The academic changemaker

Helping climate and energy researchers reflect on their role in action-oriented transdisciplinary collaborations

by

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Preface

Why would you read this master thesis?

Because you will learn something about how university researchers can help solve climate change.

Climate change poses existential challenges to humanity. These challenges call on us to transform our societies to reduce carbon emissions, for example by replacing oil and gas by solar cells and windmills (the energy transition). Transformations like these pose crucial questions for our universities: what should be their role in supporting society in transformations like the energy transition? Traditionally, universities' main task has been to produce knowledge, without being too involved in how that knowledge is used in society. However, considering the urgency of climate change, university institutes around the world are currently re-inventing their role to *transform* society through their knowledge production. The academic researcher becomes a change-maker, rather than merely a neutral knowledge producer. What does this new role mean for researchers? And how can they be prepared for this daunting task?

Interested? Read on!

You can read this thesis whatever your background is

I am delighted that you are reading my master thesis! Maybe you are a (starting) researcher, like me? Or maybe you seek guidance from science in the energy transition? Or maybe you are just interested in how universities support society in the face of climate change? Whoever you are – this thesis report is written for you!

- **All readers –** Most of this thesis assume no previous knowledge of the topic. And I have avoided scientific jargon. Some sections do become a bit technical though – you can recognize them by this symbol: ⚙. Feel free to skip these sections.

- **Readers with an academic background in climate studies AND in Science communication, Science and technology studies or Philosophy of science -** You might be interested in sections with the symbol ⚙. These sections assume previous knowledge of the field of study and are written in jargon-rich, academic language.

Acknowledgements

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Summary

When it comes to climate change, there is no time to lose. We need proper solutions to emit less greenhouse gasses and to prepare us for the impacts of climate change. Universities can provide the knowledge needed for those solutions. An increasing number of research projects attempts to provide such knowledge through collaborative approaches where scientific and societal actors closely interact – often referred to as 'transdisciplinary research'. These approaches are, however, neither without contestation nor without challenges. This master thesis focuses on challenges with transdisciplinary research at a specific academic research institute: the Center for climate and energy transformation (CET) at the University of Bergen in Norway.

CET is a research center where PhD-candidates engage in transdisciplinary research partnerships and students develop innovations with and for societal case-owners. These forms of transdisciplinary collaborations come with a myriad of challenges and complexities that untrained scientists might not be adept to deal with. Especially, it is hard for transdisciplinary researchers to determine which roles they should adopt in the collaboration. Several roles are possible. In some roles, the researcher is more focused on providing knowledge, in others on mediating perspectives and in yet others on facilitating learning processes between societal actors or engaging actively in these learning processes. At CET, there is need for a tool that can aid starting researchers (students and PhD-candidates) to reflect on these roles to help them make purposeful choices about which role to adopt.

To design a reflection tool for CET, this master thesis uses design-based research. First, the research builds an analytical framework of researcher-roles that is suitable for CET. Next, the research conducts a descriptive case-study at CET. The case-study analyzes how CET-researcher conceive their roles and which challenges they face related to these roles. These challenges are what the reflection tool focuses. Next, the insights of the case-study are used to design a reflection tool. For the case-study, data is collected through semi-structured interviews, logbooks and focus groups. The design of the reflection tool is built on brainstorming techniques to develop two prototypes, prototype evaluation sessions and a test session of the final tool.

The final tool is a card-game that makes CET-researchers exchange ideas about which roles to adopt in a playful way. In the game, the researchers read a challenging transdisciplinary situation that is related to real-life challenges CET-researchers have faced. They then choose which unique contribution they want to make in that situation and which actions they will perform to achieve that contribution. The actions belong to specific researcher-roles. Through the game, the CET-researchers learn a new language about researcher roles: they widen their repertoire to think and speak about what they want to contribute to transdisciplinary collaborations and how they can do that. This can help them when making role-divisions in researcher-teams, when discussing expectations with collaboration partners and when they are faced with challenges that require shifting between roles.

The game is developed specifically for CET and has a low generalizability to other contexts. Nevertheless, with some adaptions, elements of the game can also be used in different contexts. Moreover, besides developing a reflection tool, this research also established connections between two frameworks of researcher roles (theory-building).

Reflexivity for transdisciplinary researchers is crucial. Helping the academic changemaker reflect on their role in transdisciplinary collaboration – it is a crucial step towards creating more conscious and purposeful collaborations with the ability to transform society in the face of climate change.

1. Introduction

1.1 Problem description

When it comes to climate change, there is no time to lose. We need proper solutions to emit less greenhouse gasses and to prepare us for the impacts of climate change. Universities can provide the knowledge needed for those solutions. An increasing number of research projects attempts to provide such knowledge through collaborative approaches where scientific and societal actors closely interact – often referred to as 'transdisciplinary research'. These approaches are, however, neither without contestation nor without challenges. This master thesis focuses on challenges with transdisciplinary research at a specific academic research institute: the Center for climate and energy transformation (CET) at the University of Bergen in Norway.

Let us first look at what I mean with 'transdisciplinary research' and how it is different from other forms of interactions between science and society. Then let us look at why transdisciplinary research is challenging and how this master thesis will aid researchers at CET to overcome these challenges.

1.1.1 Transdisciplinary research

Interaction between science and society can happen in many arenas, such as science journalism, policy advisory and lobbying. In these arena's the interaction generally happens *parallel* to scientific research or *after* scientific research was conducted. Although different arenas can overlap, 'transdisciplinary research' is in this master thesis seen as a distinct arena where science-society interaction happens *during* the research, through collaboration between academic researchers and societal actors. By involving societal actors in the research, researchers can ensure that that they include relevant perspectives in their research, increase the support for the research outcomes and give people the democratic power to influence research that might affect them (Verhoeff & Kupper, 2020). Transdisicplinary research approaches come with specific collaboration challenges that might not be present in science journalism, policy advice or lobbying. It is these specific transdisciplinary collaboration challenges this master thesis focuses on (see section 1.1.2).

Let us look at a few examples of 'transdisciplinary research' to make the concept more concrete. An example is knowledge co-production in transdisciplinary partnerships. CET is participating in such partnerships, like the one around the project *CityFreight*[1], funded by the Norwegian research council. The partnership consists of public actors (like the municipality of Bergen and the regional county of Vestland), private actors (like a business council and a bank) and research institutes (like CET). The goal of the partnerships is to develop tools with and for regional authorities to decarbonize logistical freight transport. You can read more about this partnership and other partnerships CET is engaged in, in section 2.2. Other forms of transdisciplinary partnerships are Horizon 2020 partnerships, funded by the Horizon 2020 program of the EU. They often consist of universities, public, private and civil society actors and have the goal of co-producing knowledge and developing implementable solutions, for instance for climate transitions. These projects often involve shared problem definitions, co-production workshops and co-design approaches. CET is involved in two Horizon 2020

[1] https://www.uib.no/en/cet/133736/cityfreight-freight-logistics-sustainable-cities

projects but is to the authors knowledge at the moment of writing not actively engaged in co-production activities in these projects.

Transdisciplinary collaboration also happens around single or recurring events. CET for instance co-organizes what they call 'climate hackathons'. These are multiple-day events where actors from multiple levels of public governance 'hack' a governance issue connected to climate adaptation together with researchers (Kvamsås et al., 2021). The researchers set the agenda in close collaboration with the municipal and regional actors present at the event.

Other examples of transdisciplinary research that do not happen at CET are *citizen science*, in which citizens participate in research projects by collecting and/or processing data (Silvertown, 2009); and *living labs*, which are environments for involving users in innovation and development research (Følstad, 2008). When transdisciplinary research involves the design of solutions or innovations, as is the case for many projects at CET, it is also referred to as 'participatory design'. In participatory design, the users of the designed solutions can be involved in varying degrees, ranging from 'design for users', where the users are consulted but are not involved in the designing themselves; 'design with users', where designers and users closely collaborate; and 'design by users' where the users are the main actors in the design process (Kalmar & Senfert, 2020).

Collaborative approaches in science are not new. However, they are becoming increasingly popular. In science and technology studies, Gibbons (2000) and Nowotny, Scott & Gibbons (2003) argued that a shift has been ongoing from what they call 'mode-1' to 'mode-2' science. In the new 'mode' of science, the researcher attempts to achieve *change in society* through collaborative approaches, rather than merely producing *knowledge about society*. This 'new mode' of 'participatory' science is however an idealized picture of a fuzzy and contested reality. For instance, human geography, the discipline in which CET is rooted, has for a long time been oriented towards change processes and local stakeholders. Nevertheless, Haarstad et al. (2018, p.194) argue that 'much of the critical discussion has taken place within the discipline rather than through active engagement with society.' Getting out in society requires 'venturing outside the comfort zone' and comes with a myriad of challenges and complexities that uncritical and entrenched scientists are not adept to deal with. Let us therefore have a look at some of these challenges.

1.1.2 Challenges for transdisciplinary researchers

First of all, it is not obvious how a researcher should engage in transdisciplinary collaboration. There is a multitude of possible roles (e.g. Whittmayer & Schäpke, 2014) or 'modes of engagement' (e.g. Haarstad et al., 2018). A researcher could engage in a collaboration as a traditional scientist, producing scientific knowledge and presenting their findings to the collaboration partners. They could go a step further and act as a *knowledge broker* by 'translating' their research to non-academic language or to specific contexts ('situating' the knowledge), or by picking out findings relevant to the specific people they are collaborating with. Or they could act as a *change agent* by also actively thinking along about solutions for practical societal challenges and helping societal actors to widen their scope of action. Moreover, the researcher could bring actors together and organize or even lead the collaboration as a *process facilitator*.

Choosing which role to play can be a challenge in itself. However, even when researchers know which roles to play, they might run into the challenge that many of these roles require skills they were not trained in (Hilger, Rose & Keil, 2021; Vinke-deKruif et al., 2022). Presenting scientific research might require translating academic jargon to daily language and it requires organizational skills to bring people together and lead discussion between them. Moreover, different roles can be in

tension with one another (Bulten et al., 2020) and different parties to the collaboration might have diverging expectations of which roles the academic researcher should adopt (Haarstad et al., 2018; Bulten et al., 2021; Vinke-deKruif et al, 2022).

Because of these challenges, it is important that researchers have an awareness and understanding of the roles they assume in transdisciplinary collaboration (Pohl et al, 2010). For instance, Haarstad et al. (2018) contend that researchers with a limited understanding of how they can engage in societal transformation can be type-cast into roles with limited potential to achieve societal change. Bulten et al. (2021) argue that a better awareness and understanding of roles allows for purposefully dividing conflicting roles over multiple researchers. A thoughtful role-division could mitigate tensions between roles and prevent researchers from taking up roles they do not have the skills for (Hilger, Rose & Keil, 2021; Vinke-deKruif et al., 2022). Moreover, a better understanding of researcher roles allows for openly discussing the expectations of all participants to the collaboration, which can reduce unrealistic and competing demands from researchers (Hilger, Rose & Keil, 2021).

Several scholars argue that improving researchers' awareness and understanding of their roles in transdisicplinary collaboration requires *reflexivity* (Bulten et al., 2021; Hilger, Rose & Keil, 2021; Huning, Räuchle & Fuchs, 2021; Vinke-de Kruijf et al.; 2022). Bulten et al (2021) refer to Hilger et al. (2018), by stating: "Education can stimulate students to be reflective about their intentions as researchers. After all, it depends on these intentions which roles they should adopt."

Nevertheless, these topics are not part of most university studies and for starting PhD-candidates, there is little time to reflect on this. Moreover, although the above scholars call for reflection on researcher-roles, they provide little guidance on *how* to reflect.

1.1.3 Helping CET-researchers reflect on their role in transdisciplinary collaboration

The above mentioned challenges are visible in practice at the Center for climate and energy transformation (CET), a research institute of 15 full time academic researchers and a ring of affiliated academic researchers at the University of Bergen in Norway. CET actively collaborates with governmental actors, business actors and civil society organizations in several of its research projects. At the time of writing this master thesis, CET was not involved in research projects which actively involved citizens in research (such as citizen science), therefore this master thesis focuses only on collaboration with public, private and civil society actors. See chapter 2 for more information about CET and the transdisciplinary collaborations they are involved in.

At CET, there is little time to reflect and exchange ideas on how to organize these collaborations and which roles the CET-researchers should adopt in them. Moreover, the center runs mostly on PhD-candidates, some of which leave after four years. Tacit knowledge about transdisciplinary collaboration disappears with them. Additionally, CET organizes a course for bachelor students in which the students engage in transdisciplinary collaboration. However, there is little explicit reflection on the collaboration process built into the course program. Therefore, the supervisors at the center have trouble guiding the new starting researchers (students and PhD-candidates) in their transdisciplinary collaboration processes.

This leads to the following problem statement for this master thesis:
Students and starting PhD-candidates at CET who collaborate with people outside academia need to reflect explicitly on which roles they assume in these collaborations. However, there is limited training and guidance on how to do this reflection.

1.2 Research aim & questions

1.2.1 Aims of the research project

Primary aim

The primary aim of this research project is to **develop a reflection tool** to help students and starting PhD-candidates at the Center for climate and energy transformation reflect on their role in transdisciplinary collaborations.

To analyze the problem on which this reflection tool should focus, this master thesis conducts a descriptive case-study at CET. The insights of the case-study are then used to design a reflection tool.

Secondary aims

- **Generating insights useful for CET**: The descriptive case-study additionally aims to generate useful insights for CET-researchers about the roles they currently adopt in transdisciplinary collaboration, which roles they might additionally adopt and (how to overcome) challenges related to their roles. These insights are accessible in this thesis, even if you do not engage with the reflection tool.
- **Theory building**: The case-study additionally aims to contribute to theory building about the roles of researchers in society. Based on the case-study, I verify existing frameworks of researcher-roles and add to them.

1.2.2 Research questions

To achieve the primary aim, I focus on the main research question:
How can a reflection tool help starting researchers at the Center for climate and energy transformation in Norway to reflect on their role in collaborations with policymakers, business actors and civil society actors?

The research is divided into two phases. First, I do a descriptive case-study at CET using qualitative social science research methods to find out what problems the refection tool should focus on. Next, I use design methods to design a reflection tool. Both phases are guided by sub-questions.
The sub-questions are color-coded, so you can recognize them in the overview of the research process in section 1.4. Color-blind readers can look for the bold keywords in the sub-questions.

Problem-analysis (descriptive case-study)

Before a reflection tool can be designed, it is necessary to understand which challenges this reflection tool should focus on. For this, this master thesis conducts a descriptive case-study at CET.
Sub-question 1: How do CET-researchers conceive their **roles** in transdisciplinary collaborations?
Sub-question 2: Which **challenges** do CET-researchers face related to these roles?
Sub-question 3: How can **reflection** be conceptualized in the problem-context?

The problem analysis leads to a problem summary and a list of design principles for a reflection tool that can help address the problem.

Solution design

To design a reflection tool, I first step out of the problem context to generate multiple innovative ideas for reflection tools. After that, I test these multiple ideas so that the best suited tool can be chosen and worked out in detail.
Sub-question 4: Which reflection tool **prototypes** could help the researchers to reflect on their role?
Sub-question 5: Which reflection **tool** is best suited in the context of CET?

1.3 Scientific relevance

This master thesis adds to a growing body of literature on the different roles that researchers can assume in the science-society interface and which roles are best suited for which aims (e.g., Pohl et al., 2010; Wittmayer & Schäpke 2014; Haarstad et al., 2018; Hilger at al., 2018; Bulten et al., 2021; Hilger, Rose & Keil, 2021; Huning, Räuchle & Fuchs, 2021; Vinke-de Kruijf et al., 2022).

Because of the challenges mentioned in the problem description (section 1.1.2), several scholars like Bulten et al. (2021), Hilger, Rose & Keil (2020), Huning, Räuchle & Fuchs (2021), and Vinke-de Kruijf et al. (2022) call for researchers to explicitly reflect on the roles they assume. However, to the author's knowledge, only Vinke-de Kruijf et al. (2022) propose a simple tool to guide that reflection (which Is discussed further in section 3.2.3 in the theoretical framwork). The lack of guidance on *how* researchers can reflect is a significant research-gap, especially considering that most starting researchers receive no teaching and training in transdisciplinary collaboration.

This research fills the research gap by designing a reflection tool. For the reflection tool, this master thesis first assesses the scientific literature on researcher roles. From that literature, I choose a framework of researcher-roles that is most adequate to use as analytical framework for the case-study at CET, and I operationalize the framework so it can be used in data collection. This thesis then performs the case-study. Finally, I design a reflection tool to help the CET-researchers reflect on their role. The design process is both grounded in the theory, through the analytical framework of researcher-roles; as well as tailored to a specific transdisciplinary research context, through the case-study at CET.

This master thesis applies the research expertise of the research group Communication design for innovation (CDI), which hosts my master program at the Technical University in Delft. The expertise of the CDI research group lies in aiding transdisciplinary teams to deal with complex communication and collaboration challenges. CDI does this by building capacity in the transdisciplinary team for dealing with their complex context. The theoretical focus of CDI is (among other things) on learning sciences, collaboration processes and reflection. CDI's methodological expertise lies in design-based research using a methodological mix of social science research methods, system analysis methods and design-thinking. This mix of theoretical and methodological expertise is adequate for designing and testing a reflection tool for the researchers at CET to reflect on the complex topic of their roles in transdisciplinary collaboration.

1.4 Research approach

To answer the research questions, this research uses design-based research. Simply put, this means that the research involved a design-process (more explanation about 'design-based research' in *section 3.1 in the methodology*).

The rest of this report proceeds as follows. The next chapter (chapter 2) describes CET (the case-context) in more detail. After that, the theoretical framework (chapter 3) discusses theory on transdisciplinary collaboration and develops an analytical framework for the case-study. The methodology (chapter 4) describes the methods used during the case-study and during the design of the reflection tool. Then, the case study results are described (chapters 5 and 6). After that, I make a problem summary and formulate design principles for a reflection tool that could help address the problem (chapter 7). Finally, I design a reflection tool based on those design principles, as a solution to address the problem (chapter 8 and 9). The thesis closes off with a conclusion (chapter 10) and a discussion (chapter 11).

Figure 1.1 on the next page visualizes the research process. The figure is simultaneously a reading guide. The blue boxes indicate chapters and sections in this thesis report. The arrows show how the chapters feed into later chapters. The two grey diamonds represent the two phases of research. See section 3.1 in the methodology for further explanation. For a precise planning of the research process, see appendix 1.

Finally, it is good to know that before I started with the research process, I already did short explorative research to determine what topic my research should focus on. You can see it the top of figure 1.1 on the next page. Here, I explored existing literature and had informal conversations with CET researchers.

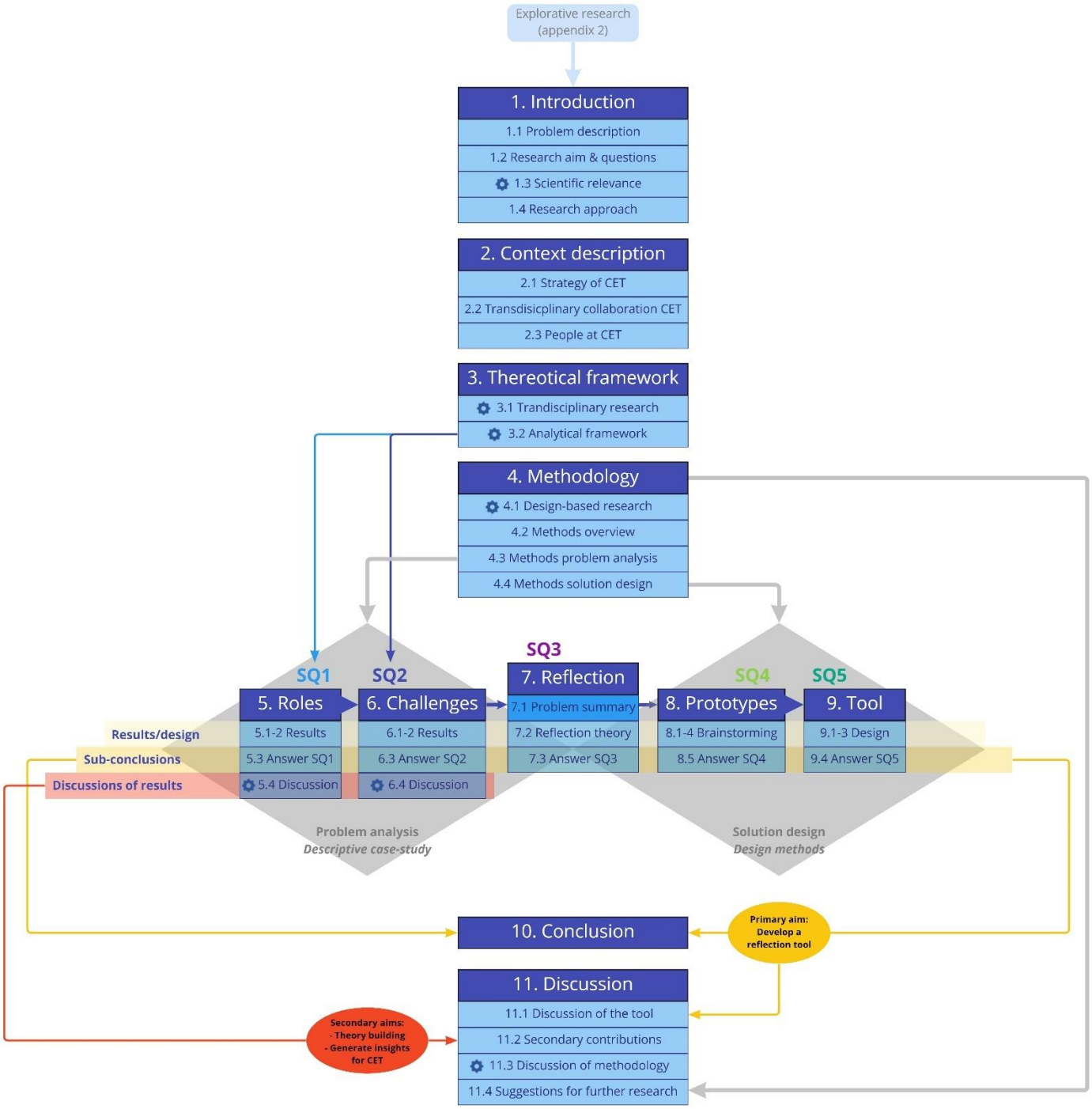


Figure 1.1. Overview of the research process & Reading guide. The blue boxes indicate chapters and sections in this thesis report. The symbol ⚙ indicates that a section is rather technical and contains a lot of scientific jargon. The arrows show how the chapters fed into later chapters.

2. Context description

Several PhD-candidates and students at the Center for climate and energy transformation (CET) were respondents in this research. Therefore, it is useful to get to know CET and learn about the people who work there, before we dive into the research.

CET is a partnership between the University of Bergen (UiB), research center NORCE and the Norwegian school of economics (NHH). It is housed by the department of geography at the Faculty of Social Sciences at UiB. Although CET has its base in geography, CET performs inter- and transdisciplinary research.

2.1 Strategy of CET

The center produces actionable knowledge about how to achieve a sustainable transformation of society to prevent climate change. CET summarized its vision and three main goals in figure 2.1 below, which can be found on its website[2].

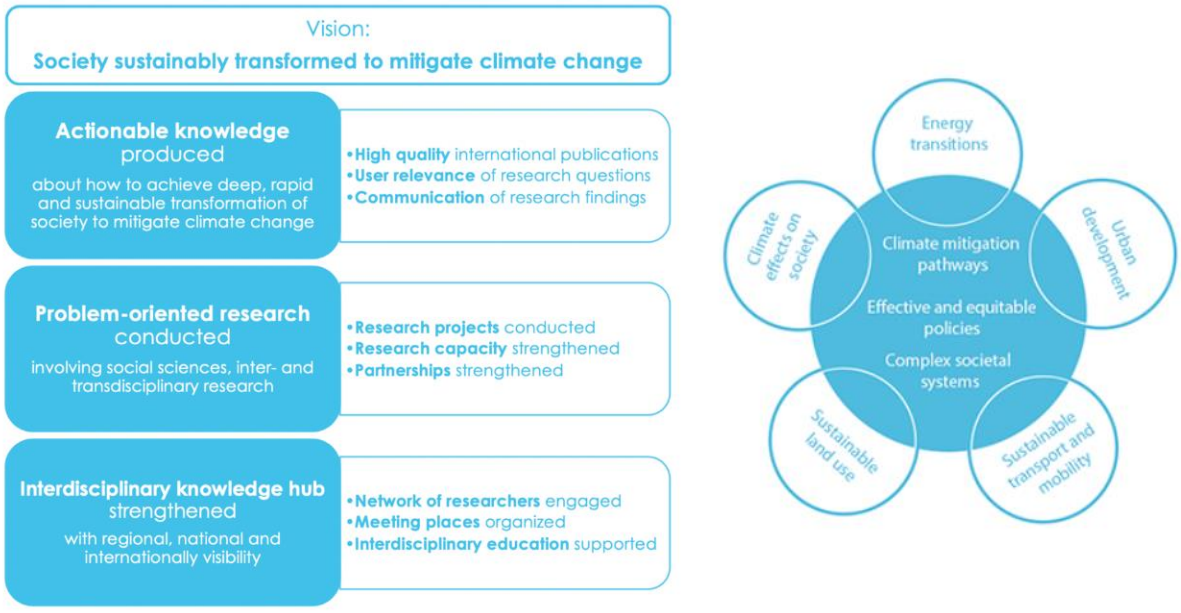


Figure 2.1. LEFT: Vision and goals of the Center for climate and energy transformation[3]. RIGHT: Priority areas of CET[4].

CET's research focuses on three core priority areas (figure on the next page, inner circle) and five applied priority areas (figure on the next page, outer circle). In each priority area, CET runs projects. In several of these projects, CET-researchers engage in knowledge co-production and transdisciplinary collaboration with societal actors.

[2] https://www.uib.no/en/cet/134672/strategy-2020-2022#goals
[3] https://www.uib.no/en/cet/134672/strategy-2020-2022#goals
[4] https://www.uib.no/en/cet/134672/strategy-2020-2022#priority-areas

2.2 Transdisciplinary collaboration at CET

Producing actionable knowledge through transdisciplinary co-production is a cornerstone in CET's strategy. Such a strong focus on co-production, however, came with contestation and with significant complexities and challenges. Some of these have been discussed in section 1.1.3 in the introduction. For a full overview of challenges with transdisciplinary collaboration in the early years of CET, please read Haarstad et al. (2018). This article contains a lot of the rationales behind the actionable knowledge strategy of CET.

To give you an idea what transdisciplinary collaboration at CET currently looks like, let us look in more detial at one research projects where CET-researchers engage in knowledge co-production (Cityfeight). For two other projects, I only shortly discuss how they differ from Cityfreight.

2.2.1 Cityfreight

A research project that builds strongly on knowledge co-production is *Cityfreight*, funded by the Norwegian research council. Two PhD-candidates at CET are involved in this projeect – they wer both respondents in this master thesis. The project is connected to the applied priority area *Sustainable transport and mobility.* The goal of Cityfreight is to 'provide authorities with concrete evaluation tools for regulating freight transportation in smaller cities'[5]. Knowledge co-production is used in the project to ensure that the evaluation tools onnect to the problems that transport authorities face and that they can be implemented in their daily practice. To achieve this, the project is set up as a partnership between CET, the Norwegian School of economics, Vestland County, the City municipality of Bergen, The Norwegian public roads administration, the Bergen business council, Sparebanken Vest (a financial bank), Nordic edge (an innovation cluster for smart cities) and three foreign universities with relevant knowledge (one in France, one in Italy and one in China).

The project consists of five working packages. CET is responsible for working package 1: Mapping governance challenges for sustainable city logistics. The professor and two PhD-candidates from CET are involved. Both PhD-candidates were respondents for this master thesis. The PhD-candidates have conducted interviews and a survey for Cityfreight. These had the aim of gathering data about governance challenges, but also of analyzing the stakeholder network to identify which stakeholders should be involved in the co-production during the project. The researchers are now planning workshops in three Norwegian cities – Bergen, Trondheim and Stavanger. In the workshops, they want to involve planners and officials from municipalities, regional authorities, road authorities, business interest organizations and others. The workshops use problem-oriented group work and mix different types of user partners and stakeholders in the same groups. The workshops contribute to setting the problem formulation and gathering data input for other work packages, like the work package focused on modelling logistical problems and solutions (which is done by researchers at the Norwegian school of economics).

2.2.2 Klimabudsjet 2.1

Klimabudsjett 2.0 also builds on a transdisciplinary partnership, in this case between multiple Norwegian and Swedish municipalities and regional authorities. It is funded by a regional research fund. In this project, researchers, counties and municipalities co-produce 'participatory tools in municipal planning to bring out deep reflections on the various actors' room for maneuver in order

[5] https://www.uib.no/en/cet/133736/cityfreight-freight-logistics-sustainable-cities

to contribute to achieving a local carbon budget'[6]. The PhD-candidate at CET involved in this project has organised several co-production workshops with representatives of municipal and county governments. This PhD-candidate was a respondent in this research.

2.2.3 Climate adaptation hackatons

CET co-organizes what they call 'climate hackathons'. These are multiple-day events where actors from multiple levels of public governance 'hack' a governance issue connected to climate adaptation together with researchers (Kvamsås et al., 2021). The researchers set the agenda in close collaboration with the municipal and regional actors present at the event. The events are the result of a previous research partnership called 'Hordaklim', but the Klimathons now stand on their own as a yearly recurring event. Several phD-candidates at CET were involved in these Klimathons. These were all respondents in this research, but only one of them was interviewed specifically about the klimathons (the others were interviewed about their other transdisciplinary projects).

2.2.4 The Collaboratory

CET houses its own community of students, including four master students who are writing their master thesis at CET and a group of bachelor and master students connected to the 'Collaboratory'. The Collaboratory's ambition is to 'bring students, researchers, and practitioners together in innovative, interdisciplinary and problem-oriented forms of education, research and outreach activities.'[7]. The Collaboratory houses the yearly Bergen International Student Conference, a conference by and for students. Also, the Collaboratory is responsible for the course *Sustainable innovation,* which is student-led, meaning that the course-coordinators are students. In this course, students engage in transdisciplinary collaboration with societal actors to develop a sustainable innovation with and for these societal actors. The two student-course coordinators and the leader of the Collaboratory were respondents in this master thesis.

2.3 People at CET

At the time of writing, CET has 15 researchers[8] with office space at the center, 12 of which are PhD-candidates, 1 research-assistant, 1 postdoc and 1 full professor (who is also the director of CET). Most of them engage in interdisciplinary research (integrating multiple scientific disciplines), about half in transdisciplinary research (including non-academic actors in research) and their disciplinary backgrounds include, among others, geography, political science, economics, psychology, environmental sciences and system dynamics. Additionally, 44 affiliated researchers[9] with an even larger disciplinary spread have their main office elsewhere. Five of the six PhD-candidates wo engage in transdisciplinary collaboration were respondents for this master thesis. Aditionally, four full-time master students were writing their master thesis at CET.

The secretariat[10] (daily leadership) of CET consists at the time of writing of 4 full-time employees, including the director/professor of CET. The steering committee[11] consists of 11 representatives from

[6] https://www.uib.no/en/cet/150696/klimabudsjett-20
[7] https://www.uib.no/en/cet/110160/collaboratory
[8] https://www.uib.no/en/cet/150516/researchers
[9] https://www.uib.no/en/cet/118913/affiliated-researchers
[10] https://www.uib.no/en/cet/105802/about-centre-climate-and-energy-transformation scroll to the bottom
[11] https://www.uib.no/en/cet/118084/steering-committee

the Faculty of Social Sciences; the Faculty of Mathematics and Natural sciences; the Bjerknes Center for Climate Research, NORCE and Norwegian School of Economics.

The picture below shows most of the 15 researchers, the four master students and some of the affiliated researchers.

Figure 2.2. CET researchers in 2021[12].

2.2.3 Location of CET

CET houses in the social science building, in the university quarter in the city center of Bergen.

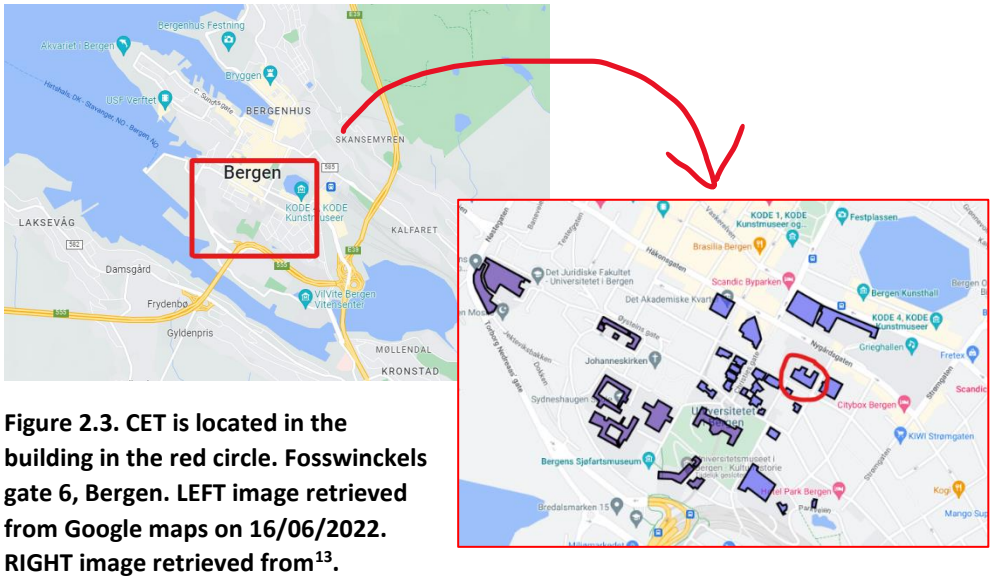


Figure 2.3. CET is located in the building in the red circle. Fosswinckels gate 6, Bergen. LEFT image retrieved from Google maps on 16/06/2022. RIGHT image retrieved from[13].

[12] https://www.uib.no/en/cet/105802/about-centre-climate-and-energy-transformation
[13] https://www.uib.no/en/about/79263/campus-map

CET has one hallway in the social sciences building with 10 offices and 3 communal meeting rooms.

Figure 2.4. TOP LEFT: The CET-banner awaits you when you walk to CET's hallway. TOP RIGHT: The Hallway of CET. BOTTOM LEFT: The office of the author of this master thesis at CET. BOTTOM RIGHT: The office of The Collaboratory. All four pictures taken by the author of this master thesis on 16/06/2022.

2.2.4 The position of the author of this master thesis at CET

During the research for this master thesis, I was a guest researcher at CET. I had an office together with one of the PhD-candidates at CET. CET involves its master students actively in the research community. Consequently, I was invited to participate in most of CET's activities, like the two-weekly Monday meetings where everyone updates each other on their work, the weekly Wednesday lunch seminars, where guest speakers talk about topics relevant to CET, and the Friday cakes, a weekly social gathering. Through these activities, I got to know all the researchers with an office at CET.

This had advantages for my master thesis. It was for example easy to reach my respondents. But it also had disadvantages. For instance, because my respondents knew me well, the risk for socially desirable answers in interviews and focus groups was high. I will discuss this further in the methodology (chapter 4) and the discussion (chapter 11).

3. Theoretical framework

To analyze the roles of CET-researchers in transdisciplinary collaboration, we need an analytical framework. This chapter first conceptualizes transdisciplinary research (section 3.1) and then builds an analytical framework on that (section 3.2). The analytical framework will be used later to analyze the data collected for sub-questions 1 and 2 (in chapters 5 and 6).

3.1 Conceptualizing transdisciplinary research

The theory in this section is the result of explorative literature search (see section 4.3.1 for an explanation of the searching process).

The term 'transdisciplinarity' is thought to have been coined during the first international seminar on interdisciplinarity in 1970. The term was then defined as 'a common system of axioms transcending the narrow scope of disciplinary worldviews through an overarching synthesis' (Pohl et al., 2021). In this definition, interdisciplinarity and transdisciplinarity have a similar conceptual focus. However, fueled by discussions of 'Mode 1' vs 'Mode 2' knowledge production (e.g. Gibbons, 2000), the term transdisciplinary has acquired new meanings related to the involvement of new actors in scientific research (Pohl et al., 2021). According to Maasen, Lengwiler & Guggenheim (2006), interdisciplinarity refers to the integration of knowledge from multiple academic disciplines, while transdisciplinarity moves beyond the borders of academia by including non-academic actors in the production of knowledge. However, Kalmar & Senfert (2020) see transdisciplinarity as going beyond interdisciplinarity with non-academic stakeholders. Inspired by Pohl & Hirsch Hadorn (2008), they understand transdisicplinary research as 'an integrative process in which scientists work together to develop a shared conceptual framework that synthesizes and extends discipline-specific knowledge, creating new models and language to address a common problem.' (p. 3).

The term transdisciplinarity closely relates to the term 'co-production'. The "co" is generally understood as meaning collaboration of researchers and practitioners during knowledge production. Transdisciplinarity and co-production convergence when the transdisciplinarity is aimed at addressing societal problems by involving societal actors in the knowledge production.

However, not all scholars conceptualize transdisciplinarity in this way. Klein (2015) identified three dominant discourses on transdisciplinarity. Firstly, the discourse of *transcendence* is aimed at achieving unity of knowledge, through re-organizing the structure of knowledge (e.g. general systems theory, feminist theory, cultural critique and sustainability studies). Secondly, the discourse of *problem-solving* has a focus on solving 'real-world' problems and 'socially robust science'. In this discourse, transdisciplinarity and "knowledge co- production" converge, as there is often a focus on involving non-societal actors in the knowledge production process. The involvement of non-academic actors is seen as a means to ensure that research includes relevant perspectives, to increase the support for the research outcomes and to give people the democratic power to influence research that might affect them (Verhoeff & Kupper, 2020). The discourse became widespread in environmental research in the 1980s and 1990s. Thirdly, the discourse *transgression* moves beyond reorganizing the structure of knowledge and problem-solving by philosophically reflecting on the foundations of knowledge production and education *(e.g.* cultural critiques, socio-political movements, and conceptions of post-normal science and wicked problems).

I chose to situate this master thesis in the discourse of *problem-solving*, as I am interested in how research can contribute to solving societal problems. Moreover, this discourse resonates best with the case-context of this master thesis: the Center for climate and energy transformation sees as a core part of their strategy to do 'problem-oriented research' and to 'co-produce' 'actionable knowledge' that can achieve 'sustainable transformation of society'[14]

Within this literature discourse, Pohl et al. (2021) argue, transdisciplinary research should not be defined by the number of researchers, disciplines, fields, and practitioners involved. Rather, the key defining aspect should be whether the research contributes to solving real-world problems. They identify four aims research should achieve in order to be 'transdisciplinary' (based on Pohl and Hirsch Hadorn, 2007):

1. Grasp the complexity of the issue at stake,
2. consider practitioners' and researchers' diverse perceptions,
3. link abstract and case specific knowledge,
4. develop descriptive, normative and transformative knowledge.

Furthermore, Pohl et al. (2021) argue that transdisciplinarity inherently involves collaboration between researchers and practitioners that contributes to:

a. improving the situation for both researchers and practitioners,
b. co-producing and exchanging knowledge artefacts,
c. mutual and transformational learning by both the researchers and practitioners.

In short, this conceptualization of transdisciplinary research makes clear what is meant by 'addressing societal problems' (aims 1-4) and by 'collaboration between researchers and practitioners' (contributions a-c).

Focusing more specifically on sustainability research, Norström et al. (2020) identified from the literature four principles for knowledge co-production in sustainability research:

i. context-based
ii. pluralistic
iii. goal-oriented
iv. interactive.

