role, motives, and the fact that they are still part of your research project. This back-and-forth between researcher and the persons she studies requires delicate social abilities from the researcher, and sometimes considerable emotional labour. It also requires mutual trust between participant and researcher, and thus careful ethical consideration, for example knowing when something is said in confidence without this being stated explicitly and therefore should not be part of your paper – no matter how interesting you find it.

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Up to this point, I have outlined the landscape and context of my research, presented my research questions, described previous research on disciplinary transgression, and introduced and discussed the methods my research is based on. The second part of the dissertation consists of the four research papers that the dissertation is based on.

PART II

Paper 1

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

Authors: Maria B. Hesjedal and Heidrun Åm

Status: In revision in *Science and Public Policy*

ABSTRACT Transdisciplinarity is a much-used concept in research policy to emphasise an urgent need for new collaborations in science to solve societal challenges. However, scholars have argued that the lack of a common definition of transdisciplinarity is a major barrier for achieving such collaborations and have identified a need for detailed empirical studies. The paper explores the translation of policies on transdisciplinarity and analyses the diverse meanings scientists made of the term, asking: how do scientists interpret transdisciplinarity, and what do transdisciplinarity policies mean for their work? The paper is based on an empirical study of a Norwegian biotechnology centre founded to stimulate a transition in biotechnology research towards transdisciplinarity and digitalisation. Drawing on the concept of translation and interpretive methods, we identify three interpretations of transdisciplinarity, as well as fears of negative impact on academic careers. We conclude that the science policy idea of 'transdisciplinarity' can fade away in practice.

This paper is awaiting publication and is not included in NTNU Open

Paper 2

Relying on relay: Flows in interdisciplinary collaborations in biotechnology

Authors: Maria B. Hesjedal and Knut H. Sørensen

Status: Submitted to *Social Studies of Science*

ABSTRACT Funding agencies demand interdisciplinarity in research. Achieving interdisciplinarity in practice has, however, proven to be challenging. In this paper, we analyse how scientists working in biotechnology research describe their collaboration across disciplines. We study how they make materials and data flowing to learn more about interdisciplinarity, asking how flow practices may be characterised and what kind of communication skills that participants need to facilitate flows. The paper is based on 22 qualitative, semi-structured interviews and ethnographic observation at the Centre for Digital Life Norway (DLN). DLN is a national biotechnology research centre established in 2015 consisting of 17 large research projects and 19 associated partner projects. The paper develops the metaphor of *relay* to describe the interdisciplinary epistemic machineries of three different DLN projects and discusses implications of organizing research as scientific relays.

This paper is awaiting publication and is not included in NTNU Open

Paper 3

Socializing scientists into interdisciplinarity by place-making in a multi-sited research center

Authors: Maria B. Hesjedal

Status: Accepted in *Science, Technology, & Human Values*

ABSTRACT The importance of physical place for interdisciplinary research collaborations are often taken for granted by scientists and policymakers. One result of this is a trend of funding interdisciplinary research centers where scientists are co-located in the same building. Previous research findings on the matter are, however, ambiguous, and show that though geographical proximity clearly matters, proximity is insufficient to foster interdisciplinary collaboration. This paper is based on an ethnographic study of a multi-sited Norwegian biotechnology research center – the Centre for Digital Life Norway (DLN), funded in 2015 to stimulate a transition in biotechnology research towards inter- and transdisciplinarity and digitalization. The multi-sited character makes DLN different from the much-studied trend of co-location of research groups in research centers. The paper asks: how are scientists socialized into an interdisciplinary mentality in a multi-sited research center? The analysis focus on three aspects: place, socialization, and the role of affective features and experiences. The paper's main contribution is to demonstrate the role of place-making in motivating for inter- and transdisciplinary collaboration, in particular by allowing for development of affective relations among the participating scientists.

Introduction: Placed scientific collaborations

Place is believed to matter for interdisciplinary[a] research collaborations. Examples abound of the underlying assumption that co-location – gathering scientists in the same physical place – will facilitate and improve collaboration across disciplinary borders (Palmer 2001; Frickel, Albert, and Prainsack 2017; Hackett et al. 2021). Nevertheless, previous research findings on the importance of physical place for interdisciplinary

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[a] I use interdisciplinarity to describe what occur when scientists and scholars from two or more disciplines or professional fields, engage in combining, exchanging, or integrating concepts, data and methods.

collaboration are ambiguous. On the one hand, economic geography scholarship claims that “geographical proximity, or spatial colocation, increases the opportunity for frequent face-to-face interactions between partners” and that this is fundamental for the establishment of trust and “reduce[s] communication costs” (Rekers and Hansen 2015, 252). Livingstone (2003) argues that places influence knowledge creation, while places are shaped by knowledge.

On the other hand, scholars do not consider physical place and geographical proximity *sufficient* to foster interdisciplinary collaboration. They found that place may facilitate other processes important in interdisciplinary collaboration, such as other forms of proximities and the sharing of tacit knowledge (Boschma 2005; Hautala and Jauhiainen 2014; Jeffrey 2003). Much of this scholarship thus gives more attention to spaces in science, rather than to place (Knorr-Cetina 1991; Vermeulen 2018; Palmer 2001; Felt 2009). The difference between the two is that place is “space filled up by people, practices, objects, and representations” (Gieryn 2000, 465). Although physical place in practice entails geographic location and physical proximity of – in this case – scientists, place must not be understood merely as physical buildings or architectural structures. Following the definition of place, place-making thus involves efforts to transform spaces of encounter into places of social interactions and sense-making.

This paper is based on an ethnographic study of a Norwegian biotechnology research center – the Centre for Digital Life Norway (DLN), that was initiated and funded by the Research Council of Norway (RCN) in 2015 to stimulate a transition in biotechnology research towards interdisciplinarity and digitalization. DLN is an interesting deviant case. While there is a much-studied trend of co-locating research groups in research centers (Palmer 2001; Padberg 2014; Vermeulen 2018; Hackett et al. 2021), DLN is a *multi-sited* center. This means that DLN scientists, research groups, and management are located in several Norwegian cities and buildings. There is not one physical center or building that is a natural meeting point for DLN members. The question thus arises: How are scientists socialized into an interdisciplinary mentality in a multi-sited research center?

The paper’s main finding is that place-making played a prominent role in DLN to facilitate interdisciplinarity despite its multi-sited character. The paper presents what was involved in this effort, examining three empirical vignettes from DLN’s practice that connect the issue of socialization into interdisciplinarity through place-making. Affective aspects emerged as an important dimension of place-making. Affective aspects have traditionally not received much attention in scholarship on interdisciplinarity. The paper therefore also contributes to emerging attention in scholarship on interdisciplinarity in science and technology studies (STS) by showing the important role that affective aspects play in establishing new interdisciplinary collaborations.

What role does place play in interdisciplinarity?

The notion of socialization may be useful to understand how a multi-sited research center works for its members to acquire an interdisciplinary mentality. Scholars have shown the importance of socialization processes at universities and in higher education (Tierney 1997; Weidman, Twale, and Stein 2001; Maher et al. 2019; Boden, Borrego, and Newswander 2011), and Van Maanen (1987) argues that socialization strategies have enormous consequences for both individuals and organizations, regardless of whether they are intended or not.

The premise of socialization theory is that individuals learn knowledge, skills, values, meanings, and norms through social interaction and societal context, making them effective members of their society (Mead 1972; Rabinow 1996; Weidman, Twale, and Stein 2001; Austin and McDaniels 2006). For example, if interdisciplinarity is a highly appreciated value in a funding policy for a biotechnology research center, the question is how researchers in such a research center learn this new norm and integrate it socially. Socialization should not be viewed as a one-way process where new members 'acquire' an organization's 'culture', but rather as an "interpretive process involved in the creation – rather than the transmittal – of meaning" (Tierney 1997, 6). The implication of this is that both individuals and organizations are affected by the socialization process.

The role of places of socialization in interdisciplinary collaboration have received little explicit attention. One exception is Boden, Borrego, and Newswander (2011), who suggest that place may be important to the growth of interdisciplinary communities, emphasizing the importance of a shared place that encourages informal interactions and promotes student socialization. Thus, we might assume that places are important to study when it comes to socialization into interdisciplinarity, as they normatively integrate newcomers into social lives and customs. This is supported by the findings of Maher et al. 2019, who analyzed doctoral students' experiences with laboratory rotations, showing aspects of socialization processes at play when the students rotated between different places, that is, different laboratory communities. The role of place in socialization thus needs further study.

Scholarship on socialization rarely distinguishes between the concepts of place and space. We find a similar shortcoming in existing studies of scientific collaboration. For example, the concepts *place* and *space* tend to be used interchangeably, although the distinction between the two (see for example Campbell 2018) is important – particularly for the question of socialization into unique meanings and values. In his review of the sociological literature on place, Gieryn (2000, 465) clearly distinguishes between place and space, arguing that:

> (…) place is not space—which is more properly conceived as abstract geometries (distance, direction, size, shape, volume) detached from material form and cultural interpretation. Space is what place becomes when the unique gathering of things, meanings, and values are sucked out.

Thus, place must be made. First when filled up with people, practices, objects and representations, space becomes a place.

Place-making is rarely discussed in studies of interdisciplinarity. For example, when Barry and Born (2013, 2) propose mending the "paucity of empirical studies of how interdisciplinarity unfolds in practice", they mention place only briefly, without further discussion or explanation. One example is when they write that "(…) university-based salaried artists were able to achieve intensive collaborations with scientist colleagues through prolonged encounters with or immersion in scientific environments, thereby incorporating scientific problematics into their work to occasionally extraordinary synergistic effect" (29).

The lack of attention to place may be due to *space* being considered a broader term that also could entail physical place (see for example Hautala and Jauhiainen 2014 who distinguishes between different spaces of knowledge). However, as Gieryn (2000, 466) reminds us,

> A sensitivity to place must be more than using two "places" simply to get a comparative wedge. The strong form of the argument is this: place is not merely a setting or backdrop, but an agentic player in the game—a force with detectable and independent effects on social life.

If we accept that place is indeed an agent, it is then interesting to investigate what role it plays in socializing scientists into interdisciplinarity. There is often assumed to be a link between interdisciplinarity and place. One example is Palmer's (2001) ethnographic study of boundary work in an interdisciplinary research center, where the center was founded on the premise that "reducing the barriers between traditional scientific and technological disciplines through the architectural design of the building can yield research advances that more conventional approaches cannot" (3). Another example is Vermeulen (2018), who argues that "putting system biologists together in buildings" in the form of dedicated research centers has "probably been the main achievement to centralise systems biology" (1776).

In research policy, an underlying assumption is that disciplines work as silos – clearly a spatial metaphor – thereby hindering interdisciplinary collaboration (Frickel et al. 2017). This assumption has resulted in attempts to solve the perceived problem by creating organizations and processes to foster interdisciplinarity that may amount to place-making:

> Innovative organizational forms have been designed to promote epistemic integration, ranging from constant co-location of researchers in specifically designed centers or campuses to large-scale networks, such as the European Framework Programmes and COST networks, which bring researchers together over space and time (Hackett et al. 2021, 2).

Studies of these organizations highlight the importance of providing for regular encounters when promoting epistemic integration (Cummings and Kiesler 2008; Hampton and Parker 2011; Vermeulen 2018; Hackett et al. 2021). Moreover, Allen and Henn (2007) suggest that the frequency of interaction within an organization depends "very heavily ... [on] the physical location of the people and the structure of the physical space", showing that "a mere 50 meters' separation between people essentially results in the end of regular communication" (63). Physical proximity seems to be important for establishing social connections:

> [G]eographical proximity may be a necessity for some collaborations, as it allows for the creation of specific social relations and social proximity… This is particularly likely to be important for collaborations in interdisciplinary research where the participants come from different backgrounds (Rekers and Hansen 2015, 245).

Still, co-location does not necessarily need to be permanent or happen daily. In so-called synthesis centers, researchers are not co-located in a single physical building every day. They work at several universities, but the groups do occasionally meet at the center's premises, where the scientists engage in intensive work over shorter periods of time during the year. This seems to create patterns of social interaction that promote collaboration (Hackett et al. 2021; Hampton and Parker 2011). Hackett et al. (2008) and Parker and Hackett (2014) observed that "[s]cientists emerge from these intense and successful research interactions with strongly favorable orientations towards research collaboration (Hackett et al. 2008, 293)".

To create synthesis centers is clearly a relevant place-making effort that could have been an option when Digital Life Norway aims to stimulate interdisciplinarity. The experience of such centers also provides important insights regarding the social processes involved in place-making. But is physical proximity the only proximity needed to achieve interdisciplinarity?

Indeed, place-making involves more than a shared physical place or space. Palmer (2001) finds that epistemic proximity often is as important as physical proximity (64**.** This is consistent with Jeffrey's (2003, 539) argument that "substantive and meaningful cross-disciplinary collaboration will not miraculously 'emerge'" from physical proximity. Thus, place-making is not just about facilitating face-to-face encounters but also about motivating for collaboration and developing shared identities of scientists and research groups (Schönbauer 2017, 2019; Hansen 2014).

In this context, the role of emotions and feelings needs to be systematically analyzed (Parker and Hackett 2014, 551). Mansilla, Lamont and Sato (2016) claim that successful interdisciplinary collaboration "pivots on the construction of a shared space for cognitive, social, and *emotional* transactions" (601, my italics). While their paper nicely shows how these three dimensions are intertwined in practice, place is not given much attention in the analysis, and none of the markers and indicators discussed shows the role of place in the three dimensions. Parker and Hackett (2012, 24) state that emotions "are central elements of scientific collaborations (…). Emotions spark creativity, tighten social bonds, and lower barriers to collaboration", and argue that "emotive and epistemic elements of collaborations are inseparable". In the paper, they use the concept of "island time" to describe the collective affectivity that occur when scientists meet to work together for shorter but intense time intervals. How to achieve the emotional or affective qualities that are crucial for well-functioning interdisciplinary collaboration needs further study. Kerr and Garforth (2016, 17) argue that the iconic STS laboratory studies "rarely show the patterns of affect and care for colleagues, careers and futures that, alongside work with materials and knowledge-objects, also constitute laboratories and their work". Recent scholarship has given more attention to the role of affect in science (Swallow and Hillman 2019; Parker and Hackett 2012; Fitzgerald 2013; Kerr and Garforth 2016; Smolka, Fisher, and Hausstein 2020). The paper at hand draws inspiration from these, noticing with Parker and Hackett (2014, 549) that

> [w]hat is odd is not that emotion shapes science—this has been known for almost a century—but rather that the vital role of emotion in science, so clearly seen early on, is only now re-emerging as a cumulative area of sociological research.

Therefore, I investigate in this paper the efforts of a multi-sited biotechnology center that aims to provide a climate for interdisciplinarity. The specified research question is this: How do the socialization efforts in DLN involve place-making, that is, efforts to transform spaces of encounter into places of social interaction and sense-making that motivate further collaboration across disciplines and projects? I expect the socialization efforts to involve community building with shared norms and values as well as developing interest in interdisciplinary collaboration. Thus, my analysis will focus on three aspects: place, socialization, and the role of affective features and experiences in socializing into interdisciplinarity.

Method

I began my ethnographic research into interdisciplinarity with anthropological fieldwork and participant observation in the laboratory of one DLN research project in a department of biotechnology at a Norwegian university. In addition to helping and observing in the lab, I attended meetings, workshops, and other activities at the department, taking extensive field notes in the office I shared with five early-career researchers in biotechnology.