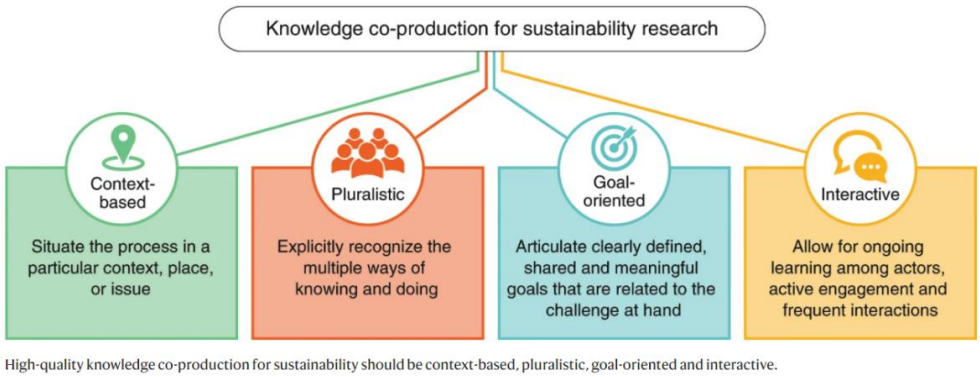


Figure 3.1. Four principles for knowledge co-production in sustainability research. Image copied from Norström et al. (2020).

There are links between Pohl et al. (2021)'s and Norström et al. (2020)'s conceptualizations: they both focus on situating knowledge in specific case-contexts (3 & i), they both stress the importance of including a diversity of perspectives (2 & ii), they both aim for addressing real-life challenges (a &

[14] https://www.uib.no/en/cet/134672/strategy-2020-2022

iii) and they both build on interaction and learning (c & iv). In this master thesis, I will follow these principles in my conceptualization of transdisciplinary research. Because the four principles of Norström et al. (2020) are formulated most hand-on, I will take their principles as a guidance.

In my master thesis CDI, interaction and learning processes are a central theme. Moreover, my personal interest lies in the interpersonal interaction and learning processes between academic researchers and societal actors and the roles scientists can take in these processes. Therefore, although I use all four principles to conceptualize what transdisciplinary research is, the inquiry in this thesis leans towards the realm of *interaction* (the fourth of Norström et al. (2020)'s four principles for knowledge co-production).

To make clear that this master thesis does not consider how societal knowledge can be integrated with scientific knowledge, or how transdisciplinarity can be embedded in research programs, I will generally avoid the terms 'transdisciplinary research' and 'co-production of knowledge' in this thesis. Instead, I use the term 'transdisciplinary collaboration' to make clear I am interested in interpersonal collaboration processes between academic researchers and non-academics.

Altogether, I conceptualize 'transdisciplinary collaboration' as a problem-solving-oriented research practice, where academic researchers and societal actors co-produce knowledge together in a way that is context-based, pluralistic, goal-oriented and interactive. Within this conceptualization, I focus on interaction and learning processes at the interpersonal level. We can now move on to build an analytical framework for sub-questions 1 and 2 – aimed at analyzing the roles of researchers and related challenges in the interaction and learning processes in transdisciplinary collaboration.

3.2 Analytical framework: Roles of researchers in transdisciplinary collaboration ⚙

To analyze data for sub-questions 1 and 2, we need an analytical framework. To build that framework, we will first explore two perspectives on roles of researchers (3.2.1). We will choose the perspective which is most suited for CET and then build a framework of roles from that perspective (3.2.2). We will also look at what the literature says about challenges for researchers in transdisciplinary collaboration, since this is useful later for answering sub-question 2. This section ends with an operationalization of the analytical framework, so it can be used during data analysis (3.2.3).

3.2.1 Two perspectives on the roles of researcher in transdisciplinary collaboration

During my explorative literature review, I found two strands of research that are often cited in relation researchers-roles in problem-oriented transdisciplinary collaboration.

1. *'Idealized roles for scientists in decision-making'*
   This first strand focuses on science communication and policy-advice in the science-policy nexus. Roles of scientists are distinguished on the basis of the role of science in society and the role of experts in democracy. A seminal publication in this strand is Pielke (2007). Examples of roles are the *honest broker* (showing possible policy-options and their consequences based on science) and the *issue advocate* (advocating a narrow policy direction based on science).
2. *'Roles of researchers in transdisciplinary research'*
   This second strand is focused on knowlegde co-production in the science-society interface. A

seminal publication in this strand is Wittmayer & Schäpke (2014), which speaks about 'ideal-type roles that researchers take when dealing with key issues in creating and maintaining space for societal learning'. Examples of roles are the *knowledge broker* (translating research findings), the *process facilitator* (facilitating interaction and learning) and the *change agent* (participating in and/or affecting the outcome of the learning).

Although Pielke (2007) is often used to analyze and theorize about interaction and communication between actors in science and society (specifically: policy), I would argue that Pielke's framework of roles does not capture the full complexity of the participatory forms of knowledge production associated with transdisciplinary collaboration. The framework of Pielke (2007) has been criticized to focus on science communication processes with a large distance to society. For example, Turnhout et al. (2013) assert that 'even the role of the [honest] broker, which includes the most interaction with knowledge users, is still fairly distant, offering different knowledge-based alternatives to knowledge users' (p. 355). For this reason, Vinke-de Kruif et al. (2022) state that Pielke's view on knowledge production is 'sometimes associated with knowledge-first approaches' (p. 397). These are in contrast with process-oriented approaches common in participatory forms of knowledge production. The frameworks based on Whittmayer & Schäpke (2014) better describe these participatory forms of knowledge production as they focus on researcher-roles in the interpersonal learning processes during close collaboration between academics and non-academics during research.

I would say that Pielke (2007) is focused on *policy advice* rather than transdisciplinary collaboration. As also mentioned in the introduction (section 1.1.1), I see policy advice and transdisciplinary co-production as two different forms of interaction between science and society and the challenge associated with transdisciplinary collaboration do not necessarily apply to policy advice. On the one hand, policy advice generally happens *parallel to* or *after* the research – it is not an integral part of the research itself. Moreover, as also mentioned above, it happens at a distance from society. This means that the challenges associated with the complex interactions between scientists and societal actors (see section 3.2.3 for more information about these challenges) are less pressing in policy-advice. Knowledge co-production on the other hand happens at the heart of the research and involves societal actors, or rather: co-production with society *is* the research. There are overlaps, off course: a transdisciplinary researcher can give policy advice and a policy advisory body can use transdisicplinary approaches. But the conceptual focus of the two literature strands differs.

CET engages primarily in transdisciplinary co-production, and less in policy-advice. Moreover, because of the focus of my master program CDI and my personal interest, I focused this master thesis on researcher-roles during the interaction and learning processes between academic and non-academic actors in transdisciplinary collaboration. Therefore, the second strand of literature - 'roles of researchers in transdisciplinary research' - (Whittmayer & Schäpke, 2014) is more suitable for the analytical framework of this master thesis.

Additionally, I use one article outside the literature strand of 'roles of researchers in transdisciplinary research'. This extra article is a publication of my supervisor Haarstad about 'modes of engagement' of scientists in societal transformations (Haarstad et al., 2018). It does not focus on interpersonal interaction processes during transdisciplinary collaboration, but rather on the goals and outcomes of co-production processes. However, the article summarizes the rationale behind the strategy of CET (producing transformative research through the co-production of actionable knowledge). Therefore, Haarstad et al. (2018) is valuable resource to interpret how the CET-researchers look at their roles in transdisciplinary collaboration.

3.2.2 Five roles of researchers in transdisciplinary collaboration

To build the analytical framework, I did a systematic literature review. See section 4.3.1 in the methodology for information on the search strategy.

Most of the literature on *'roles of researchers in transdisciplinary research'* builds on Pohl et al. (2010). They established roles of researchers against the need in transdisciplinary collaboration to address power relations, integrating different thought styles and maintaining the orientation towards sustainability. From the analysis of four comparative case-studies, they concluded on three roles. Firstly, the *reflective scientist* is 'capable of providing expertise based on scientific knowledge validated according to the norms of the natural or social sciences'. Secondly, the *intermediary* is 'able to make different thought styles visible and to link them around common interests'. Finally, the *facilitator* is 'capable of enhancing communicative processes between thought collectives, based on respect, openness and deliberation'.

Wittmayer and Schäpke (2014) built on these three roles with a focus on the concepts of power, sustainability, ownership, action and reflexivity. As a case-study, they analyze a sustainability-oriented transition management process, where transdisciplinary spaces of societal learning are created. In these spaces, they identify five new roles that researcher can employ when engaging in transdisciplinary collaboration (besides "traditional scientific practice"):

1. The *reflective scientist* (based on Pohl et al., 2010) holds the role closest to tradition scientific practice and is tasked with producing knowledge for the collaboration using traditional scientific methods. For reference, this role is sometimes also referred to as 'knowlegde provider' or simply 'traditional scientist'. However, 'reflective' scientists are reflective of the quality criteria of their disciplines. This can mean that they strive for objectivity and neutrality in their knowledge production, but it can also mean their knowledge production is participation oriented.
2. The *knowledge broker* (which shares resemblance with Pohl et al.'s, 2010 *intermediary*) is aimed at mediating different perspectives. This entails translating ideas and findings from one perspective to another and identifying and bridging where different people have different understanding of the same concept. Also, the knowledge broker makes knowlegde tangible in specific contexts. The process of brokering should lead to knowledge that is 'socially robust, recognizes system complexity and uncertainty, acknowledges multiple ways of knowing and incorporates normativity and ethics' (Whittmayer & Schapke, 2014, p. 488).
3. The *process facilitator* (which shares resemblance with Pohl et al.'s, 2010 *facilitator*) is tasked with organizational aspects of the collaboration (selecting participants, organizing sessions) and facilitating the learning process. The facilitator can facilitate learning by organizing deliberative problem formulation processes, stimulating the exchange of ideas, and shaping processes that are 'just, inclusive and future oriented' (Whittmayer & Schapke, 2014, p. 488).
4. The *self-reflexive scientist* is focused on reflexive practice with regards to their own normative orientations and their role in the power dynamics. The self-reflexive scientist reflects on which role they have in the collaboration, how they affect the collaboration and how that in turn affects them. They can also help colleague-researchers reflect on this.
5. The *change agent* participates in the learning process by engaging in discussion with societal actors and thinking along towards solutions for sustainability challenges. Moreover, the change agent motivates and empowers participants to engage actively in change processes.

According to Whittmayer and Schapke (2014), these roles overlap in practice, change over time and are context dependent. The definitions of the roles above are rather abstract. Therefore, I see it as

an important step to operationalize the roles into concrete behaviors to be able to recognize and discuss the roles at a tangible level at CET. I will do this operationalization in section 3.2.5.

More recent contributions use the framework of Wittmayer and Schäpke (2014) but deepen the framework with regards to one specific aspect. For example, Bulten et al. (2021) deal with 'the struggles of individual researchers in dealing with the demands and expectations of different actors.' In particular, they identify which roles can be in tension with one another when performed by the same researcher. Hilger, Rose & Keil (2021) propose a framework of 15 roles for actors in transdisciplinary collaboration, whithout pre-supposing which actors groups take which roles. In other words: they look at roles that could be performed by both researchers and societal actors. Vinke-deKruif et al. (2022) synthesize the framework of Wittmayer and Schäpke (2014) with that of Pielke (2007) to provide a more all-encompassing view on roles of researchers in the science-policy and the science-society interface. From their analysis, they identify three 'orientations' for the researchers in these interfaces: *knowledge-orientated* researchers (reflective scientist, self-reflexive scientist), *intermediating* researchers (knowledge broker, process facilitator) and *change-oriented* researchers (process facilitator, change agent).

Because the more recent articles build strongly on Wittmayer and Schäpke (2014)'s framework, I use their framework of five roles as analytical framework for sub-questions 1 and 2 in this thesis. However, Bulten et al. (2021); Hilger, Rose & Keil (2021); and Vinke-deKruif et al. (2022) each provide valuable insights on the challenges researchers can face when employing the five roles of Wittmayer and Schäpke (2014).

3.2.3 Challenges for researchers in the five roles

In chapter 6, I will analyze which challenges CET-researchers face in transdisciplinary collaboration (sub-question 2). Therefore, it is useful to know what the scientific literature says about challenges for researchers in the five roles we established.

Tensions between roles

The five roles come with their challenges. Bulten et al. (2021) identified tensions between roles from their case-studies:

- For example, researchers in the role *process facilitator* can use so much time on facilitation that they have not enough time to produce and document knowledge as a *reflective scientist*.
- Also, some process facilitation activities are hard to 'justify' at the home institute, because they are not part of traditional scientific tasks.
- Additionally, as *reflective scientist* it requires extra care to strive for 'neutrality' and 'objectivity' in your research, if you simultaneously commit to normative goals as *change agent*.
- Furthermore, as *change agent*, a researcher positions themselves on an equal level to the other participants in the learning process, while the role *process facilitator* requires taking responsibility over leading the process. These tensions can make it hard to combine roles.

Challenges related to knowledge-, change- and intermediating orientations

From their own case-studies and from literature, Vinke-deKruif et al. (2022) established challenges for researchers who assume one of the three orientations (knowledge-oriented, intermediating and change-oriented).

- Firstly, knowledge-oriented researchers (*reflective scientist* and *self-reflexive scientist*) in transdisciplinary collaboration are inevitably faced with knowledge integration challenges (even though knowledge integration is more the realm of the *knowledge broker* and the *process facilitator*). Therefore, even knowledge-oriented researchers should reflect on how the societal actors receive knowledge. Moreover, 'objectivity' and 'neutrality' are under pressure when engaging in collaboration, so knowledge-oriented researchers should also reflect on their own role and power in the process.
- Secondly, change oriented researchers (*change agent* and *process facilitator*) can be faced by societal actors questioning their credibility when they implicitly promote a specific solution. Therefore, it is crucial that change-oriented researchers are reflexive and transparent about their role and intentions. Furthermore, when aiming for societal change as an outcome, the process can take longer than when merely doing research. Consequently, change-oriented researchers risk raising expectations with regards to time they cannot deliver on.
- Thirdly, intermediating researchers (*knowledge broker* and *process facilitator*) can run into the challenge that their role is time-consuming and resource intensive. Moreover, a lack of facilitation and knowledge integration skills can impede researchers with this orientation, unless they can fall back on previous work experience as practitioner. Moreover, if intermediating researchers are unaware of power dynamics among the participants to the collaboration, their intermediating efforts might further entrench unequal power relations.

Competing expectations

Another source of challenges for researchers is that they can be faced by competing demands. These derive from diverging expectations from the researcher's self, their scientific peers and the societal participants to the collaboration.

- **Quick fixes versus learning processes**
  According to Bulten et al. (2021), participants to knowledge co-production can expect concrete and directly implementable answers and data from scientists, while the scientists are looking to create these answers *together* in a social learning process. A similar mismatch in expectations is discussed by Haarstad et al. (2018), who state that during co-production practices, societal partners often ask the researchers for numbers and hands-on solutions, while the researchers are more interested in learning about the matter by 'critically examining the governance processes', and to prevent impartial or problematic 'quick fixes'.
- **Objectivity versus applicability**
  Vinke-deKruif et al. (2022) point out that researchers who want create change in society can face societal stakeholders who expect scientists to produce objective and neutral knowledge. In the words of Haarstad et al. (2018, p. 195): 'How do we balance this activity of trying to change things with the fact that the legitimacy of our place in these collaborations comes from our supposed objectivity?' Interestingly, Bulten et al. (2021) saw that researchers who want to produce objective knowledge for scientific advancement can be faced by the claim from societal participants that the outcomes of the process are not applicable in real-life. This shows that societal partners can expect both objectivity and applicability, while these can be conflicted goals
- **Facilitator versus participant**
  Bulten et al. (2021) saw in their case-studies that the societal participants to the collaboration expected the academics to organize and facilitate the process. These same participants, however, expected the researchers to participate in the knowledge co-

production process. It proved very hard to both facilitate and participate. Moreover, the researchers are not always the ones with the best organizational and facilitation skills (Hilger, Rose & Keil, 2021). Similar conclusions are made by McKee, Guimaraes & Pinto-Correia (2015) and Huning, Räuchle & Fuchs (2021), and the latter suggest that an external facilitator can mitigate this challenge.

These insights on challenges for transdisciplinary researchers will be used in the analysis of the challenges that CET-researchers face (in section 5.3).

3.2.4 Why reflection on roles is needed

Because of the above-mentioned challenges, scholars call for explicit reflection on researcher-roles to increase researchers' awareness and understanding of their roles in transdisciplinary collaboration (Pohl et al., 2010; Bulten et al., 2021; Hilger, rose & Keil, 2021; Vinke-de Kruijf et al., 2022). I already elaborated on this need in the problem description (section 1.1.2).

Let me add here that Bulten et al. (2021) argue that future transdisciplinary researchers should be taught both the skills they need to fulfil roles in transdisciplinary research, and a sense of reflexivity with regards to the roles they adopt and the skills they need for that.

What we should teach researchers, according to Bulten et al. (2021):
1) how to integrate knowledge and action
2) a set of transdisciplinary skills ("systems-thinking competence, anticipatory competence, normative competence, strategic competence and interpersonal competence", but also practical skills like "facilitation and mediation")
3) reflexivity. Bulten et al (2021) refer to Hilger et al. (2018), by stating: "Education can stimulate students to be reflective about their intentions as researchers. After all, it depends on these intentions which roles they should adopt."

Few scholars give guidance on *how* to reflect. Only Vinke-de Kruijf et al. (2022) propose an overview of elements that researchers should reflect on (see figure 4.2 on the next page), based on research-orientation (knowledge-oriented, change-oriented or intermediating), norms and values, expectations and resources (which include skills). Still, this overview does not provide guidance on *how* to reflect on the mentioned elements.

TABLE 2 Overview of elements that researchers should reflect upon when engaged in transdisciplinary research projects

Elements to reflect upon	Check
1. *Orientation*: My primary role as a researcher is	
a. to provide decision makers and other stakeholders with relevant objective, scientific knowledge (knowledge-oriented);	☐
b. to be influential and promote societal change (change-oriented);	☐
c. to integrate multiple knowledge sources and types in support of decision-making processes (intermediating).	☐
2. *Norms and values*: I am aware of	
a. my personal opinions about my research topic (such as solution types, need for action);	☐
b. how my own values and norms influence my decisions during the research process (for example related to stakeholder involvement, open or closed agenda, top-down or bottom-up);	☐
c. the potential societal impacts of my research, including the political and societal values and norms that play a role	☐
3. *Expectations*: I have adequately informed my research collaborators and stakeholders about	
a. the objectives and orientation of my research project;	☐
b. the potential impacts of my research project.	☐
4. *Resources*: I have or have access to	
a. capacities and skills (e.g., research, organizational, communication) to fulfill required role(s);	☐
b. resources (e.g., time, financial, support) available to fulfill required role(s).	☐

Figure 3.2. Elements that transdisciplinary researchers should reflect on. Image copied from Vinke-de Kruijf et al. (2022).

3.2.5 Operationalization of researcher-roles

The final step in creating an analytical framework is operationalizing the researcher roles, so they can be identified during the data analysis.

According to Hilger, rose and Keil (2021), the aim of role-theory is to identify ideal types of behaviour. Consequently, the literature operationalizes roles as sets of *behaviors* that actors in that role perform.

However, Vinke-deKruif et al. (2022) argue that researcher-roles cannot be seen separate from the *motivational orientation* of researchers taking those roles and that specifically these orientations require reflection. Bulten et al., 2021 emphasized the importance of reflecting on *intentions* for certain roles. Moreover, Wittmayer conceptualizes roles "as a set of recognizable *activities* and *attitudes* used by an actor to address recurring situations" (Wittmayer, 2016, p.105 *in Hilger, Rose & Keil, 2021*). So, important in operationalizing roles are on the one hand *behaviors / activities* and on the other hand the *motivations / attitudes / intentions* behind the role-taking. Therefore, I operationalize roles as *behaviors* and connected *motivations* of the role-taking actor for that behavior, based on Vinke-de Kruifs three motivational orientations. Table 3.1 gives concrete indicators of behaviors and motivations for the five roles of Wittmayer and Schäpke (2014).

Table 3.1. Operationalization of behaviors and motivations connected to the five researcher roles in Wittmayer and Schäpke (2014). ***K = knowledge-oriented motivations, I = intermediary motivations, C = change-oriented motivations (Vinke-deKruif et al., 2022).***

Roles	**Behaviors**	**Indicators of behaviors** The researcher...	**Moti-vations K, I, C ***	**Indicators of motivations** The researcher wants to…
Reflective scientist	Investigate application-oriented knowledge (Hilger et al. 2018) or analyse dynamics, actors and action (Wittmayer and Schäpke 2014)	- collects data about legislation, best practices, and governance networks (Hilger et al. 2018); collects data from practice experts, or observes events where scientific knowledge is applied (Wittmayer and Schäpke 2014)	K	- produce knowledge to inform decision-making but does not want to change the decision-making.
	Provide scientific knowledge to inform decision making (Pohl et al. 2010; Wittmayer and Schäpke 2014)	- uses traditional scientific techniques (theory building, data collection and analysis detached from practice) and communicates findings to decision-makers (Wittmayer and Schäpke 2014)	K	*same as row above*
Self-reflexive scientists	Reflect on own normative orientation and on internal and external power dynamics (Wittmayer and Schäpke 2014; Hilger et al. 2018)	- conciously observes the process (Hilger et al. 2018) - writes field notes or research diaries Hilger et al. 2018)	K	- deal with the challenges of conducting research within a normative framing and dynamic transdisciplinary setting
	Provide feedback to other researchers to facilitate reflection about their interactions with practitioners (Hoes et al. 2008)	- talks to colleague-researchers about their interaction with other practitioners (Hoes et al. 2008)	K	- help colleague-researchers who find it challenging to conduct research within a normative framing and dynamic transdisciplinary setting
Knowledge broker	Mediate different perspectives (Pohl et al., 2010; (Wittmayer and Schäpke 2014). Translate, interpret and connect knowledge to different audiences and contexts (Adelle et al. 2019).	- gives presentations in accessible language (Adelle et al., 2019) - identifies what scientific knowledge means for the people, processes, and places in a specific context (Adelle et al., 2019) - has previous experience in the job or role of the practitioners in the collaboration and uses this experience to mediate between academic and practitioner perspectives (Pohl et al., 2010)	I	- improve the communication between different actors (because that improves the collaboration)
	Link scientific analysis to public debate and matches expert to stakeholder groups (Adelle et al., 2019)	- looks for insights in scientific articles, books or presentations that are applicable to debates and problems in society (own contribution) - looks for researchers who have scientific insights on topics that specific societal actors have interest in (own contribution)	I	- help societal actors find the right knowledge or experts
Process facilitator	Organize and prepare work sessions co-production sessions (Adelle et al. 2019; Wittmayer and Schäpke 2014)	- locates, select and invite participants (Adelle et al. 2019; Wittmayer and Schäpke 2014) - takes care of organizational affairs (organise location, agenda and invitations for a work session) (Adelle et al. 2019; Wittmayer and Schäpke 2014)	C	- help the participants to collaborate well by taking care of organizational conditions for learning and collaboration
	Facilitate learning, design and reflection processes (Wittmayer and Schäpke 2014)	- encourages expression of different viewpoints (Wittmayer and Schäpke 2014) - provide space for critical reflection and deliberation (Pohl et al. 2010; Hilger et al. 2018)	C	- help the participants to collaborate well by creating a proper learning and reflection process
Change agent	Actively intervene in system innovation (Wittmayer and Schäpke 2014)	- motivates participants to address local (sustainability) challenges with new approaches (Wittmayer and Schäpke 2014) - publicly voices concern about societal processes and not shying away from confrontation (Wittmayer and Schäpke 2014)	C	- change aspects of the societal system
	Participate in the learning process aimed at addressing real-life problems (Hilger et al. 2018; Wittmayer and Schäpke 2014)	- participates in joint efforts to find concrete solutions for local societal problems (Wittmayer and Schäpke 2014) - networks with stakeholders outside the collaboration (Wittmayer and Schäpke 2014)	C	- learn from societal actors because researcher needs that to achieve change in society

Summary chapter

We have now operationalized an analytical framework of researcher-roles in transdisciplinary collaboration (section 3.2.5). This operationalized analytical framework allows us analyze researcher-roles in a case-study at CET. In the next chapter, the methodology, we look at how I collected data at CET and analyzed it. The methodology also explains the design methods I used to design a reflection tool.

4. Methodology

The main research question of this master thesis is:
How can a reflection tool help starting researchers at the Center for climate and energy transformation in Norway to reflect on their role in collaborations with policymakers and business actors?

To answer this research question, I have conducted *design-based research*. This chapter first explains why I used design-based research and what it is (section 4.1). Then, section 4.2 gives an overview of the methods used to collect data and the methods used to design a reflection tool. In section 4.3 and 4.4, each method is discussed in more detail.

4.1 Design-based research (DBR)

4.1.1 Why design-based research

DBR emerged in educational science to bridge the gap between science and practical implementation. Epistemologically, DBR falls in the family of pragmatism. It shares many characteristics with action-research but is unique in its focus on an interplay between theory building and practical design (Anderson & Shattuck, 2012).

There are four reasons why I used design-based research in this master thesis. Firstly, the aim of this research project is to *design* a reflection tool for researchers-in-training. DBR was established to design and test solutions in educational contexts (Anderson & Shattuck, 2012). Secondly, besides designing a reflection tool, I want to engage with theory about transdisciplinary collaboration. I want to use theory to support the tool and I want to use the insights from a case-study at CET to contribute to theory. DBR allows for the combination of designing a practical, contextualized solution, while also taking from and adding to scientific theory. In DBR, theory and practice come together in the use of design principles, which are derived from theory, yet contextualized in the specific context the design takes place in (Anderson & Shattuck, 2012). Thirdly, the students and PhD-candidates at CET have much more experience with transdisciplinary collaboration than I have. So, their perspectives should be involved closely in my research. DBR often involves for participatory design, meaning collaboration between the designer (me) and the end-users of the design (the students and PhD-candidates at CET). Fourthly, DBR allows for the uses of mixed methods. In this research, I will use descriptive qualitative social science methods to do a case-study at CET and design-thinking methodologies to design a reflection tool for CET.

4.1.3 Design-thinking as the structure of the design process

I used elements of *design-thinking* to structure the design of a reflection tool. "Design-thinking" and "design-based research" sound similar but are not the same. Design-based research is a type of scientific research design. Design-thinking is rather a hands-on approach to design innovations. It is not necessarily a scientific process, although it can be, as is the case in this master thesis.

I have chosen to use elements of design-thinking, because it allows me to design a solution specifically tailored to the needs and wishes of the end-users (Sanders & Stappers, 2008). Moreover, the context in which this research takes place is complex. Design-thinking allows you to deal with complexity, because it is less rigid than traditional scientific research. In design-thinking, the precise research process is not determined from the start, so that you can creatively adapt the research process as the complex context is unraveled bit by bit (Sanders & Stappers, 2008).

To make concrete what design-thinking is, it might be easiest to look at a visualization in figure 4.1 on the next page. You can see that design-thinking follows a 'double-diamond' (Design council, 2019). The first diamond is aimed at identifying the problem (problem-analysis phase). The second is aimed at generating solutions (solution-design phase). The problem-diamond starts with *diverging* (the diamond gets wider), which means I gather as much information as possible about the **roles** of CET-researchers in transdisciplinary collaboration (**sub-question 1**). The diamond ends with *converging* (the diamond gets narrower), which means I analyze and categorize the data to define the most pressing **challenges** surrounding CET-researchers' roles (**sub-question 2**). Based on this, I make a "problem summary" and a list of "design principles". The design principles describe what **reflection** means in this problem context (**sub-question 3**). For a reflection tool to be successful at CET, it must meet the design principles. The second diamond starts diverging by generating multiple **prototypes** for reflection tools (**sub-question 4**). The second diamond ends converging by testing and refining the one prototype which best fits the design principles, leading to a solution: a final reflection **tool** (**sub-question 5**).

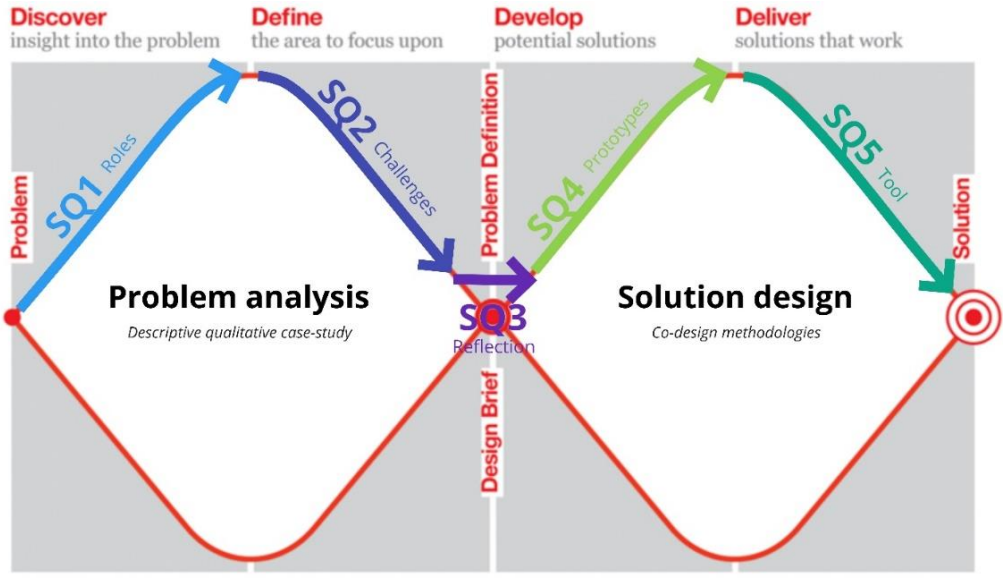


Figure 4.1. The double diamond of design-thinking with the sub-questions of this master thesis (Figure from Design council, 2019). Arrows with "SQ1-5" were added by the author of this thesis.

Sub-question 1: How do CET-researchers conceive their role in transdisciplinary collaborations?
Sub-question 2: Which challenges do CET-researchers face related to these roles?
Sub-question 3: How can reflection be conceptualized in the problem-context?
Sub-question 4: Which reflection tool prototypes could help the researchers to reflect on their role?
Sub-question 5: Which reflection tool is best suited in the context of CET?

4.1.4 Iterating between theory and practice

The double diamond visualizes the research process. Another way to visualize the same research process is by showing how I iterated between theory and practice. One of the strengths of design-based research is that you can combine insights from theory and practice to design a solution. You can see in figure 4.2 below which chapters in this thesis have a more theoretical focus, and which have a more practical (empirical) focus.

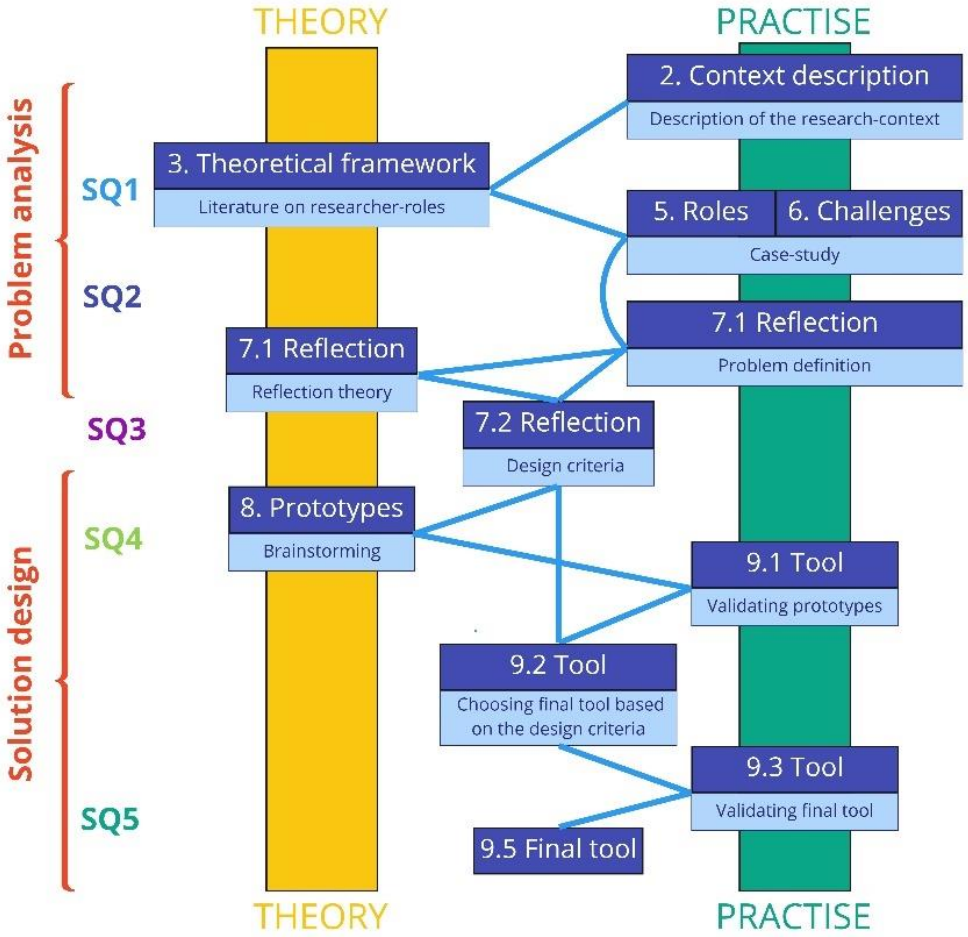


Figure 4.2. The theory-practice diagram shows which chapters had a more theoretical focus and which were more practice-focused.

We have now seen that I applied design-based research. To structure the research, I used design-thinking, which means I split up the research in a problem analysis phase and a solution design phase. This is visualized with the double diamond. To use the full power of both theory and practice, I iterated between theory and practice. This is visualized in the theory-practice diagram.

Now we understand the research process, we can have a look at the methods I used during the problem analysis phase and the solution design phase.

4.2 Overview of data collection and design methods

To answer the five sub-questions, I applied multiple data collection and design methods.

Data collection methods (problem analysis)

- Literature review
- Semi-structured interviews
- Logbooks
- Focus groups

Design methods (solution design)

- Brainstorming techniques
- Prototype evaluation sessions
- Test session

For a quick overview of which methods were used roughly where in the research process, see figure 4.3 below. Table 4.1 on the next page provides more details of the methods per sub-question. See section 4.2.3 (two pages ahead) for more details about the respondents for each method.

4.2.1 Methods per sub-question – visual overview

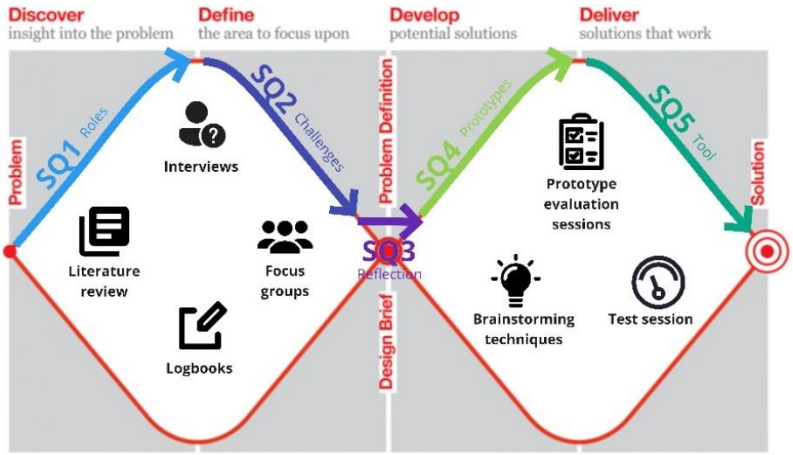
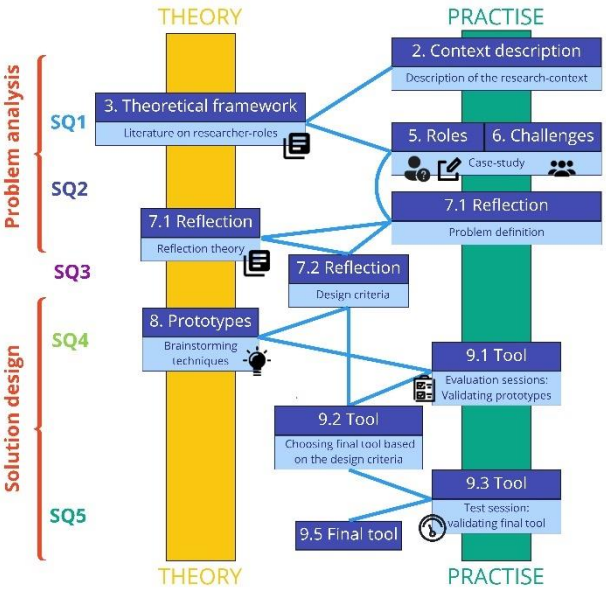


Figure 4.3. Two visualizations of the same research process. LEFT: The double diamond with the sub-questions and methods (Figure from Design council, 2019). The research progresses from left to right →.



RIGHT: The theory-practice diagram with the sub-questions and methods. The research progresses from top to bottom ↓.

4.2.2 Methods per sub-question – detailed table

To understand the table below, note that I gathered data and design ideas from four different sources: theory, experience, intuition and creativity. Using this wide range of sources helped me to empathize with the end-users of the tool during the problem analysis and to think out of the box while designing the tool. With these four sources, I follow the *communication decision chart* developed for my master CDI (figure 4.4 on the right).

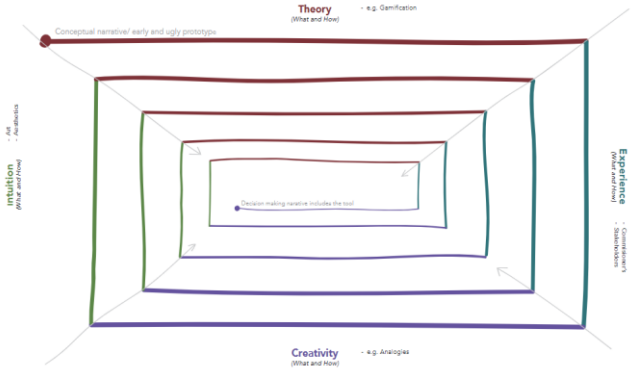


Figure 4.4. Communication decision chart (developed by the CDI research group).

Table 4.1. Data collection and design methods used to answer the sub-questions. The research progresses from top to bottom ↓.

Sub-question	Source	Methods	Respondents	Chapter in report
PROBLEM ANALYSIS				
SQ1: How do CET-researchers conceive their role in transdisciplinary collaborations?	Theory	**Literature review**	-	Chapter 3
	Experience of CET-researchers	**Semi-structured interviews**	4 PhD-candidates 3 student-course coordinators	Chapter 5
	Experience of CET-researchers	**Logbooks**	3 PhD-candidates 2 student-course coordinators	Chapter 5
SQ 2: Which challenges do CET-researchers face related to these roles?	Theory	**Literature review**	-	Chapter 3
	Experience of CET-researchers	**Focus groups**	4 PhD-candidates (focus group A) 3 student-course coordinators (focus group B)	Chapter 6
SQ3: How can reflection be conceptualized in the problem-context?	Theory	**Literature review**	-	Chapter 7
	Creativity & intuition of the author	**Further analysis of results SQ1&2**	-	
SOLUTION DESIGN				
SQ4: Which reflection tool prototypes could help the researchers to reflect on their role?	Theory and experience, creativity & intuition of the author.	**Brainstorm techniques**	-	Chapter 8
SQ5: Which reflection tool is best suited in the context of CET?	Experience, creativity & intuition of the CET-researchers	**Prototype evaluation sessions**	1 student course-coordinator (no PhD-candidates) (session 1) 2 fellow CDI students (session 2 - outsider perspective)	Chapter 9
	Creativity & intuition of the author and the CET-researchers	**Test session**	2 PhD-candidates + 1 supervisor	Chapter 9

4.2.3 Respondents

Respondent-groups

Group A (n=5): PhD-candidates operate at the heart of CET. There are five research projects ongoing where CET PhD-candidates are involved in transdisciplinary collaboration: Klimabudsjett 2.0 (1 respondent), Climate-adaptation hackathons (1 respondent), Cityfreight (2 respondents), Arqus (1 respondent) and the Bus riders union. See section 2.2.1 for more information about these projects. The PhD-candidate involved in the bus riders union unfortunately had no time to participate in the research. All other 5 PhD-candidates participated, although not all of them had time to participate in all methods. See table 4.2 below.

Group B (n=3): Course coordinators at CET coordinate the course *Sustainable innovation*, which involves transdisciplinary collaboration. The bachelor and master students taking the course collaborate with societal case-owners to develop innovations. The two students who coordinate this course, and the CET-researcher that supervises them in this, were respondents to my research. I chose to involve these 3 course coordinators (instead of the students participating in the course) because the course coordinators determine to a large degree which role the students in the course adopt in their collaboration with the societal case-owners.

Group C (n=3): Outsider perspective (2 fellow CDI students & 1 supervisor). In one prototype evaluation session and the test session, people who are not involved in research at CET participated. This provided an outsider perspective during the validation of the prototypes and the final tool.

Approaching the respondents

Because I was guest researcher at CET, with my own desk space at the center, I could approach the respondents in person and asked them in person to participate in the research.

Which respondents participated in which methods

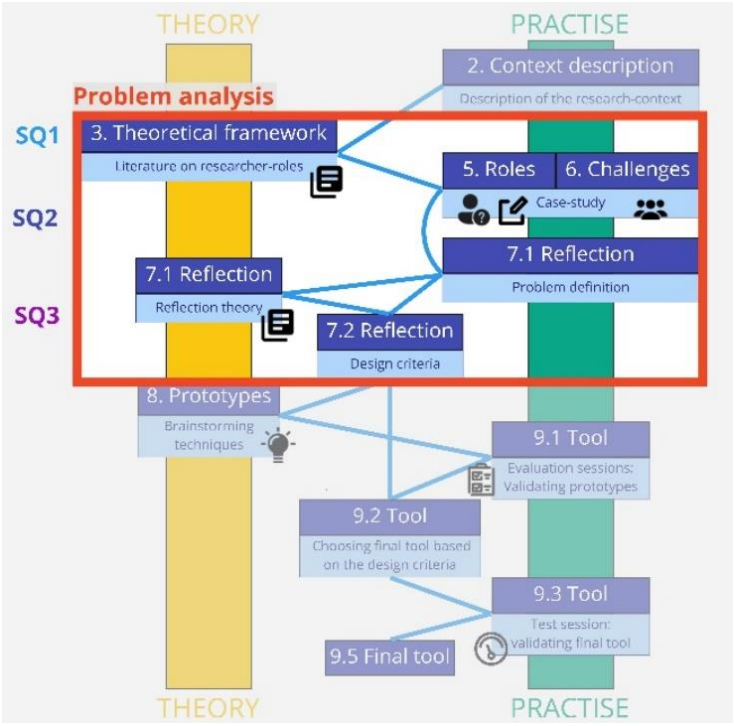
See table 4.2 below. The aim was to have all respondents in groups A and B participate in all problem analysis methods (interview, logbook and focus group). However, some of them were too busy, hence the gaps in the table. Ideally, more respondents would have participated in the prototype evaluation and test sessions. Again, their limited availability made this impossible. This somewhat reduces the validity and reliability of the research, as is further discussed in section 11.3 (Discussion).

Table 4.2. Overview of the respondents to this master thesis.

#	Group	Research project	Function title	PROBLEM ANALYSIS	Interview protocol A or B	Logbook A or B	Group A or B	SOLUTION DESIGN	Session 1 or 2	Test session
1	A	Klimabudsjett 2.0	PhD -candidate		A (24-3-2022)	A	A		-	Yes
2	B	Student-led course *Sustainable innovation*	Student course-coordinator		B (25-3-2022)	B	B		-	-
3	A	Cityfreight	PhD-candidate		A (28-3-2022)	-	A		-	Yes
4	B	Student-led course *Sustainable innovation*	Supervisor of the student course-coordinators		B (28-3-2022)	-	B		1	-
5	B	Student-led course *Sustainable innovation*	Student course-coordinator		B (29-3-2022)	B	B		-	-
6	A	Cityfreight	PhD-candidate		A (30-3-2022)	A	-		-	-
7	A	Klimathons	PhD-candidate		A (30-3-2022)	-	A		-	-
8	A	Arqus-project	PhD-candidate		-	-	A		-	-
Group C was involved only for an outsider perspective during the solution design:										
9	C	-	Fellow CDI student						2	-
10	C	-	Fellow CDI student						2	-
11	C	-	My 4th supervisor						-	Yes

4.3 Methods problem analysis phase

Let us now discuss the methods in more detail one by one.



4.3.1 Literature review

The literature review resulted in the theoretical framework in chapter 2 and the theory section on reflection in chapter 7.

Literature was gathered in three stages: an explorative literature scan about transdisicplinary research, a systematic literature review about researcher-roles and literature review on reflection.

<u>Explorative literature scan about transdisciplinary research in general</u>

I did an explorative literature scan to decide on the precise topic of this master thesis, but I also used the results in section 3.1 of the theoretical framework (conceptualizing transdisciplinary collaboration). Because the literature scan was explorative, it followed an unstructured process. I first re-visited all the literature I had read during my master CDI on the topic of transdisciplinary collaboration. Then, I used Google scholar to do an orientational search, using the following keywords:

- Mode 2 science
- Socially robust science
- Stakeholder participation in science
- Co-production
- Interaction + transdisciplinary
- Social learning + transdisciplinary

- Climate change + transdisciplinary
- Environment + transdisciplinary

Furthermore, I gathered more literature through snowballing: when I found an interesting article, I checked the references and I checked similar papers with the website 'connected papers' (https://www.connectedpapers.com/), which scans public databases for articles that have highly overlapping citations and references. It also has a 'prior works' function showing you the seminal works that have been cited by many scholars in the sub-field.

Systematic literature review to build an analytical framework

I conducted a systematic literature review to build an analytical framework to analyze roles of researchers in transdisciplinary collaboration, and to gather theory on challenges related to these roles. I searched for articles in a specific literature strand (see section 3.2.1 in the theoretical framework for more explanation).

The search strategy for this was as follows: I did searches in *Web of science*, using the search terms in table 4.3 below. Some initial trial-searches and historic citation tracing using *Connected papers* quickly showed that most articles on this topic were published after 2014 and built on two seminar articles: Pohl et al. (2010) and Wittmayer & Schapke (2014). Therefore, 2014 was chosen as starting year for the searches to limit the number of results.

Table 4.3. Search term used in Web of Science to find literature on the roles of researchers in transdisciplinary collaboration.

Search term	**Search engine**	**Publication date range** (search done begin March 2022)	**# Results**	**# After screening articles**	**Resulting literature**
TI=(sustainability transitions) AND TI=(roles) AND (TI=(scientist) OR TI=(researcher))	Web of Science	2014 - feb 2022	2	2	*Review articles*: - *Case-studies*: (Wittmayer & Schapke, 2014); (Bulten et al., 2021)
TI=(transdisciplinary) AND TI=(roles) AND (TI=(scientist) OR TI=(researcher))	Web of Science	2014 - feb 2022	4	3	*Review articles*: (Hilger, Rose, Keil, 2021) *Case-studies*: (McKee, Guimaraes & Pinto-Correia, 2015); (Vinke-de Kruijf et al., 2022)
TI=(transdisciplinary teams) AND TI=(roles)	Web of Science	2014 - feb 2022	2	1	*Review articles*: - *Case-studies*: (Huning, Räuchle & Fuchs, 2021)
TI=(coproduction) AND TI=(role) AND (TI=(scientist) OR TI=(researcher))	Web of Science	2014 - feb 2022	1	1	*Review articles*: - *Case-studies*: (Adelle, et al., 2020)
			9	**7**	

I screened the search resulting before including them in the final list of resulting literature. Articles were included if they:

- Were based on systematic literature review
  OR
- Were based comparative case-studies *and* were not included in one of the systematic literature reviews I found (to avoid 'double' literature)

AND

- Provided frameworks for ideal-type roles of researchers in problem-oriented transdisciplinary research / knowledge co-production in a European context (**sub-question 1**)
  OR
- Gave information about the challenges researchers can experience related to roles in problem-oriented transdisciplinary research / knowledge co-production in a European context (**sub-question 2**)

Four articles were not established through the search in Web of science as described above but were found a different way. They each met the criteria of the screening, however. As mentioned above, Pohl et al. (2010) was found in a trial search and added to the literature list because of its seminal status. Haarstad et al. (2018) was added to the literature list because it described the rationale behind the transdisicplinary strategy at CET (Haarstad is the director of CET and the third supervisor for this master thesis). Two additional articles turned out to necessary to make a complete conceptualize of the analytical framework: Hoes et al. (2008) and Hilger at al. (2018). These were found by tracing the references of the resulting literature from the search in Web of Science.

Table 4.4 below shows to which topics the search results relate.

Table 4.4. Overview of the search results of the systematic literature review on researcher-roles in transdisciplinary collaboration.

Topic	**Search results**
Frameworks of researcher-roles *Sub-question 1*	Pohl et al. (2010); Wittmayer and Schäpke (2014); Bulten et al. (2021); Hilger, Rose & Keil (2021); Vinke-deKruif et al. (2022).
Challenges associated with these roles *Sub-question 2*	McKee, Guimaraes & Pinto-Correia (2015); Haarstad et al. (2018); Bulten et al. (2021); Hilger, Rose & Keil (2021); Huning, Räuchle & Fuchs (2021); Vinke-deKruif et al. (2022).
Detailed operationalization of researcher-roles *Sub-questions 1 and 2*	Hoes et al. (2008); Pohl et al. (2010); Wittmayer and Schäpke (2014); Hilger et al. (2018); Adelle et al. (2019).

<u>Literature review about reflection</u>

To find theory on reflection, I used a less structured process than for the theory on researcher-roles, because I already had access to a lot of knowledge about reflection through my master CDI. The advantage of this approach is that I embedded my thesis well within the research-expertise at the CDI research group. The limitation of this approach is that I built my theory of reflection on a rather limited scope of literature. A wider search could have led to a different conceptualization of reflection. I discuss this further in section 11.3 in the discussion.

I started my literature review with a set of articles that were presented to my during my master. Specifically, in CDI, I had learned about the following concepts:

- 'triple-loop learning' (Argyris & Schön, 1974)
- 'system 1 and system 2 thinking' (Kahneman, 2003)
- 'ALACT reflection model' (Korthagen, 2001)
- 'experiential learning cycle' (Kolb, 1967)

For the literature review on reflection, I needed more information about these concepts and how they could be applied in practice to shape reflection practices. Therefore, I searched on Google

scholar with the above four concepts as search terms. Additionally I used the search term 'reflection' on Google scholar. I filtered out results that related to reflection practices in the context of transdisciplinary collaboration and to the context of sustainability or environmental research. I identified a few additional articles through snowballing (retracing citations in articles). Table 4.5 below gives an overview of the literature that I used for the theory on reflection in section 7.2.

Table 4.5 Overview of the literature included for the theory on reflection in section 7.2.

Subsection	Included literature
2.3.1 Conceptualizations of reflection & relations to learning	Argyris & Schön (1974); Schön et al. (1983); Hatton & Smith (1995); Korthagen (2001); Kahneman (2003); Kinkhorst (2010).
2.3.2 Reflection models	Kolb (1976); Korthagen (2001); Korthagen & Vasalos (2005); Kayes (2005).

4.3.1 Semi-structured interviews

The interviews contributed to sub-questions 1, see chapters 5 for the results.

Reasons to use interviews

The semi-structured interviews were choses as a method because they allowed me to ask in-depth questions and flexibly adapt the follow-up questions to the answers of the interviewees. This was needed, because the interviews were used to answer sub-question 1 on how CET-researcher conceive their role in transdisciplinary collaboration. This meant I had to go along in their way of thinking and clarify and deepen their answers with flexible follow-up questions. Interviews, however, risk interviewer bias and interaction effects which cause the interviewee to withhold or differently convey information. For example, the interviewee could give socially desirable answers to satisfy the interviewer. This risk was even larger because I knew all my interviewees (apart from one) personally, since I was their direct colleague as guest-researcher at CET. Therefore, the interviews were complemented by a logbook, which has these limitations less (see section 4.3.2).

Respondents & Data collection

All respondents from groups A and B, apart from respondent 8, participated in the interviews. See section 4.2.3 for more information about the interview respondents.

The interviews were conducted over a period of a week (March 24 - March 31), in person in a meeting room in the CET-hallway at the university building in Bergen. I chose this room because it was a safe and familiar environment for all interviewees who work in the same hallway.

I aimed to establish a relationship of trust at the beginning of the interview, with some small talk, by expressing interest in the respondent and by showing my own vulnerability (e.g.: 'I am just a master student. I think you have more expertise on this than me, so I am very excited to hear your insights'). After some small talk, each interview started with a short introduction of the interview topic, terminology and structure, followed by an informed request for consent to record the interview (all interviewees agreed). I aimed to limit the interview to 45 minutes, to not exert the interviewees. Interview 1 and 3, however, lasted 60 minutes.

I worked with two interview-protocols. One for the PhD-candidate's (protocol A) and one for the students (protocol B). Within these two groups, each interviewee was asked the same *main questions.* However, *follow-up questions* were adapted to the progress of the interview. Appendix 2

shows the interview protocols. The questions are all open, mostly starting with 'how' and 'what', as 'why'-questions can come over as accusatory. The protocol starts with an easy-to answer question as a 'warm up'. Some questions in the interview are on purpose open (e.g., 'Could you reflect how your role [which we talked about in the previous part of the interview] influenced the collaboration?'). These questions are so open, because it gives the interviewees the space to explain in their own words how they conceive their role in transdisciplinary collaboration. The open questions are followed in the protocol by guiding questions that provide more direction. This order ensures that the guiding questions do not influence the answer of the interviewee to the open questions. The guiding questions are based on the operationalization of the analytical framework: they entailed me going through the behaviors from the analytical framework with the interviewee and asking the interviewee to indicate for each behavior if they performed it in their transdisciplinary collaboration.

Data management & informed consent

At the start of the interviews, the interviewees were explained the data management strategy and asked for consent for this. All interviewees gave verbal consent at the start on the recording. The data management was as follows: interviews were recorded and transcribed. The recording was stored on my computer. I uploaded the recordings to otter.ai, an online transcription software. Otter does not share recordings and transcripts with third parties, according to their privacy statement. When transcribed, I deleted the recording from otter.ai and from my computer. The transcripts, which do not contain any names, have been deleted from otter.ai but remain stored on my computer and are available on request to only my supervisors or peer-reviewers in case I publish an article based on this master thesis. After that, I will delete them from my computer.

Data analysis & interpretation

The analysis of the interviews consisted of four steps.

1. Transcribing interviews: The recording of each interview was transcribed as literally as possible. I used the transcription software 'Otter' (https://otter.ai/) and went through the computer-generated transcripts to correct mistakes and remove names and personal identifiers (I asked the interviewees to not use names during the interviewee, and did not do so myself, but sometimes a name slipped through). The interview transcripts are not added in the report, but are available on request to my supervisors.

2. Structural Coding (Mason, 2002; Saldaña, 2015)**:** I read all transcripts to identify which parts of the interviewee's answers related to which topics in the operationalization of the analytical framework. I gave each topic a structure 'label' with the comments function in MS Word. Such a label starts with a letter (A, B, C...) as an identifier and then states to which part he operationalization the text relates. For example, one label is '*A. Change agent – motivation & behavior'*. An overview of the structure labels can be found in appendix 3.

3. Constructing mental maps: After all text had been structurally coded, I compared all chunks of text that were assigned the same structure label. In these text-chunks, I identified what precisely the interviewee had said. I translated this to a schematic representation of their thoughts on the topic in the form of a mental map. The mental maps contain entries for motivations, behaviors and expected effects, following the operationalization. Each entry in the mental map starts with the identifier (A, B, C…) from the structural label, so it can be looked up in the interview transcript. Constructing the mental maps involved a lot of my own interpretation. The mental maps are added in appendix 4.

4. Using mental maps to write results: I used the mental maps to decide which quotes to use in my results chapters. To reduce interpretation bias, the interviewees were asked to assess their own quotes in the results chapter – had I interpreted their statements correctly?

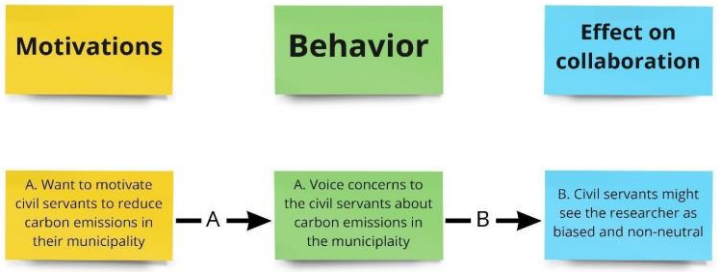


Figure 4.5. Fictional example of an entry in a mental map, based on two chucks of text in the interview transcript (with label identifiers A and B).

4.3.2 Logbooks

The logbooks contributed to sub-questions 1, see chapter 5 for the results.

Reasons to use logbooks

The logbooks complement the interviews because they are free from interviewer bias and interaction effects. The logbook used in this study is essentially a short 'semi-structured survey'. The logbook was held after the interview, so that I could introduce my study in person (at the interview) before the respondent received the logbook.

Respondents & Data collection

Only four respondents filled in the logbook: two PhD-candidates and two student course-coordinators. The others were too busy to fill in the logbook. After two reminders, I decided to accept they did not fill in the logbook. See section 4.2.3 for more information about the respondents.

To let the logbook respondents reflect on their role in collaboration, I took inspiration from a logbook-structure based on the reflection model of Korthagen (1999). Following the Korthagen-model, the logbook asks respondents to reflect on a *concrete action* (related to their role in the collaboration). However, because the goal of the logbook is to help answer sub-question 1 about how researchers conceive their role in transdisciplinary collaboration, the final question in the logbook is a rather open question as to not *direct* the respondents' answer in a certain direction. The logbook is short (15-20 minutes to fill in) to increase the chance that many respondents fill it in (although still many did not fill it in, as mentioned above). The filled in logbooks are added in appendix 5.

Data management & informed consent

Each logbook contains a paragraph on the first page, in plain sight, with the title 'Processing of your entries and privacy'. This paragraph describes how the logbook results would be handled after the respondent sent the filled in logbook back to me. The paragraph ends with: 'By filling in this logbook, you give permission for the use of your entries as described above.' See appendix 5 for the whole paragraph.

Data analysis & interpretation

The logbooks were analyzed the same as the interviews. First, the logbooks were structurally coded. Here, there were no letters (A, B, C…) used as identifier, but simply the identifier "logbook", since each logbook contained only one chunk of text. For example, one label is '*Logbook. Process facilitator – behavior*'. After assigning labels, the data from the logbooks was added to the mental map of the respondent, with the identifier 'logbook'.

4.3.4 Focus groups

The focus groups contributed to sub-question 2, see chapter 6 for the results.

Reasons to use focus groups

The focus group was held because both the interviews and the logbooks collect data from individual respondents. However, transdisciplinary collaboration is, by definition, a group process. Therefore, the focus group was held where the respondents could react to each other and where I could observe the group dynamics and culture in action. By having the focus group after the interviews and logbooks, I could use the results from the interviews and logbooks The main goal of the focus group was twofold. Firstly, to let the participants identify challenges for CET-researchers related to their role in transdisciplinary collaboration (sub-question 2). Secondly, to gather some first input on what is needed to address these challenges. The latter was an element of co-design. A secondary goal for me as researcher was to make the participants enthusiastic for the design-phase of the research.

Respondents & data collection

Two focus groups were held. One with four of the five interviewed PhD-candidates at CET (the fifth unfortunately had no time to join) and one with the three course coordinators of the CET-course *Sustainable innovation.* See section 4.2.3 for more information on the background of these respondents. Before the focus group, all participants received an email explaining the goal and structure of the focus group. The focus group was recorded and proceeded as follows.

Table 4.6. The setup of the focus groups.

Part	**Actor**	**Goal**	**Action**	**Time** (min)
1	Joran	**Motivate the respondents** to participate in this focus group and in the solution-design phase	1a. Joran presented the goal of the solution phase and explains why the input of the participants in this focus group is crucial for this. 1b. Joran presented the goal and structure of the focus group 1c. Joran invited participants to also participate in prototype evaluation sessions later.	8
2	Partici-pants	**Identify which challenges** the respondents want the reflection tool to help with	2a. The participants engaged in a case (related to 1 of the relevant aspects of the researchers' roles in collaborations) > they got a case description (based on logbooks and interview results) with a problem to solve > they discussed how to address the case > once they had formulated a response, they were asked to identify what challenges situations like these pose. They wrote down the challenges on post-its. 2b. The participants were asked to write more post-its about challenges (unrelated to the case) and were asked to categorize the challenges in groups.	25
3	Partici-pants	**Identify which design principles** the respondents want the reflection tool to meet	3a. The participants brainstormed about how to address the identified challenges. To get thoughts flowing, there were shown four generic solution directions (providing more knowledge, training skills, providing inspiring examples and creating a safe space to share uncertainties) and asked to respond to those.	8
4	Joran	**How does the process go on?**	4a. Joran thanked the participants and explained next steps in the research (prototype evaluation sessions).	4

Data management & informed consent

The email before the focus group also contained a consent form with an explanation of how data would be collected during the focus group (e.g. recording), and how that data would be handled after the focus group. At the focus group, I brought printed versions of the same form, which the participants could then sign by pen. The two online participants could sign the form online in Adobe Acrobat reader. All focus group participants signed. See the signed consent forms with an explanation of the data management in appendix 6.

Data analysis & interpretation

The output of the focus group consisted of post-its and a recording. I transcribed the recordings.

Each post-it contained one challenge. I read the transcripts to identify what the focus group participants had said exactly about each challenge. Also, I reviewed the mental maps and re-read the interview transcripts and logbooks to analyze if the focus group participants voiced similar or opposing thoughts during the interviews, logbooks and focus group. The analysis went directly from transcript to result - there was no coding of the focus group transcript involved. To reduce interpretation bias, I retained many quotes in the results chapter and tried to stay close to the words of the respondents. Moreover, for sub-question 2, when categorizing the challenges, I used the categorization the focus group participants had started during the focus groups as a basis.

4.3.5 Problem summary & essence

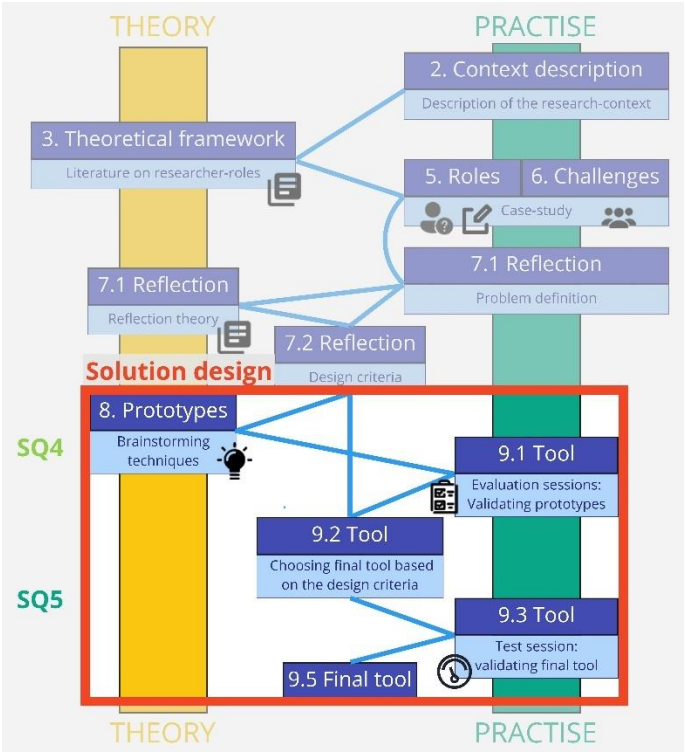
After the case-study at CET, I determined what problem the reflection tool should precisely focus on.

Firstly, in section 7.1, I summarized what I had learned about the CET-context in the empirical case-study: a **problem summary.** Keeping this *problem summary* in mind, I boiled down the challenges that CET-researchers face (sub-question 2) to an "***essence***". This is a concept developed at the research group CDI (which hosts my master). The essence is the one theme where all the challenges come together. The essence is simple, yet still holds all the complexity. It inspires the imagination of possible ways forward where the identified challenges for CET researchers (SQ2) no longer exist. In this master thesis, the essence functioned as a starting point for brainstorming about prototypes to solve the challenges in sub-question 4.

Secondly, in sections 7.2 and 7.3, I identified what reflection looks like in the light of the problem summary and essence. For this, I did a literature review on 'reflection' and conceptualized reflection in the problem-context of CET. Based on this, I drafted **design principles**. These are the principles a reflection tool should meet to solve the problem. By using these design principles, I made sure the reflection tool built on both the CET-context (practice) and literature on reflection (theory). The design principles were used later for sub-question 5 (chapter 9) to determine which reflection tool prototype best suited the problem-context.

3.4 Methods solution design phase

The problem analysis phase ended with a problem definition. This was the starting point for designing reflection approaches. The design started with diverging (sub-question 4) and ended with converging to one final tool (sub-question 5). Moreover, the design alternated between theory and practice.



This research applied some elements of 'participatory design'. For instance, the whole design process was based on an assessment of the challenges that the respondents face in transdisciplinary collaboration. This can be described as 'design for users' (Kalmar & Stenfert, 2020). Moreover, two of the three methods in the solution design phase included participation of researchers (the prototype evaluations and the test session). Nevertheless, only a few respondents participated in the participatory design and their involvement in the design process itself was limited. Rather, they gave input in prototypes and tested the final tool. Therefore, some activities happened at the level of 'design with users', but the active participation was limited.

4.4.1 Brainstorming techniques

<u>Reasons to use brainstorming techniques</u>
In design-thinking, you first diverge by gathering and generating many ideas for your solution design (sub-question 4). Only afterwards, you develop the best idea (sub-question 5). During the diverging process, brainstorming techniques help to think out of the box, and to use theory, your creativity, intuition and experience to come to new ideas.

Brainstorming techniques explained

I brainstormed alone (there were no respondents involved), using four techniques. Firstly, I used the *essence* as inspiration to envision the desired outcome of reflection. Using my creativity and intuiting as a source, I wrote a **decision narrative** (a fictional creative story) that described what it would look like after the CET-researcher successfully reflected on the identified challenges. Secondly, I used my creativity to find **analogies** of the *essence* in other contexts than CET and I identified what I could learn from that for reflection in the CET-context. Thirdly, I brainstormed about which reflection methods I have **experience** with (e.g. as a teacher and in my CDI master). Finally, I gathered examples of reflection methods from the **theoretical framework** that connected to the *essence.* From these brainstorming techniques, I established two prototypes for reflection tools to present to the research participants in the prototype evaluation sessions.

4.4.2 Prototype evaluation sessions

Reasons to use prototype evaluation sessions

The prototype evaluation sessions provided a first validation of the protypes in the context of CET, and from an outsider perspective. The reflection tool is to be used by (future) CET researchers. Therefore, it is crucial that the reflection tool is validated in practice and that the needs of the users are considered during the design. In a prototype evaluation session, a respondent can react to the prototypes from their practical perspective and adjust the direction of the design process based on their needs. Moreover, by also having an evaluation session with people who have not been involved in my research, I could test if the prototypes were also clear to people who knew nothing about the topic of this master thesis. Finally, people who were not involved in my research might be less like to give socially desirable answers.

Respondents & set up of the prototype evaluation sessions

I held two prototype evaluation sessions, which took 60 minutes each. The first session was physical with respondent 4 (course-coordinator of the course *Sustainable development).* I held the session with this respondent, because this was one of the only respondents who had time and because this respondent had experience with the design of educational tools. Getting more respondents to join proved too difficult due to their busy agendas. The second session was online with two fellow students from my master CDI for an outsider perspective. See section 4.2.3 for more information about these respondents.

Each session proceeded like this:

- [Preparation before the session] Participant(s) read the **decision narrative** (the narrative was sent in an email which explained the purpose of the prototype evaluation session and the purpose of reading the decision narrative).
- [15 min] **Welcome**: Coffee, small talk, and introduction to the session
- [5 min] I asked the participant(s) how they felt about the **decision narrative**. For instance: would this be a good endpoint after using a reflection tool?
- [5 min] I presented the identified **challenges** and the **essence** to the participant and asked for their reaction. For instance: do they identify with the essence?
- [10 min] I asked the participant what they thought would be needed to overcome the challenges and achieve the ideal situation described in the decision narrative (a short **open brainstorm**).
- [20 min] I presented the **two prototypes** and asked the participant to react to each. For instance: which strengths and weaknesses do they see in each prototype? I also asked which

criteria the final reflection tool should meet to make it realistic that it is used (to generate input for the design principles).

In the session with respondent 4 (course-coordinator of the course *Sustainable development)*, I used the decision narrative about students. In the session with two fellow CDI students, I used the decision narrative about PhD-candidates.

Data management & informed consent

I asked the prototype evaluation participants to sign a consent form. This form included an explanation of how data would be collected during the focus group (only by writing comments, see next paragraph), and how that data would be handled after the focus group. All three participants signed the form digitally in Adobe Acrobat reader. See the signed consent forms with an explanation of the data management in appendix 6.

Data collection & analysis

The prototype evaluation sessions were not recorded, due to a lack of time to transcribe the recording. To have written output, I wrote down comments in a word document during the session and I repeatedly asked the respondents if I had captured their thoughts well in those comments. Some design principles were added after the prototype evaluation session, so chapter 7 contains "revised design principles". Finally, and most importantly, with the input from the prototype evaluation sessions, I improved both prototypes and next chose one protype to develop into a final reflection tool, based on the revised design principles.

4.4.3 Test session

Reasons to use test sessions

After refining and building the chosen prototype, it was time to validate it further in the CET-context by testing it. Just like the prototype evaluation sessions, the test was crucial to ensure that the needs of the end-users are considered during the final development stages of the reflection tool.

Respondents & set up of the testing session

I held one testing session of 60 minutes. Two respondents to my research participated in the test session: respondents 1 and 3. Additionally, another employee at CET participated: the fourth supervisor to this master thesis. This supervisor is not involved in transdisciplinary collaboration but is familiar with the topic through working at CET and through supervising this master thesis. See section 4.2.3 for more information about these respondents.

The participants played two rounds of the game. The first round generated input about unclarities in the game rules and game cards. The second round generated input about the degree to which the game spurred reflection and how the game could be changed to improve the reflection.

The test session proceeded like this:

- [5 min] **Welcome**: Coffee, small talk, and introduction to the session
- [20 min] The participants read the game instruction and **played a first round** without my help. They posted post-its where they found the game cards unclear.

- [5 min] I led a **discussion** on how the participants had experienced the game and what could be improved to **make the game easier to learn and play**.
- [10 min] The participants **played a second round**.
- [10 min] I led a **discussion** on which changes in the game could **improve the reflection** generated by the game.
- [5 min] The participants filled in **questionnaire** which measured to which degree the design principles were met by the game.

Data management & informed consent

I asked the test session participants to sign a consent form. This form included an explanation of how data would be collected during the focus group (post-its, video and questionnaire), and how that data would be handled after the focus group. I did not upload the video recording to otter.ai for transcription (like I did with the interview sounds recordings). Like with the interview sounds recordings, the video was only stored on my laptop. It is kept untill I receive a grade for my master thesis and will then be deleted, as stated in the consent form. All three participants signed the consent form digitally in Adobe Acrobat reader. See the signed consent forms with an explanation of the data management in appendix 6.

Data collection & analysis

Data was collected in three ways. Firstly, during the first round of play, the participants posted post-its where they found the game rules or game cards unclear. I asked them to shortly explain their post-its. Secondly, the testing session was filmed. I transcribed the two discussions between the participants and me. Thirdly, the participants filled in a short questionnaire which measured to which degree the design principles were met by the game.

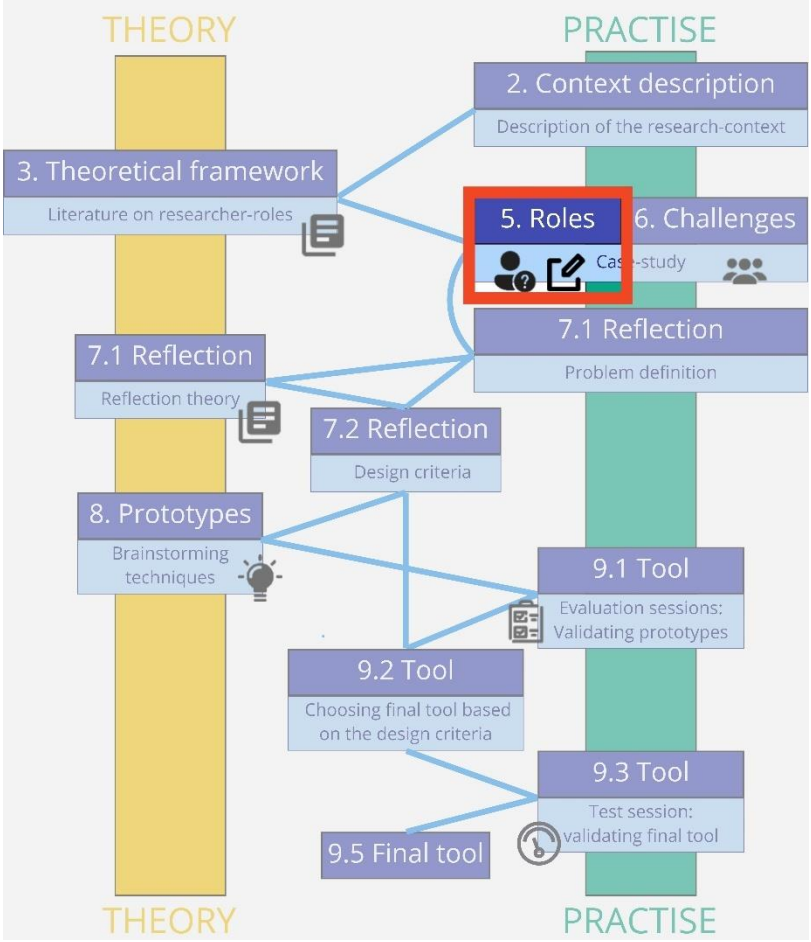
I used the collected data to make an overview of how the tool could be improved further. This led to the final result of this master thesis: a validated reflection tool.

Summary chapter & link to next chapter (this subheader will change)

You now know that this master thesis used design-based research to design a reflection tool for starting researchers at CET. During a problem analysis, data was gathered in a literature review, semi-structured interviews, a logbook and two focus groups. During the solution design phase, a reflection tool was designed using brainstorming techniques, two prototype evaluation session and a test-session. The next chapters will present the results of the data-gathering and analysis, and of the design process.

5. Roles of CET-researchers in transdisciplinary collaborations

***Sub-question 1**: How do CET-researchers conceive their role in transdisciplinary collaborations?*
***Data-collection**: Semi-structured interviews, logbooks*
***Data-analysis**: Structural coding & drafting mental maps*



Based on the interviews and logbooks, I have made mental maps of each interviewee, describing how they conceive their role in transdisciplinary collaboration (see appendix 4). This chapter analyzes the mental maps to answer sub-question 1. Let us first look at how PhD-candidates conceive their role and then at how the course-coordinators see the role of their students in transdisciplinary collaboration.

The chapter is structured according to the five roles of the analytical framework. The italic sentences at the beginning of each subsection are added to remind you how the five roles were operationalized (in section 3.2.5).

5.1 CET PhD-candidates about their roles in transdisciplinary collaborations

5.1.1 PhD-candidates as reflective scientists

Actions connected to this role include: doing traditional scientific research (literature reviewing, interviewing, surveys, data-analysis etc.), developing science-informed models and tools, and gathering data about the collaboration process.

The PhD-candidates in Cityfreight and Klimathons saw traditional scientific research as the main activity in their PhD.

> 'Gathering and analyzing scientific theory and data from interviews, surveys, documents, discourse analysis, etc. to produce scientific knowledge? That is my PhD in a nutshell.' (Respondent 6, interview).

However, in relation to the transdisciplinary side of their PhD, they saw scientific activities rather as a means to prepare other activities (related to other roles). Some elements of their research were used as input or presented during co-production workshops. For instance, the PhD-candidate in Klimabudsjett developed a tool that was discussed during the co-production meetings. Furthermore, the respondents described scientific analysis methods as useful in the preparation of collaborative sessions, for example by analyzing actor-networks and identifying low-power actors, to determine who could best be invited to co-production workshops.

> 'Based on [research] findings, I can identify certain stakeholder groups that I know are sort of at the bottom of the power chain. (…) So trying to find those smaller organizations or stakeholders who have not actively been identified previously, to make sure that they are part of the conversation.' (Respondent 3, interview)

In Klimabudsjett and Cityfreight, traditional research activities were dominant in the early phases of the project. The PhD-candidates saw collaborative sessions like co-production workshops as an opportunity to let societal actors share their input about the research done so far or the tools that the researchers were developing.

> 'It is also going to be the idea at the workshops that we get people to bring forward things that we might not be aware of.' (Respondent 6, interview).

The PhD-candidate involved in the Klimathons emphasized the importance of involving societal stakeholders early in the research process, instead of performing only scientific activities:

> 'The whole planning process of the Klimathon (…) is sort of co-production in itself. But then of course, it is very heavy on the research side, and less on the non-academic side. But there was a lot of negotiations going on between the natural and social scientists and regional county representatives, as the non-academic actors. (…) That was one of the most helpful things. (…) Because when you sit a lot of scientists in one room, you have a lot of terminology, and you have a lot of ideas. It is about making it so concrete that it makes sense to the people in the room who are not academics.' (Respondent 7, interview).

5.1.2 PhD-candidates as knowledge brokers

Actions connected to this role include: re-wording and translating research findings, finding insights or best practices that could be directly useful to societal actors and applying scientific insights to specific societal contexts.

Several respondents saw it as their role to make sure that research is applicable in the daily context of the societal actors they collaborated with. Both PhD-candidates in Cityfreight elaborated on the importance of tailoring co-production workshops to the needs and contexts of specific cities. So they could:

> 'use all of the knowledge to co-produce context-specific solutions for each city, because our assumption is that the context of each city is different actors collaborate differently, the power dimensions are different.' (Respondent 3, interview).

The PhD in Klimabudjett was motivated by making his research efforts directly useful to society.

> 'I really want them to see me as a tool they can use.' (Respondent 1, interview).

Later, respondent 1 said:

> 'We have this ambition to create either an online platform, or an Excel sheet. Something that civil servants can actually use in their day to day work. So explicitly aligning global carbon budgets with how Norwegian municipalities work at the moment.' (Respondent 1, interview).

All PhD-candidates translated and re-worded scientific insights that they thought would be directly useful to the societal actors in the collaboration. The PhD-candidate in Klimabudsjett and one of the PhD-candidates in Cityfreight mentioned they (planned to) share best practices from other cities.

5.1.3 PhD-candidates as process facilitators

Actions connected to this role include: Locating and inviting participants, organizing meetings and facilitating knowledge exchange and learning.

All PhD-candidates saw the organization of collaborative meetings as one of their central tasks. The PhD-candidate in Klimabudsjett performed most of the organizational tasks for a workshop alone. The other PhD-candidates operated more in a team.