After a first round of fieldwork for about 1.5 months at the biotechnology department, I continued my empirical exploration with a round of interviews in the project where I had been in the lab, followed by interviews in two more DLN projects in other Norwegian cities to be able to compare. In total, I conducted 26 semi-structured interviews and two focus group interviews with scientists of diverse disciplinary backgrounds and positions, including PhD students, postdocs, lab technicians, associate professors, and full professors. The interviews afforded greater understanding of the interdisciplinary processes, both within the research projects and within the center more generally.

In parallel, I followed the interdisciplinary movements in DLN by participating in conferences, meetings, workshops, center evaluations, and courses. I also took part in organizing the second annual research school conference, and a DLN walkshop (see Wickson, Strand, and Kjølberg 2015) on value creation in Norwegian biotechnology.

The last quarter of 2020, I did participatory observation in the Networking Project, the leadership group of DLN, working on a report on transdisciplinarity.[b] During these three months, I conducted several informal interviews with the DLN leader and others in the Networking Project and attended weekly group meetings and discussions on the everyday organization of the center. This fieldwork provided insights into the organization's priorities and decision-making.

All participant observation was documented by field notes. The interviews were transcribed and analyzed in NVivo. I coded for organizational or intellectual challenges and barriers, interdisciplinary interactions, conflicts within the research group, and with the home university, with DLN, or with RCN. Furthermore, I coded situations of emotion, scientists' affective expressions when talking about people or situations, also noticing when emotion and affect were not expressed. I also analyzed relevant policy documents and scientific papers from the landscape that DLN was a part of. The different kinds of data thus complement each other. They were analyzed together and cover different levels of the center – the individual experiences of scientists, the research projects, the project-transcending work in the Networking Project, and the policy strategy behind the Digital Life initiative – together making up an assemblage of the interdisciplinary efforts DLN engaged in.

[b] This report, as well as additional research (see author et al., forthcoming) show that transdisciplinarity in practice is used as interdisciplinarity in DLN, and I therefore do not distinguish between inter- and transdisciplinarity in this context, despite the differences in scholarly definitions.

Data from my fieldwork is indicated here by the date and context of the field notes. Interview data are labelled with the discipline and career stage of the interviewee. The Norwegian biotechnology community is small, and to ensure anonymity, gender is not always indicated. Documents are referred to where they are used.

A short presentation of Digital Life Norway (DLN)

DLN is a multi-sited national center for biotechnology research established in 2015 by the RCN; it represents a substantial public investment of approximately 50 million EUR. DLN's mandate is to "create economic, societal and environmental value in Norway from biotechnological research and innovation", by encouraging interdisciplinary research (RCN 2014, 4).

Interdisciplinarity is thus a clear norm that the DLN scientists should be socialized into. The norms, values and meanings that DLN scientists were attempted socialized into were, however, not only related to interdisciplinarity. In addition, DLN scientists should be integrated into a more comprehensive way of thinking about their own research, that is, into unique values and meanings related to societal relevance, innovation, and utility-oriented research, where the scientists become change agents in a transformation of Norwegian biotechnology.

DLN consists of a Networking Project hosted by several Norwegian university institutions and a gradually increasing research portfolio that in 2021 included 35 research projects spread across all these institutions. The research projects were funded so as to combine life sciences, mathematics, informatics, and engineering throughout biotechnological innovation (RCN 2014, 8). The multi-sited structure was an attempt to avoid favoring one biotechnology community but instead to include and merge communities in all the university cities in Norway (personal communication with DLN leader and DLN coordinator, 08.07.2020 and 23.02.2021).

What distinguished DLN from regular project funding streams was that the center, by means of a networking project, also did cross-cutting, project-transgressing work. The Networking Project was a socialization agent whose task was to manage the center's links among research groups, and between science and society. It consisted of the DLN director, group leaders and coordinators divided into six workgroups that reflect the center's focus areas: Governance, Responsible Research and Innovation (RRI), Innovation and industry involvement, Training and recruitment, Competence and infrastructure network, and Communication. (DLN 2020). DLN also had a research school for early-career researchers, a board, and an international advisory board. I will return to the Networking Project and the Research School in the last part of the paper.

How did DLN approach its mission? During the first five years of center activity, the DLN organized a variety of events and initiatives: conferences, meetings, courses, committees, forums, and workshops. Such events and structures have a long tradition in the sciences (see e.g., Mullins 1972[c]).

The Digital Life Research School offered courses for early-career researchers on broader topics, such as transdisciplinary life science and RRI, as well as more specialized science-oriented courses. All in all, the Networking Project made considerable effort to get the scientists in the center to meet face to face at physical locations.

What did this place-making entail, beyond creating physical meeting places? What happened in these spaces, and why were they considered important? In the following, I first analyze three DLN place-making initiatives. Secondly, I do a cross-cutting analysis of the initiatives, emphasizing the affective aspects of place-making. The three initiatives analyzed are the socializing agents in the Networking Project and its project-transgressing work, the Digital Life Norway Annual Conference, and the Digital Life Norway Research School. I have selected these initiatives because they were core activities of the center and because they illustrate what place-making entails and implies in a multi-sited research center.

Initiative 1: The DLN Coordinating Group

Most of the DLN work was done within the center by working with existing research projects and with scientists in the center. This work was oriented towards place-making, that is, bringing the scientists in the center together for meetings, conferences, and workshops. The spaces used for this were usually hotels, conference rooms, and sometimes meeting rooms at different Norwegian universities. This place-making was always grounded in DLN values: the topics of these events were related to

[c] Mullins (1972) shows that both formal and informal initiatives such as summer courses, writing retreats, and camping trips, were important in the formation of a new specialty. These initiatives are examples of place-making in science, although Mullins himself does not use this term to describe them.

interdisciplinarity/making new acquaintances, innovation, societal relevance, and/or reflections on the meanings and outcomes of DLN.

Interviews with scientists and observation in the center showed that the participating scientists considered the DLN meeting places valuable for creating new interdisciplinary collaboration. They described how they had met other scientists by attending center events, which had resulted in new partnerships. What was created through these place-making efforts was opportunities to meet new people, but also, more importantly, "getting to know" others and to build personal professional relations. We see here that affective aspects of collaboration were at play, in that the personal professional relations were considered important. "Getting to know" others was considered difficult to achieve by other means than through face-to-face encounters.

> But what I think was good – in the beginning [of the center's activities] at least, it was that we were also forced to meet with the other projects and get together for a bit... – we had at least one or two project manager meetings that those of us who were in the first round [of funded DLN projects] participated in. (…) These project manager meetings slipped [ceased] a bit at one stage or another. And I don't think it was so wise that it slipped. But it could have [been helpful], and at least for me it did something to be in these meetings. These cross-project activities that we have started were due to, among other things, the contacts we established there (professor).

When asked further about cross-project collaboration, the professor emphasized that s/he did not know the scientists from the other projects before they became participants in DLN and met in person at DLN initiatives. S/he doubted that they would otherwise have met and collaborated, and s/he considered the project manager meetings to be particularly important professionally as well as an opportunity to meet nice people relevant for future collaboration. The affective aspects of place-making in this case were understated by the scientist, but nevertheless seemed to matter in the actual collaboration that resulted from the project manager meetings: being nice was clearly seen as a valuable trait. Ironically – and as indicated in the quote – only one or two project manager meetings were held before they were terminated. Thus, an important place where project managers could meet, disappeared. Consequently, new research projects struggled with identifying potentially relevant partners, especially when joining the center during the COVID-19 pandemic restrictions:

> We are a brand-new project in the Digital Life Norway format, so, so far, we have initiated collaboration with one other project, but both of us did, like, cell work, so it wasn't like collaboration between a wet lab and computational science. However, for some months already, we were thinking that we really needed a partnership with some bioinformaticians and computational biologists, and we do know that this kind of expertise is available in Digital Life Norway. However, we haven't found the right platform or the right approach to find these people in this consortium, because, like, we don't know many people in the consortium so far, and we can't just say "hey, you, who can do this computational biology stuff for us?" (Senior scientist).

The lack of place as agentic force became even more evident during the pandemic in 2020, when the scientists no longer could meet physically. During this period, scientists described challenges in making new interdisciplinary project groups run smoothly due to the lack of face-to-face meetings:

> *Scientist 1*: I have a question for all of you. Is there any way you can stimulate cross-disciplinary communication in Corona times? Cause you cannot be co-located. Now they write that you cannot go to work anymore.
> *Scientist 2*: Yeah, I think it's extremely difficult to initiate if you haven't had any physical connection before and then to initiate novel close collaboration on Zoom, at least I am really bad at it. But if I know you from before it's easier.

The quotes above show how collective affectivity is difficult to achieve when people cannot meet in person. Conversations with scientists during field work suggested that the digital platforms provided insufficient opportunities for affective relations; the scientists often described how digital meetings gave no opportunities for small talk by the coffee machine, and how the digital format made it difficult to build personal connections and relationships with persons they had not previously met.

In addition to providing physical meeting spaces, the place-making of the coordinating group involved targeted processes to encourage interdisciplinarity. Funding for cross-project activities is one such example. Constructing a place where scientists could harvest "synergies between projects and exchange of competence" was considered important by the coordinator group, as they saw it as one of the benefits for the research projects of being part of DLN.

To stimulate such interdisciplinarity, the center offered limited funding for cross-project activities that projects could apply for online (DLN 2021b). These cross-project activities where the ones referred to by the professor in the first quote of this section.

From 2018 to 2020, DLN place-making efforts related to this initiative entailed 11 cross-project activities, including collaborative workshops, exchanges regarding methods, and a pilot testing of antibodies with another DLN-project prototype system. At first glance, such initiatives might not seem to require physical encounters. However, in practice, as apparent in the quotes above, cross-project activities were highly dependent on face-to-face encounters. Firstly, the scientists claimed that they needed such encounters to become acquainted before they began collaborating. This had to do with the affective aspects linked to 'getting to know' each other. Secondly, interdisciplinary collaboration almost always resulted in physical meetings to discuss scientific matters and/or for working together in the lab.

In the next section, I analyze the Digital Life Norway Annual Conference as another instance of place-making. This example highlights how place-making was used to socialize scientists to an interdisciplinary mentality by promoting the DLN's mission though articulating norms and values at the events. The extent to which such socialization happened is unclear, but the annual conferences show the importance of place-making for the initiation of interdisciplinary collaboration in DLN.

Initiative 2: The Digital Life Norway Annual Conference

The DLN Annual Conference has been arranged by the Networking Project annually since 2017. The intention was to create a sense of belonging, engagement, community feeling and trust in the center (personal communication with center director and coordinators 2018 & 2020). All DLN research projects, partner projects and the members of the DLN research school were invited to attend, together with members of the DLN international scientific advisory board, international scientists, and actors from biotechnology industry. The conference was each year held at a hotel, the location alternating each year between different Norwegian university cities. As the largest shared meeting place of the center, the annual conference was an opportunity for the Networking Project to attempt to socialize the members into interdisciplinarity consistent with the DLN mission.

An important part of this socializing consisted of addressing and demonstrating interdisciplinarity in the center, always emphasizing its value and importance. This was done both implicitly and explicitly. The DLN director and RCN representatives addressed interdisciplinary issues explicitly in their presentations. Not only disciplinary transgression was addressed this way, but also the other cross-cutting features of DLN: innovation, digitalization, and RRI. This can be interpreted as an attempt to normatively integrate newcomers into customs and to promote specific norms and values. In 2018, in his opening speech at the conference, the DLN director spoke about DLN and what changing the Norwegian biotechnology landscape meant more broadly:

> And this is about transdisciplinary biotechnology research, digitalization and modelling, more and better collaboration in Norway, taking into account the FAIRDOM principles for data storage, data sharing, open access, training of young researchers, career development – not only for academia but also elsewhere, more innovation out of the excellent research that is going on, and also fully taking advantage of the unique platform that has been created for responsible research and innovation.[d]

A representative from the RCN who had been deeply involved in the DLN initiative also held a normative, value-laden presentation. In his talk, he considered DLN important because it was a big investment in a policy experiment that was considered a "change-oriented", "highly strategic effort" that would be "transforming the [biotechnology] landscape" as well as providing opportunities to "meet the full range of [the research program's] goals", and to create "political attention and impact beyond biotechnology". Both presentations used strongly normative and value-laden language, making it explicit to the audience why the center was important and what the audience should identify with. We see that the unique meanings and values that the DLN scientists should be socialized into thus are related not only to interdisciplinarity but also to impact, relevance and to becoming a change agent.

The efforts to provide a mentality for interdisciplinarity were also implicit, often tacit. The outline of the conference program exemplifies this. The conference was traditionally structured, with two days of presentations of scientific results and of cross-cutting topics.

The scientific presentations dominated the conferences, especially the first year. However, gradually more time was devoted to presentations that addressed cross-cutting topics. Examples of such sessions were "Realizing the Future Together" and "Digital Life

[d] https://www.youtube.com/watch?v=PkiCh3hjWuU

Innovation Day". Again, we see efforts to socialize participants into a change and impact-oriented way of thinking about science. The Networking Project invited the speakers for these presentations to address topics such as the importance of digital biotech economy in Norway, how digitalization is transforming the biotech sector, how to make industry-university partnerships work, and value creation and the public good in research. Participating in the annual conference is thus a way individuals can learn values, meanings, and norms through social interactions.

A session from the DLN 2018 conference illustrates in greater detail the normative and value-laden aspects of the conference's place-making features (field notes, 21.03.2018). One of the presenters of this "Trust and Accountability" session was a professor of research communication with a background also in biotechnology. He discussed trust, asking the questions "how to come in contact with the people biotechnology earlier have excluded?" and "how to ask the relevant questions in research?". In the Q&A period after his talk, members of the audience raised some critical issues. For example, a scientist in his/her mid-thirties said s/he disagreed with the idea of creating trust at all costs because "we [as scientists] are right" and the public "cannot disagree with the science". The professor responded by saying that "perhaps we are right but continuing to insist that we are right is a bad way to convince someone. Humility and understanding other perspectives are extremely valuable".

This illustrates how some of the cross-cutting presentations challenged the biotechnology audience by raising topics that addressed wider aspects of scientific work that related to the values and meanings in the DLN mission. Challenging norms and values of scientific practice became an integral part of the place-making.

Other examples of the tacit socialization efforts at the annual conferences include the emphasis on poster sessions (with refreshments), which provided for extensive mingling and networking and thus opportunities for exploring epistemic proximity. The care taken to orchestrate the conference dinner was another effort, where the intention was to facilitate interdisciplinary encounters through the seating at the tables. The conference dinner, with after-dinner drinks and mingling, was considered important for networking across disciplines that could result in new partnerships (field notes 2018 and 2019, and interviews). The latter is illustrated by the following excerpt from my field notes:

> At the conference dinner, the conference participants were seated at different tables, about eight at each table. The conference organizers had decided the seating to make sure that we met new persons. During dinner, I observed two scientists started talking about their respective research projects [here I call them project A and B]. The scientist from project A was a female postdoc and coordinator of her project, and the scientist from project B was a female early-career researcher. They were sitting next to each other, and during their conversation they realized that they had a lot to talk about scientifically. They started out discussing the work done in Project B with viability in cells in alginate, as project A might be interested in testing this out. As the evening continued and the participants at other tables finished their dinners and moved on into the lounge area, another scientist from project B, who was also one of the developers of the project, passed by our table. She initially stopped only to have a brief chat with us, but when she realized the conversation was about the two projects, she stayed and joined the discussion. The three scientists became increasingly engaged in the discussion and started to talk about the possibilities for a collaboration between the projects or a side project. After some time, the project coordinator from project A invited the scientist from project B with her to meet "the others", meaning the project manager of project A for further discussion about a possible collaboration (field notes, September 6, 2019).