The PhD-candidates all thought they should have a role in facilitating knowledge exchange among societal actors. However, they used different arguments to involve certain actors in the collaborations and to encourage them to voice their opinion. The arguments they mentioned can be categorized in the four types mentioned in the theoretical framework:

1) instrumental arguments (involving stakeholders to build support for the outcome of the process)
2) democratic arguments (involving stakeholders to make the process more democratic)
3) substantive arguments (involving stakeholders so their input can improve the research)
4) learning-oriented arguments (involving stakeholders to build capacity by letting them collaborate and learn from each other).

Firstly, the PhD-candidate in Klimabudsjett gave an *instrumental* reason.

> 'That was a bit of the ambition of this workshop, to really make the case for carbon budgets. That these are an important way of thinking about climate mitigation. (…) bringing those

> people from Sweden was to also show that [the carbon budget tool] had benefits, it had sort of sides that are valuable when you plan your local climate plan.' (Respondent 1, interview).

The quote shows that respondent 1 strategically invited actors who were enthusiastic about the tool and assumed that these actors would increase the enthusiasm of other societal actors. This action arguably also connects to the role of *change agent*, see the next paragraph.

Secondly, respondents 3 and 6 (Cityfreight) gave a *democratic* reason to invite stakeholders. They wanted to identify and invite actors with low power to give them access to the decision-making process in the collaboration.

> 'Particularly the actors in the private sector feel that they are either not included in public planning processes, or if they are then basically it is done too little too late. (…) So one main outcome of these production sessions or workshops or whatever they end up being is to potentially give more access and more insight, hopefully at earlier stages, stages of the planning process.' (Respondent 6, interview).

> 'The sharks are easier to identify, right? But then the little fishes you miss out on. So trying to find those smaller organizations or stakeholders who have not actively been identified previously, and making sure that they are part of the conversation.'
> (Respondent 3, interview).

Thirdly, all PhD-candidate's gave the same *learning-oriented* reason. They argued that an important goal of their transdisciplinary collaboration was to create new partnerships between people who previously did not exchange ideas. Therefore, they made sure to invite a wide range of actors, for example from multiple countries (Klimabudsjett), from public and private sector (Cityfreight) or from multiple levels of public governance (Klimathons). For the Klimathons, the societal actors were even involved during the planning process of the collaborative Klimathon meetings, which resulted in a closer partnership between the researchers and those societal actors.

All PhD-candidate's encouraged societal actors to share their thoughts at meetings, again because of different types of reasons. It would lead to actors – especially the less powerful ones – 'speaking more freely' (respondent 3, Cityfreight, interview) and 'feeling the space to share their ideas' (respondent 7, Klimathons. interview). They considered this as something intrinsically good (*democratic* argument) and they thought it contributed to the partnership formation mentioned above (*learning-oriented* argument). However, they also saw it benefitting the researchers: an open environment would lead to the societal actors sharing more honest and complete input on the research (*substantive* argument). For instance, one of the PhD-candidates in Cityfreight said:

> 'It's important to find out what's not going to work, especially for people who are stakeholders who are not in such powerful positions' (respondent 3, interview).

Respondent 6 (Cityfreight) argued in the interview that encouraging everyone to share their opinion might lead to societal stakeholders 'feeling like the forum [the collaboration] is valuable', consequently increasing the trust of the societal actors in the researchers and the process and motivating them to keep participating in the future (*instrumental* argument).

Respondent 3 (Cityfreight) imagined that explicitly encouraging silent or low-power actors to share their opinion might lead the PhD-candidate to come over as biased. Therefore, they suggested to ask a neutral external moderator to lead the meetings.

5.1.4 PhD-candidates as change agents

Actions connected to this role include: actively steering the outcome in a certain direction to achieve change in society, openly voicing personal opinion about societal processes around sustainability and actively thinking along towards solutions for societal problems.

The PhD-candidate in Klimabudsjett had the explicit goal to increase the use of the carbon budget tool they were developing, and thus chose to engage as change agent. As stated in the previous paragraph too, the PhD-candidate strategically invited municipal civil servants who were already enthusiastic about the carbon budget tool and asked them to present their experience with the tool. The goal of this was 'making a case for the carbon budgets' and 'justifying more and more institutional attention.' The PhD-candidate's motivation to make a case for the carbon budget tool lay in the desire to see their scientific research contribute to society.

> 'What was motivating me is that my contribution (…) is relevant to the world of people working on these issues in cities. (…) I think it's really: what knowledge do these people need to navigate that space better, and to reach the ambitious goals that they have set themselves?' (Respondent 1, interview).

Moreover, the PhD-candidate was motivated by the fact that several political actors already supported the tool.

> 'What I think is relevant: our carbon budget [tool] is also supported by this whole network that we have. So that's why we stand behind this method. And why we advocate for it.' (Respondent 1, interview).

So, the PhD-candidate in Klimabudsjett stood by the tool because it had support, while part of that support seems to have been created by strategic acting on the part of the PhD-candidate self.

Some other PhD-candidates also sought to affect the opinions and behavior of societal actors in the transdisciplinary collaboration, but they did so in a more subtle way. Respondent 6 (Cityfreight) mentioned that their interviews with societal actors had given them a network in the public and private sector they could now use actively, for example to spread their survey or to validate ideas. Respondents 1 (Klimabudsjett) and respondent 3 (Cityfreight) mentioned that they would not share their opinion about what sustainability solution they thought should be pursued, unless they were explicitly asked to do so, or could clearly back up their opinion with scientific research findings.

Most PhD-candidates rather stayed away from openly engaging in actions related to the change agent. They assumed that sharing their personal opinion about what should happen, would lead to them being seen as 'biased' (respondent 3, Cityfreight, interview) or the societal actors feeling 'blamed' for not doing enough to address sustainability issues (respondent 6, also Cityfreight, interview). When I asked respondent 7 (Klimathons) whether they voiced their opinion to societal actors about whether these actors do enough to address sustainability challenges, they said:

> 'God, no. I think that would be really counterproductive. (…) I think that would be (…) disrespectful and judgmental. It will be counterproductive because then it's pointing fingers. That would sort of stop the conversation and stop the focus on bringing about solutions.' (Respondent 7, Interview).

The same respondent later remarked that societal perceptions around young age and female gender might also play a role in them not sharing their personal opinion. Similarly, respondent 1 said:

> ‘I think I'm not comfortable enough yet to take my research as a basis to then voice my concern. For the moment I am just describing it as this is what I found.’ (Respondent 1, interview).

Also, the PhD-candidate’s in Cityfreight and Klimathons remarked in interviews and focus group that it is better if the researcher is not too involved in the learning process. They would rather see the societal actors share knowledge among each other, than the researchers answering questions of societal actors or thinking along towards solutions.

> ‘In the early Klimathons especially, we had these discussions a lot. Like how much information do we need to give them in the workshop? We've tried to keep [our contributions] as short as possible, but we've had like a short introduction to the theme, by some scientific, academic, scientific actor. And then we tried to keep it as short as possible and then have the main focus on the on the group collaboration.’
> (Respondent 7, focus group 1).

They have this focus on collaboration between the societal actors because they see as an important goal of transdisciplinary collaboration to ‘stimulate collaboration’ among the societal actors and make them ‘feel the space to share their ideas’ (respondent 7, interview) and to ‘bring societal actors together’ (respondent 6, interview). These statements again affirm the importance the PhD-candidates ascribe to the role of a more neutral *process facilitator*. It also shows that openly acting as a *change agent* can be in tension with a more neutral role as *process facilitator*.

This is different when acting as a *change agent* in a more obscured way, like the strategic inviting of societal actors as mentioned above by respondent 1, or using the network obtained during interviews. If the societal actors are not fully aware that the researcher tries to steer the outcome of the collaboration, this is expected to harm the neutral status of the *process facilitator* less.

5.1.5 PhD-candidates as self-reflexive scientists

Actions connected to this role include: silently observing and reflecting on the collaboration process and their own role in it, writing field notes of diaries about the collaboration process, talking about and reflecting on the collaboration process with other researchers.

This final role is one the PhD-candidates were least outspoken about. During collaborative activities, none of the PhD-candidate’s had time to observe the collaboration process or write diaries about what was happing around them. They were focused on their presentation or process facilitation tasks. However, outside the collaborative activities, the PhD-candidates did talk with colleague-researchers about collaboration process. For example, among each other (respondent 3 and 6) or with their supervisors (all PhD-candidate’s). However, in the interview, they mentioned this only shortly and did not elaborate on it further.

In essence, the interviews forced the PhD-candidates into the self-reflexive role, as the interview questions asked them to reflect on their role in the collaboration process. The interviews revealed that, when asked, all PhD-candidates show a rich set of process-oriented reflections. Even in the first part of the interview, where they were not explicitly asked to reflect on their role or the collaboration process, they already shared reflection on this. For example, respondents 1 and 3 referred to frameworks of researcher roles (including the one used in this master thesis) and respondent 3 quickly delved into power dynamics among the societal actors in the collaboration. Thus, the self-reflexive behavior is present, but the PhD-candidates do not seem to see themselves as self-reflexive scientists.

5.2 Students and course-coordinators of the CET-course *Sustainable innovation* about their roles in transdisciplinary collaborations

The course *Sustainable innovation* teaches students to develop sustainable innovations that are directly implementable in society. Through projects where they collaborate with a societal case-owner, the students practice transdisciplinary skills that they might later use as researcher in transdisciplinary collaboration. The course is coordinated by three 'course-coordinators', two of which are students themselves, and one is their supervisor. The course-coordinators determine to a large degree which role the students take in collaboration with their societal case-owner. Therefore, the interviews were conducted with the three course-coordinators.

The students performed most roles in the collaboration themselves. The course coordinators only engaged in activities related to the role *process facilitator.* The course-coordinators had, however, influence on all the activities the students performed.

5.2.1 Students as reflective scientists

Actions connected to this role include: doing traditional scientific research (literature reviewing, interviewing, surveys, data-analysis etc.), developing science-informed models and tools, and gathering data from societal actors.

The course-coordinators of the course *sustainable innovation* argued that the role of the students might not be categorized as 'fully scientific', because they followed a design-thinking approach.

> 'In a scientific process, you will use data and you will triangulate it, and you would like to put it in dialogue with theory and research and so forth. But I think, in the design-thinking, more or less, all of this more feeds into some kind of inspiration. So it's kind of a more creative relationship with that.' (Respondent 2, interview).

Most students did read some reports. The 'scientific' input for the innovations came mostly from the student's previous knowledge from their study programs and the articles suggested by the course-coordinators. Thus, the course-coordinators thought the students mildly engaged in the role of the *reflective scientist*, which normally employs scientific methods.

5.2.2 Students as knowledge brokers

Actions connected to this role include: re-wording and translating research findings, finding insights or best practices that could be directly useful to societal actors and applying scientific insights to specific societal contexts.

Respondents 2 and 5 answered short to questions related to the actions connected to the knowledge broker. This gave the impression that these respondents had not extensively reflected on behavior related to this role before. However, respondent 4 reflected on the fact that the assignment to make a protype for an innovation challenged the students to make their ideas as concrete as possible and translate their insights into something applicable in the case-context:

> ‘I hoped they would re-word the research findings. And I will say that the good groups do that. Ideally, the group would summarize their findings from the inspiration phase when they observed and talked to people. And maybe they would also summarize some conclusions from that and then explain: how did that fit into the prototyping? (…) When they do that they definitely also translate their insights into something applicable, right?’
> (Respondent 4, interview).

5.2.3 Students as process facilitators

Actions connected to this role include: Locating and inviting participants, organizing meetings and facilitating knowledge exchange.

The course-coordinators ascribed themselves the largest responsibility for process facilitation tasks. For instance, they saw themselves as responsible for identifying potential case-owners and inviting them to submit a case for the course. Also, they saw themselves as responsible for organizing the main meetings between students and case-owners:

> ‘We've had one or two structured sessions, which should be organized by the student coach coordinators, where the student groups have met their case owners.’ (Respondent 4)

Besides three planned meeting moments, the course-coordinators encouraged the students to contact the case-owners when they had questions, but they did not explicitly ask from them to organize meetings with the case-owners themselves. Nevertheless, some groups took initiative for this. One group even took initiative to talk to several other actors. I asked respondent 4 how they thought this initiative from the students affected the collaboration with the case-owners:

> ‘I think it's, of course, really cool when students take that initiative, and get that ownership of the product. And I think what might happen then is (…) they move one step further than the course expects them to, because in a sense they really move into implementation. And that's when the more fun things happen, right? (…) The way they would reframe and revise their ideas would be - it would be different quality, in closer contact with different stakeholders.’ (Respondent 4, interview).

Here we reach the border between the process facilitator and the change agent. Actively organizing meetings can lead to a closer *engagement* with the case-owners and even stepping into the context of the case-owner and moving to *implementation*.

5.2.4 Students as change agents

Actions connected to this role include: actively steering the outcome in a certain direction to achieve change in society, openly voicing personal opinion about societal processes around sustainability and actively thinking along towards solutions for societal problems.

Students who interacted more with their case-owners became more involved in the problems the case-owners faced. Respondent 5 thought that it was educative and fun for students to engage in such a close way with actors outside the university, because they had engaged in such interaction themselves before and enjoyed that.

Nevertheless, all three interviewed course-coordinators saw that there was large difference in the degree to which the students-groups engaged with the case-owners. Respondent 2 thought this might be caused in part by the fact that different students came into the course with different expectations.

> ‘It is pretty different how much effort each student put into the course. Because some have entered the course with the idea: wow, this is an exciting course I want to learn more, I want to take an active part. And some just have the course as some additional thing, where they just think: oh, this sounds nice. It is just a short time. It sounds pretty easy, just 10 sessions.’ (Respondent 2, interview).

Moreover, several student groups had trouble to contact the case-owners.

> ‘People that own the cases are quite busy people. (…) So I think some [students] have struggled a bit to be in touch.’ (Respondent 5, interview).

The course-coordinators saw this as a challenge for students and for themselves. So I will elaborate further on the causes of this in chapter 5 about the challenges in the collaboration.

The students who had little interaction with their case-owners, whatever the cause, fell into a negative spiral of low motivation and decreasing effort to sustain interaction with the case-owners. In contrast, when students were motivated to interact and the case-owners reacted with enthusiasm, the students and case-owners grew closer together.

> ‘For some students, the role has been pretty engaging and pretty active with the case owner. (…) Together, they have come up with a lot of great thoughts and ideas. So I think for some of the groups, or some of the students, at least, they have kind of gotten into the role as not just student, but kind of (…) like they've stepped into the business. (…) And with other groups, the students really feel that they are just students taking the course doing some group projects. It's when the case owners are almost MIA, they don't answer emails, they don't engage with the students as much. And we have gotten some feedback that the students feel like they work hard on the project, and they don't feel like they can use it to anything. So then they just have the very inactive role just sitting there.’ (Respondent 2, interview).

Besides an active engagement with case-owners, the course-coordinators saw another element of change agent behavior as crucial for the students and therefore encouraged them to engage in it: critically assessing the case-question. This was actually one of the course goals. Respondent 4 explained that this course goal followed from an interest in the university's contribution to society.

> ‘One thing I'm interested in is kind of: what is the role of universities in higher education in relation to what we might call the grand challenges of our time or kind of the challenges of sustainable development or the climate change?’ (Respondent 4, interview).

> ‘We want to remind our students that as university we could play a special role in society, and the contribution that our students can make in this type of processes a different contribution than for example, a consultant or another or an NGO. So perhaps one of our roles would be to also take the time to think longer and more complex thoughts and reframe questions and ask what if questions and ask questions about what might go wrong, and so forth. And have a more reflexive relationship to the problems. (Respondent 4, interview).

The outcome of this ‘reflexive relationship to problems’ is, ideally, more space for reflection on the ethics and long-term consequences of solution-directions.

> ‘[Universities] are basically places for slow critical thinking. (…) I won't say that everything that comes out of university lives up to the standard, but at least, if there's some place in society where we should be able to take the time to reflect, I think it's here.’ (Respondent 4, interview).

Respondents 2 and 5 also mentioned the course goal of learning to critically assess case-questions, but they did not mention a connection to the role of the university in society. Respondents 4 and 5 argued that a critical attitude of the students, for example by clearly voicing their opinions about societal processes around sustainability or even about the case-owners’ role in sustainability, contributed to the critically reframing of the case-questions.

Respondent 2 mentioned that in reaction to such a critical attitude ‘case-owners could get kind of fed up with hearing that they need to do more'. Respondent 6, however, said:

> ‘I think it would only be a good thing if they would voice concerns and be critical and approaching.’ (Respondent 6, interview).

The respondent saw ‘voicing their concerns’ as a means of being ‘critical’ and explained ‘approaching’ as ‘curious and humble’ and ‘open to change your opinion’. They thought this combination of critical and approaching would lead to ‘an open safe space to share struggles’ where students and the case-owners could together shed light on problems and to try to find new solutions to them. Respondent 6 imagined that through this process, the case-owners could see that they can collaborate with students or universities on sustainability issues. The students, on the other hand, might realize through this intensive interaction with the case-owner that there are limitations to implementing sustainable ideas in the practice outside the university. However, respondent 5’s statements in the focus group suggest that not all students were ‘critical’ enough to achieve these outcomes (see chapter 5 - challenge 8 for the students).

5.2.5 Students as self-reflexive scientists

Actions connected to this role include: silently observing and reflecting on the collaboration process and their own role in it, writing field notes of diaries about the collaboration process, talking about and reflecting on the collaboration process with other researchers.

Behavior related to this role was not encouraged a lot by the course-coordinators, suggesting they did not see it as one of the most important roles. As mentioned before (in the paragraph *students as process facilitators*), some students struggled with the interaction with the case-owners, for example because the case-owner did not reply to emails. The course-coordinators noticed that these students asked students from other groups for advice about the collaboration with the case-owners. Furthermore, the course contained a few built-in reflection moments, for example in the form of reflection assignments. This was mostly reflection on the innovation, but sometimes led to reflections about the collaboration process.

5.3 Answer sub-question 1

This chapter set out to answer sub-question 1: **How do CET-researchers conceive their role in transdisciplinary collaborations?**

The students and PhD-candidates performed activities related to all five roles. However, they emphasized the importance of some roles more than others, as summarized in table 5.1 below.

Table 5.1 Roles that the interviewees saw as their main role are marked with an 'X'.

Roles	PhD-candidates see this as a crucial role for themselves	Course-coordinators see this as a crucial role for their students
Reflective scientist		
Knowledge broker	X	
Process facilitator	X	(Course-coordinators saw themselves as most responsible for process facilitation)
Change agent		X
Self-reflexive scientist		

Notably, the course-coordinators of the students saw themselves as responsible for the main *process facilitation* tasks, while they saw the student as responsible for critically reframing the case-question as *change agent*. The PhD-candidates emphasized the importance of *process facilitation* to stimulate equal deliberation and mutual learning between societal actors, and most PhD-candidates rather stayed away from openly critical behavior or engaging too much in the learning process themselves as *change agent*. The PhD-candidates also emphasized the importance of making research findings specific and embedded in the societal context, behavior related to the role of *knowledge broker.* The students were less conscious about knowledge brokering. All PhD-candidates saw scientific research tasks, as performed by the *reflective scientist*, as an important part of their PhD. However, in the transdisciplinary context, they saw these tasks as a means to achieve goals related to other roles, such as creating tools that are useful in a societal context (knowledge broker) or investigating actors and their power dynamics to take those into account when organizing co-production workshops (process facilitator). The same means-ends relationship applied to the views of the course-coordinators. Behavior related to the *self-reflexive scientist* was generally not engaged in deliberately but triggered by struggles about the interaction with societal stakeholders, or by feedback meetings with supervisors.

5.4 Discussion sub-question 1

5.4.1 Two different ways to engage in change-oriented behavior

To base a reflection tool on the results on sub-question 1, it useful to do discuss the results a bit further. Moreover, a secondary goal of this master thesis is to contribute to theory building. Therefore, this discussion compares the findings of sub-question 1 to literature and proposes a theoretical addition in section 4.4.2.

Both the PhD-candidate's and the students at CET engaged in change-oriented behavior (Vinke-de Kruijf et al. 2022). However, as said before, the PhD-candidates were more careful to openly perform *change agent* behavior than the students were, because the PhD-candidate's thought *change agent* behavior could be in tension with a more neutral and objective role as *process facilitator.* A similar

tension between the change agent and the process facilitator was also identified by (Bulten et al. 2021) and a similar trade-off is commented on by Haarstad et al. (2018, p. 195): 'How do we balance this activity of trying to change things with the fact that the legitimacy of our place in these collaborations comes from our supposed objectivity?' To avoid losing a face of neutrality, the PhD-candidates tried to affect the process in more subtle ways, like strategically inviting participants and presenting personal opinions as 'findings' if they could be backed up by scientific research. Some of the students in the course *Sustainable innovation*, on the other hand, had an openly critical attitude and shied away less from confronting societal case-owners. The course-coordinators saw this as a useful attitude to open the discussion about societal processes around sustainability. A reason for this different approach could be that the PhD-candidate's and students had different *types* of societal effect in mind. The PhD-candidates emphasized the importance of what Haarstad et al. (2018) call 'connecting actors and processes.' In other words: bringing diverse actors, who normally hardly interact, together and letting them deliberate about solutions. The societal impact lies in facilitation new spaces for social learning between societal actors and therefore connects well to the role of *process facilitator.* The students worked more towards what Haarstad et al. (2018) call 'critically reframing discourses', which involves opening the way societal actors think about sustainability and the scope of solutions they consider. This requires actively changing societal actors' thought patterns; thus, it suits the more confrontational role of *change agent.* The students were pushed into this role by their course-coordinators. In this respect, it must be mentioned that the supervisor of the course-coordinators was a co-author in Haarstad et al. (2018). Another explanation for the different approach to achieving societal impact is that the PhD-candidates were more thoughtful of the effect of their behavior on their reputation and legitimacy than the students were. This could connect to experience, age, and gender. For instance, multiple respondents commented that more research experience would have made them more comfortable to take a critical attitude.

Both students and PhD-candidates worked as *reflective scientists* and *knowledge brokers* on what Haarstad et al. (2018) coin as 'producing & situating actionable knowledge'. PhD-candidates who presented tools or research outcomes to societal participants at co-production workshops, tried to tailor the presentation to the specific city the workshop was held in. The students had the assignment to produce an innovation for a societal case-owner. This assignment forced students to make specific how their work would contribute to the daily practice of the case-owner.

5.4.2 Connections between 'modes of engagement' and 'researcher-roles'

Judging from the discussion above, connections can be established between the modes of engagement of Haarstad et al. (2018) and the five researcher-roles of Whittmayer & Shapke (2014).

Table 5.2. Modes of engagement in climate and energy transformations (Haarstad et al. 2018) connected to roles of researchers in transdisciplinary collaboration (Whittmayer & schapke, 2014).

Mode of engagement	Objective of this mode of engagement	Required behavior	Related researcher-roles
Producing and situating actionable knowledge	Generating insights and facts that can catalyze change and positioning it in contexts where they can influence particular sustainability transformations	- co-producing knowledge - tailoring knowledge production and communication to specific contexts	- Reflective scientist - Knowledge broker

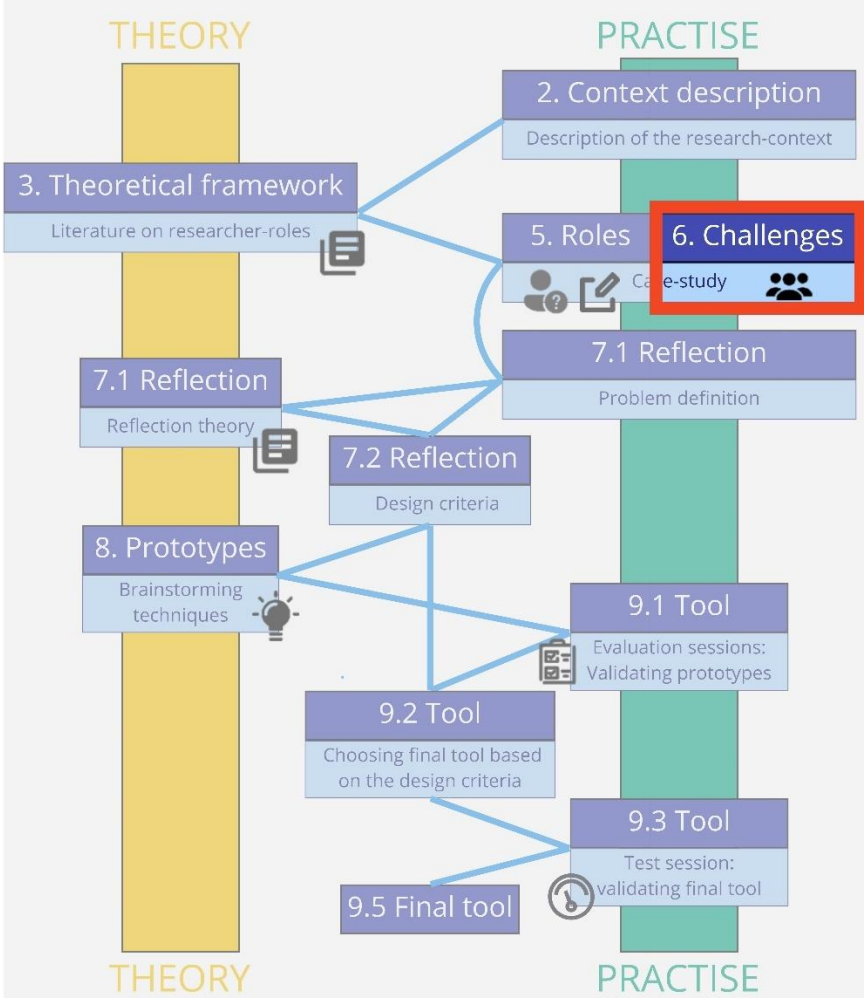
Critically reframing discourses	Identifying novel approaches to problems, envisioning new solutions, and enlarging the space for possibilities	- co-producing knowledge - opening up the discussion and reframing the discourses of the societal actors	- Reflective scientist - Change agent
Connecting actors and processes	Connecting fragmented processes, disconnected policy networks, governance agents, or stakeholders	- bringing actors from different governance levels and networks together - facilitating learning between them	- Process facilitator - Process facilitator

6. Challenges for CET-researchers in transdisciplinary collaborations

***Sub-question 2**: Which challenges do CET-researchers face related to their roles in transdisciplinary collaboration?*

***Data-collection**: Semi-structured interviews[1], logbooks[1], focus groups[2]*

***Data-analysis**: Structural coding[1,2] & drafting mental maps[1]*



In the focus groups, the respondents have identified challenges that CET-researchers face related to their roles in transdisciplinary collaboration. I cross checked their input on challenges with the 'mental maps', which were based on the interviews and the logbook (appendix 4). Let's first look at challenges for PhD-candidate's, then at challenges for students and after that compare them.

6.1 CET-PhD-candidate's about challenges related to their role in transdisciplinary collaboration

In focus group A, the PhD-candidate's identified challenges for starting PhD-candidate's at CET. I compared what they said in the focus group to what they had said earlier in the interviews. Based on that, I divided the challenges into three categories: Organizing 'real' transdisciplinary with limited resources, managing expectations and mitigating power differences.

6.1.1 Organizing 'real' transdisciplinary research with limited resources

Challenge 1: How to organize 'real' transdisciplinary research in the time frame of a PhD-candidate
Related to determining what your role should be in a limited timeframe.

Respondent 1 argued during the focus group that PhD-candidate's with the task of organizing transdisciplinary research might struggle to understand what 'real' transdisciplinary research actually is.

> 'What are the implications of doing transdisciplinary research? What are its goals? What are its ethics, and all of that. I still struggle to kind of imagining what the transdisciplinary ideal - transdisciplinary research would look like. And how I would set one up with other people - that I think it would need a lot of discussions.' (Respondent 1, focus group A).

As a case in point, respondent 7 mentioned that 'transdisciplinary research' and 'co-production', two terms I had been using interchangeably during the focus group, do not necessarily have the same meaning.

Extending the discussion about the challenge of defining what transdisciplinary research is, respondent 1 reflected on the time needed to do 'real' transdisciplinary research:

> 'I don't think I understand transdisciplinary research or engagement as a one-off session, I think it takes a long time to develop. And I think as PhD-candidates, we might not have the time, or the capacity by ourselves to do that. (…) I imagine a big research project with multiple collaborations all around that.' (Respondent 1, Focus group A).

Respondent 7 reacted that their PhD-candidate was part of a larger project, with more people spending time on the organization of the transdisciplinary research.

> 'I think you can do it [transdisciplinary research withing one PhD-candidate], but you depend on a whole lot of other actors and former projects.'

Respondent 8 summarized:

> 'I think we're all in very different situations in terms of our PhD-candidate, so like respondent 6 and respondent 7 are connected to a project, whereas respondent 1 and I had these very open PhD-candidate positions where you could do anything, which was actually scary.' (Respondent 8, focus group A).

From the ongoing discussion, it followed that being alone in organizing transdisciplinary research does not only pose time-related challenges, but also challenges related to recruiting participants to the collaboration.

Challenge 2: Recruiting participants when you do not have previous successes to build on
Related to the role of process facilitator.

Most respondents agreed that 'real' transdisciplinary collaboration requires enough and the right participants. In interviews, respondents 3, 6 and 7 emphasized the importance of inviting a diversity of stakeholders to the collaboration.

However respondent 8 commented on the challenge involved in this inviting:

> 'One of the really basic challenges is just recruiting participants. (…) Because in my experience, if we're thinking about collaboration with people in the city government, for example, they get lots of master's students. If they're working on a hot topic, they get lots of people asking them [to contribute to their research].' (Respondent 8, focus group A).

This challenge did not seem to resonate much with the other participants during the focus group. From the interviews, I know that the other participants in the focus group indeed did not worry about this, because they were involved in bigger projects which involved past activities, they could build on to recruit participants. In the project of respondent 1, it was the societal actors who *asked for* collaborative meetings about the new carbon budgeting tool "2.0", because most of them already had good experience with the "1.0" version. Respondent 6 also expressed no worry during the interview for getting enough participants to the planned co-production workshops for Cityfreight in the summer, because the project has societal actors as core partners. Also respondent 7 had no worries about this, because succesfull previous editions of the Klimathon made that societal actors needed no more convincing to engage in the next Klimathon.

The fact that respondent 8 had struggled more with getting participants to collaborative meetings than the other respondents had effect on how they envisioned a successful co-production workshop.

Respondent 8 argued that:

> 'Some way to really recruit [societal actors] is to demonstrate that you will be able to provide an experience that's not only valuable for yourself, but also valuable for them.'
> (Respondent 8, focus group A).

Consequently, respondent 8 suggested that a PhD-candidate candidate could best start a co-production session 'showing that you have expertise and knowledge, and therefore [the societal actors] should trust you to lead them through whatever comes next', for example by presenting what insights you gained in scientific research. However, respondents 3 and 7 replied that it is important to do rather the opposite and establish at the start that the researchers do *not* have all the expertise, because one of the goals of transdisciplinary research is to have an equal playing field (more about that in the final challenge on mitigating power differences).

Possibly -but this is speculation on my part-, the fact that respondents 3 and 7's had to worry less about the time frame and recruiting participants, gave them more space to create an equal playing field than respondent 8 had. In any case, the context the PhD-candidate operates in seems to determine how much they are faced with challenges 2 and 3. For the PhD-candidate's that were part of a larger team focused on transdisicplinary research it was easier to fit transdisciplinary research into the 4-year timeframe (challenge 1). PhD-candidate's that could build on previous successes in transdisciplinary collaboration had to worry less about recruiting participants (challenge 2).

6.1.2 Managing expectations

Challenge 3: Different expectations of the co-creation
Related to the roles of knowledge broker and process facilitator.

Respondent 6 explained this challenge:

> 'My feeling from having talked to different people in the past is that maybe one of the most important things is to agree beforehand is what their expectation of us is.' (Respondent 6, focus group A).

Respondent 8 added:

> 'Are they expecting to be treated as experts? And you're just screening information of them? Or are they expecting to, you know, quote unquote, get something out of the workshop? And therefore, there's an expectation of, you know, the latest research or best practices.' (Respondent 8, focus group A)

Respondent 6 argued that even if participants to the collaboration ask researchers to answer their question with research insights, they would problematize doing as asked:

> 'It's not that we're going to give answers. We give our input based on our research, knowledge and experience. Because it's not like we have all the answers. And I think that's something that needs to be always established when you start.' (Respondent 6, focus group A).

In the interview, respondent 6 had explained the importance of 'deliberation', where societal actors discuss the ideas they have for sustainability solutions while the researcher acts rather as a process facilitator than being engaged in that deliberation. Also respondent 7 had argued in the interview for the importance of facilitating an equal discussion rather than giving answers.

I asked the respondents what they would do if the societal actors in a co-production meeting ask the researchers to just share their research insights, while the researchers rather want the societal actors to deliberate together. Respondent 8 replied to this:

> 'Sometimes collaborative exercises, like systems mapping or things like that, are a way to break through that challenge of people saying 'we want information'. Because you can use these exercises as a way of people helping to identify the information that they already have. And then, you know, not: what are the questions that they specifically have? But: what are the larger questions that emerge out of the discussion, more overarching?' (Respondent 8, focus group A).

Respondent 7 agreed:

> 'Yeah, I think that's a very good phrasing. People know more than they think they know. (Respondent 7, focus group A).

All respondents agreed that to deal with this challenge crucial to talk about mutual expectations before you start talking about the content.

6.1.3 Mitigating power differences

Challenge 4: Facilitating for an equal playing ground between stakeholders with power differences
Related to the role of process facilitator.

Respondents 6 and 7 brought up the importance of mitigating power difference several times during the workshop. Also respondent 3, who was not present at this focus group, had reflected elaborately on that during the interview.

> 'How are we going to do it in a way that's not challenging the power relationship within the whole workshop when the idea is that everyone has an equal part or equal level of discussion?' (Respondent 7, focus group A).

Respondent 7 further explained how this was dealt with in the Klimathons:

> 'We've had groups with one natural researcher, one social science researcher, one person from the municipality, one from the county and one from the state level. You have the most diversity possible in the group. So you come with your academic input, but at the same time, everybody come with theirs.' (Respondent 7, focus group A).

Respondent 8, who has been part of one of the Klimathons as a participant, added:

> 'I remember, there was somebody from a very large city, and then somebody from a really, really small town. And I think the person from the small town kind of struggled with their legitimacy because the person from the bigger town - discussing that topic was their full time job, whereas the person from the small town had seven different responsibilities and didn't have the same feeling of 'I'm an expert or a specialist in this topic'. I could see that that was a challenge for the facilitator to overcome.' (Respondent 8, focus group A).

Respondent 7, who has been facilitator in the Kimathons, commented in the interview that the process facilitation task was so intense, that there was no time to take notes and gather data on the collaboration process.

Respondent 3 (Cityfreight) was not present at the focus group. In the interview, they had said they imagined that explicitly encouraging silent or low-power actors to share their opinion might lead the respondent to come over as biased. Therefore, they suggested to ask a neutral external moderator to lead the meetings.

6.2 Students and course-coordinators of the CET-course *Sustainable innovation* about challenges related to their role in transdisciplinary collaboration

In focus group B, the course-coordinators of the CET-course *Sustainable innovation* identified challenges for the students. Next, they divided these challenges in three categories: challenges related to interaction with the case-owners, uncertainties about expectations, and challenges related to critically reframing the case-question.

6.2.1 Interaction with the case-owners

Challenge 1: Getting in contact with case owners
Related to the role of process facilitator and change agent.

Several student groups had trouble to get in contact with the case-owners. This challenge came to the forefront in the interviews with all three course-coordinators and in the focus group.

> 'Some case-owners were almost MIA*' (Respondent 2, interview).

* MIA means *missing in action*, a phrase used when a soldier cannot be contacted and is suspected to have been killed in action. The respondent used the term figuratively.

Respondents 2 and 6 suggested in the interviews that the case-owners had differing levels of motivation for the project. The course-coordinators noticed this when inviting the case-owners: some doubted longer than others before submitting a case. Respondent 2 commented in the interview that some case-owners came to the first meeting less prepared than others, and that this might have been prevented if the course-coordinators had met with the case-owners before the first meeting with students, instead of only exchanging emails. Respondent 5 commented the same during the focus group. Relatedly, the course-coordinators thought the less motivated case-owners might have different expectations with regards to the amount of interaction with the students. Respondent 5 added that the challenges around getting in contact can also by explained from the fact that some students might not have a clear idea of how interaction with (busy) societal actors works. This leads to the second challenge.

Challenge 2: How to interact with busy case owners
Related to the roles of process facilitator and change agent.

Respondent 5 explained:

> 'I don't think students are used to being in contact with [societal case-owners]. Because if you just send one email and then give up, then yeah... It's what you can expect in dialogue with actors outside of university.' (Respondent 5, focus group B).

This respondent had previous experience with such interaction themselves. Respondent 2 agreed that the fact that case-owners might not react after one email is inherently connected to collaborating with busy societal actors.

Challenge 3: Getting the full picture of the case and its context
Related to the roles of process facilitator and knowledge broker.

Respondent 2 brought up:

> 'I think some of the groups in this year had some problem getting the full picture that the case was in. So they didn't see how the case interacted with and affected other areas in society or in the organization. (…) This year, we had the case with the municipality, working with furniture - to recycle them. And it was just until a couple of weeks before the hand-in moment that the students understood that the municipality (…) already has some agreements with the university about furniture.' (respondent 2, focus group B).

In the interview, respondent 4 had mentioned that to develop an innovation that is useful to the case-owners, it is important that students contact the case-owners, for example to discuss the precise context of the case. This suggests that this challenge relates to challenges 1 and 2 about the interaction with the case owner.

6.2.2 Uncertainty about expectations

The students were uncertain about what was expected from them in the course. This is an uncertainty that could also have arisen in a course without transdisciplinary collaboration. We will

nevertheless discuss the uncertainties, as they were larger in this course than in a “normal” course, because in this course the student had to *balance* the expectations of course grading and of a case-owner.

Challenge 4: Balancing expectations from the case-assignment and from the course grading
Balance between the role of reflective scientist and more engaging roles like knowledge broker

Respondent 5 explained that the case poses the students two different tasks. They need to develop an innovation to get a (good) grade, but they also want to develop an innovation that is useful to the case-owners. And these two objectives are not necessarily in line with each other.

> ‘How do they balance that?’ (Respondent 5, focus group B).

Challenge 5: Understanding what to expect from the case-owners
Related to multiple roles

Challenge 4 made respondent 2 think of another challenge:

> ‘What do the case owners do with the solution? Are they supposed to implement the solution? Or is it just for the students to understand [how to apply design thinking]?’ (Respondent 2, focus group B).

Respondent 5 said later in the focus group:

> ‘Different team members have different expectations from the case owners. Because I think you saw that some of the groups organize meetings, and the other ones are like: what is happening?' (Respondent 5, focus group B).

6.2.3 Critically reframing the case-question

Challenge 6: Getting on the same page as the case-owners and agreeing on a problem definition
Related to the roles of Knowledge broker and change agent.

Respondent 2 said in the focus group:

> '[The case-owners] are so into this kind of area they work in, and the students are completely new to the case. So, then kind of getting on the same page to know exactly what the other one expects [is a challenge].' (Respondent 2, focus group B).

Respondent 5 added:

> 'To kind of agree on that problem definition of what the problem actually is.'
> (Respondent 5, focus group B)

Earlier, in the interview, respondent 2 had indicated that some case-owners had less structured presentations of their case than others. This meant that some groups received vague and large case-questions. Respondent 5 mentioned the same in the interview, and explained what challenge this poses to the students:

> '[SME Norway gave the students the following case -] How can we reduce the threshold for Small and Medium Sized Enterprises (SMEs) to become more sustainable? Like that's massive. You know, it's not very specific. So then, like, how do we narrow that down to a problem definition that's actually something that you can work with?' (Respondent 5, interview).

Respondent 4 saw a link between this challenge and the uncertainty among students whether they can do something slightly different that the case-question prescribes (challenge 4).

Challenge 7: Students are loyal to the question of the case owners
Related to the role of change agent.

The discussion about how 'flexible' students can deal with the case-question led respondent 5 to argue that many students were very loyal to the case-question of the case-owners:

> 'It seems like most of the students there were loyal to their case owners. They have only thought like: how can we innovate something for [the case-owners]? They've not really been thinking: how can this is something that we can create?' (Respondent 5, focus group B).

Judging from the interview with respondent 5, they see this a missed opportunity. They said in that interview that they thought a 'critical' attitude (for example by critically reframing the case-question) in combination with an 'approaching' attitude would lead to 'an open safe space to share struggles' where students and the case-owners could together shed light on problems and to try to find new solutions to them (see chapter 4 – students as change agents). Both respondents 4 and 5 emphasized in the interview that one of the learning goals of the course was to learn to re-frame the case question.

6.3 Answer sub-question 2

This chapter set out to answer sub-question 2: **Which challenges do CET-researchers face related to their roles in transdisciplinary collaboration?**

The challenges that PhD-candidates and students face in transdisciplinary collaboration are summarized in figure 6.1 below. The icons at the bottom of the post-its indicate to which of the five researcher-roles the challenge relates. Post-its without icons relate to all roles.

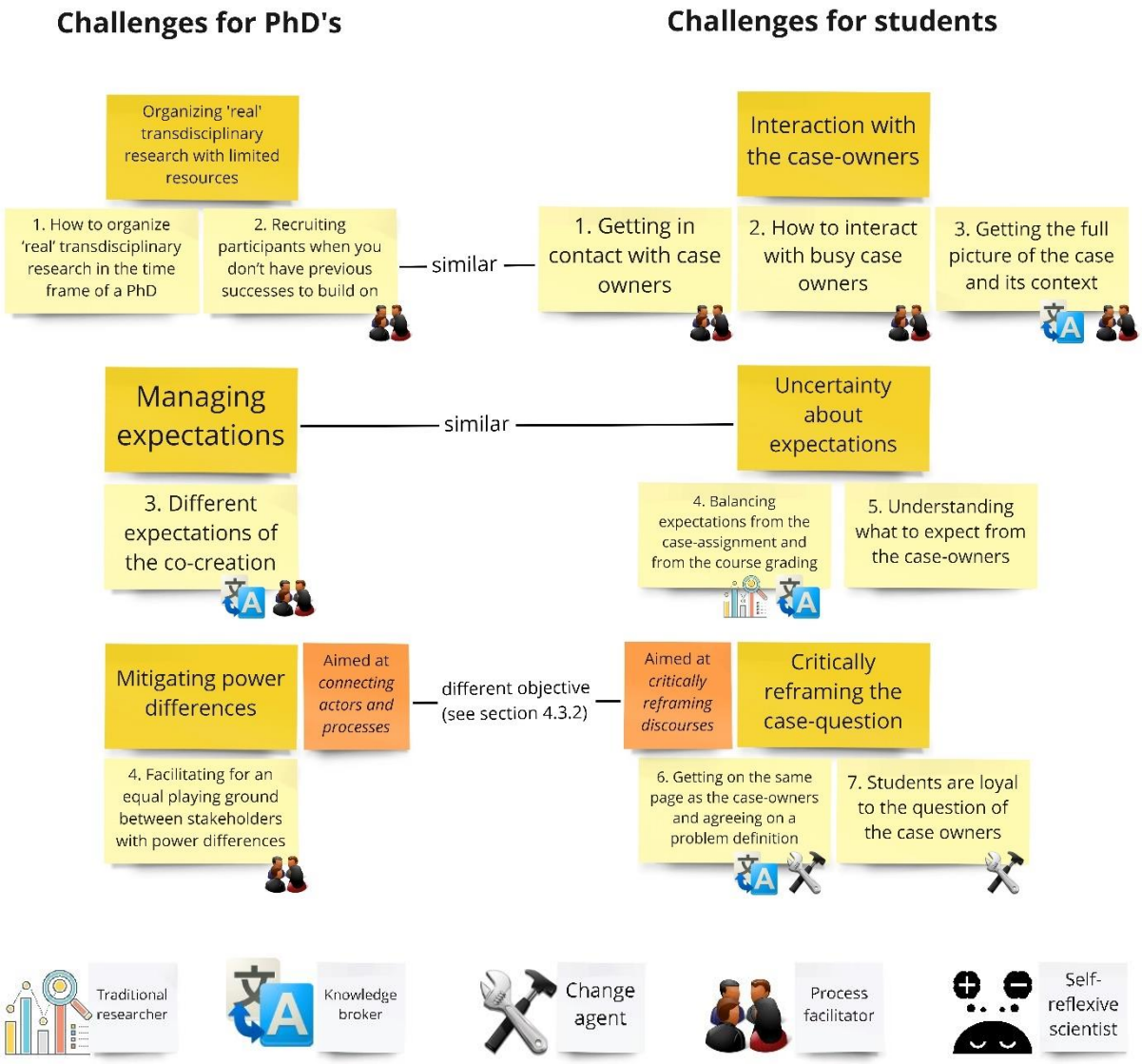


Figure 6.1. Challenges that PhD-candidates and students face in transdisciplinary collaboration.

6.4 Discussion sub-question 2

6.4.1 Comparing challenges of PhD-candidates and students

A secondary goal of this maser thesis is to generate insights about the case-context that can be directly useful to the researchers at CET. Therefore, it is interesting to shortly reflect on the similarities between the challenges of the students in the course *Sustainable innovation* and of the PhD-candidates, even though this master thesis does not do comparative research. The comparison is nevertheless useful, because if the course teaches the students to deal with challenges that PhD-candidates also face, this means that the course can prepare them for transdisciplinary PhD-research.

Both the students (challenge 1) and the PhD-candidates (challenge 2) face difficulties getting busy societal actors to join their collaboration. The results how this is easier if you build on an existing partnership or have a previous successful transdisciplinary project to build on. If not, you need persistence and good arguments to convince societal stakeholders to join – useful skills to start learning as a student. Moreover, students an PhD-candidates can be fishing in each other's water. Respondent 8 (a PhD-candidate) said that 'people in the city government, for example, they get lots of master's students. If they are working on a hot topic, they get lots of people asking them [to contribute to their research].' (Respondent 8, focus group A).

Both groups deal with diverging expectations. In the case of the PhD-candidates, the diverging expectations are present between (multiple) societal actors and the PhD-candidates themselves (challenge 3). Dealing with diverging expectations and explicating expectations at the start of collaboration is thus a crucial skill. The students engage with this skill as they are faced by uncertainty about what is expected from them. They struggle to balance the expectations between the teachers and course grading on the one hand and the societal case-owners on the other hand (challenge 4). Moreover, the students are uncertain about what to expect from the case-owners (challenge 5). Wehrmann & Van den Boogaard (2019) describe sources of uncertainty in a course that is similar to the course *Sustainable innovation* in the sense that it involves collaboration in 'living labs' (groups of students from multiple disciplinary backgrounds and external case-owners) and uses design methodologies. According to Wehrmann & Van den Boogaard (2019), uncertainty in such courses can be attributed to three sources:

1. Uncertainty attributed to the individual: feeling like not having the required knowledge, rules or skills for the problem at hand.
2. Uncertainty attributed to the social context: feeling like it is unclear how others understand the situation, what others expect from you or how to gain their trust.
3. Uncertainty attributed to the task in the design process: feeling like lacking understanding of the task or problem at hand, or a lack of understanding how to apply the tools provided in the course.

The uncertainty that the students in *Sustainable innovation* experienced around what was expected from them and what they can expect from the case owners can be described as a combination of *task-attributed uncertainty* and *social context-attributed uncertainty.*

6.4.2 Linking challenges to scientific literature

Another secondary goal of this master thesis is to contribute to theory building. Therefore, I will shortly discuss the results of sub-question 2 in the light of the scientific literature in the theoretical framework (section 2.2.3). The literature describes challenges related to *tensions between roles*, related to *knowledge-, change- and intermediating orientations* and related to *competing expectations.*

Tensions between roles

Challenge 4 of the PhD-candidates (Facilitating for an equal playing ground between stakeholders with power differences) relates to two of the tensions Bulten et al. (2021) identifies between the process facilitator and other roles. Firstly, researchers in the role *process facilitator* can use so much time on facilitation that they have not enough time to produce and document knowledge as a *reflective scientist*. This was also the case for respondents 1 and 7 (interviews). Secondly, maintaining your 'neutral' status as process facilitator can conflict with participating in the learning process as change agent. For this reason, the PhD-candidates debated in focus group A whether it was a good idea to be involved in the learning process (by sharing research finds, best practices etc.) or whether the researcher should rather stick to a neutral facilitation role.

Relatedly, according to McKee, Guimaraes & Pinto-Correia, (2015) and Hilger, Rose & Keil, (2021), researchers are not always the ones with the best organizational and facilitation skills. Huning, Räuchle & Fuchs (2021), suggest that an external facilitator can mitigate the challenges of the time-consuming facilitation, the desire for a 'neutral' facilitator and the lack of facilitation skills. Many PhD-candidates at CET have organizational and facilitation skills from previous work experience or activities during their earlier studies. Nevertheless, respondent 3 suggested involving an external facilitator so that the respondent could participate in the discussions themselves and avoid being seen a 'biased researchers' when trying to give low-power actors a stage.

Finally, Bulten et al. (2021) show that some process facilitation activities are hard to 'justify' at the home institute, because they are not part of traditional scientific tasks. This was rather the opposite at CET, where all the interviewed researchers (about half of the researchers at the center) and the center director see value in facilitating transdisciplinary exchange.

Challenges related to knowledge-, change- and intermediating orientations

Challenge 1 of the PhD-candidates (doubting whether it is possible at all to do 'real' transdisciplinary research in the course on one PhD, relates to the fact that properly intermediating between research and society and trying to achieve change are inherently time-consuming processes (Vinke-deKruif et al., 2022).

In chapter 4, we discussed that most PhD-candidates stayed away from openly critical behavior or advocating certain best practice. Even when societal actors asked the PhD-candidates to share best practices, they would rather stick to neutral facilitation tasks because they did not want to lose their 'neutral' status. Relatedly, Vinke-deKruif et al. (2022) argue that change-oriented researchers, like the change agent and the process facilitator, can be faced by societal actors questioning their credibility when they implicitly promote a specific solution.

Vinke-deKruif et al. (2022) further emphasize that all roles can be faced with knowledge integration challenges and should therefore reflect on how their knowledge is received by societal actors. The

students and PhD-candidates at CET did not have many reflections on this topic and did not mention knowledge integration as a challenge. Related to knowledge integration, however, some students had trouble understanding the case-context of their societal case-owner.

Competing expectations

The uncertainties of students with regards to what is expected from them have already been discussed in the light of design-education in the previous section (5.4.1). Here, we will further discuss the competing expectations reported by the PhD-candidates (challenge 3). In the theoretical framework, I discussed three categories of competing expectations.

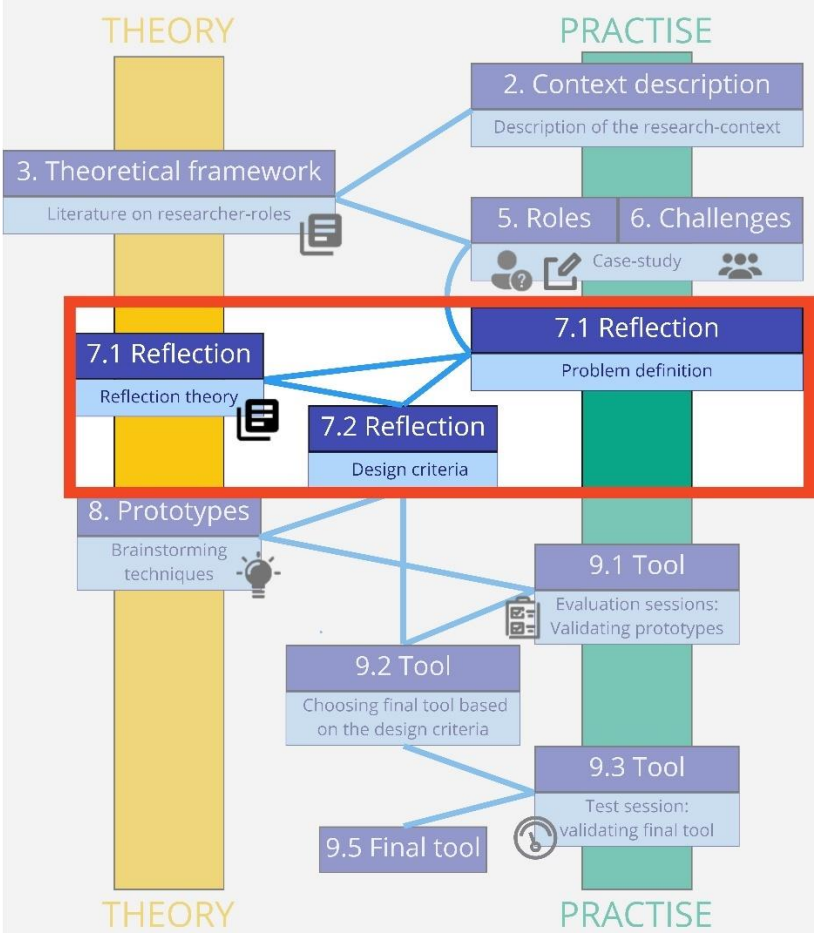
The first category is *quick fixes versus learning processes*: societal actors expect numbers, and directly implementable quick fixes, while researchers want to facilitate a learning process to come to answers together and have a more critical view on the matter at hand (Haarstad et al., 2018; Bulten et al., 2021). This mismatch was clearly present in the CET-context. There was some disagreement between the PhD-candidates with regards to how to deal with the mismatch. Some advocated giving quick fixes if asked to, others would refrain from that even if asked, to safeguard the learning process (as discussed above).

The second category, *objectivity versus applicability*, was not discussed explicitly in any interview of focus group. The third category, *facilitator versus participant*, has already been discussed under *tensions between roles* above, second paragraph, in relation to involving an external facilitator.

7. Reflection in the context of CET

***Sub-question 3**: How can reflection be conceptualized in the problem-context?*

***Builds on**: Theoretical framework (chapter 3), sub-questions 1 & 2 (chapters 5 & 6)*



This chapter discusses what reflection looks like in the CET-context.

- First, section 7.1 converges the findings from the previous two chapters to a **problem** summary, from which I distill an **essence** (which problem should the reflection tool focus on?).
- Next, section 7.2 reviews **scientific theory on reflection**.
- Finally, in section 7.3, the problem definition and the theory on reflection are combined to conceptualize reflection in the problem context. This leads to **design principles** for a reflection tool. In other words: what requirements should a reflection tool meet to help CET-researchers reflect on the challenges they face in transdisciplinary collaboration?

For more information about what a problem definition, an essence and design principles are, see section 4.4.5 in the methodology.

7.1 Problem summary & essence

We have identified how CET-researchers conceive their roles in transdisciplinary collaboration (chapter 5) and which challenges they face relates to these roles (chapter 6). This means we can now determine that the reflection tool should focus on. I first give a summary of the problems identified in chapter 5 and 6 (there is some repetition here with what you have already read) and next I distill an *essence* from that summary.

7.1.1 Problem summary

The students and PhD-candidates at CET engage in transdisicplinary collaborations. In these collaborations, they assume different roles, like the role of *reflective scientist, knowledge broker, process facilitator, change agent* and *self-reflexive scientist.* Section 5.3 summarizes which roles the student course-coordinators and the PhD-candidates find most important and why. Section 6.3 summarizes which challenges they face related to these roles.

Several of the challenges are related to the students' and PhD/candidates' preference for critically reframing discourses and connecting actors and processes, respectively. On the one hand, students have trouble critically reframing the case-question they receive from their societal case-owner and run into the problem that this critical engagement requires intensive interaction with the societal case-owners, for which these case-owners do not always have time. The students are uncertain about how far they can go in their critical attitude and about whether their contribution will be useful to the societal case-owner. PhD-candidates, on the other hand, are focused on different challenges like mitigating power differences between societal actors and creating lasting partnerships in the short timespan of a PhD. They face a complex dynamic social landscape with intricate power relations that are hard to navigate during collaboration. Moreover, they are uncertain how to balance their image as neutral and objective knowledge providers with their wish to take a leading role in breaking power relations and creating lasting partnerships. Some challenges occur whatever role is assumed, such as managing conflicting expectations between researchers / course-coordinators and societal actors.

Finally, it must be noted that the students refresh every year and PhD-candidates at CET refresh every 3-5 years. Although the secretariat at CET and the professor carry form a stabel factor factor at the center, a part of the tacit knowledge about transdisicplinary collaboration disappears from CET with the disappearing students and PhD-candidates. To some degree, the new students and PhD-candidates thus must 're-invent' the wheel on their own. This makes it harder to deal with the complexities and uncertainties described above.

7.1.2 The *essence*

Can we boil down all the challenges described above to one essence that is simple, yet still holds all the complexity?

Let us start with two observations. Firstly, the problem summary shows that the roles the students and PhD-candidates engage in, and the resulting challenge they face, are to a large degree determined by *why* they engage with societal actors (e.g. to critically reframing discourses or to connect actors and processes). Moreover, this is an important topic to learn to reflect on, according to Bulten et al (2021), who refer to Hilger et al. (2018), by stating: "Education can stimulate students to be reflective about their intentions as researchers. After all, it depends on these intentions which roles they should adopt."

Secondly, the students and PhD-candidates at CET operate in a complex and uncertain landscape. Moreover, they have a rather unique and demanding position in this complex landscape, as they take ownership of a case-project (students) or take the lead in facilitating collaboration (PhD-candidates). This landscape might be described as the 'complex' domain in the Cynevin model, where the relationship between cause and effect is clouded (Kurtz & Snowden, 2003). In this domain, you cannot build on good practice, but must develop your own 'emergent practice' by trying things out ('probing'). Probing in this concept requires a sense of purpose to your action, to not lose the courage and self-confidence to act in the muddied waters. This is another reason it is crucial that the students and PhD-candidates reflect on *why* they engage with societal actors.

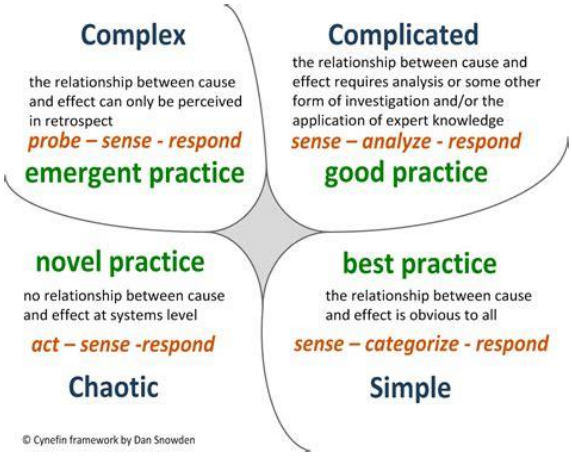


Figure 7.1. The Cynevin framework. Figure copied from Ding (2018), based on the Cynevin framework of Kurtz & Snowden (2003).

Boiling down the challenges to one underlying theme thus leads to the question: *why do researchers at CET engage with society?*

I decided to make the phrasing of this question a little spicier. For this phrasing I was inspired by the fact that the respondents all ascribed themselves some form of a "unique contribution", that was thus far missing in the field (e.g. reframing case questions, which normal consultants or NGO's do not do or connecting actors that normally do not meet)

Therefore, I rephrased the question as: *What is a CET-researcher's unique contribution to society?*

The director of CET gave me the advice to use the word 'CET' in the essence, because this formulation could create the association with a branding exercise for CET, which the reflection tool is not about.

This I changed it to: **Your unique contribution to society**

When a team of researchers reflects together, it might be reframed to a more generalized statement about academics: **The unique contribution of the academic changemaker to society**

Reflecting on this unique contribution can form a sense of purpose that gives direction to dealing with the challenges identified in chapter 5. Additionally, reflecting on what you want to achieve, makes it easier to reflect on what skills and resources you need for that and how you can consequently best divide roles in the team. This arms teams better for dealing with the challenges from chapter 5. Finally, reflecting on this together can form an inspiring focal point that brings the people at CET together by increasing enthusiasm, collaboration and knowledge sharing around transdisciplinary collaboration.

7.2 Theory on reflection

The problem definition tells us *what* a reflection tool for CET-researchers should focus on. Now let us look at the *how*: how can people reflect?

This section gives an overview of literature on reflection, which I learned about in my master CDI. We will first look at how reflection is conceptualized in academic literature. After that, we will look at two reflection models and their relation to double-loop learning and system-1 vs system-2 thinking.

7.2.1 Conceptualizing reflection

It is important to conceptualize reflection before designing a reflection tool. Reflection-scholar Korthagen (2001) explains: '*Often it seems that the term reflection is used without careful conceptualization, in a loose way, which makes it almost synonymous to "thinking".*'

Trying to facilitate reflection without having a clear idea of what reflection is can lead to facilitating shallower types of "thinking" or "evaluating", without achieving the potential of true reflection. Moreover, the ones who are to engage in reflection might not know what precisely is expected of them, creating confusing and decreasing their motivation to reflect (Kinkhorst, 2010).

So, what is reflection? The early scholars in the field of reflection often focused on reflection on actions and experiences. In other words, if a person performed an action, they might reflect on that action. Or if a person experienced a certain event, they might reflect on that event.

As early as 1984, Schon made a distinction between *knowledge-in-action, reflection-in-action* and *reflection-on-action.* Knowledge-in-action is the use of tacit knowledge. You act, whithout having to think about it, because you just *know* what to do. Reflection-in-action is closely related to *experimentation* and involves consciously assessing a situation as you are engaged in it, immediately implementing the result of your assessment in your next actions. Reflection-on-action, on the other hand, happens after you have been engaged in an activity and is oriented towards the next time that such a situation might arise. People often reflect-on-action if they were confronted with an unexpected result.

The distinction between knowledge-in-action on the one hand and reflection-in-action and reflection-on-action on the other hand has some conceptual resemblances with the distinction between system-1 and system-2 thinking, as described by Kahneman (2003) (see figure7.2). Like knowledge-in-action happens on the fly and is a fast, nearly automatic process; system-1 thinking / intuition is the fast, automatic and associative cognitive process that determines our split-second reflections and decisions. Like reflection-in-action and reflection-on-action involve conscious thinking and takes more time; system-2 thinking / reasoning is a slow, controlled and rule-based cognitive process that determines how we consciously assess a situation and determine our actions.

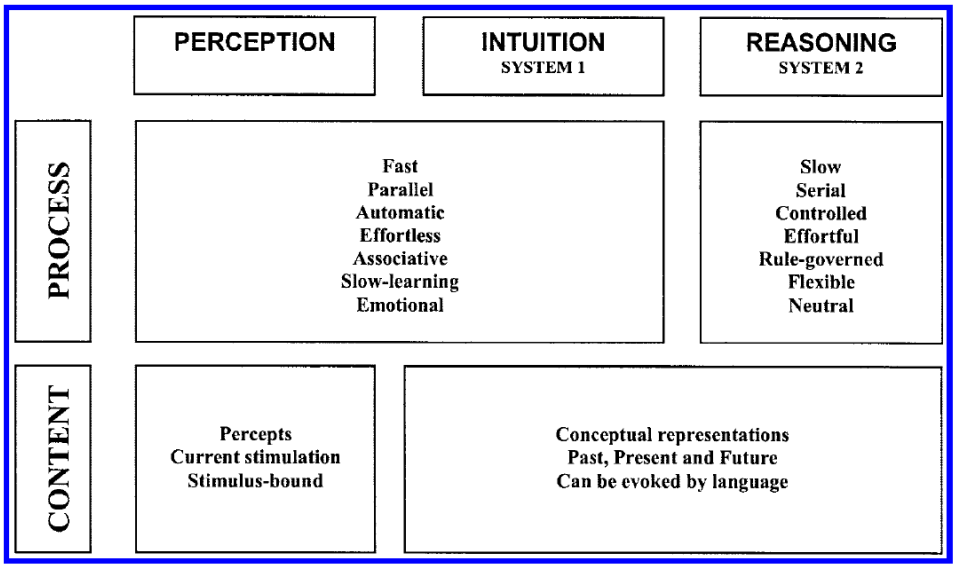
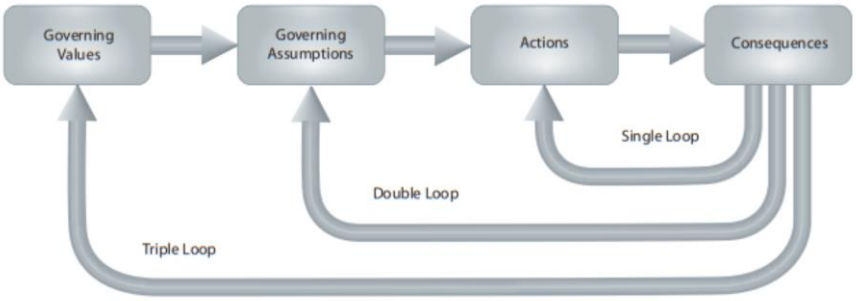


FIGURE 1. THREE COGNITIVE SYSTEMS

Figuur 7.2. System 1 and system 2 thinking (Kahneman, 2003).

In this master thesis, the conscious elements of system-2 thinking / reasoning are more relevant than system-1 thinking / intuition. This is because I want to develop a reflection tool that helps CET-researchers to become consciously aware of the challenges they are facing and to widen the scope of actions they consider addressing them. The reflection could both use reflection-in-action (then it would be used *while* engaging in transdisciplinary collaboration) or reflection-on-action (then it would be used outside of the collaborative setting).

Hatton & Smith (1995) argue that reflection on an action or event involves delving into the reasons or justification of that action / event, instead of just describing the action / event. Thus, reflection goes deeper than just 'evaluating' an action or event. Similarly, Kinkhorst (2010) suggests distinguishing between 'evaluation' and 'reflection'. He hypothesized about reflection in educational context based on his experience with Dutch education. Reflection in an education context is relevant for this master thesis, since the students and starting PhD-candidates at CET are educated to be researchers. Kinkhorst (2010) links evaluating versus reflecting to the concepts of single- and double loop learning as described by Argyris & Schon (1974). He suggests that 'evaluating' is a form of single-loop learning: you evaluate the results of your actions. And change your actions based on your evaluation. However, 'reflection', Kinkhorst (2010) argues, constitutes double-loop learning: you do not just think about the results of your actions, but you also assess the assumptions that were underlying your actions. By reflecting on these assumptions, you can control the assumptions. This is a way to not just change a single instance of behavior, but alter the underlying reasoning of your behavior, thus opening up the scope of possible actions and leading to a sustainable behavior change. Another level deeper would be reflection on the values that underly your assumptions, constituting triple/loop learning (Argyris & Schön, 1974).



Source: Modified from Argyris (1999)

Figure 1.5 *Multiple-loop learning*

Figure 7.3. Multi-loop learning. Modified from Argyris (1990).

Hatton & Smith (1995) and Kinkhorst (2010) emphasize the importance of *dialogue* for reflection. Since reflection in their view is aimed at generating alternatives for action, it is useful to gather multiple perspectives on the experience or action on which you are reflecting. These multiple perspectives can be called upon in an internal dialogue or a dialogue between multiple people.

Like Kinkhorst (2010), Korthagen (2001) conceptualizes reflection for an educational context. However, Korthagen builds on an extensive reading of scientific literature on reflection (also in other contexts). Korthagen (2001) defines reflection as '*the mental process of trying to structure an experience, a problem or existing knowledge or insights*.' I would argue that this conscious and structured mental process requires system-2 thinking / reasoning (Kahneman, 2003). Korthagens definition seems less goal-oriented than the reflection-on-action and the double and triple loop learning discussed above. Nevertheless, Korthagens reflection model (which we will discuss later) is goal oriented: aimed at the creation of alternatives for action.

The discussion of Schon (1984), Hatton & Smith (1995) and Korthagen (2001) gives a vague idea of what makes reflection different from 'thinking' and 'evaluating':

- Reflection is *situational*: we often reflect on a specific situation where we were confronted with unexpected or unwanted results.
- Reflection is *goal-oriented*: aimed at improving the (unexpected) results, often by changing your own behavior.
- Reflection is *conscious & structured*: it involves conscious mental processes (system-2 thinking) to structure knowledge or insights (about) experiences and actions.
- Reflection involves assessing *assumptions or values*: assessing the assumptions (double-loop learning) or values (triple-loop learning) that underly your behavior helps widen the scope of future action and helps constitute a sustainable behavior change.
- Reflection requires *dialogue*: a dialogue between multiple perspectives on the experience or action. This could be an internal dialogue or a dialogue between multiple people.

This conceptualization gives an idea of what reflection is. But it is not concrete enough for the design of a reflection tool. Therefore, we will look at two reflection models.

7.2.2 Reflection models

We discuss two models: the experiential learning style of Kolb and the ALACT reflection model of Korthagen. The experiential learning cycle is not actually a reflection model, but a leaning model, in which reflection is an important stage of the learning. Nevertheless, the experiential learning model and the ALACT reflection model show interesting similarities that shed light on how a person can reflect. I chose to discuss these models, because they are both widely cited in the literature, they both fit my conceptualization of reflection and they are both focused on reflection on 'action' (Korthagen) / action in the form of 'active experimentation' (Kolb). *Action* is a relevant focus, because I have operationalized 'roles of researchers' as a set of actions. So, to reflect on their roles, the CET-researchers need a reflection tool that helps them reflect on actions.

Experiential learning cycle of Kolb

The experiential learning cycle has been the most influential learning model in the development on scientific literature on learning (Kayes, 2005). The experiential learning cycle of Kolb describes a learning process. One stage in the cycle is an explicit reflection-stage. Kolb (1976) writes: 'The core of the model is a simple description of the learning cycle – how experience is translated into concepts, which in turn are used a guidelines in the choice of new experiences.'

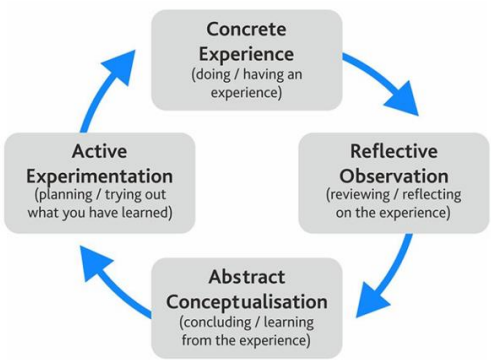


Figure 7.4. Experiential learning cycle (Kolb, 1976).

Learning according to Kolb starts with a *concrete* experience (the top of the cycle), generalizes this experience to *abstract* concepts (the bottom of the cycle) and next applies the abstract knowledge in new *concrete* situations (back at the top). In other words, learning is an interplay between concrete and abstract. Reflection (the right side of the cycle) is a means to move from concrete experience to abstract conceptualization. As an example, a person who has had an experience might talk about that experience with someone else and find out that there is a different way of looking at what happened. The next step is that that person generalizes the gained insight into an abstract concept that they can be applied in other contexts too. Thus, the reflection entails looking back at the concrete experience from multiple perspectives, comparing these perspectives with you own, and abstracting generalized lessons from that comparison. Moving back from abstract to concrete implementation requires experimentation (the left side of the cycle).

The difficulty in applying this cycle is that you must alternate between involvement (at the top) and analytical detachment (at the bottom); and between observing (at the right) and acting (at the left).

The ALACT reflection model of Korthagen

The ALACT reflection model of Korthagen (2001) prescribes a cycle of reflection on action, which shows some resemblances with the experiential learning cycle of Kolb. The model was developed for the context of teacher-education. It is nevertheless relevant to this master thesis, since the students and teachers at CET are being educated to be researchers. Moreover, typical for the contest of a teacher-in-training is their interpersonal interaction with pupils. Similarly, typical of the context of starting CET-researchers in transdisciplinary collaboration is their interpersonal interaction with societal actors.

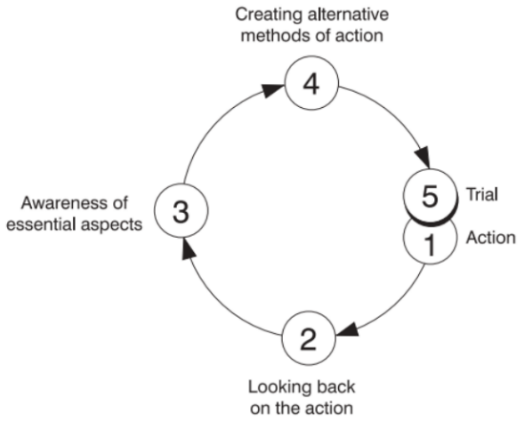


Figure 7.5. The ALACT reflection model (Korthagen (2001).

Like the experiential learning cycle, the ALACT models starts *concrete* (1)*, abstracts* generalized knowledge (2-3) and implements these insights in *concrete* plans for action in new situations (4-5). You might day the ALACT model is 90 degrees turned over compared to the experiential learning cycle:

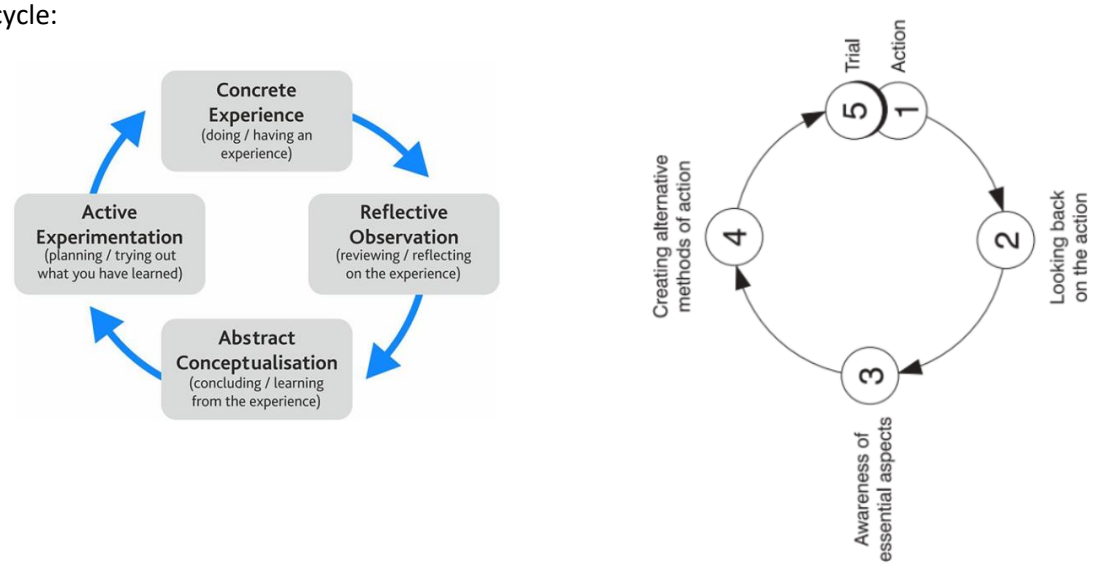


Figure 7.6. The experiential learning cycle compared to the ALACT reflection model

Korthagen & Vasalos (2005) extended the ALACT model with deeper levels of reflection. They contend that people who reflect often do so too shallow, focusing only on finding quick behavioral fixes to problems, instead of reflecting on the underlying issues. One might argue that a focus on behavioral quick fixes is a form of single-loop learning, while proper reflection would involve double-loop learning by looking at the underlying assumptions and feelings that drive of behavior. To ensure a focus on the underlying issues, Korthagen & Vasalos (2005) argue two things are important in step

2. Firstly, they say: 'Important in this approach to reflection is the balanced focus on thinking, feeling, wanting and acting, whereas in many other views on reflection there is a strong focus on rational analysis.' For instance, the experiential learning model of Kolb 'stresses conceptualization much more than the development of an awareness of less rational sources of teacher behaviour', according to Vasalos & Korthagen (2005). Secondly, the reflecting person should engage in a dialogue to get an awareness of multiple perspectives on the action, and that the reflecting person makes these perspectives concrete. Korthagen developed guiding questions for teachers-in-training to achieve a balanced and multi-perspective outlook on the action, see figure 7.7

0. What was the context?	
1. What did you want?	5. What did the pupils want?
2. What did you do?	6. What did the pupils do?
3. What were you thinking?	7. What were the pupils thinking?
4. How did you feel?	8. How did the pupils feel?

Figure 3. Nine areas relevant when concretizing in Phase 2

Figure 7.7. Guiding questions for teachers-in-training to achieve a balanced and multi-perspective outlook on the action (Vasalos & Korthagen, 2005).

These guiding questions open up the reflection processes of the teacher-in-training. However, they focus only on the interaction processes going on between teacher and pupil (in this master thesis that could be: between CET-researcher and societal actor). Often, however, even deeper lying factors such as one's idea of their professional identity and their mission determine hoe a teacher answers to the questions in figure 7.7 above. Therefore, Korthagen & Vasalos (2005) suggest the use of the onion model as a guiding tool to distinguish between different 'levels of reflection'.

The inner levels influence how the outer levels play out, although there can also be a reverse effect. Looking for quick fixes in behavior is reflection at the behavior-level. I would argue this can be equated with single-loop learning. Reflection at the level of competencies and beliefs equates, I argue, to double-loop learning, as this means you consider how you approach problems and which assumptions you have about the situation. Reflection at the level of (professional) identity and mission, however, goes even deeper and has the potential to generate, I argue, triple-loop learning, by addressing the underlying values that shape your beliefs. Korthagen & Vasalos (2005) refer to this latter level of reflection as 'core reflection': 'In essence, this level is concerned with what inspires us, and what gives meaning and significance to our work or our lives.' Questions at this level deal with why someone became a teacher (in the context of teacher-education) or why someone engages in transdisciplinary collaboration (in the context of this master thesis).

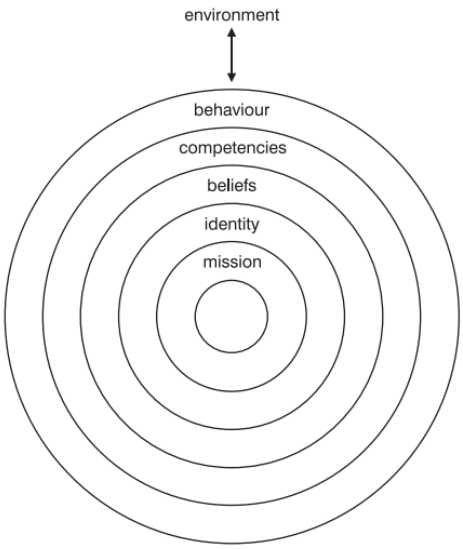


Figure 7.8. The onion model: a guiding tool to distinguish between different 'levels of reflection' (Vasalos & Korthagen, 2005).