Thus, a partnership was initiated, later resulting in a collaborative effort where one of the postdocs from project B travelled to project A's lab in another city to see whether project A could use the techniques of project B.

The example, demonstrating the effects of place-making in practice, highlights the potential importance of physical encounters that the annual conferences provided to facilitate and motivate for interdisciplinarity. This – combined with available funding – allowed for the collaboration between the two projects to happen and shows how collaboration does not happen out of nowhere. Establishing new interdisciplinary collaboration seems to benefit from personal knowledge about potential partners. Note that the scientists had other things in common than merely their research, and that the conversation was guided by affective aspects that influenced the scientists' decision to collaborate. I elaborate on the affective aspects in this example in the discussion.

Initiative 3: The Digital Life Norway Research School (DLNRS)

The DLNRS represents a third example of place-making efforts in DLN. The research school was considered to be instrumental in creating an interdisciplinary digital life community consistent with the DLN mission (RCN 2014) and was thus a priority of the

Networking Project. The place-making efforts in DLNRS aimed at socializing early-career researchers into a set of shared norms and values, such as increased interdisciplinarity, an innovation culture, and societal relevance and responsibility – all considered important for the future of biotechnology.

The research school was open to all early-career researchers within the field of biotechnology in Norway (not limited to participants in DLN-funded projects), so scientists from a variety of disciplines within the natural sciences participated. This may in itself be interpreted as a place-making effort to support interdisciplinarity. In September 2020, the school had 237 members, of whom 150 were postdocs (RCN 2020, 39-41).

The main approach of the research school to realize the DLN mission was to offer dedicated physical spaces where early-career scientists could meet and network. The research school provided members with a variety of events and initiatives, around 20 per year, including for example an annual conference, scientific and more general courses, travel grants, networking opportunities, reading groups, and industry internships.

The socialization into an interdisciplinary mindset, that is, making interdisciplinarity an integral part of early-career scientists' practices, was a distinctive feature of DLNRS's place-making. Compared to the two previous initiatives, the research school offered more explicit socialization, as the training aspect allowed discretion regarding the values, meanings, and norms that early-career scientists should learn. Thus, the activities were guided by the DLN cross-cutting topics: interdisciplinarity, innovation, digitalization, and RRI. DLN was from the outset made up by a set of unclear intentions regarding what interdisciplinarity, innovation, digitalization, and RRI should mean in practice. As previously noted, socialization into interdisciplinarity was not the only socialization effort in DLN. It was one of several normative demands. DLN scientists should be integrated into a more comprehensive way of thinking about their own research, that is, into unique values and meanings related to societal relevance, innovation, and utility-oriented research, where the scientists are change agents. Furthermore, socialization into interdisciplinarity did not replace other socialization efforts or identities but was an addition to scientists' existing identities, mindset, and practices. One result of this was an unclear identity – both for DLN and for the early-career scientists in the center, and a consequence was that the early-career scientists maintained other – and sometimes competing – identities (Bock von Wülfingen 2021; Felt et al. 2013).

The RRI efforts of the research school are illustrative of the socialization efforts in making scientists concerned with societal relevance and inclusion of a variety of disciplinary fields in knowledge production. From the very beginning, RRI was a topic at several research school initiatives, for example at its annual conference and at its signature course, "Transdisciplinary Life Science". My field notes from these events suggest that the ensuing socialization efforts managed to change participants' values and ways of thinking (Author et al. 2020). In 2017, at the first annual meeting of the research school, none of the participants was familiar with the concept of RRI. Later, however, participants demonstrated greater familiarity and understanding of RRI.

The DLN considered the research school to be a great success in creating a collective team spirit and community among the early-career researchers (interview DLN leader 05.10.2020, interview DLN coordinator 23.10.2020). Many of the scientists and participants in the Networking Project considered it as the place in the center where one could most clearly observe a sense of belonging and community feeling (field notes 2018 & 2019).

An analysis of accounts from early-career scientists addressing their participation in the research school from 2017 to 2021 supports these notions, indicating that the research school had been an important place for many (field notes, 2017-2021). Several PhD students described that they felt more at home in DLNRS and DLN than they did in their department and/or pointing to DLN as crucial for their development of a network with scientists with similar interests. One reported that "DLN, or really the [DLN] research school is where I have my network, and where I feel I belong. I don't have a large network in my department, and I feel much more at home in the research school" (field notes from a conversation with a systems biology PhD candidate in 2018).

Another PhD student, participating at the DLNRS annual conference in 2019 for the first time and not knowing anyone in advance, said: "I'm so happy that I decided to come here! In my daily work no one, not even my supervisor, knows what I'm doing", explaining that s/he had met several people engaging with similar research, who now s/he could get in contact with "when I need to discuss my work" (field notes, Annual Conference 06.06.2019).

But what was the reason for this? In what way did the research school differ from the other DLN initiatives? Could other aspects of the place-making in the research school also contribute to a greater understanding of the research school's success? The research school's main event for facilitating for networking, the DLNRS Annual Conference, illustrates some of them. The DLNRS was organized by members of the research school, together with an administrative coordinator, and the conference was promoted as a "great opportunity to build your network, exchange research ideas, share your experiences, and have a lot of fun!" (DLN 2021a). The conference was an overnight event held at hotels.

The program consisted of a mix of scientific presentations and "soft skills". Another integral part, "having fun", consisted of icebreakers, group work, hiking, Kahoot quizzes, stand-up shows, scientific speed dating, and social team activities (e.g., outdoor Viking games and obstacle courses), and lunches and dinners with quizzes and mingling. The interviews with early-career scientists at the annual conferences highlight the affective and relational aspects rather than the professional program. Before and after the conferences, the early-career scientists always highlighted "the social" aspect: getting to know new people, hanging out in the evenings and nights, making friends, and catching up with people they knew from other DLN events (field notes, 2018, 2019, 2020). For example, in 2019, every evening of the conference a group of 15-20 scientists went to the beach to light a fire, drink beer, and talk. The first night, a PhD student who was part of the organizing committee said: "I've missed hanging out with you guys! I see you talking, and having fun, and all I want is to join you. But I have responsibilities", further explaining that s/he looked forward to conclude the responsibilities the next day so s/he could "fully commit to just having fun" (field note, 06.06.2019).

The affective aspects were also evident in the feedback to the research school during the COVID-19 pandemic. Due to the pandemic, all physical meetings were cancelled. Early-career scientists expressed their sadness at this: They felt isolated and alone, missed the activities, and hoped that some events might still happen (interview DLN coordinator, June 2020). The annual conference was the last in a series of research school events that in 2020 was shifted to a digital platform. The research school leaders, the organizing committee, and many of the members expressed strong disappointment about the change, saying things like "I am so disappointed that I cannot go to [the place of the conference]", "It sucks" [that it was cancelled], "I had really looked forward to it [the conference] and to finally meet people", and "I'm sick of not meeting anyone, and really hoped that the this [the conference] would happen (field notes, August 2020).

The accounts from the early-career scientists suggest that the DLNRS place-making afforded a construction of relevant shared places for cognitive, social, and emotional transactions between research school members. We see that place here is an agent that contributes to transfer of values, meanings, and norms through social interaction. The examples above show how filling DLNRS places with people, practices, values, and representations created patterns of social interaction that promoted both an interdisciplinarity mindset, as well as RRI and increased attention toward societal relevance in research. The affective aspects of the place-making dominated in the accounts and must be considered an important reason for the research school's success in creating a community of early-career scientists across the participants' disciplines.

Discussion: Affective aspects of interdisciplinarity

In the theory section, we saw that place-making involves more than just a physical place to meet. The three cases analyzed above showed how attempts of DLN place-making involved socialization of scientists into membership in and appreciation of an interdisciplinary community through shared norms and values. We also saw that networking aspects such as "getting to know each other" and "having fun" represented a significant part of place-making.

The cases bring two main aspects of place-making into focus. First, it facilitated community building and establishment of new interdisciplinary partnerships in DLN. Second, this achievement largely depended on cultivating affective features through the place-making that facilitated relations between the scientists in the center. I will now elaborate on the second point.

First, consider the previously described encounter at the Digital Life Annual Conference dinner in 2018 (in the Initiative 2 section). The importance of physical proximity of scientists was clear, but above all the role of building of professional friendships to establish new collaborative relations. The two scientists from projects A and B, though they might not have known it at the time, had much in common. Both were women scientists around 35-40 years in leading positions within their research groups. Both were passionate about their work, had given birth to several children while getting their scientific degrees, and had studied in the same city. They got along well immediately, and their conversation was a mix of deep scientific exchange and a lot of laughing.

The affective aspects of scientists' personal relations at work, such as liking each other and forming friendship, seem an important steppingstone to enter scientific collaboration. The above-mentioned event is one such example where both place-making and affective aspects enabled a new collaboration. Another example is the professor who described how encountering other DLN project managers had resulted in side-projects (in the Initiative 1 section). However, the affective aspects of science and collaboration were seldom discussed openly among the scientists in DLN as far as I could observe during my fieldwork, and it is not emphasized in the scholarship on interdisciplinarity. Nevertheless, the affective features of interdisciplinary collaboration were quite evident from my fieldwork and interviews.

When over the course of my fieldwork I became aware of the importance of friendship and emotions, I invited scientists to talk about their relationships with their project partners. I asked why they chose to collaborate with this or that person, how the collaboration started, and if they ever met with their project collaborators outside of the university. However, all my attempts at such disclosure failed. Only when I asked directly about the importance of friendship and getting along when starting a new partnership did the scientists address the issues, but often in quite general terms: "Yes, [personality] is important [to create well-functioning collaboration groups]. I do think it's nice to work with people who are positive and enthusiastic rather than the opposite" (professor).

This hesitation was especially evident among the more senior scientists. On a more general level, and as the quote above shows, many readily admitted that personality was important in interdisciplinarity groups and teams. However, when asked directly about their own relationships with collaborators – for example, if they knew their collaborators prior to initiating the project – most answered vaguely that they knew some of them and were not at all eager to talk about it.

I interpreted this as indicating that the scientists were concerned that their scientific endeavors would become less prestigious if others believed they collaborated only with "old friends". For example, a professor told during an interview when asked if s/he already knew the other project managers in the project: "Yes, well, I knew of them, I probably knew [name] better since we were down here [at the department] together, while I had probably only met [name] a few times”. Later I found out that s/he was a close friend of one of the group managers, and that they in fact had known each other more than 20 years. In contrast, when talking about recent collaborators, the interviewees offered more information.

The early-career scientists were less careful and often emphasized the importance of becoming friends and having fun to ensure good collaboration. When informally asked why they wanted to collaborate with others, they offered reasons such as: “We just wanted to do something together because we thought it would be fun”, “He’s great guy”, and “I met her at the annual conference”. In more formal settings and during interviews, however, the early-career researchers also only talked about the scientific reasons to collaborate.

When establishing a new group of early-career researchers in the research school, one of the coordinators wrote to me that “I’m not the one who is going to lead it, but I’ll have a lot of contact with it – and need GOOD people”, following up with “It MUST be a pleasant bunch if it’s going to work!”. When later asked about what ‘good people’ meant, s/he explained this referred to people s/he knew and liked. “And of course, I want people that I know are going to contribute so that we get things done”.

Affective aspects are important in interdisciplinary collaboration. In DLN, such aspects are realized through place-making through the DLN events and initiatives for the members. These places are crucial also for DLN’s socializing of scientists into an interdisciplinary mindset. Drawing on Parker and Hackett (2012) we may say that some of the DLN place-making efforts were attempts to create ‘hot spots’, that is brief but intense periods of collaboration undertaken in remote and isolated settings. Furthermore, facilitating for ‘island time’ seemed also to be considered important. This was most noticeable in the research school, where travelling to someplace outside of the universities was considered crucial for deep concentration, engagement, and for creating and tightening social bonds. In sum, the three vignettes above show that place, socialization, and affective aspects were intertwined in DLN’s initiatives to promote interdisciplinarity in a multi-sited research center.

The empirical accounts from scientists during the pandemic describing challenges of collaborating with scientists they had not met in person before, show the importance of affective aspects in interdisciplinarity. Furthermore, it has implications for organization of science and knowledge production. Though digital platforms provide new opportunities for collaboration across the world, face-to-face encounters prior to collaboration – even if only once – is considered crucial for well-functioning interdisciplinary research. This is largely due to the affective, and often tacit, processes at play when scientists meet by the coffee machine, talk informally in breaks and before meetings, or go out together for drinks after seminars and workshops. This shows that place is indeed an influential agent in this context. These findings show some of the limitations of relying mainly on digital communication in scientific collaboration.

Presumably, place-making and affective aspects are important in most forms of research collaboration, interdisciplinary as well as disciplinary, because of the need for trust and appreciation in the sharing of knowledge and data. Still, it may be of greater significance in interdisciplinary teams where one often lacks the competence to assess the efforts of partners from other disciplines, so trust based on affective relations is key to be able to work effectively together. As place-making involves people getting to know each other and affords the building of a personal-scientific base for mutual trust, place-making is of particular importance in interdisciplinary collaborations. The paper shows that the significance of place-making and affective aspects were appreciated by both senior and early-career researchers since trust is equally important to them. However, regarding the socialization of scientists into an interdisciplinary mindset, the analysis suggests that this was more apparent and influential in the accounts of the early-career scientists in the research school compared to those more senior. This may be due to the fact that many early career researchers were part of education programs where interdisciplinarity was explicitly addressed as a choice to make, while the senior researchers often saw interdisciplinarity as required to get grants.

Conclusion

This paper has shown that place-making matters for interdisciplinary collaboration in science. When facilitating for interdisciplinarity, the Centre for Digital Life Norway created meeting places for scientists, hoping that these places would in themselves initiate new collaborations. I argue that the spaces created by the Networking Project initially were just that: spaces. To work, the spaces must, however, be transformed into places where proximity and affectivity can work. Place-making thus transforms general spaces such as hotels and conference rooms to local places by filling them with norms, values, affects, people, meaning and content. This is how places may become meaningful to scientists and help develop the potential to create community feeling and new collaborations across scientific disciplines. The DLN Networking Project used place-making as what I consider as efforts to socialize scientists into a mentality for interdisciplinarity. This worked largely due to the affective aspects at play in the DLN place-making. Though often tacit and under-communicated, affective aspects, for example, personality and good chemistry between scientists, played a fundamental role when the scientists decided to establish new interdisciplinary research projects.

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Paper 4

Transforming Scientists' Understanding of Science–Society Relations. Stimulating Double-Loop Learning when Teaching RRI

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ABSTRACT The problem of developing research and innovation in accordance with society's general needs and values has received increasing attention in research policy. In the last 7 years, the concept of "Responsible Research and Innovation" (RRI) has gained prominence in this regard, along with the resulting question of how best to integrate awareness about science–society relations into daily practices in research and higher education. In this context, post-graduate training has been seen as a promising entrance point, but tool-kit approaches more frequently have been used. In this paper, we present and analyze an experiment—in the format of a Ph.D. course for early-career researchers—deploying an alternative approach. Drawing on Argyris and Schön's (1974) framing of reflective practice, and their distinctions between espoused theories and theories-in-use, the analyzed course endeavored to stimulate double-loop learning. Focusing on dislocatory moments, this paper analyses how the course tried to teach participants to reflect upon their own practices, values, and ontologies, and whether this provided them with the resources necessary to reflect on their theories-in-use in their daily practices.