Whereas reflection on the shallower levels focuses on the problematic aspects of a situation, core reflection focuses on the ideal outcome a person would want to achieve (in line with their mission and identity) and the situational aspects that prevent that from happening. Separating this ideal outcome from the situational limitations prevents teachers, according to Korthagen & Vasalos (2005), from getting stuck in the problematic situation and seeing no ways out. It allows core reflection to look at the core qualities that a person has, following from their mission and identity, and how they can use these core qualities to overcome limiting situational factors. The ALACT cycle of core reflection, consequently, has different guiding questions:

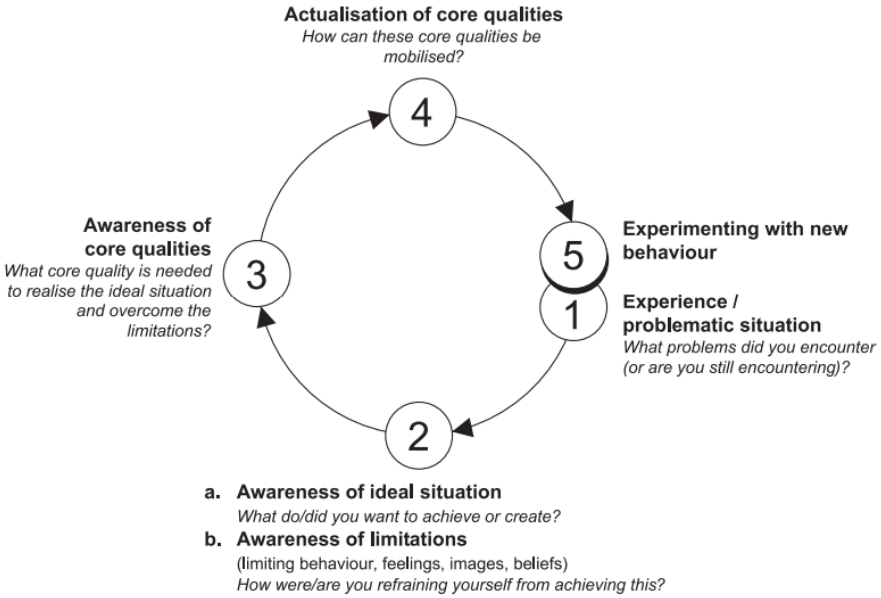


Figure 7.9. The ALACT cycle of core reflection (Vasalos & Korthagen, 2005).

Vasalos & Korthagen (2005) describe several concrete examples from teachers-in-training to show how this model is used in practice.

7.2.3 Summary of the literature on reflection

I have conceptualized reflection as *situational*, *goal-oriented* (often aimed at changing behavior), *conscious & structured* (system-2 thinking), involving assessing the *assumptions* or *values* that underly your behavior (double-, or triple-loop learning) and involving *dialogue* between multiple perspectives.

The experiential learning cycle of Kolb and the ALACT reflection model of Korthagen fit in this conceptualization. Especially the core reflection on identity and mission in the ALACT model led to deeper levels of learning (arguable triple-loop learning).

7.3 Answer sub-question 3: Conceptualizing reflection in the problem-context

We now know theoretically what reflection is. Let us make concrete what this means in the context of CET, to answer sub-question 3: *How can reflection be conceptualized in the problem-context?*

With the help of the problem definition (section 6.5), we can translate the conceptualization of reflection (section 7.1.1) to the problem-context of CET. This gives us a set of design principles for the reflection tool. See table 7.1 below.

Table 7.1. Conceptualization of reflection in the problem-context. Based on section 7.1.1 (conceptualization of reflection) and section 6.5 (problem definition).

Concept	**Explanation of concept**	**Indicators in the problem-context of CET = Design principles for a reflection tool**
Reflection is …		
… situational	We often reflect on an action or experience in a specific situation where we were confronted with unexpected or unwanted results.	CET-researcher takes time to look back at: - a specific action related to their role in the collaboration - or an experience during the collaboration where they faced one of the challenges in figure X.
… goal-oriented	Reflection is aimed at improving the (unexpected) results, often by changing your own behavior.	CET-researcher aims to improve the outcome by generating new alternatives for action in a future situation related to the transdisicplinary collaboration.
… conscious & structured	Reflection involves conscious mental processes (type-2 thinking) to structure knowledge or insights (about) experiences and actions.	CET-researcher reflects consciously and explicitly. The CET-researcher could use rational and/or intuitive tools to structure experiences and actions.
… assessing assumptions and/or values	Reflection involves assessing the assumptions (double-loop learning) and/or values (triple-loop learning) that underly your behavior. This helps to widen the scope of future action and helps to constitute a sustainable behavior change.	CET-researcher does not merely seek quick behavioral fixes but assesses how assumptions in their own thinking and/or their personal values affect their actions. Particularly assumptions and values related to the *essence* are relevant (which unique role do they seek as academic researcher in society?)
… dialogue	Reflection is a dialogue between multiple perspectives on the experience or action. This could be an internal dialogue or a dialogue between multiple people.	CET-researcher considers multiple perspectives on the matter. For instance multiple frameworks of researcher roles or modes of engagement, or by engaging in conversation with other (CET) researchers.

The rows in table 7.1 describe different elements that together make up reflection. The final column shows what each element could look like in the CET context ("indicators in the problem-context"). In other words: to be "real" reflection at CET, the reflection tool must engage with all indicators.

The indicators can thus function as design principles for the reflection tool. Using these indicators as design principles ensures that the tool is both grounded in theory (as the indicators are based on a conceptualization of reflection from scientific theory) and embedded in the context at CET (as the indicators build in the problem definition).

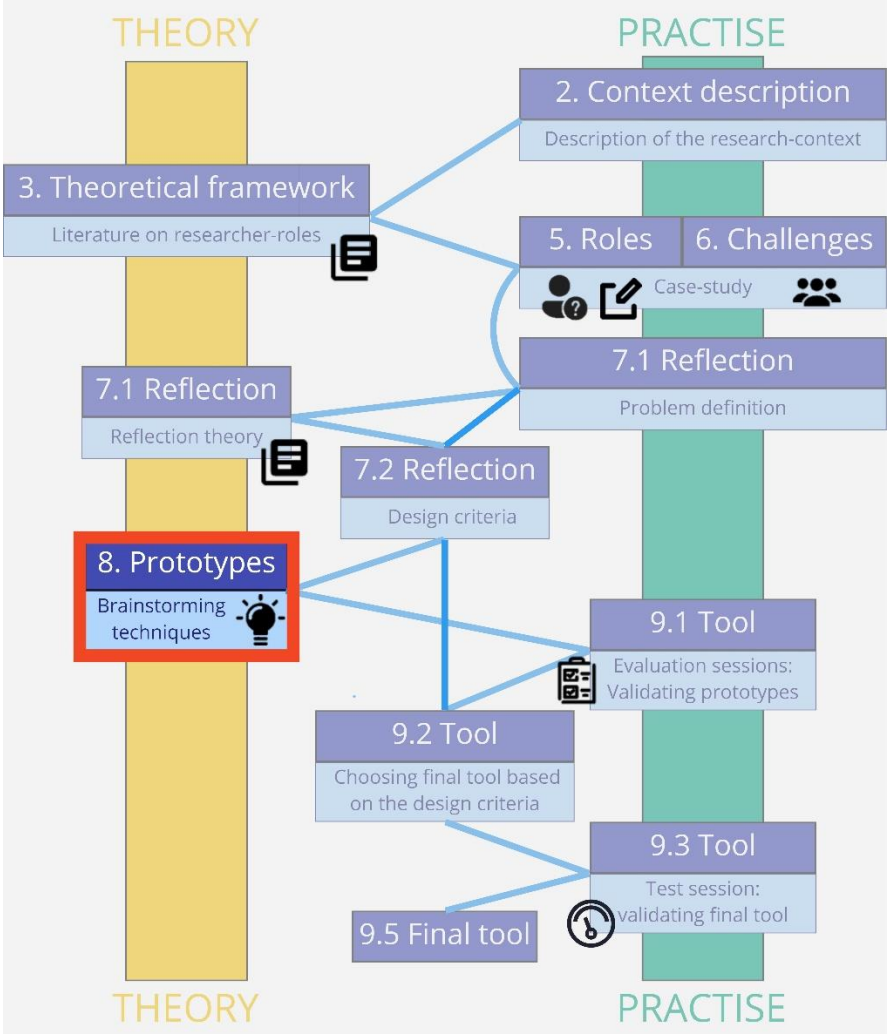
With these design principles, the reflection tool becomes specific for the CET-context. This means that it might not be applicable in other contexts. I have chosen for this, because my data gathering was limited to the CET-context. Moreover, I find it most interesting to develop somethings that works well for CET, rather than developing something general at the cost of implementability at CET.

We have now conceptualized what reflection looks like in the problem-context of CET. Let us put this in practice and start designing a reflection tool in the next chapter.

8. Prototypes for reflection tools

***Sub-question 4**: Which reflection tool prototypes could help the researchers to reflect on their role?*

***Design-methods**: Decision narrative, Analogy, Experience, Prototype evaluation-sessions*



This chapter describes how I brainstormed about reflection approaches to address the problem definition. I used several sourses of inspiration. Section 8.1 describes how I used a decision narrative. Section 8.2 shows analogies. Section 8.3 outlines my previous experience with reflection methods. Section 8.4 looks back at reflection models in the literature. Finally, in section 8.5 I explain how I used all this inspiration to propose two prototypes for reflection tools.

For an explanation of the design-methods used, see section 4.5.

8.1 Decision narrative

To brainstorm about reflection tools, I took the essence as a starting point:
Your unique contribution to society.

With this essence in mind, I wrote a fictional story describing the ideal situation *after* using the yet to be designed reflection tool (such a story is called a 'decision narrative'). This story is a just an aiding tool and not a goal in itself: by describing the ideal situation it becomes easier to brainstorm about reflection tools that might achieve that ideal situation.

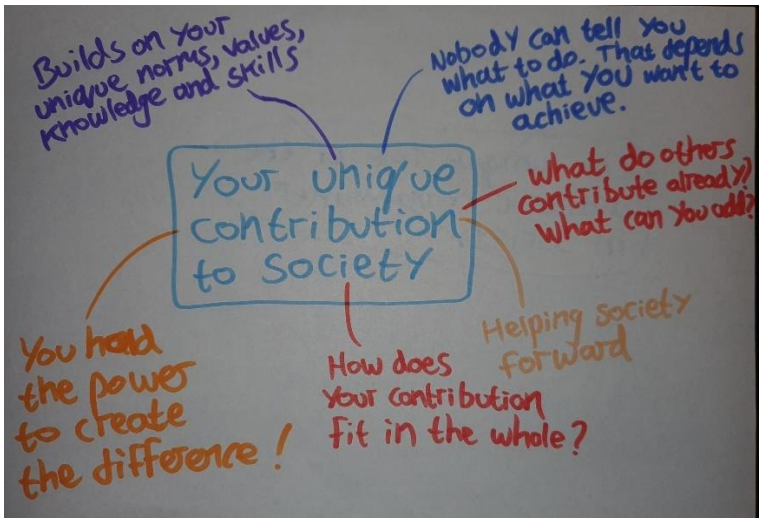
I wrote one story from the perspective of a student in the course *Sustainable innovation* and a different story from the perspective of a starting PhD-candidate at CET, because their context is slightly different. Both stories are written as a diary. They both focus on the first few weeks the student / PhD-candidate is involved in the course / PhD-project, because this is the phase where it is crucial to reflect on *why* you want to engage in transdisciplinary collaboration and what you correspondingly think is your unique contribution could be.

You can read the decision narratives in appendix 7.

8.2 Analogies

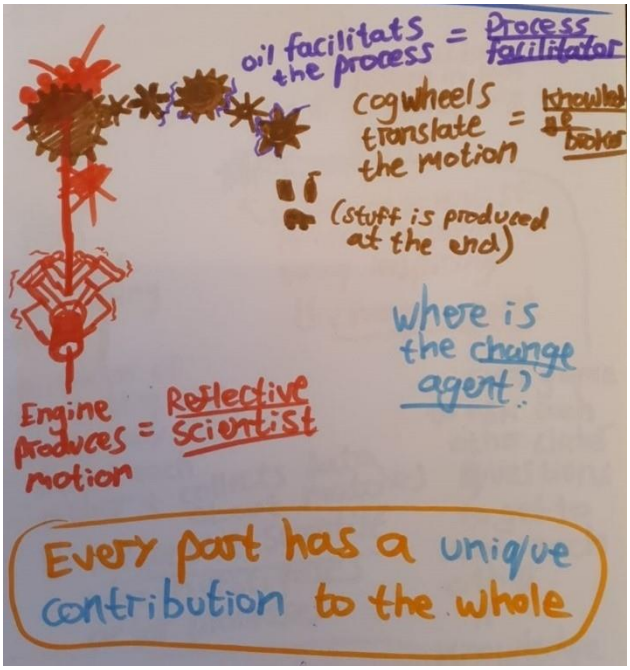
With the essence in mind, I thought about analogies in different contexts. I first expanded on the essence, and then brainstormed about four analogies based on that.

Expansion on the essence



8.2.1 Analogy 1: Machines in a factory

All components complement each other

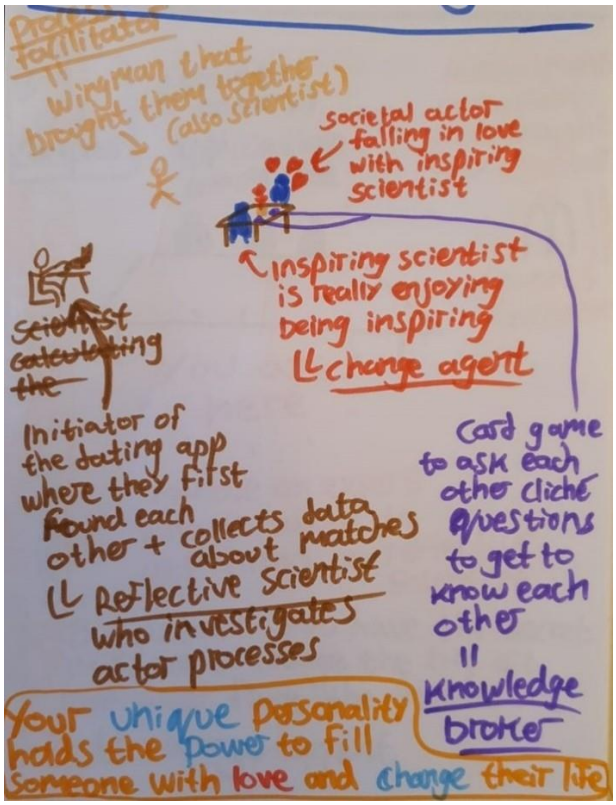


The engine produces motion (reflective scientist who produces scientific knowledge). The cogwheels translate the motion (knowledge broker who translates knowledge). Oil is applied to the cogwheels to facilitate the process (process facilitator). In this analogy, I did not find a place for the change agent or the self-reflexive scientist.

The analogy does not hold as much complexity as the problem context of this master thesis. It made me think, however, about that you cannot contribute properly to society on your own. You need a collaboration between multiple researcher-roles to have a proper contribution to society. So it is important that the reflection tool helps students and starting PhD-candidates at CET reflect on how they can **complement** the activities and skills of their colleagues.

8.2.2 Analogy 2: dating

Dare to dream!

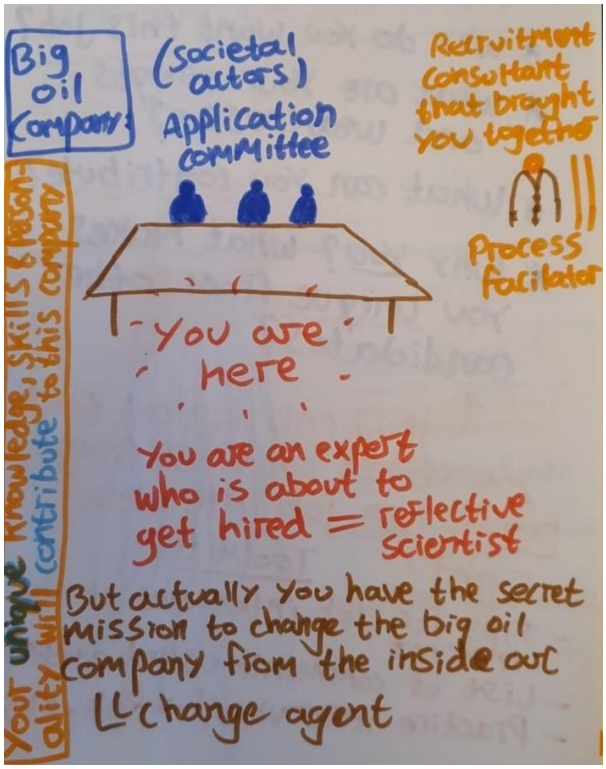


A scientist and a societal actor are romantically dating. The scientist is anxiously analyzing everything she said – wondering if she is making the right impression (self-reflexive scientist). But as the date moves along the societal actors seems to be falling heads over heels in love with the inspiring scientist. The scientist is really enjoying being inspiring and having this effect on a real person (change agent). They found each other on a dating app (the person who own the dating app is analyzing data about matches between scientists and societal actors – reflective scientist). The scientist and her lover are playing a card game with cliché questions you can ask each other to get to know each other and find common interests (the card game acts as knowledge broker).

This analogy suggests that the reflection tool should make you feel **confident** and **dare to dream**: you can make societal actors fall in love with you and change their life forever!

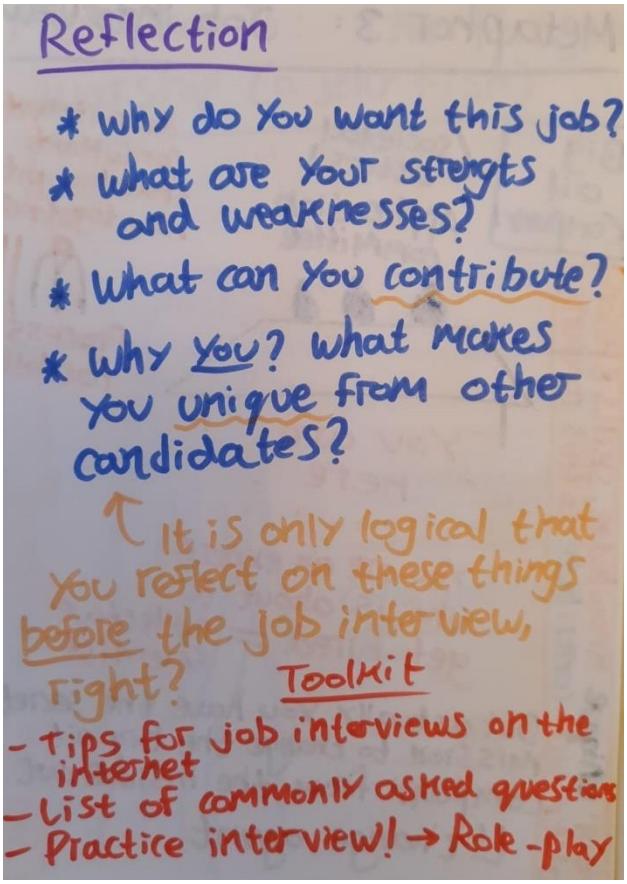
8.2.3 Analogy 3: Job interview

How would you prepare a job interview?



An expert is applying to a job at a large oil company (the expert is the reflective scientist, and the application committee are societal actors). A recruitment consultant matched them (process facilitator). Just like in the date dinner, the scientist is anxiously analyzing everything she said – wondering if she is making the right impression (self-reflexive scientist). In secret, the scientist has a mission: to change the oil company from the inside out and make it more sustainable (change agent), but she cannot say this in the job interview!

The most useful aspect of this analogy arose when I started thinking about how you normally prepare for a job interview – see the next image.



Analogy 3 continued

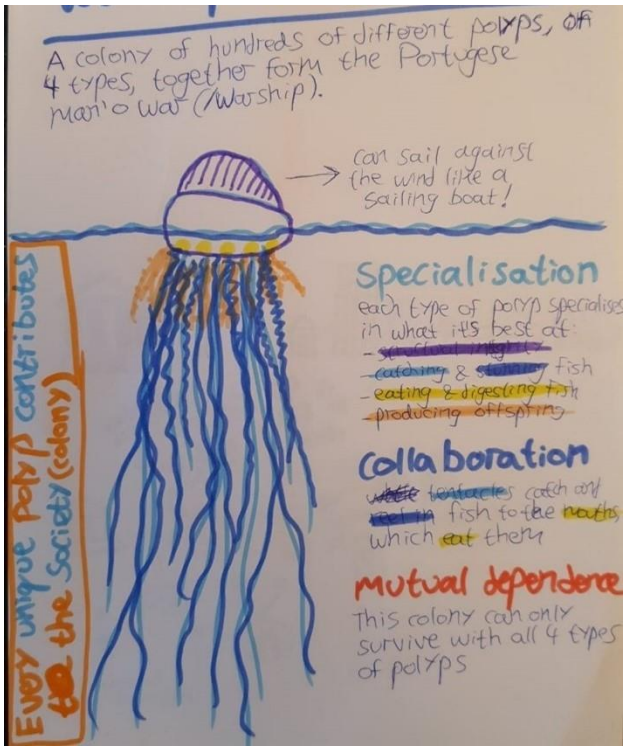
When preparing for a job interview, you normally reflect on *why* you want the job and what you can *uniquely contribute*, right? They will ask for it, so you'd better! This relates closely to the essence for this master thesis.

Moreover, here the analogy also connects to some of the identified challenges. Societal actors have certain expectations of you and if you had a different goal for the collaboration in mind, you must be very clear about that. But you still need to maintain the trust of the people you collaborate with. Applying for a job is like starting a partnership: you must be very clear about your expectations, but simultaneously make the application committee trust your knowledge and skills.

For a recent job interview, I did the **things in red at the bottom of the image**. These might be interesting elements for a reflection tool.

8.2.4 Analogy 4: The Portuguese man o' war

Specialization, collaboration and mutual dependence



This intriguing sea creature consists of hundreds of individual organisms (polyps) who work closely together in one colony.

Each type of polyp *specializes* in one task it is best at (one researcher-role which connects best to your skills). However, there is close *collaboration* between the polyps: they complement each other seamlessly (the different researchers must be aware of how they complement each other). Finally, all polyps are *mutually dependent*. Take one type of polyp out, and the whole colony dies.

Like machines in a factory, this analogy suggests that different researchers should complement each other. But this analogy also suggest you should **specialize** in what you are best at and know what others specialize in. Thus, a reflection tool might require **interaction between multiple students / PhD-candidates** who will work together in a team.

8.3 Experience with reflection methods

With the decision narrative and the analogies to aid me, I thought about reflection tools I and my research participants already had experience with. Were there elements I could copy from those?

8.3.1 Experience of the author with reflection methods

I have experience with several reflection methods that could be useful for this master thesis.

The reflection methods are color coded:
Orange = reflection based on words - written reflection exercises
Blue = reflection based on words - personal development plans
Purple = reflection based on visuals - tools using diagrams, objects, icons, visualizations etc.
Red = reflection based on conversation - structured reflective feedback dialogues
Green = reflection based on experimental action - role-playing games & gamification

<u>This master thesis</u>

- **Written logbook** | One of the data-collection methods in this master thesis could be used as a reflection tool: the logbook (see section 3.4.2).
- **Mental maps** | The interviews and logbooks in this master thesis were analyzed by making mental maps, which shows graphically how the respondents think about their role in transdisciplinary collaboration.

Master program CDI

- **Personal development plan** | In my CDI master, for the course *Personal professional development*, I drafted a personal development plan.
- **Role-playing game for C-lab** | For the course *Communication-lab (C-lab)* in my master CDI, my team developed a role-playing game to help researchers from different disciplinary backgrounds reflect on what they add to the collaboration from their background.
- **Role-playing game for PPD** | For the course *Personal professional development*, my team developed a role-playing game to reflect on the fit between your own personality and the work floor culture you work in.
- **Written reflection exercises** | The typical reflection exercise at the end of each course. Hated by many, unless very well formulated.
- **Gamification** | Using elements of games to make reflection fun. For instance: an epic story, a reward system (e.g. earning points), competition between players and collaboration between players towards a common goal.

Teacher-trainer at educational institute SSL

- **Role-playing games for teachers-in-training** | When I was teacher-trainer at an educational institute, I played role playing games with the teachers-in-training, followed by a guided reflection conversation. By playing a role-play and reflecting on what happened in that role-play, the reflection could be made very concrete.
- **Feedback dialogue with "core reflection" for teachers-in-training** | As teacher-trainer, I gave feedback to new teachers. Sometimes, concrete tips were enough for the teacher to improve their teaching. Sometimes, "core reflection" was needed. For instance, reflection on the personality of the teacher or the motivation to become a teacher. In these instances, we looked for the "core qualities" of the teacher and how we could use these to address challenges. I named this reflection "core reflection" because it relates, I realize now, closely to the ALACT model for "core reflection" of Korthagen & Vasalos (2005) (see section 7.3.2).

Other

- **Personal life vision book** | At high school, for the subject *Religion and life vision*, I wrote a "levensvisieboek" (creatively translates to: "live vision book"), where I reflected on my life vision, and how it relates to my personal identity.
- **Board game Terra nova** | At the Dutch National thinkTank about the Dutch education system, we played a reflective boardgame that is designed for primary and secondary school students to reflect on citizenship and democracy. The power of the game is that the participants build their own society from abstract objects, images, icons and space. This allows them to really put their own interpretation into it. The game sparks reflection through concrete challenging design questions the participants must address when designing their ideal society.

8.3.2 Experience of the research participants with reflection methods

- During prototype evaluation session 1 (see section 8.1 for more info), one respondent suggested using **character-based role-playing games** as a reflection tool. For example, we talked about Dungeons & dragons.

8.4 Reflection methods in scientific literature

In the theoretical framework (chapter 3), several reflection methods are mentioned that could be useful for the design of a reflection tool.

8.4.1 The reflection questions of Vinke-de Kruijf et al. (2022)

TABLE 2 Overview of elements that researchers should reflect upon when engaged in transdisciplinary research projects

Elements to reflect upon	Check
1. *Orientation*: My primary role as a researcher is	
a. to provide decision makers and other stakeholders with relevant objective, scientific knowledge (knowledge-oriented);	☐
b. to be influential and promote societal change (change-oriented);	☐
c. to integrate multiple knowledge sources and types in support of decision-making processes (intermediating).	☐
2. *Norms and values*: I am aware of	
a. my personal opinions about my research topic (such as solution types, need for action);	☐
b. how my own values and norms influence my decisions during the research process (for example related to stakeholder involvement, open or closed agenda, top-down or bottom-up);	☐
c. the potential societal impacts of my research, including the political and societal values and norms that play a role	☐
3. *Expectations*: I have adequately informed my research collaborators and stakeholders about	
a. the objectives and orientation of my research project;	☐
b. the potential impacts of my research project.	☐
4. *Resources*: I have or have access to	
a. capacities and skills (e.g., research, organizational, communication) to fulfill required role(s);	☐
b. resources (e.g., time, financial, support) available to fulfill required role(s).	☐

Vinke-de Kruijf et al. (2022) propose a list of elements that a researcher should reflect on when engaged in transdisciplinary research projects.

The first section *orientation* is based on their analysis of knowledge-oriented, change-oriented and intermediating researchers (see section 3.2.2 in the theoretical framework). The second section *norms and values* asks researchers to reflect on their deeper lying opinions and norms & values. This related to multiple-loop learning and "core reflection" (see section 8.4.2). The third section *expectations* relates directly to the challenges around diverging expectations identified in chapter 6 in this master thesis. Finally, the fourth section *resources* relates directly to the skills needed for the different researcher-roles in chapter 5 and the challenges in chapter 6 around doing transdisciplinary research with limited time and trying to contact busy case-owners.

Figure 8.1. List of elements that tansdisciplinary reseachers should reflect on (Vinke-de Kruijf et al. 2022).

8.4.2 The reflection model of Korthagen

Section 3.3.2 in the theoretical framework describes how the ALACT model can be used for "core reflection": reflecting on the mission and identity of a person, constituting double- or triple-loop learning. This relates to the questions around norms and values that Vinke-de kruif propose in their list of elements to reflect on (see previous section 8.3.1).

Core reflection through the ALACT model is well suited for this master thesis, for two reasons. Firstly, Korthagen focused on reflection in teacher-education. As mentioned before in the theoretical framework, the kind of challenges teachers face overlap with the challenges transdisciplinary researchers face. Both groups deal with sharing and translating knowledge, facilitating group dynamics and diverging expectations. Secondly, Korthagen & Vasalos (2005) argue that, at the level of core reflection, questions deal with *why* someone became a teacher (based on their mission and identity). This resonates with the essence I identified for CET: Reflecting on the unique contribution of the academic changemaker in society arouses questions around the mission and identity of the reflecting CET-researcher: *why* does the CET-researcher want to engage in transdisciplinary collaboration?

For these two reasons, the ALACT model for core reflection is a suitable theoretical backbone for a reflection tool for transdisciplinary researchers at CET.

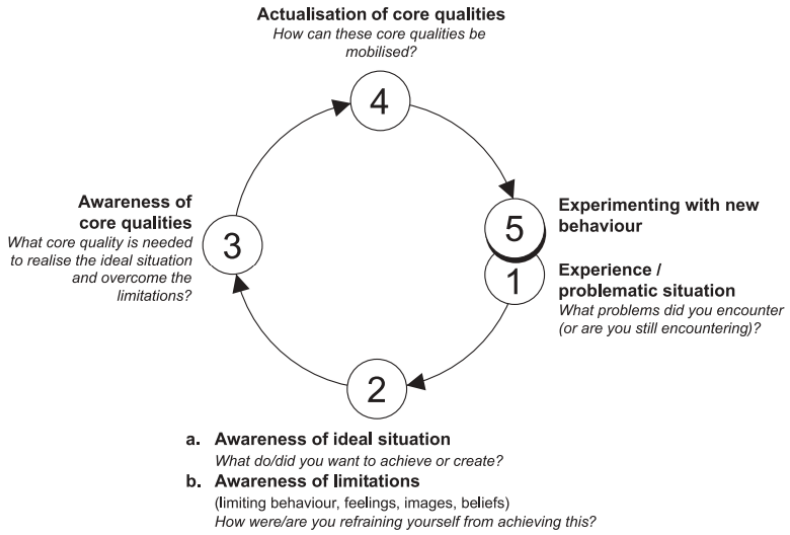


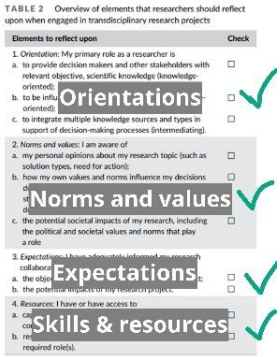
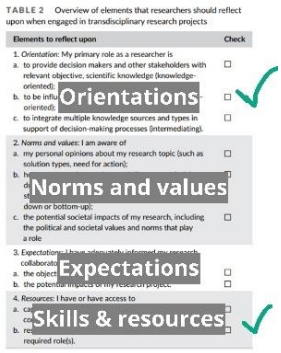
Figure 8.1. The ALACT cycle of core reflection (Vasalos & Korthagen, 2005).

8.5 Answer sub-question 4: Two prototypes for reflection tools

Let us tie everything together and build two prototypes, to answer sub-question 4: *Which reflection tool prototypes could help the researchers to reflect on their role?*

The previous sections have given us building blocks to build reflection tool prototypes – see table 8.1 on the next page. Note that the table uses building blocks to *generate* concrete prototypes, not as criteria to *decide* which prototype to develop further into a final tool. For that decision, the next chapter (9) compares both prototypes to the design principles established in chapter 7 (there is some overlap between these building blocks and the design principles, though).

Table 8.1. Building two prototypes with the building blocks established from the problem summary, the essence (chapter 6), the five researcher-roles (chapter 5), the identified challenges (chapter 6), my experience with reflection methods (section 8.3), scientific theory (section 8.4) and analogies (section 8.2).

Building blocks	**Prototype 1:** Your unique contribution	**Prototype 2:** CET'lers THE GAME
What to reflect on		
1. **Your unique contribution to society** (the essence)	You must sell your unique contribution to your conversation partner.	You make choices in the game based on your unique contribution (motivation + character).
2. The **five roles** and which skills you need for that.	You play with skill cards. Skills relate to the five researcher roles.	Players play with fictional characters based on the five roles. Each character has unique actions (relates to the corresponding researcher-role).
3. The identified **challenges** in chapter 5.		
4. The reflection questions of Vinke-de Kruijf et al. (2022) - orientations - norms and values - expectations - skills & resources		
The form of the reflection tool		
a. **role-playing games / gamification**	Role-playing game.	Character-based board game.
b. **personal development plans**	-	-

c. **reflective feedback dialogues**	 Reflective feedback dialogues guided by reflection cards.	 Reflective feedback dialogues guided by guiding question cards.
Structure of the reflection process		
ALACT-model for core-reflection - reflecting on a **problematic situation** - awareness of your **ideal outcome** - awareness how can use your **core qualities** to achieve that ideal outcome	 - **Problematic situation**: you are faced by challenging situations ('challenge cards'). - **Ideal outcome**: Defend your motivation ('motivation card') to engage in transdisciplinary collaboration. - **Core qualities**: defend why your skills ('skill cards') can help you deal with the challenge.	 - **Problematic situation**: you are faced by challenging situations ('challenge cards'). - **Ideal outcome**: Choose what you would ideally want to contribute to transdisciplinary collaboration. - **Core qualities**: defend why your unique action ('action card') can help you achieve your ideal contribution.
Ideas from analogies Reflecting researcher should…		
i. … feel **confident** and **dare to dream**	-	 Game uses elements of a medieval epic setting. This pulls you out of reality with all its limitations and lets you dream in the fantasy world of the game.
ii. … build on how one typically prepares for a **job interview** (reflecting on what you can uniquely contribute)	 Game idea based on a job-interview format.	-
iii. … **specialize** in what they are best at	 Pick cards related to your real-life skills and play the game with that.	 Pick your unique skillset and play the game with that.
iv. … reflect on how they can **complement** the activities and skills of their colleagues (though interaction between multiple students / PhD-candidates)	-	 Interaction between multiple researchers: discuss how the skills of multiple players contribute to solving one challenge.

8.5.1 Prototype 1: Your unique contribution

You want to do transdisciplinary collaboration? Cool! But do your collaboration partners also want to work with *you*?

Convince your colleagues and societal stakeholders that you are worth investing their time in! Sell to your potential collaboration partners why you can make a unique contribution.

This reflection tool mimics a job interview setting: An application committee member asks you *why* you want to engage in transdisciplinary collaboration and *what* you can contribute to that collaboration. You can make the *why* concrete by putting forward 'motivation cards'. You can make the *what* concrete by putting forward 'skill cards'. You will reflect on how your motivation and skills can come into play when you are faced by different real-life transdisciplinary challenges (described on 'challenge cards'). The application committee member helps you by asking you reflection questions that are written on 'reflection cards'.

For more details on this reflection tool prototype, including a step-by-step guide how it would work if it were developed into a reflection tool, see appendix 8.

8.5.2 Prototype 2: CET'lers THE GAME

You want to transform society? Cool! But how are you going to conquer the lands outside the ivory towers of your social sciences castle?

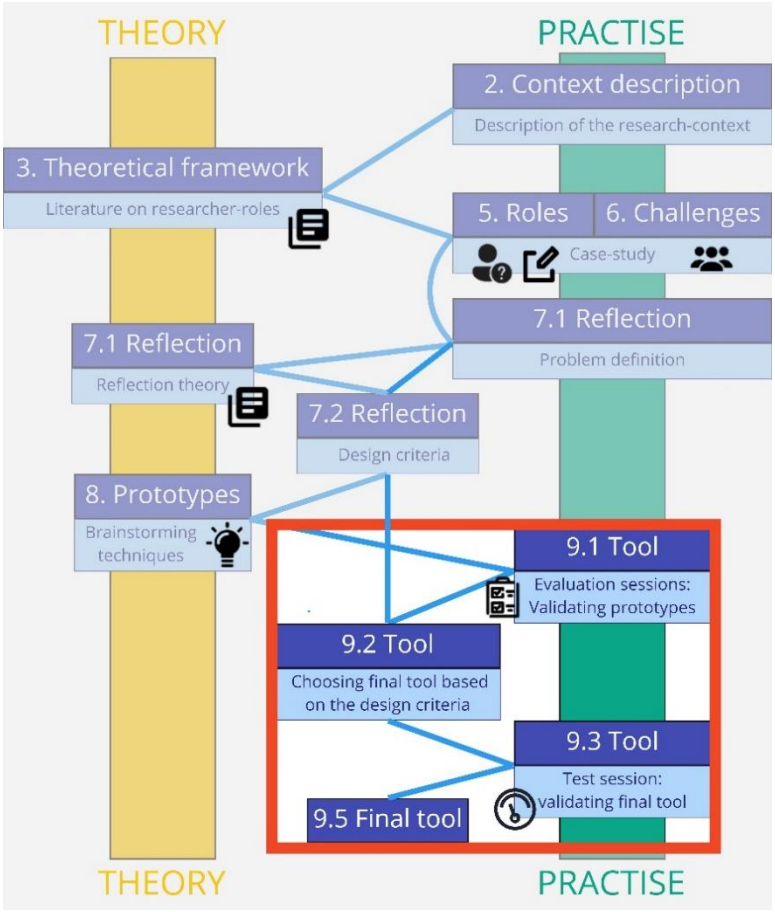
Plan your campaign and CET'le in society!

In this board-game, you pick a character. Examples of characters are: the mad professor (reflective scientist), the respected king (process facilitator) and the charming rebel leader (change agent). Each character comes with three actions they can put into action during the game. Besides picking a character, you also pick an 'objective': what kind of impact do you want to have in society? The game is played on a board. As the team moves around the board together, they are faced by challenges, which are based on real-life transdisciplinary challenges. Each player determines which of their actions they want to put into use to address the challenges and achieve their personal impact-goals. The player who gets closest to their personal impact goal wins the game.

For more details on this reflection tool prototype, including a step-by-step guide how it would work if it were developed into a reflection tool, see appendix 8.

9. Final reflection tool

***Sub-question 5**: Which reflection tool is best suited in the context of CET?*
***Validation-methods**: Prototype evaluation sessions, test session*



This chapter shows how I validated the two reflection prototypes and developed a final reflection tool. If you are only interested in the final tool (and not the process of how I got there), please skip to section 9.4.

The theory-practice diagram above shows that the previous chapter (8) leaned strongly to the theory side. The brainstorms I did in that chapter happened in isolation from the CET-context: I performed them alone based on my own experience, creativity, intuition and theory on reflection. This means that it is crucial that the prototypes are now validated in practice – to find out if they work in the context of CET. Therefore, this chapter leans towards the practice side. Nevertheless, there is some iteration between theory and practice even within this chapter, as I assess both prototypes against the design principles, which were partly derived from theory about reflection.

This chapter first describeed the validation of the two protypes in section 9.1. Then, in section 9.2, the decision which of the two prototypes to develop to a final tool is explained. After that, section 9.3 explains the validation of the final tool in a test session. The result, in section 9.4, is the final tool.

9.1 Prototype evaluation sessions

For an explanation of how the prototype evaluation sessions were organized and who precisely participated, see section 4.4.2 in the methodology.

I did two prototype evaluation sessions to validate the two prototypes. One session was with respondent 4 (course-coordinator of the course *Sustainable* innovation) and the other was with two fellow CDI students to have an outsider perspective. In the sessions, I asked the participants hoe they felt about the essence and the decision narrative. Moreover, I presented the two prototypes and asked them which advantages and disadvantages they saw in both prototypes.

The detailed input of the participants to the prototype evaluation session can be found in appendix 9. Below, I distilled take-home messages from the prototype evaluation sessions.

9.1.1 Take-home messages from the prototype evaluation sessions

Stick with the essence.
The essence seemed to resonate with all prototype evaluation session participants. They agreed that this was a good way to facilitate useful reflection for the students and PhD-candidates.

Add design criterium: reflection should be iterative.
This means: the reflecting people reflect in multiple rounds, each time refining their reflections and gaining new insights. Two prototype evaluation session participants agreed explicitly with each other on this. A third said the tool should help the users to extract insights they could keep talking about later. So, iterative reflection can happen during the use of the reflection tool, or the tool can stimulate an ongoing conversation after use of the tool.