Introduction: Training for Responsibility

For a long time, research policy communities have given increased attention to science–society relations. At the European level, policies directed at such issues have gone through several shifts. "Responsible Research and Innovation" (RRI) is a recent development, where the underlying idea is to promote a set of practices to help shape research and innovation to respond to society's general needs and values (von Schomberg 2011). Considering these policy efforts, we may ask how science–society policies, such as RRI, are translated into practice. There are several approaches and strategies to achieve or "do"

RRI. However, translating RRI into practice has proven to be anything but straightforward (Macnaghten et al. 2014; Fisher and Rip 2013; Owen et al. 2013; Ribeiro et al. 2016). Existing scholarship on the issue points to substantial challenges in aligning RRI policy with research and innovation practices (Solbu 2018a; Åm 2019a, b; Davies and Horst 2015; Blok and Lemmens 2015; Glerup et al. 2017; van Hove and Wickson 2017).

In order to amend the situation, there has been a range of RRI training initiatives. Many of these are web-based, offering what they often present as tool-kits and with instructions for using these tools.[4] The number of such tools has grown at great speed. For example, the website www.rri-tools.eu contains links to more than 1100 descriptions of tools and procedures. Post-graduate research training represents another possible strategy for creating and developing RRI awareness, for teaching RRI skills such as public engagement, and for helping early-career researchers in the natural and engineering sciences to engage with science–society relations to a greater extent (Mejlgaard et al. 2018; Bernstein et al. 2017; Tassone et al. 2018; Heras and Ruiz-Mallén 2017; Limson 2018). These efforts also tend to employ tool-kit approaches to introduce researchers to RRI. In this paper, we present and discuss an alternative approach that aims to nurture sensitivity to important underlying aspects of RRI, such as reflexivity and responsiveness with regard to social concerns (Stilgoe et al. 2013). We argue that this alternative approach potentially is a more fruitful way of aligning the intentions behind RRI with research and innovation practices than training in the use of instrumental tools, not the least due to a greater focus on developing reflexive skills.

This effort is in part motivated by deliverables from EU projects that point to "a lack of knowledge about how to develop RRI-curricula in HE curricula and about RRI capabilities" (Tassone et al. 2018, p. 339; cf. McKenna 2016; Mejlgaard et al. 2016). The EU project EnRRIch has worked with higher-education policymakers to map the links between RRI and policy priorities for teaching and learning in higher education. Teachers' concerns (de Vocht et al. 2017) and adaptions (Okada et al. 2018) to RRI in teaching as well as reports from inclusion-oriented deliberations and actions in emerging

[4] E.g., EU projects HEIRRI (http://heirr i.eu/), Fit4RRI (https ://fit4r ri.eu/), RRI Tools (https ://www. rri-tools .eu/), IRRESISTIBLE (http://www.irres istib le-proje ct.eu/index .php/en/), and FOSTER (https :// www.fosteropenscience.eu/). For other examples, see: https ://www.parri se.eu/other-rri-proje cts/.

RRI practices that focus on scientists (de Jong et al. 2016) have also received attention. Still, it is not clear how one should teach RRI and what the content of the training should be. This knowledge gap becomes even more apparent when we are concerned with the efficacy of RRI training.

This paper addresses this knowledge gap by presenting and analyzing an experimental 5 ECTS Ph.D. course that aimed to prepare early-career biotechnology researchers for engaging with science–society relations by strengthening participants' ability to reflect on RRI challenges and opportunities. The field of biotechnology comprises many disciplines, including biology, organic chemistry, computational modelling and medicine. This research is very relevant to RRI due to its potential for risk and other, potentially transformative effects on society. Consequently, the field has been given substantial attention in the RRI context. The course ran in Norway during the spring of 2018. Its main underlying idea came from the observation that RRI is based on previous social science and humanities scholarship on emerging technologies (Rip et al. 1995; Nowotny et al. 2001; Irwin 2006; Felt and Wynne 2007; Callon et al. 2009; Felt et al. 2013). This paper highlights the potential benefits of teaching the intellectual background for RRI as a resource for reflecting about science–society relationships, rather than mainly focusing on arguments why RRI is needed and how to use tools for doing RRI in research and innovation projects. In this manner, the paper addresses the wider RRI community as well as scholars engaged in training scientists and engineers in ethical issues and science-technology-society concerns.

Challenges of Reflecting About Research and Innovation

Our point of departure is that RRI training can learn much from Chris Argyris' and Donald Schön's work on teaching professionals about reflection. In particular, their concept of 'double-loop learning' may be an appropriate and effective guiding principle for RRI training. This is due to the general emphasis on reflection as an important goal and a key competence both in the European commission's approach to RRI and in Stilgoe et al.'s (2013) widely cited framework for responsible innovation. The European Commission (EC) emphasizes what it calls six policy keys that RRI should advance: ethics, gender equality, governance, open access, public engagement, and science education. Stilgoe et al. (2013) offer a more scholarly oriented alternative that highlights four dimensions of what it should mean to do RRI: anticipation, reflexivity, inclusion, and responsiveness. This approach also provides a theoretical consistency that facilitates teaching, compared to the topical articulation of RRI of the EC.

The dimensions presented by Stilgoe et al. originate from a set of questions (product, process, and purpose questions) found in public debates about emerging technologies and new areas of science in the UK (ibid., p. 1570). In their RRI framework, *reflexivity* is described as asking "scientists, in public, to blur the boundary between their role responsibilities and wider, moral responsibilities. It therefore demands openness and leadership within cultures of science and innovation" (p. 1571). Stilgoe et al. argue that institutional reflexivity is needed in governance and that reflexivity at this level means holding up "a mirror to one's own activities, commitments and assumptions being aware of the limits of knowledge and being mindful that a particular framing of an issue may not be universally held". They call this 'second-order reflexivity', referring to Schuurbiers (2011). Stilgoe et al. also propose a set of indicative techniques and approaches to strengthen reflexivity, such as focus groups, consensus conferences, and collaboration with social scientists (Stilgoe et al. 2013, p. 1573).

When teaching RRI, the challenge then is to find effective ways of developing early-career researchers' reflective competence, which arguably is an important basis for addressing other RRI keys or dimensions. For example, Mejlgaard et al. (2018) find that critical reflection is "of vital importance when teaching RRI or RRI related issues in higher education" (p. 7), and they identify problem-based learning (PBL) (Wood 2003) and inquiry-based learning (IBL) (Hutchings 2006) as two promising teaching methods. Importantly, they recognize that

> the aim of RRI is not that students know the specific concept and terminology of RRI, but that they know how to practice reflexivity: that they can interpret their context, think and act responsibly in research and innovation processes, or in other words, that they possess administrative ability (Mejlgaard et al. 2018, p. 604).

One may argue that reflection has long been a key idea in education. A classic example is Dewey's *How We Think* (1933). Since then, more has been written on the features and the importance of reflection, for example Kolb's (1984) experimental learning theory and cycle, Argyris' and Schön's (1974) theory of action/espoused theory/theory-in-use and double-loop learning, and Schön's work on the reflective practitioner (1983, 1987). These concepts remain central in the field of organizational learning (e.g., Basten and Haaman 2018).

In more recent research on reflection in teaching (Bharuthram 2018; Smith and Trede 2013; Sunderland et al. 2014; Edwards and Thomas 2010), a common denominator is that scholars caution against having an instrumental understanding of reflection. Boud and Walker consider the increased attention to reflection and reflective practice, warning that

> (a)longside these positive initiatives have grown more disturbing developments under the general heading of reflection. They have involved both misconceptions of the nature of reflection which have led to instrumental or rule-following approaches to reflective activities, and the application of reflective strategies in ways which have sought inappropriate levels of disclosure from participants or involved otherwise unethical practices (Boud and Walker 2006, p. 191).

Moreover, as Beauchamp (2015) notes in her literature review of studies of reflection in teacher education, reflection is a complex concept that should be addressed as such rather than as an educational tool.

The concept of double-loop learning is particularly useful in the RRI context as a strategy to stimulate reflexivity. Argyris and Schön distinguish between single-loop learning, which is learning without changing one's mental model of the problem at hand, and double-loop learning, which includes a feedback loop that allows individuals' and organizations' experience to result in reconsideration and revision of the mental model. In this paper, we use their way of framing reflective practice in organizational learning (Argyris and Schön 1974) as inspiring learning objectives of RRI-related training but also as a point of departure to assess our teaching experiment.

According to Schön (1983), reflective practice is the ability to consider carefully one's actions so as to be able to engage in continuous learning. Thus, as previously noted, reflective practice is a key competence to engage with the four dimensions of responsible innovation as outlined by Stilgoe et al. To be sure, scientists (like all professionals) can hardly avoid engaging in some form of reflective practice, but—as Schön (1983, p. 243) argues—"they seldom reflect on their reflection-in-action" (p. 243), that is, there is little double-loop learning. Consequently, the art of reflection is under-articulated and thus remains inaccessible to other people than the individual professional who is reflecting introvertly. It was exactly this problem of organizational learning that was a central issue in the scholarship of Schön and Argyris.

An important point of departure of Argyris and Schön's approach is the distinction between espoused theory and theory-in-use. Espoused theories are those that individuals claim to follow. Theories-in-use are those that can be inferred from studying the individual's action (Argyris et al. 1990, p. 82). For example, instrumental tool-kit approaches run the risk of producing merely an espoused theory (say, of RRI) among its users rather than a theory-in-use. If so, the result is what Argyris and Schön (1974) call single-loop learning, because the previously existing (non-RRI) mental model of the problem to be managed will remain unchanged and still be the theory-in-use regarding practices of responsibility. In turn, this results in the repeated use of the same approach to the problem of responsibility.

We believe that the overarching ideas and values articulated through RRI policies, such as the dimensions articulated by Stilgoe et al. (2013)—anticipation, reflexivity, inclusion and responsiveness—require double-loop learning, in the sense that scientists should be trained to reflect on their daily practices in the context of RRI as an espoused theory. The training would encourage participants to reflect on the differences and discrepancies between espoused theory and theory-in-use, to question both, and in some cases to reconsider and revise the latter. Thus, we did not embark to develop a course that covered all aspects of RRI.

Method

The organization of the Ph.D. course that this paper presents, analyses, and discusses, is outlined in the next section. It was inspired by Argyris and Schön's way of framing organizational learning. However, we did not aim to contribute to the development of their theories or theories regarding the role of reflection in teacher education. As previously noted, Argyris and Schön's concepts helped us to shape the course, above all by clarifying the benefits of engaging the participants in the intellectual traditions that informed the understanding of science–society relations of RRI policies rather than presenting RRI as an espoused theory. These traditions were explained in depth. It was an implicit assumption that any exploration of science–society relations entails learning, but the presentation of the intellectual background of RRI was meant also to invite the course participants to reconsider their ontologies: “which resemble passing through a portal, from which a new perspective opens up, allowing things formerly not perceived to come into view” (Land et al. 2010: ix). Arguably, double-loop learning stimulates processes that can lead to a shift from one set of preconceptions of the world to another.

Besides, the course was based on the assumption that RRI does not make sense as a source of reflection unless one is familiar with research that shows how development of science and technology is neither pre-determined nor value-free, and unless one understands why engagement with society is called for (Åm 2019b, p. 175). A further conjecture was that the participants, all of whom were recruited from the life sciences, were unlikely to be deeply knowledgeable about such research previous to the course. Rather, we believed that they held beliefs closer to the so-called received view of science (Rommetveit et al. 2013) as a value-free enterprise of producing objective knowledge. The course was intended as a counter-point to this view.

We analyze whether this effort to stimulate double-loop learning was effective, using data generated through participant observation in the course by the first author who wrote extensive field notes. We chose to use participant observation because this allows a documentation of processes and events that cannot be reconstructed with similar validity through retrospective interviews. The second and fourth authors developed and conducted the course but did not collect data during the events. The first author acted as the lecturers’ teaching assistant in preparing group work and in providing feedback on the homework assignment but focused singularly on her fieldwork during the course days. After the course, all the authors carefully analyzed and discussed the field notes and the collected texts. In this, the third author contributed with an important outsider perspective to the analysis, which was conducted as follows.

The first round of working with the data dealt with ordering what happened during the course and plenary dialogues. The second round of analysis examined participants’ articulated reflections and categorized discussions, comments, and reactions to the course topics into different kinds of expressed reflections. In this second round, the analysis focused on moments of disruption or dislocation. This was based on the presumption that early-career researchers first need to recognize that things could be otherwise in order to reflect and question their routine practices in action and to become prepared for disrupting existing orders. ‘Moments of dislocation’ (Howarth 2000, p. 111; Åm 2019a, p. 458) can trigger such recognition.

Dislocatory moments occur when people become aware of discrepancies between their established practices and other practices, views, identities, or organizational policies. Such moments may trigger learning processes that encompass the revision of mental maps, that is, double-loop learning (Schön 1983). For dislocation to happen, RRI-training therefore needs to aim at “ontological transformations that are necessarily occasioned by significant learning” (Land et al. 2010: xi), unhinging early-career researchers’ mental maps about science and society. In the following, we describe how the analyzed course set out to reach this aim.

Course Organization

As indicated, this paper is an account of a Ph.D. course for early-career biotechnology researchers called “Science, Technology and Society: RRI Course Digital Life Norway”, to share the experiences from organizing and running this initiative. The main objective of the course was to enhance participants’ knowledge of how scientific work is intertwined with changes in society and to introduce them to ideas of democratization of science and current international discussions on RRI. The course introduced the body of academic knowledge that according to our reading of the RRI concept underpins it, namely science and technology studies (STS) and the history, philosophy, and sociology of science. The course combined lectures that presented theoretical insights with long group discussions and hands-on exercises that trained participants how to reflect in the context of their research projects. Deliberation about RRI as a guide to good research practices was also part of the course. The participants were introduced to the definition of RRI in EU’s Horizon 2020 program, the RRI framework as outlined by Stilgoe et al. (2013), how this framework has been integrated into policies articulated by the Research Council of Norway, and how research grant applications could be assessed with a view to the way RRI concerns were addressed in the project plan.

The course was offered through the Centre for Digital Life Norway’s Research School (DLNRS). Digital Life Norway (DLN) is a national center for biotechnology training, research, and innovation. The course consisted of two three-day sessions held two months apart, at two locations in Norway during spring 2018. Recruited mainly from

DLN research projects, participants came from four cities in Norway. Seventeen biotechnologists participated throughout the course: thirteen Ph.D. students, three postdoctoral fellows, and one researcher. Except for those participants working on the same project, most participants did not know one another beforehand. The participants' disciplinary backgrounds varied from molecular systems biology, organic chemistry, and microbiology, to various kinds of computational modelling, medicine, and environmental toxicology, to chemical neuroscience and microbial biotechnology.

The course was structured through envisioned learning goals for each session that built on each other. The topics of the first three-day gathering were, in order, interdisciplinarity, "exploring societal dimensions of science", "governance and regulation of biotechnology", "self-regulation and ethical guidelines", "science and innovation policy", as well as "Responsible Research and Innovation in theory and practice". The topics of the second gathering two months later were "co-production of science and society", "transdisciplinarity", "public engagement", "gender and science", "responsibility conditions", "risk, uncertainty, post-normal science" as well as "life sciences and modelling". Thus, the content of the course clearly reflected its ambition of focusing on the understanding of science–society relationships that underpins RRI.

In the following, we focus on dislocatory moments that we identified during this Ph.D. course. When we analyzed the field notes of the first author, some moments in the course stood out as showing a change in the participants' expressed perceptions, thoughts, or opinions of a topic, which suggested new reflections and responses by the participants that seemed to reflect a shift in their ontologies. We identify tendencies towards double-loop learning and reflection-in-action in these moments.