Add design criterium: the tool should be easy to use. This means:
- Low effort & time-investment needed to understand how it works
- Low effort & time-investment needed to use the tool

Adaptions to prototype 1:
- Change the context of a 'job interview' (because this is too intimidating) and make it more playful.
- Make it more focused on collaboration than on competition.
- Make it focused on convincing yourself (with the help of others) that you can have a unique contribution, rather than convincing others that you can have unique contribution.
- Make the 'game mechanics' and the task cards clearer.
- Add an iterative element to the reflection or facilitate the extraction of insights that spur further conversation after the use of the tool.

Adaptions to prototype 2:
- Make sure characters are not gendered and all formulated positively.
- Simplify the game. Less focus on medieval context, fewer cards, super easy and clear explanation of the game.
- Add an iterative element to the reflection or facilitate the extraction of insights that spur further conversation after the use of the tool.
- Build on the game mechanics of an existing game to make it easier to build the game.

Taking these take-home messages into account, I updated the design principles and improved both prototypes. The improved protypes (first iteration) are available on request. The updated design principles are discussed in the next section.

9.2 Choosing which prototype to develop into a final tool

To choose a prototype for the final reflection tool, I used two types of arguments:
1) Arguments based on the updated design principles,
2) Arguments based on which prototype was most popular during the prototype evaluation sessions.

9.2.1 Arguments based on the updated design principles

CET'lers THE GAME is the winning prototype for four design principles. Your unique contribution wins for two design principles. See table 9.1 below.

Table 9.1. Both prototypes asessed against the design-criteria.

Design principles for the reflection tool: The reflection is …	**Design criterium is best met by…**
… situational CET-researcher takes time to look back at: - a specific action related to their role in the collaboration - or an experience during the collaboration where they faced one of the challenges in figure 6.1.	Both equally meet the design criterium, as both prototypes contain cards with challenges/situations that are similar to real challenges the respondents to this master thesis have faced. In both prototypes, advanced players can use the game to reflect on a real-life challenge they recently experienced.
… goal-oriented CET-researcher aims to improve the outcome by generating new alternatives for action in a future situation related to the transdisicplinary collaboration.	CET'lers THE GAME can lead to a richer set of action-alternatives, due to a more dynamic group discussion and access to more action cards.
… conscious & structured CET-researcher reflects consciously and explicitly. The CET-researcher could use rational and/or intuitive tools to structure experiences and actions.	CET'lers THE GAME provides more a structured process from reading the situation to discussing the final action-set. *This could go at the cost of flexibility though, making the game less fun for people who like to follow their own structure. For them, Your unique contribution might be better.*
… assessing assumptions and/or values CET-researcher does not merely seek quick behavioral fixes but assesses how assumptions in their own thinking and/or their personal values affect their actions. Particularly assumptions and values related to the *essence* are relevant (which unique role do they seek as academic researcher in society?)	Your unique contribution enforces a discussion about underlying assumptions and values through the roles of the counsellor. CET'lers the game does not have a role like this, leaving it up to the players to what degree they want to use the guiding question cards that ask question about underlying assumptions and values.
… dialogue CET-researcher considers multiple perspectives on the matter. For instance multiple frameworks of researcher roles or modes of engagement, or by engaging in conversation with other (CET) researchers.	CET'lers THE GAME contains a richer and more dynamic dialogue, because of the larger number of players and because the dialogue is gamified: arguing why your viewpoint is best (i.e. why the 'action' you chose is best) can help you win the game.
… iterative (added after the prototype evaluation sessions) The CET-researchers reflect in multiple rounds, each time refining their reflections and gaining new insights. This can happen during the use of the tool. Or the tool can stimulate an ongoing conversation after use of the tool.	Your unique contribution is built around an iteration of trying to find links between skills, motivation and challenge. The role of the counselor forces the main player to iterate. CET'ers the game, however, can be played with relatively little iteration, if players decide to use guiding question cards little in their discussion.
The tool is easy to use (added after the prototype evaluation sessions) Low effort & time-investment needed to understand how the tool works. Low effort & time-investment needed to use the tool.	CET'lers THE GAME is the easiest to learn and play. This goes at the cost of some flexibility. This can be solved however, by tailoring situation cards to specific contexts (e.g. one set for CET PhD-candidates and one set for CET students). Also, experienced players can make their own situation cards, based on real-life situations they encountered

9.2.2 Arguments based on the prototype evaluation sessions

The prototype evaluation session participants saw more advantages of prototype 2 over prototype 1 than the other way around. For instance:

- Prototype 2 builds more on collaboration and group reflection
- Prototype 2 is more playful
- Prototype 2 is less intimidating and competitive

More information about these arguments can be found in the detailed input in appendix 9.

It must be noted that the preference of the prototype evaluation session participants was affected by the fact that I presented prototype 2 more enthusiastically. I was not aware of this – one participant commented on this. Therefore, I do not see the fact *that* the prototype evaluation session participants were enthusiastic about prototype 2 as an argument for prototype 2 but look at *why* they claimed prototype 2 was the better prototype (the three points above).

9.2.3 Choice of prototype

The assessment of the design principles showed that prototype 1 contains some strong elements of reflection, like iteration and assessing assumptions and values. Someone experienced with reflection might do well with prototype 1. However, the whole idea of the reflection tool is to make the reflection more accessible to people who have little experience with reflection on researcher-roles in transdisciplinary collaborations. Prototype 2 better achieves this goal, as it is more structured, easier to use, and more playful. Moreover, it better meets the design principles for dialogue and generating a rich set of action-alternatives ('goal-oriented'). Furthermore, the prototype evaluation session participants saw more advantages of prototype 2. Therefore, I develop prototype 2 to a final tool.

To develop the final tool, I made game instructions and game cards in the program Miro. To have an outsider perspective, I asked one fellow CDI student to read the game rules and game cards with me, and they suggested some final improvements before I tested the tool in the CET setting.

The version of the tool which I used in the test session (second iteration) is available on request.

9.3 Test-session

The test session validated the tool in the CET context. Three CET-employees (two PhD-candidates and one supervisor of this master thesis) played the game without my help, to simulate natural playing conditions. The test session collected data in three ways: 1) in a questionnaire, 2) in a video of the gameplay and of the discussion about the game and 3) through post-its that the participants could post on things they found unclear in the game instructions and game cards. For more information about how the test session was organized and who participated, see section 4.4.2 in the methodology. The raw data of the questionnaire, the transcript of the discussions and the comments on the post-its can be found in appendix 10.

This section discusses the results of the test session according to the design principles for the reflection tool. To what degree does the test show evidence that each design criterium is met? And how can the reflection game be improved to better meet each design criterium?

9.3.1 Design criterium: Easy to use

Low effort & time-investment needed to understand how the tool works and to use the tool.

The time needed to read the game instructions (about 5 min) and the time spent on one round (about 15 min) were as long as I intended. The participants played the game without my help. Also, the positive questionnaire results give me the impression that the instructions of the game were clear enough. The one "disagree" below likely relates to an unclarity in the action cards, see section 9.4.3.

Questionnaire results

It was easy for me to understand the rules of the game	Agree, agree, agree
It cost me little time to understand the rules of the game	Agree, strongly agree, agree
It was easy for me to play the game	Disagree, strongly agree, agree
Each game round went fast enough to keep me engaged	Agree, strongly agree, strongly agree

9.3.2 Design criterium: Situational

CET-researcher takes time to look back at:
- a specific action related to their role in the collaboration
- or a situation during the collaboration where they faced one of the challenges in figure X.

The situation cards made the reflection game situational. The questionnaire results show these cards were experienced as largely 'realistic' and 'relevant'. During the gameplay, I observed that the test participants related the situations on the situation cards to situations they had encountered in real-life and used their real-life experience as input to the discussion in the game. Including an option to make your own custom situation card based on a real situation could further enhance the situational nature of the game. Furthermore, in the second round of playing, the test participants deliberately decided to ignore one game rule by choosing two contributions to the situation instead of one. This deepened their discussion about the situation and showed they engaged with the situation card in a proactive manner. It could be added to the game rules that choosing you own mix of contributions is allowed.

Questionnaire results

I felt like the situation cards in the game were:	
- Realistic	agree, neutral, agree
- Relevant to situations I encounter in real-life	agree, agree, agree

9.3.3 Design criterium: Goal-oriented

CET-researcher aims to improve the outcome by generating new alternatives for action in a similar future situation.

In the game, players chose a team contribution and chose which action they want to perform to help achieve that team contribution. This is meant to make the players think about how they can improve the outcome of a challenging situation, and which action-alternatives there are for this. The questionnaire results show that the test participants gained new insights about which actions they could perform in transdisciplinary collaboration and how multiple people could combine their actions. However, they were "neutral" about having gained insights on how actions affect the outcome of a transdisciplinary collaboration activity. Relatedly, in a discussion about the game, test participant 2 commented that it could be useful if you would play multiple rounds with the same

situation card, ‘so we could build on the first actions, so it is like: what should we do next?’ In this way, keeping the same situation card multiple rounds could simulate making progress in the situation and make it clearer how actions can lead to an outcome.

In the questionnaire, 2 out of 3 test participants reacted with “neutral” to the statement *I felt like the action cards were realistic*. In line with that, the participants commented on post-its that the action cards were “vague” and that sometimes it was hard to pick an action card to address the situation. This might explain why one participant answered “disagree” to the statement *It was easy for me to play the game* in the questionnaire (the other two answered “agree” and “strongly agree”). In a discussion about the game, test participant 3 said:

> ‘The situation cards are very specific and to tackle these your action cards are much broader, I felt. So you can either make the situation also a little bit broader or maybe the action cards a little more specific.’

Later, test participant 2 suggested that the players could get new action cards every round to increase the chance that you get action cards that fit the situation.

Some struggles around the action cards also arose from the fact that different test participants interpreted the purpose of choosing action cards differently. Test participant 3 saw the action cards as something to improve the teams contribution to the situation: ‘I did not think of defending my action cards. I thought about what is best for the situation.’

Test participant 2, however, reacted:

> ‘To me, that you have to defend your own card actually makes it a bit more exciting. But at the same time it gets you trying to argue for your own card even though you actually don’t think it is the best one.’

Test participant 3 agreed: ‘It is a tension between the common good and your own individual take on that.’

I put this tension in the game on purpose. I thought defending a less-than-ideal action card could challenge the players of the game to think about how an action they previously thought not useful could be useful after all. This would force them to uncover new perspectives. However, test participant 3 reacted:

> ‘But I don’t understand the purpose of that. Because you say we work in transdisciplinary settings. And then we have to fix our ways and actions to their situation. So we need to change our actions and try to see how they benefit the situation, right?’

This discussion suggests that the tension between cooperation / going for the common good and competition / going for your individual win in the game in step 4 of the game (choosing action cards) does not work for everyone. The game could make a clearer choice. Either focus on collaboration / going for the common good, by giving players new action cards every round so they have action cards that better fit the situations. Or focus on competition / going for your individual win by emphasizing in the game instructions that the goal of step 4 is to defend you “best” action card, even if you think is not a good action to address the situation.

<u>Questionnaire results</u>

I gained new insights on:	
- Which contributions I can make in transdisciplinary settings	neutral, agree, disagree
- Which actions I can perform in transdisciplinary collaborations	agree, agree, strongly agree

- How my actions affect the outcome of a transdisciplinary collaboration activity	neutral, neutral, neutral
- How multiple people can combine their actions to achieve a desired contribution	agree, neutral, agree
I felt like the action cards in the game were:	
- Realistic	Neutral, agree, neutral
- Relevant to the transdisciplinary collaboration I engage in	Agree, neutral, agree

9.3.4 Design criterium: Assessing assumptions and/or values

CET-researcher does not merely seek quick behavioral fixes but assesses how assumptions in their own thinking and/or their personal values affect their actions. Particularly assumptions and values related to the essence are relevant (which unique contribution do they seek as academic researcher in society?).

The game attempted to make the players reflect on the assumptions and values underlying their choice of actions. The game achieved this in two ways: 1) By first choosing a contribution, and only then thinking about action to help achieve that contribution, you first think about why you want to engage transdisciplinary with the situation, before choosing how. 2) Moreover, the guiding question cards asked questions directly aimed at the assumptions and values behind choices. The test participants drew only one guiding question card, after I reminded them this was a possibility. This could explain why 2 out of 3 participants responded 'neutral' to having gained insights on why they prefer certain actions or contributions. Also, the statement *I felt like the guiding question cards in the game were helpful* received the answers "strongly disagree", "disagree" and "agree". The test participants suggested that the guiding question cards could be improved and that there should be a game element that forces the players to draw guiding question cards.

Questionnaire results

I gained new insights on:	
- Why I have a preference for certain contributions in transdisciplinary settings	neutral, strongly agree, neutral
- Why I have a preference for certain actions in transdisciplinary collaborations	neutral, agree, neutral
I felt like the guiding question cards in the game:	
- Were helpful	Strongly disagree, agree, disagree
- Made me think about the same topic in a different way	Strongly disagree, neutral, neutral

9.3.5 Design criterium: Conscious and structured

CET-researcher reflects consciously and explicitly. The CET-researcher could use rational and/or intuitive tools to structure experiences and actions.

According to the questionnaire results, the game provided a structure for the discussion about contributions and actions. Because the players must defend their chosen actions, they are forced to make all their arguments explicit. The test participants explained their arguments, listened to each other, and reacted. This indicated that the game indeed generated a conscious and structured discussion about action-alternatives.

Questionnaire results

The game provided a structure for the discussion about contributions and actions	agree, agree, agree

9.3.6 Design criterium: Dialogue

CET-researcher considers multiple perspectives on the matter. For instance multiple frameworks of researcher roles or modes of engagement, or by engaging in conversation with other (CET) researchers.

According to the questionnaire results, the test participants felt like they had learned more about why others prefer certain contributions and actions than about their own preferences ('assessing assumptions and/or values'). This suggests that the participants engaged in a dialogue that made them aware of the others' perspectives. As observer, I saw that the test participants listened to each other, and engaged proactively with each other's arguments. This was caused by the fact that they had to defend their own action cards. Thus, each players had to give counterarguments to the arguments other players made for their action cars. This required that they listened well to the others' arguments. In other words, the competition in the game forced the players to engage in dialogue.

Questionnaire results

I gained new insights on:	
- Why others have a preference for certain contributions in transdisciplinary settings	agree, strongly agree, agree
- Why others have a preference for certain actions in transdisciplinary settings	neutral, strongly agree, agree

9.3.7 Design criterium: Iteration

The CET-researchers reflect in multiple rounds, each time refining their reflections and gaining new insights. This can happen during the use of the tool. Or the tool can stimulate an ongoing conversation after use of the tool.

The only iterative element in the game design was that guiding question cards could help the players add a new perspective every time they would draw a new guiding question card. According to the questionnaire results, the participants did not feel like the question cards achieved this result. This might be in part because they drew only one guiding question card. After paying the game, the test participants flipped through the guiding question cards though, and one commented that these would have spurred quite some discussion as they were hard to answer. This again pleads for the earlier discussed need to give the guiding question cards a more prominent role in the game. In a discussion about the game, we talked about modifying the game so that you keep the same situation card in multiple rounds and refresh your action cards each round (opposite from the current version of the game where you change situation cards, but keep your action cards). This could allow you to iterate on the same situation, adding new actions to address the situation each round. Test participants 2 and 3 thought this was a good idea. Test participant 1 liked to change both situation and action cards each round. In short, iteration could have been improved by giving the guiding question cards a more prominent role and by changing situations each round.

Questionnaire results

I felt like the guiding question cards in the game made me think about the same topic in a different way	strongly disagree, neutral, neutral

9.3.8 Summary of improvements in the reflection tool

Based on the results of the test-session, I made these improvements in the reflection tool:

- **Receive the action cards after discussing the contribution**
  [relates to design criterium: goal-oriented]
  This separates the 'collaboration' and 'competition' phase of each round more clearly: from the moment you receive your action cards, the 'competition' starts.

- **Change action cards and keep the situation card for two rounds in a row**.
  [relates to design criterium: iteration]
  This increases the sense of 'solving' the situation and adds a layer of iteration to the reflection.

- **Divide all action cards among the players, instead of 3 action cards per player.**
  [relates to design criterium: goal-oriented]
  This increases the chance that each player has an action card they find useful to address the situation. Doing this can take away some of the struggles the test participants experienced around the action cards. This would mean for the game that you could no longer count points by the number of action cards in your hand. Thus, count with tokens: every time your action card gets chosen, you receive one token. The first player with three tokens wins.

- Add to the game rules that **the team must draw one guiding question card at the start of each discussion** (each step 2 and each step 4).
  [relates to design principles: assessing assumptions & values and iteration]

- **Emphasize more clearly in the game rules** that step 2 is about collaboration / going for the common good and that step 4 is about competition / going for your individual win.
  [relates to design criterium: goal-oriented]

- **Make the situation cards more flexible**
  [relates to design criterium: situational]
  To better allow the players to use the game to reflect on situations they encountered in real-life.
  - Include an option in the game instructions to make your own custom situation card based on a real situation could further enhance the situational nature of the game.
  - Include the option in the game instructions to choose multiple contributions or add your own, as long as the team comes to an agreement on what these contributions are.

9.4 Answer sub-question 5: The final reflection tool

After improving the reflection tool based on the results of the test session, I came to the final reflection tool (third iteration). This final reflection tool forms the answer to sub-question 5: *Which reflection tool is best suited in the context of CET?*

On the next pages, you can find **the final tool**:

- The game instruction (4 pages)
- All the game cards (3 pages).

Note that this final tool is **specifically developed for the context of CET** and therefore not necessarily applicable in other contexts. In the discussion (chapter 11), I zoom out and discuss to what degree this reflection game meets the research aim of helping CET-researchers reflect on their role in transdisciplinary collaboration. Also, I discuss there to what degree the insights from my design process can be generalized to other contexts.

CET'lers THE GAME

Number of players	Who can play	Time to play
3 to 5	Everyone at CET	30 to 60 min

A fun reflection game for transdisciplinary students and researchers at CET.

Introduction

In the ivory towers of the University in Bergen, a team of courageous students and researchers at CET has been brooding over a secret plan. The ultimate goal: save the world from climate change. Their plan involves the bold step of going beyond academic study and stepping out in society. There, they will engage with societal actors and produce actionable knowledge that can transform society.

The CET'lers are determined to fulfill their mission. But are they up to the challenges they will face on the way? Join the team and step out in society! Discuss what your team can best contribute when faced by challenging societal situations. And make sure that you perform the rights actions to achieve your team's contribution. If your actions are met with most approval by the rest of the team, you win the game!

Purpose of the game

This is a reflection game. It is designed to help students and starting PhD-candidates at CET to reflect on their **role in transdisciplinary collaboration** with actors outside university. Experienced CET researchers can also play (& learn).

When you play this game, you will learn about these researcher-roles:

- The reflective scientist
- The knowledge broker
- The process facilitator
- The change agent
- The self-reflexive scientist

Based on Whittmayer & Schäpke (2014).

The game in short

All players together form a team.

- In the team:
  - Read 1 **situation card** & choose your teams *contribution*.
  - Divide the **action cards** over the team.
- Individual player:
  - Choose which of your **action cards** helps achieve the team *contribution*.
  - Defend your choice to your team.
- Win: If your **action cards** are most popular you will collect most **points** & win the game.

Action cards

x15

Guiding question cards

x8

Situation cards

x3

Points

x14

It is possible to add your own cards! The game comes with a few blank cards you can write on.

Gameplay

Only at the start of the game

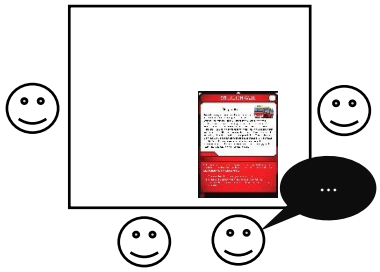
- Shuffle all decks.
- The team captain draws 1 

and reads the situation out loud. You will keep this during the whole game.

Who is the team captain? First round: the youngest player. Rotate the team captain clockwise every new round.

What the table looks like

Example with 4 players.
Main decks of cards not shown.



Every round

1. <u>What will you contribute to this situation as a team?</u>

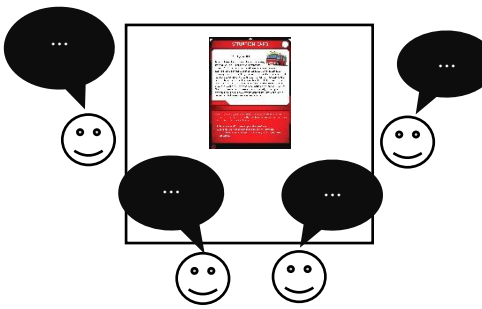
The team discusses which of the "contributions" suggested on the **situation card** is best. This becomes your team's *unique contribution*.
First round → discuss what to do *first.*
Later rounds → discuss what to do *next.*

You are allowed to suggest a contribution that is not on the situation card.

The team captain:
- starts the discussion by drawing 1 

and reading it out loud. Feel free to draw more if needed.

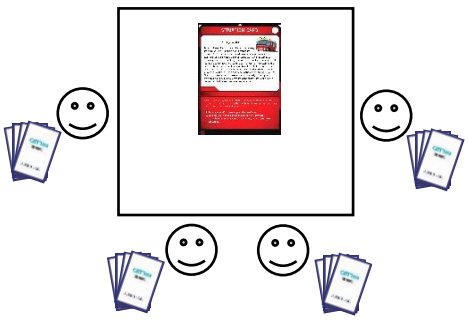
- sets a timer to 5 min. No consensus when timer goes off? Vote!
If there is an equal vote, the game leaders vote counts double.



2. <u>Divide all **action cards** over all players</u>

3 players → every player gets 5 action cards
4 players → every player gets 4 action cards (1 action card is not used)
5 players → every player gets 3 action cards

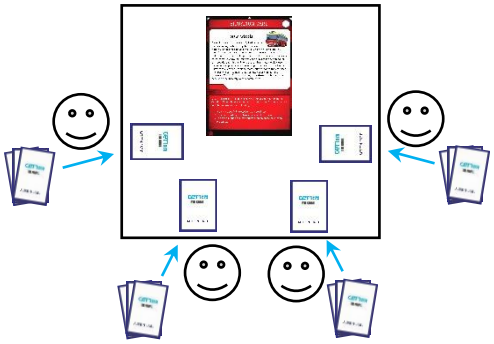
Keep your action cards closed in your hand.



3. What is the best action to achieve your team's *unique contribution*?

Each player chooses 1 **action card** from their hand and puts it face-down in front of them.

Choose the action for which you can best argue that it would help achieve the *unique contribution.*



4. Defend your action card!

Convince the others in the team that your action is the best to achieve the team's *unique contribution.* If your **action card** is chosen, you get 1 **point**!

- First, the game leader collects the **action cards** on the table, shuffles them and puts them face-up on the table.
- Next, all players discuss which 2 actions are best to achieve the *unique contribution* of the team. Make sure your **action card** is one of the 2 chosen actions. But don't say which card is yours!

Now nobody can see which action card came from who.

The team captain:

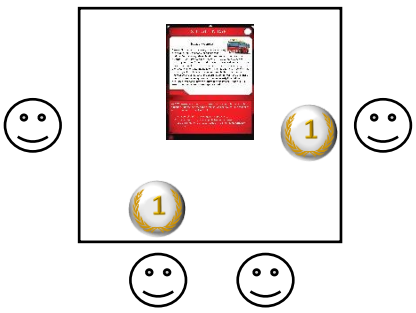
- **starts the discussion** by drawing 1 nd reading it out loud. Feel free to draw more if needed

- **sets a timer to 5 min.** No consensus when timer goes off? Vote! If there is an equal vote, the game leaders vote counts double.

5. Rouding up

The team captain gives one 

to both the players whose **action cards** were chosen. Next, the team captain collects all 15 **action cards** and shuffles them.



This is the end of the round. Start a new round at step 1. Remember to
rotate the team captain clockwise each new round.

End of the game

The game ends when a player has 3 **points:** 

This player wins the game! Multiple players can win simultaneously.

Background information

Why a reflection game?

Transdisciplinary collaboration is challenging and can be done in many ways. Most students and researchers, however, are not explicitly trained in it. Therefore, it is crucial that they are aware of what they can contribute in a transdisciplinary setting and which roles they can take during the collaboration. Awareness of this makes it easier to choose a role tactfully, for example based on your skills, your norms and values or based on what is needed in the situation. Ultimately, this leads to a better collaboration outcome.

Who designed this game?

CET master student Joran Buwalda developed this game in spring 2022 as part of his master thesis in Science communication. For more information about the master thesis behind this reflection game, please contact Joran at joranbuwalda@gmail.com.

The development of this game would not have been possible without the extensive input of several students, researchers and staff at CET, for which Joran is grateful.

How was this game designed?

Joran conducted design-based research to identify challenges related to transdisciplinary collaboration at CET and to design a reflection tool (this game) to reflect on these challenges.

The reflection is gamified by using team cooperation elements and competition elements. The actions described on the **action cards** relate to five researcher-roles as described by Whittmayer & Schäpke, (2014). The situations described on the **situation cards** are inspired by situations which CET students and PhD-candidates have faced in reality. Information about their challenges with transdisciplinary collaboration was gathered in 7 semi-structured interviews, 4 logbooks and 2 focus groups at CET between February and May 2022. The suggested *contributions* on the **situation cards** are inspired by both the data collection at CET and by Haarstad et al. (2018).

Joran Buwalda | Bergen, Norway | 16/06/2022 | **joranbuwalda@gmail.com**

Haarstad, H., Sareen, S., Wanvik, T. I., Grandin, J., Kjærås, K., Oseland, S. E., ... & Wathne, M. (2018). Transformative social science? Modes of engagement in climate and energy solutions. Energy Research & Social Science, 42, 193-197.
Wittmayer, J. M., & Schäpke, N. (2014). Action, research and participation: roles of researchers in sustainability transitions. Sustainability science, 9(4), 483-496.

CET'lers
THE GAME

ACTION CARD

ACTION CARD

Reveal ulterior motives

You ask your colleague researchers how they think their norms and values affect their behavior in the collaboration.

This action belongs to the **self-reflexive scientist**, who reflects on their own role in the collaboration, and helps their colleagues reflect on this.

ACTION CARD

Observation

You observe closely how the others engage and identify how their behavior influences the collaboration.

This action belongs to the **self-reflexive scientist**, who reflects on their own role in the collaboration, and helps their colleagues reflect on this.

ACTION CARD

Explicit expectations

You create a moment for everyone to share their expectations. You identify where they overlap and diverge.

This action belongs to the **self-reflexive scientist**, who reflects on their own role in the collaboration, and helps their colleagues reflect on this.

ACTION CARD

Expert in the room

You share your expert opinion based on your research experience.

This action belongs to the **reflective scientist**, who uses scientific research methods to provide input to the collaboration.

ACTION CARD

Back to the basics

You give a presentation of research findings in lay language.

This action belongs to the **knowledge broker**, who forms a bridge between science and practice.

ACTION CARD

Show what we know

You collect best practices and do a literature review to synthesize existing scientific knowledge.

This action belongs to the **reflective scientist**, who uses scientific research methods to provide input to the collaboration.

ACTION CARD

Objective knowledge

You help clarifying an unanswered question by doing empirical research.

This action belongs to the **reflective scientist**, who uses scientific research methods to provide input to the collaboration.

ACTION CARD

Make it relevant

You create a tool or innovation that can be directly implemented in a societal context.

This action belongs to the **knowledge broker**, who forms a bridge between science and practice.

ACTION CARD

Network

You help societal actors find the right scientists to ask their questions to.

This action belongs to the **knowledge broker**, who forms a bridge between science and practice.

ACTION CARD

Sound the alarm

You make loud and clear how urgent the sustainability issue is. You show the overwhelming evidence. No more excuses!

This action belongs to the **change agent**, who tries to actively transform societal processes, even if that requires stirring things up.

ACTION CARD

Critical assessment

You critically assess how the people think about sustainability, and show them that their view might not be the only view.

This action belongs to the **change agent**, who tries to actively transform societal processes, even if that requires stirring things up.

ACTION CARD

Safe meeting space

You organize a meeting, invite participants and actively build trust among them.

This action belongs to the **process facilitator**, who facilitates the collaboration by creating spaces for mutual learning.

ACTION CARD

Let them talk

You make societal actors deliberate together, without sharing your own knowledge.

This action belongs to the **process facilitator**, who facilitates the collaboration by creating spaces for mutual learning.

ACTION CARD

Power relief

You identify low-power actors and make sure these actors get an extra chance to share their opinion.

This action belongs to the **process facilitator**, who facilitates the collaboration by creating spaces for mutual learning.

ACTION CARD

Dirty hands

You get out in the field, talk to people, experience what they go through in their daily life and find out what they need.

This action belongs to the **change agent**, who tries to actively transform societal processes, even if that requires stirring things up.

CeT'lers
THE GAME

GUIDING QUESTION CARD

GUIDING QUESTION CARD

How do your cultural and socio-economic background affect your standpoint?

GUIDING QUESTION CARD

Whom do you want to help? Can you explain why?

GUIDING QUESTION CARD

Which perspective has been left out in the discussion?

GUIDING QUESTION CARD

Which contribution / action are you most comfortable with? Can you explain why?

GUIDING QUESTION CARD

Which contribution / action feels most "right" ? Can you explain this feeling?

GUIDING QUESTION CARD

What do you want to gain from this situation? What does that mean for your choice?

GUIDING QUESTION CARD

How can you as an academic add something that others could not add in this situation?

GUIDING QUESTION CARD

Would you prefer something that is fair or something that is effective? What does this mean for your choice?

CET'lers

THE GAME

SITUATION CARD

SITUATION CARD

Fancy umbrella's

CET is part of a funded five-year research partnership with six Scandinavian municipalities. The partnership is aimed at developing solutions for climate adaptation related to rain, heat, flooding and extreme weather. With some trouble, you have been able to organize one meeting with representatives of the municipalities. Two municipalities could not be present, and the other three joined online. One municipality says they have had some discussions about umbrella's with the city logo on it, but the others have no plans for climate adaptation because they lack clear data on how much it will rain and how much damage that rain will cause in Norwegian kroner in the next five years. They agreed that CET should come up with a proposal how to move forward in the first year of the partnership.

As CET researchers, you must choose a unique contribution to this situation. Choose between the three options below. Assume that each contribution would receive funding.

1. Bring in new partners. For instance other stakeholders. Or knowledge partners who can help create a tool to calculate how much rain will fall and how much damage this rain will do.
2. Build closer relations with and between the municipalities.
3. Find out with the municipalities what this partnership should precisely focus on.

SITUATION CARD

Many wheels

Several Norwegian provinces (Fylkeskommuner) are developing sustainable public transport options. For instance, urban diesel buses are being replaced by electric busses. However, the progress is slow when it comes to reducing emissions from long-distance routes outside urban areas. As researchers, you have noticed that each province is developing their own solutions for this, and none of them has a full overview over the technological, political and economic possibilities. There is hardly knowledge exchange, let alone coordination between the provinces. The (bus)wheel is being invented simultaneously in multiple provinces. You don't know why they don't share knowledge, but it seems they deliberately went separate paths.

As CET researchers, you must choose a unique contribution to this situation. Choose between the three options below. Assume that each contribution would receive funding.

1. Provide scientific knowledge to the provinces.
2. Enhance knowledge exchange between the provinces.
3. Use this situation as a case-study on fragmented governance processes.

SITUATION CARD

A Norwegian climate NGO asks CET to help them with the following question: How can we create awareness among the Norwegian population that Norway is performing badly when it comes to climate action? According to the NGO, the average Norwegian believes that Norway is quite green, which "obviously it is not". The NGO blames the government of green washing the population, for instance by emphasizing Norway's hydropower, which, according to the NGO, rather destroys nature than saves the climate. And by making the population believe that carbon capture and storage and electrifying oil platforms will make Norway Paris-aligned. The NGO asks CET for help, because "maybe they will listen to us if science supports us".

As CET researchers, you must choose a *unique contribution* to this situation. Choose between the three options below. Assume that each contribution would receive funding.

1. Create a mini-public (a representation of society) and facilitate a public debate in that mini-public.
2. Provide scientific knowledge to the NGO.
3. Help the NGO find out whether they are focusing on the right question.

10. Conclusion

This chapter summarized the answers to the sub-questions and answers the main research question.

Sub-question 1: How do CET-researchers conceive their role in transdisciplinary collaborations?

The students and PhD-candidates performed activities related to all five roles in the analytical framework of this master thesis. However, they emphasized the importance of some roles more than others. The PhD-candidates emphasized activities related to situating research findings in specific contexts and producing tools that are useful in practitioners daily practice (knowledge broker). Also, they saw it as an important task to facilitate deliberation and mutual learning processes between societal actors (process facilitator). The course-coordinators of the course *Sustainable innovation* saw most process facilitation tasks as their own responsibility (process facilitator). To their students, they ascribed tasks surrounding critically reframing case questions (change agent).
For more details on the answer to sub-question 1, read section 5.3.

Sub-question 2: Which challenges do CET-researchers face related to these roles?

The challenges that PhD-candidates face in transdisciplinary collaboration fall in three categories: 1) how to organize 'real' transdisciplinary collaboration with limited resources, 2) how to manage diverging expectations from societal stakeholders and researchers and 3) how to facilitate meetings while mitigating power differences. The latter challenge is a consequence of the PhD-candidate's emphasis on the process facilitation role. The challenges the students faced also fall in three categories: 1) how to get into contact and interact about the case-question with busy case-owners, 2) how to deal with uncertainties around expectations and 3) How critically reframe the case-questions. The latter category is a consequence of the course-coordinators' emphasis of a change agent role for the students.
For more details on the answer to sub-question 2, read section 6.3.

Sub-question 3: How can reflection be conceptualized in the problem-context?

I made a problem summary and distilled an *essence:* **The unique contribution of the academic changemaker to society.** For more information about this essence, read section 7.1.

Based on problem summary and essence, I could conceptualize reflection in the problem context. Reflection is…

- … *situational*: looking back on an action or experience related to one of the challenges (SQ2),
- … *goal-oriented*: aimed at improving the outcome by generating alternatives for action in future situations in the collaboration,
- … *conscious & structured*: looking back consciously, could use rational/intuitive tools to structure reflections,
- … *assessing assumptions* and/*or values*: not looking for quick fixes, but assesses how assumptions related to the *essence* (SQ3) underly behavior,
- … *dialogue*: considering multiple perspectives on the experience or action through an internal dialogue or a dialogue with colleague CET-researchers.

Sub-question 4: Which reflection tool prototypes could help the researchers to reflect on their role?

Based on a decision narrative, analogies of the essence, my personal experience with reflection methods and the literature on reflection models, I developed two prototypes for reflection tools:

Prototype 1: Your unique contribution
A role-playing game using reflective feedback dialogues, where you reflect on how your motivation and skills relate to concrete transdisciplinary challenges.

Prototype 2: CET'lers THE GAME
A character-based card game where you reflect on which actions you can be used to address concrete transdisciplinary situations in a team of transdisciplinary researchers.

For more information on these three prototypes, read section 8.5.

Sub-question 5: Which reflection tool is best suited in the context of CET?

Prototype 2 (CET'lers the game) is best suited for starting students and PhD-candidates at CET to reflect on their role in transdisicplinary collaboration. Prototype 2 is more structured, easier to use, and more playful than prototype 1. Therefore, it makes reflection more accessible to people who have little experience with reflection on researcher-roles in transdisciplinary collaborations. Moreover, prototypes 2 better meets the design principles for dialogue, structured thinking and generating a rich set of action-alternatives ('goal-oriented').

This tool was further developed and tested in a test session.

Main research question: How can a reflection tool help starting researchers at the Center for climate and energy transformation in Norway to reflect on their role in collaborations with policymakers and business actors?

The primary aim of this research project is to **develop a reflection tool** to help students and starting PhD-candidates at the Center for climate and energy transformation reflect on their role in transdisciplinary collaborations. The reflection tool I developed is a card game that lets CET-researchers reflect on their contribution in realistic and concrete transdisicplinary situations and which actions are best to achieve these contributions. The game is playful and stimulates dialogue and discussion. The two main effects of the game are 1) that it provides CET-researchers with a common language in the form of the framework of researcher roles of Whittmayer & Schapke (2014) and 2) that it helps CET-researchers to understand how these roles relate to the challenges they face in transdisciplinary collaboration – that is: how choosing specific roles can lead to specific challenges and how strategically choosing roles can help you overcome challenges.

The discussion chapter further discusses the effects of the reflection tool and the degree to which it improves the transdisciplinary collaboration of CET-researchers (section 11.1).

11. Discussion

This section discusses to what degree this master thesis has achieved its aims. Section 11.1 discusses the main product of the master thesis: the final reflection tool. Next, section 11.2 discusses the two secondary goals of this master thesis: generating insights that can be directly useful to CET and contributing to theory building about roles of researchers in transdisciplinary collaboration. After that, section 11.3 discusses the reliability, validity, and ethics aspects of the methodology, leading to suggestions for further research in section 11.4.

11.1 Discussion of the final reflection tool: does it meet the primary aim of this master thesis?

The primary aim of this research project was to **develop a reflection tool** to help CET-researchers (students and PhD-candidates) reflect on their role in transdisciplinary collaboration.

In the end, the reflection is meant to help CET-researchers deal with the challenges they face and improve their transdisciplinary collaboration. In this master thesis, we have seen several ways in which reflection could theoretically contribute to this. Let us call these the 'potential outcomes of reflection.' I will first give a recap of the potential outcomes of reflection (11.1.1) and next discuss to what degree the final reflection tool contributes to these outcomes (11.1.2). Finally, I also zoom out to discuss from a more abstract viewpoint what makes this reflection tool unique.

11.1.1 Recap: The potential outcomes of reflection on researcher-roles

This master thesis has discussed potential outcomes of reflection based on:

- Scientific literature on researcher roles (in the introduction and theoretical framework)
- The case-study at CET (in chapters 5-7)

1. <u>Potential outcomes of reflection according to scientific theory on researcher roles</u>
   As described in the problem description (section 1.1.2), scholars in scientific literature argue that researchers need to reflect explicitly on their role because they need to understand which roles they currently assume and which roles they could assume. Such an understanding can give researchers a **'language' to think and talk about roles explicitly and purposefully**. This allows researchers to:
   a) **Purposefully choose a role that helps them achieve their intended goals**
      For instance, if researchers have a change-oriented goal, they might need to adopt a different role than when they have a knowledge-oriented goal (e.g. Vinke-de Kruijf et al., 2022).
   b) **Divide roles strategically**
      Roles which are in tension with each other can be divided over multiple researchers (e.g. Bulten et al., 2021). Also, a proper role-division makes sure that each researcher has a role that connects to their skills (e.g. Hilger, Rose & Keil, 2021).
   c) **Have an open conversation about what each participant in the collaboration expects from the researcher.**

Such a conversation can reduce unrealistic and competing demands from researchers (e.g. Hilger, Rose & Keil, 2021).

2. Potential outcomes of reflection based on the case-study at CET
   The case-study in this master thesis identified challenges for students and PhD-candidates at CET who engage in transdisciplinary collaboration. Reflection on your role in transdisciplinary collaboration can help you **deal with challenges** in two ways:
   a) The challenges were to a large degree determined by *why* the CET-researchers engaged in the collaboration. A researcher who has a different intention for the collaboration often faces different challenges (see section 6.3). Therefore, reflecting on why you engage in transdisciplinary collaboration with society, helps you understand **how your intentions affect which challenges you face**. The *essence* for the reflection tool formulated 'intention' as which 'unique contribution' you pursue in collaboration with society (see section 7.1.2).
   b) An understanding of the distinct roles you could adopt allows you to think about **how adopting a different role can help you overcome the challenges you face** (reflection-on-action, following the ALACT model).

11.1.2 To what degree does the final reflection tool contribute to these outcomes?

We can now discuss to what degree the reflection tool contributed to each of the 'potential outcomes' mentioned above (1a,b,c; 2a,b) . For this, we must distinguish between the short-term effects of playing the reflection game once (which has been tested) and the long-term outcomes of integrating the reflection game in the training of students and starting PhD-candidates at CET (which has not been tested).