As mentioned above, the analytical focus on such moments was a conscious choice because we wanted to empirically highlight situations in which we observed instances of double-loop learning and/or initiatives meant to stimulate such learning and thus reflection-in-action. The selected moments are meant both as concrete examples of the perceived efficacy of the methods used to engage early-career researchers in higher education in science–society relations and as potential demonstrations of reflection and double loop learning in practice. To assess whether double-loop learning and reflection-in-action took place, we analyzed the selected moments to see if the participants used input from the course to reflect on their own practices (theories-in-action) and their understanding of these practices. The moments in the subsequent section are listed in the order in which they occurred during the Ph.D. course.

Dislocatory Moments: Reflection-in-Action

Moment 1: Governing and Regulating Biotechnology. Learning to Take Pluralist Stances

The envisioned learning goal of the following exercise was learning to take pluralist stances, and the topic of this session was governing and regulating biotechnology. This was during the first gathering. In advance, the participants had been assigned a set of readings (Baltimore et al. 2015; Jasanoff et al. 2015; Sarewitz 2015; Biotechnology Advisory Board 2018) and directed to watch on YouTube a video debate titled “CRISPR: To eat or not to eat. Debatt om genredigert mat [A debate on gene-edited food]” (https ://www.youtube.com/watch ?v=x2hKhSJ9qEM). In light of ongoing revisions of the Norwegian Gene Technology Act, we asked them to consider the following question during their preparation for the course: “What is the public invited to comment upon?” Regarding the CRISPR debate, we assigned participants the following task: “Map the arguments in this debate. What are the representatives of civil society concerned about? What are the counter arguments?”

The group exercise resulted in a panel debate in one classroom. The participants were divided into three groups. Each group was assigned one of the following roles: researchers; a network of GMO-free food and Greenpeace activists; and representatives of the relevant industry. The participants were asked to analyze the provided material (public comments from these actor groups derived from media debate and web research conducted by teaching assistants in advance) and then to prepare arguments and statements for a public debate on CRISPR. Each of the three groups should select two representatives to participate in the panel debate (six participants). The remaining 11 participants and the lecturers comprised the audience; after the panel presentation, the audience asked questions of the six panel participants.

The participants valiantly endeavored to convince the others that their assigned view was the best one. Even though some of the participants enthusiastically embraced their assigned roles from the beginning, exaggerating the assumed views, the longer the debate went on, the more the participants seemed genuinely to try to argue their designated points of view. After the debate was over, one of the participants who had been placed in the Researcher group defending the CRISPR technology told the class that "I have to clarify that my position in this panel is not my personal point of view, and I [personally] don't agree with what I just said [in the debate]. It pained me to defend this point of view." Some of the others also reported that they had found it hard to defend the position they had been assigned.

Focusing on taking pluralist stances contributed to starting the process of reflection on science–society relations amongst the participants. Having to spend time to familiarize and then defend someone else's point of view is a frequently used technique. It was interesting to see how most of the participants became so engaged in the discussion defending someone else's view that they afterwards felt the need to clarify that this was not their personal opinion.

Moment 2: Engaging in the Broader Context of Your Work: Meeting with the Director of Digital Life Norway

The second dislocatory moment came during a meeting with the director of the national Digital Life Norway (DLN) center. Before he arrived, there was a session on the topic "Science and policy: where does the money come from and why do they come?" The session on regulation and funding highlighted the co-production of science and society. In particular, the session aimed at increasing participants' understanding that research is part of a larger context and intertwined with other stakeholders' goals. The aim of the session was to help participants grasp the importance ascribed to science and innovation in Norwegian politics today, and to increase their understanding of the mandate Norwegian policymakers give to research actors. It was considered important that early-career researchers are aware of what society wants from funding research. After a lecture based on Gibbons' (1999) 'new social contract' and Vermeulen's (2009) work on 'making big science', the director of the DLN held a presentation about the center. Beforehand, participants were required to read the RCN's research policy document underlying the establishment of the DLN and to prepare questions for the visitor.

The first question came only a few minutes into the director's talk. The participants asked the visitor many important and challenging questions that were critical to DLN, and they were deeply engaged in the discussion. In this example, we traced double-loop learning from the kind of questions the participants asked as well as from the context and reflections they offered in explaining their questions. Questions included, for example, who the stakeholders were that DLN was supposed to engage with; what "Digital Life" really signified; what was meant by 'transdisciplinarity' in the policy document and how this was supposed to be achieved; and how inclusive the center should be in terms of accommodating new biotechnology projects.

We interpret this as evidence of double-loop learning because we observed that the participants asked questions that prompted the director to reflect on his espoused theories. These happened to resemble the espoused theories, which the students discovered that they used themselves at the beginning of the course. Through these questions, the participants raised important issues regarding the wider implications of Norwegian biotechnology, applying course literature, and adding a higher level of reflection than we previously had seen in the course.

Moment 3: ELSA Issues. Getting Others' Views on Your Project

The third dislocatory moment happened during a group exercise on Ethical, Legal and Social Issues or Aspects (ELSI/ELSA). As a preliminary step to the exercise, the participants listened to a lecture that aimed to provide an understanding of where RRI was coming from, such as the previous policy program of ELSI/ELSA. The lecturer argued that an activity is not necessarily responsible just because there has been engagement with risk assessment, ethical issues, or technology assessment. 'Responsibility' should signify wider concerns.

After this lecture, the participants were divided into four groups to discuss the projects they were working with, in separate rooms. First, the participants were to take three minutes to explain their project to the others in their group, and then the group was to spend five minutes identifying and discussing possible issues of concern in the project before moving on to the next. The point of the exercise was to utilize and underscore the fact that the participants were publics to each other's specialized projects. During this discussion, and unlike previous exercises, all the groups closed the doors to the rooms they sat in. We interpreted this as a sign that they wished to discuss these matters in peace and quiet, without anyone else listening.

After the exercise, the groups reunited and presented a short plenary summary of their discussions. Interestingly, we observed that several participants were surprised about how the others in their group regarded their project. One participant commented that "I never knew there were so many problematic aspects of my project!" At the end of the course, one participant commented that this exercise had been the most significant group activity because she received crucial input with perspectives on her project that she had not considered before. Such experiences indicate an increased awareness and understanding that the public may interpret a project significantly different from the participating scientists. Thus, the lesson was that the task of identifying concerns should not be done only by those undertaking the research. Such engagement should also involve actors with other interests and points of view.

Moment 4: Discussing "Something" Learnt

At the beginning of the second gathering of the course, after a break of two months, the participants were asked how they experienced the aftermath of the first gathering. Several participants described feeling that they had learnt something important. The challenge was to articulate what this 'something' was. They said that they had been unable to describe to their colleagues at home what they actually had learnt during the first gathering. One of the participants said that "I have tried to explain to people what I've been doing for three days. It's been difficult. I want to go back to the lunch discussions [at the department] and quietly ask some questions [about how and why we do things]."

The problem of finding the right words to describe what was achieved by taking the course re-occurred in the reflection notes that the participants wrote on the final day. One of them wrote that "It is difficult to put into words the learning outcome. I feel that I have learnt a lot about RRI, and this has changed and influenced my mindset regarding my view of science. But it is difficult to put into words." Another participant expressed that "After the course, I still feel RRI is hard to grasp, but a lot of new thoughts have come up. When we have discussed the theories, I follow [along], and have also been able to participate in some discussions. But I don't think I can explain this [RRI] very well to others". The challenge involved in learning how to communicate in an interdisciplinary manner what was important lessons from the course was noticeable and probably also constituted a useful experience for the participants. Developing a shared language for thoughts and reflection is essential for good discussions. We provided the participants with some relevant concepts such as co-production, technological determinism, technological fix, and value pluralism, but we are not sure that participants integrated them in their vocabulary by the end of the course.

Moment 5: Homework

At the end of the first three-day gathering, the participants were given a two-part homework assignment. First, all seventeen participants were asked to draw a map of relations identifying the actors, ideological context (promises, visions), conceptual frameworks, disciplines, funding institutions, regulations, instruments, and other relevant aspect of their Ph.D./research project. In the second part of the homework, the participants could choose one of six assignments. Five chose to send comments to the public hearing on the proposed revisions of the Genetic Engineering Act; one wrote a newspaper commentary on her research; one analyzed the gender balance in her research environment, one group working on the same project planned a RRI workshop; and two participants sought input on transdisciplinary workshop tools that they tried to implement in their project.

On the first day of the second gathering, the participants presented their homework and their reflections. This day, the lecturers' response method was to give input on relevant topics as they emerged from the presentations. Based on a review of the homework, lecturers had prepared concise input on the following, emerging themes and concepts: co-production, transdisciplinarity, public engagement (who is the public?), and science communication. From the maps of relations in the participants' presentations it was clear that many of the participants struggled with considering the broader context of their project. Most of the participants focused on human actors and gave less priority and attention to the contexts that influenced their projects, such as value systems, widespread beliefs or ideologies, funding and regulations. However, some of the participants excelled in this task. They had done a solid effort and presented complex maps that included both human and non-human actors, including political, ideological, and environmental contexts.

We consider the homework presentations important because they, along with the review of the relational maps, led to a discussion of what a relevant context might be.

Several participants commented that they had not thought that ideology, values, underlying principles, and their discipline should be indicated on their map. This event challenged each participant to critically review her or his own map while considering the maps of the other participants and reflecting upon what could be improved. This event was also an example of how to teach another way of thinking, involving other aspects and actors outside of what is often seen as the "purely scientific" aspects of a research project.

Moment 6: Imagining Desirable Futures

The sixth dislocatory moment occurred during a group exercise about imagining desirable futures. As a starting point for the exercise, the participants heard a lecture about responsibility conditions, followed by an extensive plenary discussion about transparency in science. Then they were introduced to the concepts of risk, uncertainty, and post-normal science as a background to learn about the concepts 'risk society' and 'reflexive modernization'. The participants were split into four groups and asked to discuss and propose first probable and then desirable futures. "How should the future (of science) look in 30 years?" After the group exercise, all groups presented in a plenary their desirable futures. Most of the groups used as their starting point what the world looked like 30 years ago. In the ensuing exchange, it became evident that the groups had struggled with proposing desirable futures. Rather, they tended to discuss only *probable* futures. A few participants also expressed thoughts such as "there is no point in discussing this because we don't know what will happen anyway."

During the group and plenary discussions, we observed that the participants struggled to negotiate the meaning of the desirable versus the probable. The following exchange is from one of the groups where two participants were discussing what role science should play in a desirable future. One of them asked "Are we talking about probable or possible futures? When you say that we are more tied to devices—do we wish this?". The second participant answered "Yes!" To this the first participant replied "Oh! That's not desirable for me". Another example of the way probable and desirable outcomes were negotiated was the following exchange about the future organization of a desirable research system. One participant argued that "I think it will be more interdisciplinary" while another objected that "This is about desirable futures".

The lesson was that what some find desirable may not be desirable to others. On an intellectual level, this was not a new insight to the participants, which they demonstrated in the discussions before this group exercise. However, experiencing in practice that they did not agree with one another about the features of a desirable future for research policy and the university system seemed to surprise the participants a great deal. Thus, we observed that it stimulated their reflection-in-action and their double-loop learning in practice. Apparently, the participants improved their understanding of how values and priorities influence political as well as scientific decisions, recognizing that the future is not pre-determined but a result of conscious choices. Hopefully, this helped some of the participants to adjust their priorities and their normative ideas about what science should be.

Moment 7: Discussing the Use of Models in Science

The seventh and final important development took place during the final day of the course. It exemplifies how the course challenged the participants' perspectives in order to foster double-loop learning, in this case through a session on the use of models in science. This session involved one individual exercise and one group exercise, followed by an extensive plenary discussion about the use of models. The goal was to raise issues with the traditional reductionist understanding of models; in particular by showing how representation is closely connected to intervention. This was meant as an invitation to reflect about how science does and does not affect society. The discussion revolved around what models scientists use as well as what models can teach their users.

The individual task asked participants to describe the biological question that their projects wanted to answer and their models for researching this. After a discussion about these issues, they were challenged to come up with reasons why the models they use in their project (1) do not represent reality, (2) will almost certainly be irrelevant, and (3) tell little about the questions that they are asking in their projects. Through these provocative statements, they were invited to reflect about potential weaknesses of their models and how such problems might affect their research.

The field notes from the discussion show that—although highlighting what they saw as a necessary reduction of complexity in models—quite a few of the participants did not think about models as intervening in but as representing reality. Thus, they assumed that they would be able to know how their problem-world worked when all parameters and variables were considered. A participating microbiologist, reacting to a comment by one of the lecturers that we cannot know all the parts of the world separately and then put them together, said that "this is just limited by our capacities, such as data power, storage and time. This will evolve."

During the discussion, however, other reflections emerged. One participant commented about his own work that "The sample sizes are too small. And we use predefined assumptions". Another participant, also relating the topic to his own work, argued that "Stem cells are too simplistic. What would happen if we used a dead body [other than the one we are using], not a man 42 years old? We think that the brain structures are similar [across bodies], but this is not always the case." This was followed up by a participant's more general comment on models.

> My first point is: It's just models. It's the current view of biotechnology. In the models in my project, we assume a stable state. But there are more than three hormones in [the animal we study]. They don't only have one temperature. These are difficult things to test in an experiment. Therefore, we are guessing on parameters. Nature is complex.

Toward the end of the discussion, another participant also commented on the difficulty of managing complexity. "Our models are simplistic. The liquid composition is not exactly as it is—it is fundamentally flawed."

These quotes represent only some of the participants' reflections on their use of models and on what models may and may not tell us. They exemplify double-loop learning through the emerging reconsiderations of their ontologies or their epistemological assumptions as the participants challenged their own models and saw them in a broader context. From this perspective, they assessed what models actually can tell about the relevant physical world.

The quotes also show how the participants' perspectives changed and their willingness to critically discuss and assess the use of models in science. This does not mean that everyone agreed with a critical perspective on models. However, after the discussion, several participants reflected upon these different perspectives, saying that for them, this was a new way of thinking about the use of models in science. Thus, the seventh dislocatory moment demonstrates the importance of creating arenas for discussion of and reflection on topics that often are not addressed in everyday research practices. In turn, as we saw, such situations invite consideration regarding participants' scientific practices, their theory-in-action, rendering change possible.

Discussion: Assessing Double-Loop Learning Efforts

Biotechnology is a heterogeneous field of researchers from many, often neighboring disciplines. This was reflected in the participation in the course, and the discussions and some of the group work showed that developing an interdisciplinary understanding between presumably close fields can be both challenging and beneficial. Given that people tend not to see what is surprising in practices that they consider "the normal way of doing things", engaging with others as they did during the course helped the participants to see "what [she/he] ha[s] worked to avoid seeing" (Schön 1983, p. 283). Thus, the interdisciplinary situation of the course and the plentiful opportunities of the participants to be the others' publics potentially introduced fault lines (Traweek 2000) in the discussions that took place. These fault lines were helpful in facilitating double-loop learning.

The course goal was for participants to be able to engage in broader debates surrounding their research, to address social, ethical, political, and economic aspects of their work, and to critically reflect on the R&D system and to take part in initiatives for its improvement. Thus, reflection played a crucial role in the course with the intention of facilitating double-loop learning. This was the underlying curriculum of the sessions. Moreover, for many of the participants, this was the first time they learnt about biotechnology from a social science point of view, which introduced an additional interdisciplinary fault line. This challenged participants to consider their scientific practices in new ways. The discussion about models mentioned earlier was an example of this. This effect was also present in participants' accounts of their benefits from the course, which supports the assumption that double-loop learning happened throughout the course.

In the dislocatory moments noted above, participants had to reflect upon their own practices, values, and ontologies. This helped them develop a meta-perspective on the conduct of such reflections. Though we identified instances of double-loop learning in each of the seven dislocatory moments, it was their sum, rather than each moment in itself, that provided double-loop learning and reflection-in-action to facilitate engagement in RRI. The first moment initiated a process of reflection on the implication of one kind of emerging biotechnology, establishing a starting point for asking critical questions about the relation between Norwegian biotechnology and the wider society and its stakeholders outside of academia.

This process continued in the meeting with the DLN director. Here, participants had the opportunity to ask critical questions regarding the center's role, priorities, funding, aims, and the methods for achieving these. The hands-on exercises challenged participants to articulate the wider (and to the participants) more blurred relationships, but they were close enough to the participants' own projects that they could see the implications for their daily work. Which exercises the participants found most thought provoking or important varied.

If we taught the course again, we would adapt a couple of readings for the first sessions to improve the first group exercise. However, in general, based on the experiences presented in this paper, we do not see a need for substantial changes in the set-up of the course. Dislocatory moment six—the discussion about desirable and probable futures—was also a kind of dislocatory moment for the organizers because we were surprised that so few students shared our assumptions about structural problems with responsibility conditions in today's academia. We learnt that we should aim to present students with alternative, contrasting points of views in order to trigger critical reflection on the subject. In addition, maybe our evaluation of the situation was too negative.

Admittedly, it is difficult to assess the learning outcome of such a course. First, as we did not interview the participants before the course began, we do not know to what extent their reflections during the course actually emanated from the course or from reflective practices already in place before the course. Second, to assess outcomes properly, we should have followed participants over time to observe if there were long-term changes in their research practices and their view of science. Nevertheless, we claim some effects of the course, based on participants' accounts of their perceived outcome, because their feedback was overwhelmingly positive. For example, one participant reported that she had gained a new perspective in which science was something also influenced by social actors. "One of the things I take home from the course […] I think I had this vision of science as free and curious, but I've been enlightened [by learning about other perspectives]. Now I see how much it's about governing and 'catching' words."

Another participant emphasized that she had gained new knowledge about science but complained that she found the new insights difficult to apply in her daily work. "This [the course] has really changed my way of thinking, and my ideas about science and my world. But how to do it in my daily work? But it will change how I speak about science, how I present it". Thus, she interestingly articulated a possible tension between espoused theory acquired during the course and theory-in-use related to her everyday practice, a recognition that could be a first step in a double-loop learning process. The participants also acknowledged that they had learnt something new about citizenship. As one of them formulated it, "I realize [now] that I'm also a citizen. This [course] has changed my way of thinking about the public. Now I think we are all citizens". It is these two participant accounts that most clearly articulated the kind of ontological transformations that the course was aiming at.

Conclusion

Policy demands for doing RRI in biotechnology emanate from a belief in the necessity of changing scientific practices and an assumption that this may be achieved by practicing RRI in the context of research projects. However, such achievements are demanding, not least because there is no straight-forward way to translate RRI concerns into competence, going from espoused theory to theory-in-use. The popular idea that RRI can be disseminated and implemented in the form of tools and toolkits risks catering mainly to single-loop learning, due to its emphasis on the implementation of procedures. According to Argyris and Schön (1974), such learning is not effective in providing for change.

The course that we have described and analyzed in this paper was an experiment in teaching RRI, stressing the underlying ideas and the development of reflective competence, following the tenets of double-loop learning. Since the course has run only once, with a limited number of participants, we have to be careful about generalizing the experiences. However, given what happened through the seven dislocatory moments and the feedback from the participants, we suggest that there is considerable potential gain from educating early-career researchers by providing them with the resources to reflect on their theories-in-use of their daily practices. Facilitating double-loop learning in this manner seems important, given that the objective of RRI policies is to produce real change.

In the actual world of research, innovation, and higher education, RRI is but one of many policy principles, and a quite weak one at that. Implementing RRI into early-career researchers' mental models and not merely into their repertoire of espoused theory seems desirable from the point of view of RRI policies. However, one potential challenge is with the dominant policy narratives of innovation for economic growth, where RRI may be considered a detour. In a review of a broader set of efforts to teach critical reflection on science and technology, it was observed that such efforts indeed may be marginalized because of their success: "constantly under threat 'every time there is a new dean" (Mejlgaard et al. 2016, p. 19). Still, during the conduct of our course, participants were not concerned that its content could be a problem to potential transitions from research to innovation.

Our course was driven by the desire to move beyond ritualistic reproduction of espoused theory. Mejlgaard et al. (2018) tried to capture this quality by advocating RRI as *phronesis*, that is, as practical wisdom, as opposed to the *episteme* of knowing RRI policies. Our contribution is to propose an approach to obtain that desired change, namely through the facilitation, stimulation, and support of double-loop learning through careful selection of course content and form. Whether the participants actually are able to use the espoused theory of the course to change their theories-in-use in order to reform their daily practices, remains to be seen.

New experiments with more participants, as well as subsequent research on these teaching experiments, are needed. We believe that they will provide additional insights about how to internalize theories-in-use in the context of reflecting about science–society relations. We are however confident that we observed authentic engagement during the course. Moreover, we interpret some of the discussions during the course to indicate that the participants gained knowledge of matters of concern related to biotechnology (Latour 2004, 2008), or what Solbu (2018b) calls epi-knowing. In turn, this should result in an increased awareness of the importance of reflecting about science–society relations.

Epilogue

About a year after the course, the first author by chance met seven of the participants on different occasions and took the opportunity to conduct spontaneous interviews (Henriksen and Tøndel 2017) with them: Had the course in any way influenced them and their daily work? The general response was that they had learnt a lot and were glad to have taken the course. They said that they would take it again, although they found the lessons challenging to apply in their daily research practices. Their assessment of the effectiveness of the course varied. One participant commented that she felt that she did not learn much scientifically from the course and that it had no effect on her daily work. Other participants reported that the course had influenced them considerably. One of them said that "[s]he [one of the lecturers] opened some doors for me that definitely were not open before [regarding perspectives on science and society]." Another participant added that the RRI course had impacted her and that it "so often and in so many situations pops into my head. I think about it almost every day". Yet another participant told that during the last year he had repeatedly contacted the research school of DLN to request similar courses or activities, and to find out if the course would be held again.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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PART III

4

Disciplinary transgressive epistemic machineries: Core and support practices in Norwegian biotechnology

In this concluding chapter, I return to the four research papers in part II and analyze them together to broaden the perspective on disciplinarity transgression. This 'cross-cutting analysis' is directed by the following questions: What disciplinary transgressive practices emerge in the context of policy demands for disciplinary transgression? In particular, what characterises these practices; that is, which elements do such practices consist of, and what are the dynamics and relationships among these elements? Arguably, by analyzing elements and dynamics, we can analytically find out how disciplinary transgressive practices are achieved.

By attempting to answer these questions, I am reaching for further insights into this dissertation's main research question: How is disciplinary transgression achieved? I begin this chapter by introducing the theoretical framework and concepts I employ in the cross-cutting analysis: practice theory and the concept of epistemic machineries. Practice theory constitutes the main theoretical approach and is therefore given more emphasis in the theory outline and the analysis than epistemic machineries. That being said, I draw also on Karin Knorr Cetina's concept of epistemic machineries to explore how disciplinary transgressive practices can be seen together.

4.1 Theoretical framework and concepts employed in the analysis

Practice theory

As outlined in chapter 1, my aim in this dissertation is to understand practices of disciplinary transgression in the field of biotechnology. Moreover, I want to explain *how* disciplinary transgressions happen. Hence, I need a theoretical framework that can provide a guiding tool to answer how practices can be understood, as well as answer questions regarding the emergence and demise of disciplinary transgressive practices, how such practices change, and how disciplinary transgressive practices relate to each other.

A practice theory considers all questions. STS scholarship both inspires and has been inspired by practice theory. For example, the laboratory studies within STS advocated specific attention toward the scientific practices that scientists engage with in laboratories, and what the practices mean for the construction of scientific facts (Knorr Cetina, 1981; Latour & Woolgar, 1979; Lynch, 1985). Knorr Cetina (1999) argues that 'practice' served "as a contrasting term for the laboratory studies", as the scholars "investigated scientists at work as opposed to the history of ideas, the structure of scientific theories or the institutional settings of science" (p. 9). Later scholars working within STS also have been paying attention to practices. Latour's actor-network theory (see, e.g., Latour, 1987, 2005) is one such example, though the claim that the categories of actors and action could be extended also to artefacts and material object is contested by many practice theorists (see, e.g., Schatzki, 2010; Shove et al., 2012). In *The Mangle of Practice*, Pickering (1995) seeks a middle way between social constructivism (the "strong programme" in the sociology of scientific knowledge [SKK] and the "social construction of technology" [SCOT]) and actor-network theory by suggesting that neither nature nor society should be considered the primary centre for agency (Constant, 1997; Lynch, 1996). Pickering (1995) argues for understanding agency as a mangle of practices made up of the actions of both material entities and people.

These are just a few examples of how the study of practices have been key within the field of STS, and how STS scholarship on practices has shown that practices are indeed crucial for understanding both science and its knowledge production. Based on this, I argue that drawing on practice theory is fruitful in explaining practices of disciplinary transgression, both how they emerge, disappear, and change in the world. In this dissertation, I use practice theory consistent with what Reckwitz (2002, p. 257) calls a heuristic device, that is, a sensitising 'framework' for analyzing the research papers' findings. Moreover, I argue that practice theory is useful when understanding how disciplinary transgression is (or is not) produced, and to describe and analyze change and stability without prioritising either agency or structure (Shove et al., 2012). For now, by 'practice' I mean arrays of (human) activity (consistent with Schatzki's definition, 2001, p. 11).

The history of social theory is characterised by a distinction between methodological individualism and methodological collectivism (or holism). Whereas the first approach gives primacy to individual actions to explain, explore, or understand social phenomena, the latter explains social phenomena by structures or social wholes (Postill, 2010). Practice theory is seen as a theoretical approach to bridge the gap between actor-oriented and structural approaches, or what has been called purpose-oriented and norm-oriented models of explaining action (Reckwitz, 2002, p. 246). Practice theorists, and in particular Schatzki (1996, p. 11), argue that practice theory is one of the most promising impulses that goes beyond this distinction.

Practice theory, however, is not a coherent approach (see, e.g., Hui et al., 2017; Reckwitz, 2002; Schatzki, 1996; Schatzki et al., 2001; Shove et al., 2012). A variety of theorists are seen to contribute to what can be considered the family of practice theories. Pierre Bourdieu, Michel Foucault, Anthony Giddens, and Charles Taylor are frequently referred to in this context (Postill, 2010; Reckwitz, 2002; Schatzki, 1996; Shove et al., 2012), but also contemporary scholars such as Judith Butler and, as we have seen, Bruno Latour, are sometimes understood as members of "the praxeological family of theories" due to their focus on performativity in gender studies and studies of scientific practices, respectively (Reckwitz, 2002, p. 244). The abovementioned scholars' theories differ considerably and cover a variety of approaches to questions in the social sciences and humanities. The question to ask here, however, is what is common for these theories?

Postill (2010) distinguishes between two generations of practice theorists. The first generation (consisting of, e.g., Bourdieu, Foucault, and Giddens) sought to "liberate agency – the human ability to act upon and change the world – from the constrictions of structuralist and systemic models while avoiding the trap of methodological individualism" (Postill, 2010, p. 7). According to Postill, the second generation (characterised by theorists such as Ortner, Schatzki, Reckwitz and Warde) builds on and extends the theory, for example by developing new concepts, applying practice theory to new areas, and by paying closer attention to questions of culture and history. According to this distinction, I draw on practice theory from the second generation and later works of practice theory, such as Schatzki (1996), Schatzki et al. (2001), and Reckwitz (2002), but particularly on Shove et al. (2012). How do these scholars understand practice theory?

Schatzki (1996) sees practice theory as a collection of accounts that promote practices as *the* fundamental social phenomenon. Moreover, he argues that practice theorists emphasise that practices are both crucial objects of analysis and the central phenomenon to understand other social entities, such as actions, institutions, and structures (p. 11). Schatzki writes that, although these scholars differ in many regards, they all specify "a particular type of entity, namely, practices, as the principal constitutive element in social life", and thus they have at least one common trait: they hold "the idea that practices are the site where understanding is structured and intelligibility articulated" (p. 12).

Shove et al. (2012) build on both Schatzki and Reckwitz in their development of practice theory and see it as a fruitful way of answering questions like "How do societies change?" and "Why do they stay so much the same?" Shove et al. argue that practice theories are particularly well-suited for understanding change; in the context of research policies on transdisciplinarity demanding change and DLN as an experiment to transform Norwegian biotechnology, practice theory is thus useful for understanding how change may be conceptualised and achieved in these settings. Furthermore, practice theorists want to make a difference. Specifically, they want practice theories to have an impact on public policy. Shove et al. (2012) argue, with reference to Giddens, that "the day to day activity of social actors draws upon and reproduces structural features of wider social systems", and Shove et al. seek to develop a greater understanding of how practices emerge, evolve, and disappear (p. 4). This action-orientation is also reflected in policy studies' practice turn (Griggs et al., 2014).

It is perhaps unsurprising then that the term 'practice' has been subject to discussions and different definitions within this family of theories. Despite the many definitions, most theorists who theorise practices conceive of them as 'arrays of human activity', according to Schatzki (2001, p. 11). The understanding of what such activities entails varies greatly, as does what connects them. In the next section, I outline one framework for practice theory, based on the work of Shove et al. (2012).

Elements of practice: Meanings, materials, and competences

Shove et al. (2012) conceptualise practices as consisting of three types of *elements* that are actively combined by actors. Classified as *materials, competences,* and *meanings* (p. 14), these elements are key in understanding how practices may emerge, change, and disappear. As stated by Shove et al., "[p]ractices emerge, persist, shift and disappear when connections between elements of these three types are made, sustained or broken" (p. 14).

The processes by which alterations in practices happen are complex and interwoven. For our case, examining the three types of elements, and how these make up different practices, is particularly interesting, as it may provide insights into how practices of disciplinary transgression can emerge at different places, and why similar practices may differ between places. Although separated into materials, competences, and meanings, the three elements must be considered together – they are not only interdependent but also mutually shaping (Shove et al., 2012, p. 32).

In the cross-cutting analysis, I use this element-triad – materials, competences, and meanings – as a framework for analyzing the four research papers and combine it with Knorr Cetina's 'epistemic machineries' (1999) to discuss disciplinary transgressive practices in Norwegian biotechnology. Before moving to the analysis, we look more closely at the three elements.

First, *materials* include things, technologies, tangible physical entities, infrastructures, tools, hardware, the stuff that objects are made of, and the body itself (Shove et al., 2012, pp. 14-23). According to Shove et al., elements travel in different ways. For materials, transportation and access are particularly important, as material elements of practice often involve their physical location (p. 45). This can be illustrated by how materials such as cell lines travel between scientists in the same project but located in different buildings. In my data, this transfer involved the physical relocation of cell lines carried by one scientist from one building to another scientist in another building. Access to materials is then, quite obviously, key for practices to move, as access opens up possibilities for creating networks and infrastructure necessary for practices to take hold at new places.

Second, *competences* are composed of multiple forms of understanding and practical knowledge, and thus include skills, know-how, background knowledge and understanding, and techniques. In this category, Shove et al. (2012) note the (in some instances) important distinction between knowing in the sense of what enables you to evaluate a performance and knowing "in the sense of having important skills required to perform" (p. 23). Both these forms of knowing are included when I use the term "competences".

To explain how elements of competence circulate, Shove et al. (2012) employ the concepts of abstraction and reversal. Their key point is that "[k]nowledge has to be 'abstracted' from a local situation before it can travel, and it needs to be 'reversed' when it arrives in some new destination" (p. 48). This means that transfer of knowledge is not seen as a simple, linear process of sending and receiving.

Drawing on Deuten (2003), Shove et al. (2012) suggest that knowledge has to undergo a process of decontextualisation and packaging to make it move, that movements are dependent on infrastructure, and that to make knowledge work elsewhere, it has to undergo another process of recontextualisation and standardisation (see also Collins, 1974). Let's take an example of a university biopolymer lab that orders a new machine to create alginate gels. How does knowledge of how to operate this machine travel? What must be in place for the knowledge to be able to travel? For the knowledge to be able to travel, it is dependent on agreed-upon standardised recipes and procedures. The manufacturer provides such procedures to distribute knowledge of how to work the machine, and these procedures often consist of a detailed list of steps for the actor to follow. In practice, however, such procedures are insufficient, and scientists are dependent on taking courses (e.g., by actors in the firm selling such equipment), and/or on other scientists with previous experience using the same machine. This is also one important reason for scientists to take courses or travel to other labs to learn the procedures of how to operate equipment. Furthermore, infrastructure is necessary for knowledge to travel: the practice requires not only the machine itself, but is dependent on other factors, for example, on funding from the department to pay for it, and on sufficient space in the laboratory to place and operate it. This has implications: in this kind of competence travel process, competence can travel only to places where actors are prepared to receive this competence, which again is based on prior experience. If this experience is not in place, the practice would not necessarily be re-assembled in the same way as where it came from.

Third, *meanings* are understood as a collective term encompassing mental activities, emotions, ideas, aspirations, and motivational knowledge to "represent the social and symbolic significance of participation at any one moment" (Shove et al., 2012, p. 23). To describe how meanings circulate, Shove et al. (2012) use the concept of association, arguing that meanings are extended and eroded as a result of "dynamic processes of association" (p. 55). This means that practices as a whole, and the meaning-elements they consist of, are linked to specific associations. An example of this is how disciplinary transgressions in science are often linked to ideas of (valuable) future outcomes for both science and society. In other words, meanings can change through the making and breaking of new associations.

This can be done explicitly, as in the case of the Centre for Digital Life Norway actively trying to transform Norwegian biotechnology towards increased collaboration and digitalisation. DLN's efforts can be considered an active attempt to create new associations of what doing biotechnology research in Norway entails. Other times, the social or symbolic significance of participation and meaning of a practice change more indirectly as more people become involved. By participating in some practices over others, "individuals locate themselves within society and in so doing simultaneously reproduce specific schemes and structures of meaning and order" (Shove et al., 2012, p. 54). Despite attempts by media, private firms, institutions, and policymakers to create specific associations between practices (through meaning-elements) and, for example, a product, there is no guarantee that these associations will be effective or lasting. This is an inherently local and uncertain process, as the circulation of meaning-elements depend on "successive, multi-sited, processes of de- and re-classification" (p. 56).

Shove et al. (2012) define practices both as performances and entities. In their analysis, they utilise the analytic distinction between 'practice-as-performance' and 'practice-as-entity' to show how novel combinations of elements are enacted and reproduced. To illustrate this, I build on Shove et al.'s example of skateboarding (p. 7) modified to my own data. Using the example of data modelling in bioinformatics, we can say that modelling consists of a conjunction of elements: understanding the computer code, the parameters going into making the model, rules and norms for coding, and modelling's meanings to practitioners. Modelling thus exists as a "recognizable conjunction of elements" that figures as an *entity* that can both be discussed and/or drawn upon when doing modelling (p. 7). The links between elements in modelling may change, for example with new insights or breakthroughs, or with new actors engaging in the practice bringing in new elements or associations to what modelling may entail. At the same time, Shove et al. argue that practices exist as performances: "It is through performance, through the immediacy of doing, that the 'pattern' provided by the practice-as-entity is filled out and reproduced" (p. 7). This means that it is only though "successive moments of performance that the interdependencies between elements which constitute the practice as entity are sustained over time" (p. 7). In other words, only through performance – through actors doing modelling over and over – are the interdependencies of elements reproduced, making the practice endure over time.

Another key point for Shove et al. (2012) is that actors are carriers of practice. They build on Reckwitz (2002), who understands the social world as inhabited by a variety of practices that are carried out by agents. Seeing individuals as carriers or hosts of practices means departing from seeing practices as personal traits or attributes, treating them as 'necessary elements and qualities of a practice in which the single individual participates, not qualities of the individual" (Reckwitz, 2002, p. 250). Conceptualising individuals as carriers of practices thus emphasises practices over individuals.

So far, I have focused mainly on elements and single practices. Practices are, however, interwoven and interdependent. When practices depend on each other, they constitute bundles (loose-knit patterns that sometimes form co-dependence) and complexes. The emergent characteristics of complexes are that they "cannot be reduced to the individual practices of which they are composed" (Shove et al., 2012, p. 87). According to Shove et al, such complexes arise and disappear as a consequence of competition and/or collaboration between practices (p. 88). This does not mean that the power relations between practices are symmetrical, and Watson (2017) shows how power is exerted by institutions, such as governments and corporations, focusing on how some practices are capable of disciplining and shaping others.

We now return to the previous description of elements. Following Shove et al. (2012) in assuming that practices consist of these three elements opens up for an analytical heuristic in the study of scientific practices of disciplinary transgression: Which materials, competences, and meanings characterise these practices? This is the overarching framework guiding the analysis of the four research papers presented below. In the following, I show how different elements are reflected and differently weighted in scientists' practices in different contexts. But before that, let me discuss Shove et al.'s practice theory in relation to Knorr Cetina's concept of epistemic machineries.

Epistemic machineries

Shove et al.'s focus on the different elements in practices and their interplay resembles Knorr Cetina's notion of epistemic machineries (1999), in that both approaches account for a variety of interrelated practices that together make up the world. The advantage of Knorr Cetina's approach for my study of disciplinary transgressions is that her work is applied on studying scientific practices. Knorr Cetina uses the term 'epistemic culture', rather than the notion of discipline, to "amplify the knowledge machineries of contemporary sciences until they display the smear of technical, social, symbolic dimensions of intricate expert systems" (p. 3). Based on her research on experimental high-energy physics and molecular biology, she turns her attention not to the construction of knowledge, as previous laboratory studies commonly did, but to the construction of the *machineries* of knowledge production. She argues that studying these machineries "reveals the fragmentation of contemporary science", bringing out the diversities of epistemic cultures (p. 3).

The notion of epistemic cultures is closely related to practice. For Knorr Cetina, culture is "the aggregate patterns and dynamics that are on display in expert practice and that vary in different settings of expertise" (p. 8). Culture further refers back to practice, as the notion of culture "foregrounds the machineries of knowing composed of practices" (p. 10). Knorr Cetina argues that the notion of culture in turn brings to practice "a sensitivity for symbols and meaning, a third element that enriches the idea of epistemic machineries" (p. 10). Epistemic cultures thus work well together with a practice theory framework, as presented in the previous section.

In *Epistemic Cultures: How the Sciences Make Knowledge* (1999), Knorr Cetina describes two epistemic machineries and how they operate: the community of high-energy particle physics at CERN in Switzerland, and a Max Planck Institute group in molecular cell biology in Germany. As chapter 2 mentions, Knorr Cetina concluded that these two epistemic cultures differed significantly in how they practised science, not only in the use of methods, tools, and materials, but also in their ways of reasoning and how they related theory to their empirical reality. For example, whereas high-energy physics is characterised by a loss of the empirical, molecular biological practices are characterised by maximising contact with the empirical world (p. 79). Moreover, whereas data in experimental high-energy physics are "firmly embedded in a network of anticipation, simulation, and recalculation, (…) in molecular biology they stand on their own, subject only to questions of adequacy and interpretation" (p. 79). The notion of machineries emphasizes the performative aspects of knowledge production and emphasizes how the technical aspect is interwoven with culture, meaning, and knowledge.

For Knorr Cetina's argument of the diversity and disunity of science, describing different epistemic cultures and machineries of knowledge production was important. In the context of this dissertation, that is, in the context of disciplinary transgression, the notion of epistemic machineries is useful when attempting to understand the interwoven practices of disciplinary transgression. The notion of machineries is useful because it highlights how the material, the technical, the cultural, the symbolical, and meaning and knowledge are interwoven, and thus it emphasizes the performative aspects of knowledge production. What are the components of the epistemic machineries of disciplinary transgression? In the next section I suggest some answers to the questions outlined above.

4.2 Cross-cutting analysis: Disciplinary transgressive practices in Norwegian biotechnology

In this cross-cutting analysis, I return to the four research papers and discuss their main findings and implications in light of the theoretical framework and concepts outlined in the previous section. For brevity, I typically refer to the papers as paper 1[5], paper 2[6], paper 3[7] and paper 4[8], following the order of their appearance in part II.

The four papers are stand-alone articles (and therefore must also be considered as entities on their own), and each paper has a different theoretical focus to answer its specific research questions. In this part, the aim is to analyze the papers together to carve out this dissertation's overarching contribution to STS scholarship on how disciplinary transgression is achieved.

Practices of disciplinary transgression seen though materials, competences, and meanings

The four papers show that in the context that I have studied – Norwegian biotechnology and the DLN – practices of disciplinary transgression happen through composing, highlighting, and shifting connections between the elements *materials*, *competences*, and *meanings* in various manners: Paper 1 focuses on practice theory's dimension of meaning and shows various understandings of the policy concept transdisciplinarity in DLN. Paper 2 focuses on materials and knowledge, showing the flows and practices of transgressing disciplines when enacting interdisciplinarity in research projects, and it singles out one particular practice of material knowledge and object transfer – the scientific relay. Paper 3 is also based on a particular interest in the material dimension; it shows how place-making practices are connected with socialisation in the research centre aiming for disciplinary transgression. Paper 3 also emphasizes the interconnectedness of material, cognitive, and affective aspects. Knowing and liking each other is an important but under-communicated element for establishing new interdisciplinary collaborations and for allowing existing collaborations to run smoothly.

Paper 1 shows that the main understanding of transdisciplinarity was rather narrow, defining it as interdisciplinarity, and papers 2 and 3 dig deeper into how interdisciplinarity played out. Paper 4 picks up the thread of transdisciplinarity and analyses whether it is possible to increase awareness and enactment of transdisciplinarity by raising

[5] Making sense of transdisciplinarity: Interpreting science policy in a biotechnology centre.
[6] Relying on relay: Flows in interdisciplinary collaborations in biotechnology.
[7] Socializing scientists into interdisciplinarity by place-making in a multi-sited research center.
[8] Transforming Scientists' Understanding of Science–Society Relations. Stimulating Double-Loop Learning when Teaching RRI.

competences and skills. The paper shows both learning practices and knowledge transfer practices in a PhD course for early-career researchers in biotechnology on science-society relations. In sum, we see that each of the papers emphasizes one of the three elements, as indicated in figure 2. It must be noted, however, that these elements cannot be easily disassembled in practice. In practice, the elements are co-constituting and thus overlap.

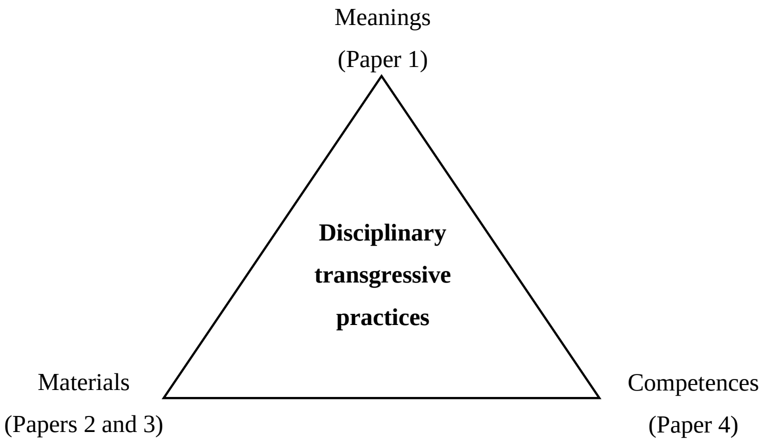

Figure 2: Conceptualisation of connections between and focus on elements in the four research papers.

The most prominent element apparent throughout the papers, when analyzed through the practice theory of Shove et al. (2012), is the material element.

Both papers 2 and 3 illustrate the importance of material aspects of disciplinary transgressions, though in different ways. The relays observed in paper 2 are in the first instance made up of materials – materials in the sense of the data, graphs, tables, cell lines, and buffer concentrations. The materials often stood in relation to each other. For example, in project B, cell lines were dependent on the right buffer concentrations for viability, and the alginate gels could not become gels (useful to the experiments) without the Kinexus machines at the laboratory used by the biopolymer scientists.

Paper 3 gives a different example of materials at play in the context of disciplinary transgression. The most visible material in paper 3 is not data, instruments, or tools as they were in paper 2. In paper 3, materials are related to infrastructure. Physical place, that is, the physical locations where DLN arranged different initiatives and events, was key.

Based on these findings, I propose *materials* as the element of particular importance in disciplinary transgressive practices. This is not to say that these practices are tied down to this element alone. Both papers 2 and 3 show that the material element is highly related to *meanings* and *competences*. The main argument in paper 3 is that place is more than just physical location. Place must be made by filling an (empty) space with people, practices, objects, and representations (Gieryn, 2000). Looking at this from a practice theory point of view, this is indeed an argument for the interplay of elements. Specifically, paper 3 shows that materials (place) and meanings (affective aspects) were dependent on each other for making interdisciplinary collaboration work.

In paper 2, the relays offer illustrative examples of how elements are interwoven. The competences-element (e.g., skills, technique, and know-how) was tied to materials in a very direct way: the scientists had to have the skill of operating the instruments, the competence to model living systems, or know-how of how to make the (computer) code work when faced with unexpected bugs and the like. The materials in play were also dependent on being understood. This was crucial for successfully interpretating the materials and making up relevant meanings in the specific settings. The skill and know-how of operating the Kinexus machine to make gels were inextricably linked to the understanding of what could be gained from using this particular machine rather than another machine. The relays showed that how materials were interpreted differed with different actors. For example, as emphasised by the mathematician in project C in paper 2: the biologists had to make the data meaningful to the mathematicians, and vice versa, for the disciplinary transgression to work. These sensemaking processes were key for the scientific outcome of the project. In sum, we see how both paper 2 and paper 3 emphasise the materials in disciplinary transgression, and that relay actions are an illustrative example of how elements are independent and mutually shaping. Paper 4 further highlights how meanings and competence are interwoven in reflexive practices. For example, when the course organizers aimed to facilitate second-order reflexivity and double-loop learning in early-career biotechnology researchers, discussing different conceptualisations of science was a first step in transforming scientists' espoused theories into theories-in-use. Understanding the context and meaning of RRI as related to more general discussions about science-society relations, realising that existing relationships between science, technology, and society could have been different, and realising that a particular framing of an issue may not be universally held were all components in developing the participants' reflective practices. In light of practice theory, espoused theories can be said to connect to the element of meanings, while theories-in-use connect to elements of competence and skills.

Core practices and support practices

When analyzed together, the papers display a variety of practices related to disciplinary transgression: socialisation, place-making, sensemaking, learning, teaching, object and knowledge transfer, and affect. All are important in achieving disciplinary transgression. But are these practices of equal importance? As stated by Shove et al. (2012), certain practices suppose and require the reproduction of others. Place-making, for example, produces elements – such as context-specific understandings, and encounters in buildings or other infrastructures – that affective practices depend upon. Following Watson (2017), we may ask: what disciplinary transgressive practices are capable of orchestrating and shaping others?

To approach an answer to the dissertation's main research question of how disciplinary transgression is achieved, I suggest that there is a distinction between a set of core and support practices. When analyzing the four papers, we see that disciplinary transgression is approached in different ways, but that some practices are aimed more directly at the actual doing of disciplinary transgression in the scientists' everyday scientific activities than others. One such practice is the already described scientific relays, and I consider relays a core practice of disciplinary transgressions. Relays are a common way of doing interdisciplinarity, and, as outlined in paper 2, relays can be done in different ways depending on the actors, disciplines, and materials involved in the research. Relays do not, however, exist independently, as was clear in the interplay of elements discussed above. A relay is enabled though a set of support practices. I understand support practices as – indicated by the name – practices or activities that facilitate and support the core practice. Papers 1, 3 and 4 give examples of important support practices. These are activities or practices of socialisation, place-making, sensemaking, learning/teaching, and affective aspects.

Regarding the last, affective aspects, paper 3 already shows that affective aspects are key for both existing and new interdisciplinary collaborations in science, and I do not repeat the argument here. I note, however, that affective aspects make up a key support for achieving disciplinary transgression. This is the case for the disciplinary transgressions described in all four papers, despite paper 3 being the only one that explicitly focuses on this. For the core practice, the relays, affective aspects supported the transfer of objects and material knowledge in a tacit but crucial way. For example, in project C, all the scientists that I interviewed emphasised the importance of an initial workshop where they got to know each other while learning about each other's scientific fields. This was essential to make the relay of materials work, as it lowered the scientists' threshold for asking questions about the materials or other uncertainties they encountered in the course of their interdisciplinary work.

Relay actions were also supported by socialisation. In the three projects described in paper 2, (especially) early-career scientists were socialised into particular ways of engaging with interdisciplinarity. In project A, all interviewed scientists emphasised that they worked in an interdisciplinary research centre. Although it differed how much the scientists worked across disciplines in the project, all interviewees talked about interdisciplinarity in positive terms. In project C, the research group was actively socialised into an interdisciplinarity mindset by a continuous focus on interdisciplinarity throughout the project. This was done by emphasising how to work together and how to develop a common language, which also implicitly and tacitly socialised the group members into valuing interdisciplinarity as something positive. The socialisation supported the core practice by making the scientists aware of and account for potential differences in disciplinary knowledge that could lead to potential communication challenges that would hinder the relay the project depended on for their scientific results. Socialisation into interdisciplinarity combined with the emergence of affective relations in which the scientists built personal ties made even some of the more skeptical scientists, who initially were not terribly interested in working interdisciplinarily, engage in disciplinary transgression.

In scholarship on disciplinary transgression, support practices are given scant attention, and there are few analyses of how these are active in facilitating core practices. Although often overlooked, support practices for disciplinary transgression should be given more attention, and I argue that core practices to a large extent are a product of these support practices. One implication of the interplay between core and support practices is that core practices can be considered to be developed through experience.

Disciplinary transgressive epistemic machineries

By drawing on Knorr Cetina's concept of epistemic cultures, I argue that core and support practices together constitute epistemic machineries – knowledge-producing complexes – for disciplinary transgression. Looking at the epistemic machineries for disciplinary transgression in the interdisciplinary research projects in paper 2, we notice that these machineries differ from the epistemic cultures of high-energy physics and molecular biology studied by Knorr Cetina (1999). The epistemic cultures studied by Knorr Cetina are disciplinary practices. When bringing the concept of machineries to the analysis of disciplinary transgressive practices in DLN, I find that there were no established machineries for disciplinary transgression. Even though neither high-energy particle physics nor molecular biology consists of one unified, unchanging culture, these fields nevertheless are more established and stable than the interdisciplinary collaborations in DLN. The epistemic machineries present in disciplinary transgression in DLN are more fluid and elusive because they are linked to research projects rather than to a single, established scientific field.

Because of the changing nature of research projects, their various collaboration constellations, and project funding, the nature of the disciplinary transgressive machineries also shifts from project to project. One result of this is that disciplinary transgressive machineries do not accumulate knowledge and a common epistemic culture in the same way as more established and long-lasting disciplinary fields do. Papers 3 and 4 focus on disciplinary transgression on network project level, rather than on the single research projects. The machineries created in the networking project do not consist of the core practices found in the research projects in paper 2 but are mainly composed of support practices that will enable scientists and projects to engage in core practices. The machineries at the network project level are also shifting in that they depend on funding, on faculty hired/dismissed, and on where the networking project decides to focus its main attention with respect to the various strategic efforts on transdisciplinarity, innovation, digitalisation, and RRI. Since disciplinary transgressive machineries do not exist in the same way as in the more defined epistemic cultures of established sciences, they must be created locally in a different way than in such disciplinary cultures.

By ‘created locally’, I refer to the way the epistemic machineries of disciplinary transgression are dependent, for example on local conditions of funding, on how research is structured and organised, and on the different disciplines involved. I do not claim that there are *no* common features of epistemic machineries of disciplinary transgression. The core and support practices in DLN described are indeed examples of such common features, although support practices – such as affect, socialisation, and place-making – are also active in collaborations within the same field. I claim these to be of particular importance in disciplinary transgression because in such collaborations there often are fewer things (methods, research questions, materials, etc.) that are jointly understood from the projects’ outset. The changing nature of epistemic machineries of disciplinary transgression with local conditions implies that these machineries cannot be taken for granted, and neither can the practices they consist of. The next paragraph elaborates on this last point.

Both practices and epistemic machineries of disciplinary transgression depend on the movements of the elements involved, and meanings, materials, and competences are crucial in establishing practices and machineries at different places and settings. What does this mean for the movement of disciplinary transgressive knowledge? As knowledge (competences) must be abstracted from a local situation before it can travel and must go through a process of reversal when it arrives at a new location, it cannot be taken for granted either how knowledge travels or how it becomes practised when re-embedded at a new place. For disciplinary transgressive knowledge, this means that, in order for it to be embedded in new contexts in a specific way, scientists are dependent on a repertoire of skills, technique, and/or knowledge where it is to be reversed. This knowledge and competence are often experience-based and need to be learned through interactions with other practitioners and by having experience with specific types of transgression. As Shove et al. (2012, p. 56) note, some kinds of knowledge and know-how can only be acquired and can travel only if there is a base or foundation of existing competence on which to build. This has implications for how to think about disciplinary transgressive practices: If the goal is to achieve or facilitate such practices, greater attention should be given to the many complex ways elements are transferred and interrelated, as this provides key insights into the nature of these practices and how they may emerge, change, or disappear at different locations.

4.3 Conclusion

The aim of this study has been to gain a better understanding of disciplinary transgression, and more specifically to answer the research question: how is disciplinary transgression achieved? I investigated this in the context of Norwegian biotechnology, and a multi-sited biotechnology research centre aiming to transform Norwegian biotechnology though transdisciplinarity.

Central topics explored in the four research papers are how scientists make sense of the research policy concept of transdisciplinary; how scientists enact interdisciplinarity in their research projects; the role of place, place-making, socialisation, and affective aspects in interdisciplinary collaborations; and how to influence early-career biotechnology scientists' visions of science-society relations through formal teaching. I examined how the actors involved in disciplinary transgression in science made sense, enacted, and learned inter- and transdisciplinarity, and showed in the cross-cutting analysis of the papers how they do this by engaging in a set of core and support practices that together make up epistemic machineries of disciplinary transgression. I described a core practice: the scientific relay, and a set of support practices related to socialisation, affect, learning, teaching, place-making, and sensemaking.

DLN is an experiment of transforming Norwegian biotechnology. From a practice theory perspective, we can say that, for transformations to take place and to create new epistemic machineries of disciplinary transgressive knowledge production, they are dependent on carriers of practice to engage in and to enact new practices or to change existing practices into something that afford this transformation. In the case of disciplinary transgression in DLN, the carriers of practice that must be enrolled are mainly scientists, but also includes the DLN management group as implementors of the DLN mission. The core practice is carried by the scientists who choose to engage in this practice. This means that relays are dependent not on more expert communicators or external consultants but on the scientists themselves to establish the interactional expertise that would enable the relay.

A challenge for disciplinary transgression in DLN is that the mission of transforming Norwegian biotechnology did not involve only a change to more and new forms of disciplinary transgression. The RCN, through the DLN initiative, also aimed for a change in scientists' practices involving digitalisation, innovation, and Responsible Research and Innovation (see also Solbu, 2021; Åm et al., 2021). As with all practices, these can become long-lasting or transformative only if enough practitioners are recruited to and enrolled in the practices, and if these carriers are faithful in continuing the practice. DLN started enrolling the carriers of these new practices (scientists) through place-making practices and attempted to influence and change their association and links between meaning elements through socialisation practices. In some cases, new links were made between elements resulting in change, as in the RRI course for early-career biotechnology researchers described in paper 4. In other cases, links were not made – as shown in paper 1 with respect to the different understandings of transdisciplinarity – resulting in misunderstandings, uncertainty, and other practices.

Shove et al. (2012) argue that individuals choose to participate in some practices but not others and, moreover, that some practices are done at the expense of other practices. Engaging in innovation, digitalisation, and RRI, as well as in transdisciplinary practices, involve a choice of time used doing something at the expense of other practices.[9] In the DLN context, I therefore question RCN's demand of a variety of new practices (disciplinary transgression, RRI, innovation, digitalisation) without investigating what such practices would entail or how they would collaborate or compete with other contemporary practices and demands in biotechnology research.

It is important to note that practices of disciplinary transgression are not a result only of policy demands. They are also a result of scientists' experiences and beliefs, and often projects of disciplinary transgression are results of carefully planned and orchestrated disciplines and scientific competences. In such projects, researchers engage in what Lamont (2009) calls cognitive contextualisation. For example, relays work because the scientists acknowledge the various scientific backgrounds in interdisciplinary collaborations, and they accept one another as different without imposing evaluation

[9] There are different ways of conceptualizing time and practices, not only as a necessarily limited and finite resource. Furthermore, note that practices not only compete but also collaborate. For an overview over time and practice, see Shove et al. (2012, pp. 127-130).

criteria from their own discipline into others. This acceptance results in a division of labor that in turn leads to relays. Paper 2 shows that biologists, for example, acknowledge bioinformaticians' competence as distinct from their own competence, and that it therefore makes sense for them to relay their knowledge to the bioinformaticians so that they can accomplish what they need to. Another example of this is afforded by the early-career biotechnologists in paper 4 who acknowledge that knowledge about science-society relations as taught by SSH scholars is another competence than their own. Moreover, double-loop reflection, as described in paper 4, would also enable scientists to engage in cognitive conceptualisation, which arguably is a reflective approach to managing disciplinary transgression in practice.

Here I add a reflection on the integration of social scientists and humanists (SSH) in biotechnology projects. These collaborations are often problematic for the social scientists and humanists (see, e.g., Balmer et al., 2015; Delgado & Åm, 2018). Considering the widespread use of relays in biotechnology research projects, it is perhaps unsurprising that knowledge for SSH is subject to a division of labor. Just as biologists would leave the modelling to the bioinformaticians or the mathematicians because they lack this competence themselves, they would leave what they consider as "the social" to the researchers they consider to be experts on this: the social scientists or humanists. But because such knowledge is of a different character and is less specific than alginate gels, cells, or computer models, and so on, it does not fit into the relays, and therefore natural scientists often do not consider such knowledge part of "the science" they engage in.

Scholarship on disciplinary transgression is characterised by a number of meta-reflections on inter- and transdisciplinarity. These meta-reflections are often of an abstract nature that provides little directional guidance on how to actually achieve disciplinary transgression in practice. I contribute to this scholarship by suggesting a set of core and support practices that together illustrate how disciplinary transgression is achieved in Norwegian biotechnology research by making up complex epistemic machineries of knowledge production that are local and situated.

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Appendices

Appendix I: Interview guide for individual semi-structured interviews

Background

- Could you tell me about your professional background?
- How did you get involved in the project?
- When did you get involved in the project?

About the project

- Could you tell me about how you work together in the project?
- What are your tasks in the project/what is it that you do in the project?
- Who do you work with/work the most with?
- What can you as [disciplinary background, e.g., biologist, bioinformatician, mathematician] do that others cannot do?
- What do you need help with from others in the project? Do you have an example?
- Is this the first time you work together with [biologists/bioinformaticians/ mathematicians]? Could you tell me more about this?
- How was your first encounter with the project?

Collaboration

- Is interdisciplinarity/transdisciplinarity a topic in the project? How? Do you have an example?
- How did transdisciplinarity become a topic in the project?
- [Name of project] is affiliated with the Centre for Digital Life Norway (DLN). Have this/how has this influenced the project?
- In [name of project] there are scientists with different scientific background. Why are these particular disciplines/groups of scientists part of the project?
- Could you describe the collaboration in [the project]? Would you say that there are important differences between the partners? Can you say more about this?

- Have you ever been in a situation where you have not understood what one of the other project members meant, e.g., because of differences in disciplinary training/background? What happened/could you give an example?
- What is the main challenge for you in the project, regarding collaboration? Do you see any other challenges? Could you give an example?
- What do you think works best I the project?
- Have you/what have you learned from others in the project? How did you learn this? Can you give an example? Are you content with what you have learned from the others? Could you tell me more about this?
- Would you say that it requires much experience to communicate well with others who have a different scientific background than yours? Can you tell me more?
- How often are you in contact with the different partners in the project? How?
- When you or your research group have new information, how do you communicate this to other project members? To whom?
- What kind of information is this? How do you communicate/convey this information/material to the others? [At meetings, via email, in the hallway, etc.?]
- Does everyone interpret this information in the same way? Or are there sometimes misunderstandings? Do you have an example?
- How are all parts of the project to be linked in the end? Who should do this? How is this envisioned?
- You have collaborators that you meet digitally [skype or other digital platforms]. How does this work? What is lost in this form of communication and collaboration?

RRI

- How do you work with RRI in the project?
- How do you understand RRI?
- How do you understand responsibility in your research?
- Is there something that you think is important to your work that we have not talked about? What? Why?

Appendix II: Interview guide for focus group interviews

- In many DLN projects there is collaboration between the "harder" natural sciences, the digital, mathematical, and numerical computational modelling on the one hand, and the "softer", biological sciences on the other. Can you tell us about your experiences with this kind of collaboration?
- To make scientific collaborations work – how should it be organized?
- When you talk about science collaboration/interdisciplinarity/multidisciplinarity/transdisciplinarity [adjust word depending on the word(s) used by the interviewees], is this what you would call transdisciplinarity? What does this word mean for you?
- What kind of project support or funding is suitable for making science collaborations work?
- If you look at science collaboration and transdisciplinarity in the context of your university: Does the university facilitate inter- or transdisciplinarity in research within the organisations? If yes: How do they do it? Does it work? Why/why not?
- In DLN, Responsible research and innovation (RRI) is a cross-cutting issue. Do you consider RRI to be a part of the transdisciplinarity discussion? Why/why not?
- In addition to RRI, innovation has also been an important issue in DLN. How would you describe the relation between the demands for innovation and for RRI in the centre?
- In DLN, transdisciplinarity has been highlighted as an important feature. Is this, in you experience, a topic also outside of Norway? Is this something you discuss with international collaborators in academia or industry?

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