Short-term effect of playing the reflection game once

Let us revisit potential outcomes (1) and (2) in turn.

First, the game introduces CET-researcher to a new framework of researcher roles. **This lays the basis for a new language to think and talk about roles in transdisciplinary collaboration.** This is a direct contribution to potential outcome (1) above.

The framework *'idealized roles for scientists in decision-making',* established by Pielke (2007), is fairly known at CET. Several PhD-candidates use it in their work and the leader of the course-coordinators is familiar with it. However, the framework used in the reflection game, which is focused on *'roles of researchers in transdisciplinary research'* (Whittmayer and Schapke, 2014), was -to the authors knowledge- unknown at CET before I introduced the reflection game. This new framework is a valuable addition, as it is more geared towards knowledge co-production during transdisciplinary research than is Pielke's framework (see section 3.2.1). Also, the reflection game connects concrete actions to the five different roles, based on my operationalization of Whittmayer and Schapke (2014)'s five roles. This means that a 'language' based on this role-framework does not merely allow researchers to discuss which role they should adopt, but also how to act out this role in practice.

Playing the game once makes researchers aware that the framework of Whittmayer and Schapke (2014) exists. Through the game, researchers learn about this framework in a playful way. Because the game instruction and the action cards mention the roles of the framework, accompanied by recognizable logo's, the roles stick. I noticed during the test session that all three test participants

were curious about the action cards and the roles they connected to. After playing the game, two test participants looked through all action cards to see which actions belonged to which roles.

Second, playing the game creates an **awareness that there can be multiple suitable roles and multiple perspectives on these roles in transdisciplinary collaboration.** This is a contribution towards potential outcome (2b) above.

Experienced researchers might already have this awareness. But for students and starting PhD-candidates with little experience with transdisciplinary collaboration, being aware that multiple perspectives on roles exist is a crucial step before they can start looking at situation from multiple perspectives to see how adopting a different role could help you overcome the challenges you face.

Playing the game creates an awareness of multiple perspectives on roles because the players experience in the game that their colleagues sometimes prefer dissimilar roles in the same situation. The questionnaire at the end of the test session showed that the test participants felt like they had learned about their colleagues' preferences for contributions to transdisciplinary situation, and their colleagues' preferences for actions.

<u>Long-term outcomes of integrating the reflection game in the training of students and starting PhD-candidates at CET</u>

The short-term effects described above could be deepened by integrating the game in the course *Sustainable innovation* and in the supervision of new PhD-candidates at CET. In the following paragraphs, I do a suggestion for a concrete training session for students in the course *Sustainable innovation*. Next, I discuss shortly how CET could adapt this training session to be useful to PhD-candidates too.

Bear in mind that the course *Sustainable innovation* is for bachelor students who might never have reflected on transdisciplinary collaboration before, while starting PhD-candidates at CET have deliberately chosen for a PhD with transdisciplinary collaboration. Therefore, the training session for students includes smaller steps and more explanation and guidance than the one for starting PhD-candidates.

Students

The students could spend one session in their course on this reflection tool. It is best to do this *after* the students have formed groups for the group projects and after they have spent some time thinking about the goals of their group project. But before they have their half-course meeting with their case-owners where they discuss how they plan to tackle the case. The session could for instance be at about 1/3 of the course. In this session, a student who followed the course last year could tell something about the challenges he or she faced in the collaboration and interaction with the societal case-owners. The reflection-game could then be introduced to learn to deal with these challenges. This creates a sense of relevancy to the reflection-game. Next, the students could play the game in their groups. Situation cards should be used that describe situations that could happen in the course (based on last years' editions of the course). The course-coordinators can also change or add actin cards to make the game more relevant for the students.

After playing, an experienced moderator could start a group discussion with the whole class about what the students found challenging in the situations and how they experienced the process of

choosing actions to address the situations. The moderator could ask different groups to share which contribution they chose, and which challenges they ran into when choosing actions. The moderator then explicitly discusses that your intention (which contribution you want to make) affects which challenges you face (outcome 2a).

The moderator can then make the translation to the framework of researcher-roles: by choosing actions in the game, the students adopted dissimilar roles in the collaboration. The framework of Whittmayer & Schapke (2014) could be shortly presented. An important last step is needed. The real reflection happens when the students iterate (go through the game process again) and translate the insights from the game to practical tips they can implement in their own collaboration with the societal case-owner. I suggest doing this by letting the students make a role division in their groups. An assignment which follows the structure of the game could help the students with this. They play the game again, but now in real-life! First, the students determine which type of contribution they want to make in their collaboration with their societal case-owner (the assignment could just like in the game suggest a few options). Next, the students determine which actions they need for that (they can look at the action cards for inspiration and add their own action cards). Finally, the students discuss who would be most suitable to be responsible for each action, based on each group member's skills and preferences. They then divide the actions over the team. To close off make up the balance: who has most action related to the knowledge broker? Who has most action related to the change agent?

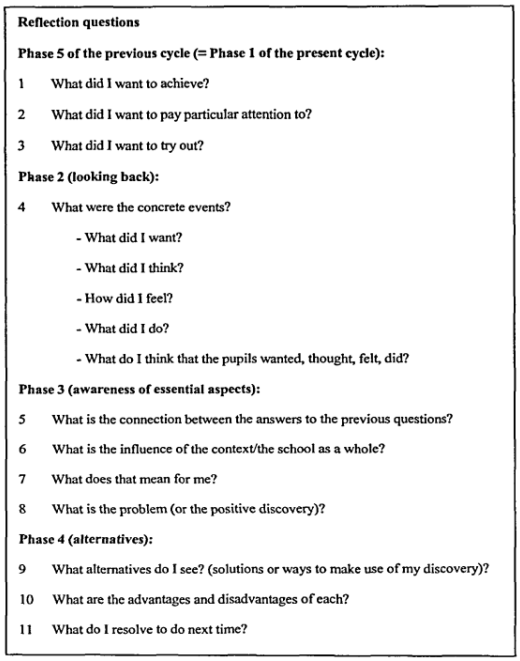
What the students have now done: they have purposefully chosen roles that help them achieve their intended goals (outcome 1a) and divided the roles strategically over the team (outcome 1b). A next step would be to discuss the contribution they want to have and their role-division with the societal case owner, to start an open conversation about what each participant in the collaboration expects from the researcher (outcome 1c).

PhD-candidates

The session for the PhD-candidates could be organized as a seminar in the time slot of the CET lunches or the work in progress meetings. The seminar could be quite similar as the session for the students but could be less structured. For instance, the moderator could take a less active role and let the PhD-candidates set their own group discussion. Moreover, since several PhD-candidates have read literature on roles of researchers in collaboration themselves, the session could be set-up more like a collaborative seminar, where multiple PhD-candidates present what they know about researcher-roles and how that relates to the situations, actions and roles in the reflection game. The assignment to divide roles in groups (like I suggested the students do at the end of their session) can be less feasible, if PhD-candidates who work on different projects visit the seminar. Instead, each PhD-candidate could be asked to present what contribution they want to have in their project, what actions connect to that and which of these actions they have the skills for themselves, and which might better be performed by others in their research-team. The other PhD-candidates can then think along in the style of the work-in-progress seminars. In this way, outcomes 1a and 1b are still achieved and the groundwork for outcome 1c is still laid.

11.1.3 Zooming out: what makes this tool different

Many reflection tools consist of a collection of reflection questions or elements you should reflect on. These often come in a list (see the images below), in the form of an assignment that asks questions, or the questions or reflection-elements can be written on cards that function as conversation starter.



Reflection questions

Phase 5 of the previous cycle (= Phase 1 of the present cycle):

1 What did I want to achieve?

2 What did I want to pay particular attention to?

3 What did I want to try out?

Phase 2 (looking back):

4 What were the concrete events?

- What did I want?
- What did I think?
- How did I feel?
- What did I do?
- What do I think that the pupils wanted, thought, felt, did?

Phase 3 (awareness of essential aspects):

5 What is the connection between the answers to the previous questions?

6 What is the influence of the context/the school as a whole?

7 What does that mean for me?

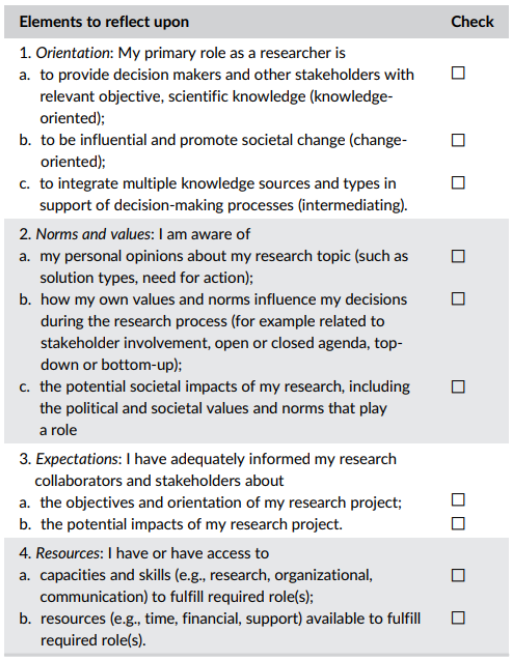
8 What is the problem (or the positive discovery)?

Phase 4 (alternatives):

9 What alternatives do I see? (solutions or ways to make use of my discovery)?

10 What are the advantages and disadvantages of each?

11 What do I resolve to do next time?



Elements to reflect upon	Check
1. *Orientation*: My primary role as a researcher is	
a. to provide decision makers and other stakeholders with relevant objective, scientific knowledge (knowledge-oriented);	☐
b. to be influential and promote societal change (change-oriented);	☐
c. to integrate multiple knowledge sources and types in support of decision-making processes (intermediating).	☐
2. *Norms and values*: I am aware of	
a. my personal opinions about my research topic (such as solution types, need for action);	☐
b. how my own values and norms influence my decisions during the research process (for example related to stakeholder involvement, open or closed agenda, top-down or bottom-up);	☐
c. the potential societal impacts of my research, including the political and societal values and norms that play a role	☐
3. *Expectations*: I have adequately informed my research collaborators and stakeholders about	
a. the objectives and orientation of my research project;	☐
b. the potential impacts of my research project.	☐
4. *Resources*: I have or have access to	
a. capacities and skills (e.g., research, organizational, communication) to fulfill required role(s);	☐
b. resources (e.g., time, financial, support) available to fulfill required role(s).	☐

Figure 11.1. Examples of reflection tools in the form of lists of questions. LEFT: Reflection question connected to the ALACT reflection model by Korthagen (1999). Meant to be filled in by a teacher-in-training alone and then discussed with a supervisor. RIGHT: The list of elements that researchers should reflect upon when engaged in transdisciplinary research projects by Vinke-de Kruijf et al. (2022).

These types of reflection tools come with shortcomings (Kinkhorst, 2010). Shortly and bluntly, these reflection tools can be boring, can feel irrelevant, can provide little help to learn about new perspectives and can be so abstract that it is hard to get concrete insights out of them. The reflection tool in this master thesis addresses many of these shortcomings.

<u>Reflection boring? This reflection game is playful and fun!</u>
Filling a questionnaire is just not very inspiring. It is purely text-based, very rational and happens in isolation of the heat of the real world out there.
The reflection tool in this master thesis takes a different approach: gamification has made the tool playful and exciting. If you just do not like reflection, you can play because you want to win! Or because you like the design of the game. Or because you want to join the excitement of your co-players. The use of lively descriptions of real-world situations and images triggers the players to *imagine* they are in the given situation and triggers their intuition and creativity.

<u>Reflection feels irrelevant? This reflection game helps you reflect on situations relevant to you!</u>
Reflection assignments and lists of reflection questions are often administered at the end of a big activity (a finished course, a finished research projects) and thus used to look *back* on something that has already happened. The person reflecting consequently does not see how the reflection will be useful in the future and does thus not see the relevance of the reflection. Moreover, looking back at things that are already finished means that there is no new catalyzer of new thoughts. Reflection

requires *cognitive tension*: a new experience or ideas spurs you to think about the why and the how or to improve the situation. Reflection after the actions has already cooled down is devoid of this cognitive tension. Therefore, Kinkhorst (2010) suggests connecting reflection to recent meaningful experiences and goals that the reflecting person wants to achieve. The reflection game in this master thesis does this by using situation cards. In this way, you reflect in the heat of the game instead of afterwards: the situation in front of you is new to you and has not been solved yet! Moreover, the situation cards describe situations that are similar to situations that PhD-candidates or students have actually faced in real-life, and the game gives you the option to add your own situations, for example a problem you faced very recently and want to find a solution to. The player can thus use the game to reflect on a specific situation they want to learn more about.

Reflection questions provide little help to look at things from a new perspective? This reflection game makes you learn about the perspectives of your colleague-researchers in a fun way!
Good reflection questions can trigger you to think from a new perspective. However, when answering questions alone, or with the help of a supervisor, you are inevitable bound by the boundaries of your own thinking. The reflection game in this master thesis builds strongly on discussions between multiple researchers. In this way, players learn about new perspectives from other people. Moreover, the game gamifies especially the *discussions.* Because you can earn points by convincing your co-players of your standpoint, the game gives you an incentive to share your thoughts. This incentivizes people to make their implicit assumptions and ideas explicit and share them with the others.

Reflection is vague? This reflection game tells you exactly what to do!
Reflection assignments and lists of reflection questions are often abstract, vague and have little guidance on how to use them. This makes it unclear what the reflecting person must precisely do and what the result should look like. The reflection thus presents a large cognitive load, and the reflecting person gets demotivated (Kinkhorst, 2010). This reflection game has a clear structure. The game instructions tell you precisely what to do for each step of the game. The questionnaire results at the end of the test session show that the test participants indeed found the game easy to learn and play. The rigid structure goes at the cost of some flexibility. The flexibility, however, is in the cards. You must choose between multiple contributions, and you can choose from multiple actions. These present endless combinations for which you could argue. What could be a challenge with this reflection game is to retain the insights from the game and translate them to future situations. A reflection assignment is better at this, because it forces you to write down your reflections in a structured way. For this reason, I suggested to integrate the use of this reflection tool in larger testing sessions, where the structure of the game is used to make concrete role-divisions in teams (which you write down and thus retain). See section 11.1.2.

11.2 Secondary contributions

The reflection tool is the main contribution of this master thesis. However, there were two secondary aims:

- **Generating insights useful for CET** (even when you do not play the game)
- **Theory building** about researcher roles in transdisciplinary collaboration

11.2.1 Generating insights useful for CET

<u>The old ways are mixing with new approaches</u>

In 2018, Haarstad and eight colleagues described the three 'modes of engagement' of CET-researchers in society (Haarstad et al., 2018). Even though CET now houses many new PhD-candidates and students in the Collaboratory, the modes of 2018 can still resurface clearly in my research results. The course *Sustainable innovation* in the Collaboratory, lead by Grandin, teaches students to 'critically reframe discourses'. This mode was indeed Grandins main contribution to the article in 2018. Many of the PhD-candidates, however, aim for the other two modes: 'connecting actors and processes' and 'producing and situating actionable knowledge'. *For more information, read section 5.3.*

At the same time, the PhD-candidates who were not involved in the article in 2018 (mostly PhD-candidates who came to CET after that time), connect new meanings to transdisciplinary collaboration. One respondent imagined creating a 'mini society' which is a full representation of society, another wanted to put use to their previous experience with giving low-power actors a stage but doubted if co-production like CET normally does is the adequate form for that, yet another took the initiative to bring municipal civil servants together, even though this was not part of their PhD.

<u>The old group of transdisciplinary-enthusiasts is slowly being replaced by a more dynamic and fragmented group of transdisciplinary CET-researchers</u>

The article in 2018 formed a focal point for the strategy for actionable knowledge production at CET and inspired the transdisciplinary collaboration currently happening in the course *Sustainable innovation*. Since that time, many of the writers have left CET and new PhD-candidates have started. More than half of the newcomers are now engaging in transdisciplinary research with enthusiasm. However, it is my experience that they are not fully aware of the plurality of motivations, assumptions and approaches towards transdisciplinary research that live at CET. For example, many PhD-candidates might not know what happens in the course *Sustainable innovation*, while this is an interesting breeding ground for transdisicplinary approaches and transdisciplinarity enthusiasts. Moreover, a few of my respondents shared unique ideas about transdisciplinary research, sometimes inspired by foreign cultural contexts, that I did not hear about from anyone else. I realize there is a lot of interaction going on at CET which I have not investigated for my thesis. For example, two PhD-candidates in different projects are currently writing an article together about researcher roles in transdisciplinary research. However, the fragmentation of ideas I noticed in the interviews could mean that both the old and the new CET'lers still miss unique opportunities to enrich their perspective on transdisciplinary collaboration. I therefore suggest letting PhD-candidates explicitly interact about this. The reflection tool I developed for this master thesis is a concrete contribution to that and I hope it sparks further conversation. But here also lies a role for the leadership at CET in facilitations of these discussions. The director of CET is aware of this.

The course *Sustainable innovation* and the Collaboratory can form an experimental ground for teaching transdisciplinarity

Sustainable innovation received an award for being innovative education because it puts students in the driving seat of their education. However, another unique aspect of the course might be undervalued: it is an experimental ground for teaching transdisciplinarity. Several of the challenges that the students and course-coordinators face in the course are similar to challenges the PhD-candidates at CET face in their transdisciplinary collaboration. Learning to cope with these challenges can thus prepare students for a transdisciplinary career: when they write their master thesis in the CET reading room, when they organize the Bergen international student conference of the Collaboratory and who knows when they become a PhD-candidate at CET? I think both PhD-candidates and students (including student course-coordinators) can learn valuable thing from each other. *For an overview of similarities between challenges for PhD-candidates and students, read section 6.3.1.*

11.2.2 Theory building

Roles of researchers (SQ1)

Based on the results of sub-question 1, I suggested connections between the 'modes of engagement' of Haarstad et al. (2018) and the five researcher roles of Whittmayer & Schapke (2014). *For more information, read section 5.3.*

Table 11.1. Modes of engagement in climate and energy transformations (Haarstad et al. 2018) connected to roles of researchers in transdisciplinary collaboration (Whittmayer & schapke, 2014).

Mode of engagement	Objective of this mode of engagement	Required behavior	Related researcher-roles
Producing and situating actionable knowledge	Generating insights and facts that can catalyze change and positioning it in contexts where they can influence particular sustainability transformations	- co-producing knowledge - tailoring knowledge production and communication to specific contexts	- Reflective scientist - Knowledge broker
Critically reframing discourses	Identifying novel approaches to problems, envisioning new solutions, and enlarging the space for possibilities	- co-producing knowledge - opening up the discussion and reframing the discourses of the societal actors	- Reflective scientist - Change agent
Connecting actors and processes	Connecting fragmented processes, disconnected policy networks, governance agents, or stakeholders	- bringing actors from different governance levels and networks together - facilitating learning between them	- Process facilitator - Process facilitator

Challenges related to roles of researchers (SQ2)

Based on the results of sub-question 2, I compared the challenges identified at CET with challenges for transdisciplinary researchers in the literature. Several of the tensions between researcher-roles as established by Bulten et al. (2021) were verified in the CET-context. Also, several of the challenges related to knowlegde-, change- and intermediary-orientations, as established by Vinke-deKruif et al.

(2022), were verified in the CET-context. Finally, I made my own categorization of literature on mismatches in expectations during transdisciplinary research: 1) Quick fixes versus learning processes, 2) Objectivity versus applicability and 3) Facilitator versus participant. Categories 1 and 3 were verified in the CET-context. *For more information, read section 2.2.3 in the theoretical framework and section 5.4.2 in the discussion of sub-question 2.*

11.3 Discussion of the methodology

11.3.1 A complex research for only 15 EC

This research has applied a relatively large number of literature reviews, data collection, data analysis and design methods for the limited time it was conducted in. This allowed me to make a detailed operationalization of researcher-roles, to apply method triangulation, to let theory and practice interact and to involve a wider range of perspectives in the design process. These elements in the researched increased the reliability and validity of the research, as we will discuss below.

The large number of methods and steps, however, made for a complex research for only 15 EC. This led to some time-shortage, forcing me do some concessions to my original research design, that in turn decreased the reliability and validity of this research. We will also discuss this below.

11.3.2 Discussion of the use of scientific literature

Theory on researcher-roles

The case-study started with a strong basis in scientific literature. First conceptualizing transdisciplinary collaboration and then analyzing several strands of research allowed me to choose an analytical framework of researcher-roles that best suited for the transdisciplinary collaboration that happens at CET. This was important for the validity of the analytical framework. Moreover, by operationalizing the roles in detail, they became so concrete that I could reliably categorize to which roles the behaviors discussed in the interviews belonged. The literature review on researcher roles was structured and elaborate, so as to ensure that I had included all relevant literature on the topic.

If I had chosen a different framework of researcher-roles, my research and the final reflection tool would have ended up quite differently. For instance, with the framework of Pielke (2007), the reflection tool would have been focused more on science communication to policy spheres and policy advice, rather than the integrative co-production processes going on during the collaboration. With the choice for this framework, the tool is useful for reflection on the researchers' role in interpersonal interaction and learning processes, and not on the researchers' role in the design of transdisciplinary research programs, policy advice, citizen science etc. Future research could assess whether frameworks of researcher-roles with a different focus would lead to new useful insights for research centers like CET. However, I think the framework I chose is the best focus for CET, as it connects well to the type of transdisciplinary collaboration that happens at CET, and because the framework is new to CET, meaning it provides a new language to reflect on researcher roles.

Theory on reflection

For the theory on reflection, I also conceptualized reflection in detail and operationalized this in the context of CET. This allowed me to draft design principles with which I could assess how well the prototypes performed on different aspects of reflection. This increased the validity of the research: I

made sure that the reflection tool built on aspects of reflection that are well established in the literature on reflection. The theory on reflection was gathered in a less structured way than the theory on researcher roles, however, and I did less effort to consider multiple reflection models and find the one best suited for CET. This was because my master CDI already taught me a lot about reflection: my own conception of reflection was already steered in a certain direction. Moreover, I had planned less time for the design phase of the research, meaning I had less time to consider multiple reflection models. The effect of this is that I am not sure if there would have been a better reflection model to base the reflection tool on – I do not know if the reflection model I used (the ALACT reflection model) is the most valid reflection model. Further research could assess if additions from other models would improve the ability of the reflection tool to meet the goals for the reflection (as discussed in section 11.1).

11.3.3 Discussion of the data collection methods in the case-study

Method triangulation

During the case-study at CET, I applied method triangulation. The methods complemented each other. For instance, the interviews are susceptible to socially desirable answers and other interaction effects. Logbooks are free of these effects but lack the ability to answer probing questions to go into more depth, which is in turn a strength of interviews. Moreover, interviews and logbooks have an individual focus, while focus groups allow participants to challenge each other's ideas. For more information about the reasons why I chose these methods, see the methodology. The method triangulation increased the reliability of the research as I could cross-check whether findings held up under interviews, logbooks and focus groups. I did this especially for the challenges (sub-question 2). Moreover, I took great care to apply the exact same coding method and structure of mental maps, to upkeep reliability. Finally, because drafting mental maps included a lot of my own interpretation, I asked some respondents to check my discussion of their views in the results chapters, where I thought there could be a risk I misinterpreted their views.

Data gaps

A limitation in my methods was that not all respondents participated in all data collection methods. A cause of this was that the CET-researchers are busy and have a high workload, making it hard for them to join sessions during work time. Moreover, I think I could have explained the purpose and the expected outcomes of my research better at the start (at the interview), so the respondents would be more convinced that participating in the research would be useful for them. The missing respondents led to data gaps. In the case-study, the gaps are limited (I still had at least 2/3 of the PhD-candidates who were engaged in transdisciplinary collaboration in each method). Also, the effect is mitigated because the interviews, logbooks and focus groups complemented each other (so I could use interview data to fill in missing focus group data). Nevertheless, the data gaps could have caused that the case-study is slightly skewed towards the perspective of the respondents who were most active in the data collection. In the results section, I tried not to generalize their input to the whole group of respondents. Section 3.2.3 shows which respondents participated in which data collection methods. Further testing of the tool with varying respondents in follow-up research and iterating on the design could mitigate this shortcoming.

Interviews

Another limitation related to the interviews. The first sub-question was about how CET-researchers *conceive* their role in transdisciplinary collaboration. I ask them to describe their role with open questions, but this often led to answers that were only partly related to what I meant by 'role'. Therefore, I also spent time in the interview to look at a list of actions (form the operationalization of

the analytical framework) and let the researchers say for each action if they performed that action in the collaboration. I asked what their motivation was to do this and what they thought the effect of this was on the collaboration. By looking at motivations and expected effects, I could see which actions the respondents saw as most important to reach their goals, as a proxy for how they conceived their role. In some case, however, I ended up gathering more information on which actions they *performed* (and to which role that relates), than about how they *conceived* their role. This led to some results describing what roles they performed then how they conceived these roles, lowering the internal validity of my research somewhat. However, not having followed this procedure could have resulted in not gathering little data that was actually related to the focus of my analytical framework. Thus, it was an 'offer' worth making. To mitigate this shortcoming, I tried to describe very clearly in the results chapters which results were related to what activities the researchers *performed* and which results were related to how researchers *conceived* their role. In this way, the reader can at least follow very well what the results actually say.

Related to sub-question 2, Some challenges mentioned by the course-coordinators did not relate to transdisciplinary research per se. I nevertheless included these challenges in the results, because they were aggravated by the transdisciplinary context of the course and were therefore worth reflecting on. I indicated in the results section which challenges these are, because they

Logbooks
It must be noted that the method 'logbook' was new to me. This method increased the validity of my data collection, as it allowed me to gauge the thoughts of the interviewees 'in the heat of the moment' (just after a transdisciplinary activity happened). However, because it was my first time using them, I made some choices in their design that lead to limited results. The reflection in the logbook were superficial and limited. This was caused by the fact that I tried to keep it short to use and because, looking back at it, I structured it too much. To mitigate this shortcoming in the logbooks, I only used insights from the logbooks, if these were clearly also supported by the interviews. Moreover, the answer to sub-question 1 leans much more on the interviews than on the logbooks.

Ethics (data management and informed consent)
Explicit informed consent was given by all respondent to all data collection and design sessions. The data management procedure and the procedure for asking for informed consent is discussed in detail in the methodology, sections 4.3 and 4.4. (each method contains a subsection on data management and consent). See appendix 6 for the consent forms.

11.3.4 Discussion of the design methods

The design phase of this research was an interaction between theory and practice, as is common in design-based research. This was meant to ensure that that the tool was both valid from a theoretical perspective (it engaged with aspects of reflection that are well-established in the literature, see 11.3.2 above) and valid from a practice-perspective (it is suitable for solving the practical challenges of CET-researchers, see the discussion below).

I attempted to enrich the design in two ways to come to a valid and useful reflection tool. Firstly, I attempted to use divergent (out-of-the-box) thinking to come with a tool that addresses the identified challenges in an innovative way. Secondly, I attempted to involve the research respondents in the design (participatory design), to contribute to the validation in practice (as mentioned above) and to adapt the tool to the preferences of the end-users. Let us discuss for each of these to what degree I succeeded.

Note that the above design characteristics (divergent thinking and participatory design) relate to the validity of the design *methods.* In section 11.1 you have already read a discussion of the validity of the *final product* (to what degree does the final reflection tool achieve the goals for which it was designed?). At the end of this section, we will also shortly reflect on the *external validity of the final tool* (how generalizable is it to other contexts than CET?).

Divergent thinking

To come with new ideas and think out of the box, I used several brainstorming techniques. This was a challenging yet exciting part of the research for me, as I feel more comfortable with convergent thinking than with divergent thinking. Especially the analogies helped me to really think creatively: the entourage of the game (CET'lers step out in society and try to transform society) was inspired by the idea that you are allowed to think big and dream about your ideal impact, which was one of the take home messages after thinking of analogies. The decision narratives helped to imagine how the tool could create a new practice, where new CET-researchers are actively engaged in the conversation at CET and start reflecting on their ideal contribution from in society from early in their PhD, or even before, as students. Nevertheless, half of my 'brainstorming' practices built on my previous experience with reflection tools and the theory on reflection, which I defined somewhat narrow, see 113.1. This is very visible in the end-result: the game is a semi-character-based card game. This is precisely the type of reflection tool I already had quite some experience with. In this sense, the final tool might be more a product of 'me' than a product of divergent out-of-the-box thinking. Nevertheless, I do not think this is a problem per se, as this 'me' way of building a reflection tool is quite different from what the people at CET are used to. I built the tool on a role-framework they were not familiar with. I broke with the typical reflection assignments and questions lists and I added a playful, interactive element to the game to create lively discussions (lively discussions and interactions are -in the stereotype view- things Norwegians are not the best at initiating out of themselves). In this sense, the tool might not be far out of my box but is certainly far out of CET's box.

Finally, it must be noted that because the brainstorming built strongly on my personal intuition, creativity and experience with reflection, this process is not reproducible, and might have happened differently if I were in a different context, or even in a different mood (so also, not very reliable). Reliability and reproducibility are, however, not per se the goals of open brainstorming. Moreover, I tried to explain my brainstorming process in detail, so the reader can at least follow what I did.

Participatory design

The design in this research was mostly done by me and included some participatory design. For instance, the whole design process was based on an assessment of the challenges that the respondents face in transdisciplinary collaboration. This can be described as 'design for users' (Kalmar & Stenfert, 2020). Moreover, two of the three methods in the solution design phase included participation of researchers (the prototype evaluations and the test session). Nevertheless, only a few respondents participated in the participatory design and their involvement in the design process itself was limited. Rather, they gave input in prototypes and tested the final tool. Therefore, some activities happened at the level of 'design with users', but the active participation was limited.

Involving the respondents more in the design could have led to a final tool that was better validated in practice, even nicer to work with for a larger range of people at CET, and more supported by the CET-community. I see a few areas where I could have involved respondents more if I -and especially if they- had more time. These could be areas interesting for follow-up research or future design projects related to reflection on researcher-roles. Firstly, I could have asked more questions in interviews and focus groups to find out how CET-researchers currently reflect on transdisciplinary collaboration. Because I asked only few questions about this, I have missed the chance to build my

reflection tool on the reflection practices already happening. Secondly, I could have organized a separate design session in which the participants engaged in design exercises in mixed groups. Here, I would provide the CET-researchers with the results of my case-study and design tools, to facilitate them in their creative thinking about solutions. This would constitute an element of 'design by users', where the designer (me) is rather a facilitator while the end-users (the CET-researchers) actually do the design (Kalmar & Stenfert, 2020). The results of this session could have led to prototypes, which I could have broadened further with brainstorming techniques and assessed according to the design principles I drafted for the final reflection tool. Thirdly, I could have involved more participants in the prototype evaluation session and test session, or I could have organizes multiple test session to iterate the design further.

External validity of the final reflection tool

This research was strongly embedded in the CET-context, making the external validity low. I knew all the respondents before the first data collection (apart from respondent 7) and they had told me things about transdisciplinary collaboration at CET before I started data collection. This means that I probably used their informal input unconsciously in analyzing my results. Moreover, I chose deliberately to make a reflection tool that is tailored to the CET context, thus losing general applicability. This tailoring to the CET-context happened by making the design principles specific to CET, by basing the title and the "story" in the introduction of the game on CET and by basing situation cards on situations that CET researchers had actually faced. Most importantly, the game builds on a framework of researcher-roles that has been specifically chosen for CET. To apply this reflection tool in a new context, one would have to reconsider if the role-framework is also suitable in that other context. Altogether, the results and the reflection tool in this master thesis cannot be generalized to other contexts without extreme caution. I tried to indicate this clearly by making context-related claims in the conclusions such as 'I verified the theory in the CET context' instead of 'I verified the theory' and referring to 'the' students and 'the' PhD-candidates 'at CET' in my results, instead of to transdisicplinary researchers in general.

There is some contextual flexibility possible in the reflection too, however. The situation cards in the reflection tool can be tailored to new contexts while the rest of the reflection tool stays the same. I built in this flexibility, because the students and the PhD-candidates operate in slightly different contexts and thus require different sets of 'challenge' cards.

11.4 Suggestions for further research

The discussion of the methods already did some suggestions for further research. Let us now close off the thesis by summarizing these suggestions.

First of all, the reflection tool could be implemented at CET and tested further with varying respondents, This would allow for increasing the participatory nature of the design, further iterating on the design, improving the practical validity and usability of the tool and smoothing out data gaps.

Second of all, additional research on reflection on researcher-roles could consider assessing different frameworks of researcher roles. For example the roles of Pielke et al., 2007, which have the advantage of being known to more researchers worldwide; or the 15 roles of Hilger, Rose & Keil (2021), which have the advantage that they are more precise and specific than the 5 roles considered in this research.

Third of all, further research could assess if additions from other reflection models than the one used in this research (the ALACT model) would improve the ability of the reflection tool to help researchers reflect on their role in transdisciplinary collaboration. This research is needed to fill the research gap on how beginning can be trained in and helped to reflect on transdisciplinary collaboration.

Fourth of all, as a further specification of the previous point, the potential to prepare students for a later transdisciplinary research career remains under addressed. How can master courses be designed in such a way that students learn the skills to address the challenges identified in this research and in the literature? The use of gamified tools to learn about researcher-roles in a fun and accessible way could be a good first step.

Helping the academic changemaker reflect on their role in transdisciplinary collaboration – it is an important step towards creating more conscious and purposeful collaborations with the ability to transform society in the face of climate change.

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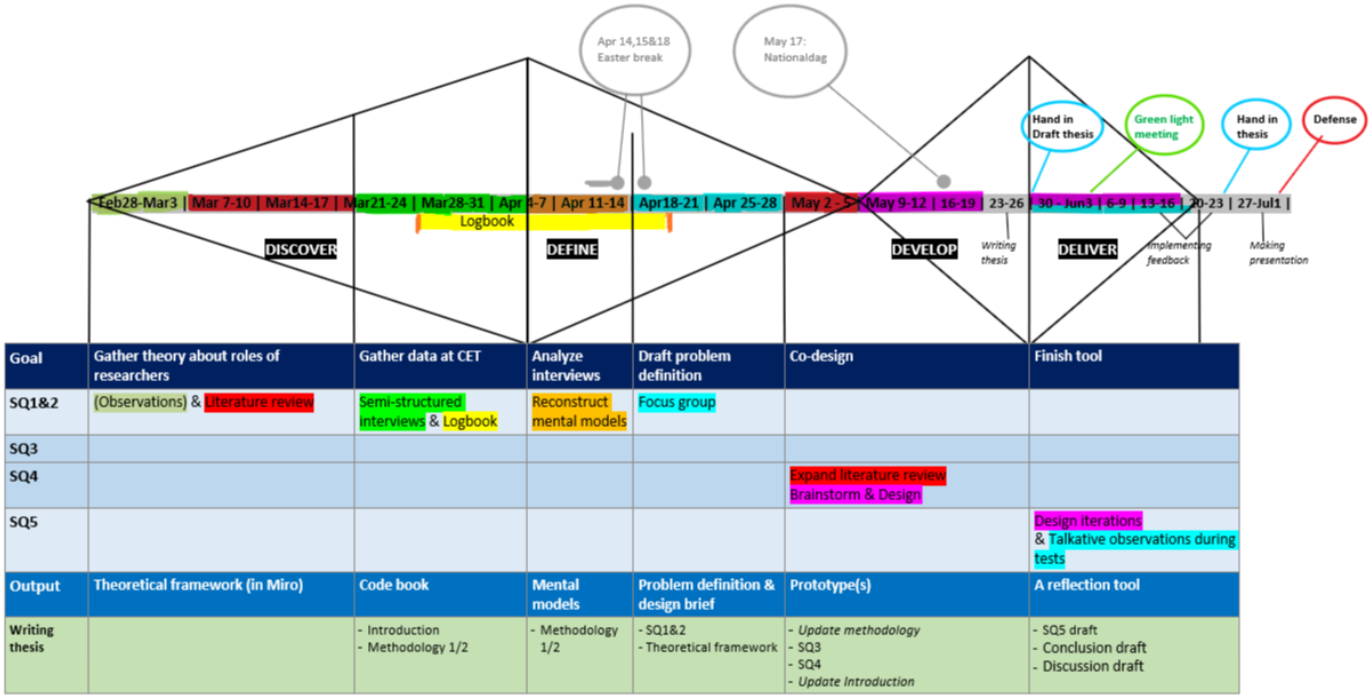
Appendix 1. Detailed Planning

See the research planning in figure A1 below. Table A1 shows the major risks of this planning with mitigation options.



Goal	Gather theory about roles of researchers	Gather data at CET	Analyze interviews	Draft problem definition	Co-design	Finish tool
SQ1&2	(Observations) & Literature review	Semi-structured interviews & Logbook	Reconstruct mental models	Focus group		
SQ3						
SQ4					Expand literature review Brainstorm & Design	
SQ5						Design iterations & Talkative observations during tests
Output	**Theoretical framework (in Miro)**	**Code book**	**Mental models**	**Problem definition & design brief**	**Prototype(s)**	**A reflection tool**
Writing thesis		- Introduction - Methodology 1/2	- Methodology 1/2	- SQ1&2 - Theoretical framework	- *Update methodology* - SQ3 - SQ4 - *Update Introduction*	- SQ5 draft - Conclusion draft - Discussion draft

Figure A1: Detailed planning of the research process.

Table A1: Risks in the research design and mitigation options.

Date	Sub-question	Method	Risk	Proba-bility	Impact	Mitigation
Mar 3, Mar 7-14	1. Roles of researchers 3. Reflection	Literature review				
Mar 17 Mar 21	1. Roles of CET-researchers 2. Challenges	Prepare logbook	Too few fill in logbook	Medium	Medium	*Prevention:* Send reminder halfway
Mar 24 Mar 28-31 Apr 4-6	1. Roles of CET-researchers 2. Challenges	Semi-structured interviews	PhD-candidates have no time	Low	High	*Prevention:* Ask long in advance (March 14) Long time window (2 weeks)
			PhD-candidate's have little experience with co-production the > interviews lead to few deepening insights	Medium	Medium	*Prevention:* Interview experienced co-producers for input. *Back-up*: April 4-12
April 4-7 April 11-13	1. Roles of CET-researchers 2. Challenges	Analyse interviews	Few relevant insights can be identified from the interviews	Low	High	*Back-up:* Fill in gaps with theory
Between Apr 18 and Apr 21 (back-up: Apr 25-27)	1. Roles of CET-researchers 2. Challenges	Focus group	Not enough PhD-candidate's show up Course coordinators cannot / do not want to join	High	High	*Prevention:* Ask Havard and Janne to promote for me. Ask for availability after each interview *Back-up:* Split up in two groups

Appendix 2 Interview protocols

Interview protocol A (PhD-candidates)

Interviews for Master thesis of Joran Buwalda about transdisciplinary collaboration

Introduction to the interview [7 min]

- ***Thank interviewee for making time for this interview***
- ***Introduce myself***
- ***Announce topic & structure of interview:***

This interview is for my master thesis. I study Science communication and my research focuses on collaborations between academic researchers and people outside academia. I will refer to these collaborations as 'transdisciplinary collaboration'. As in *trans*cending beyond academia by involving societal actors in the research. I am trying to find out how researchers think about their role in these kinds of collaborations. With the term 'researchers', I mean academics whose primary job it is to do scientific research.

I would like to ask you a few questions about how you think about transdisciplinary collaborations and about the roles you adopt in them as a researcher.

The questions in this interview are divided in three parts. We will start with some general questions about the transdisciplinary collaboration(s) you are, have been or are planning to be part of. These questions will give me some background information which helps me to understand your answers to the following questions. Next, we will discuss in more detail your role as a researcher in these collaborations. Finally, I would like to zoom out to discuss how you think your role affects the other participants in the collaboration.

- ***Ask consent for recording the interview***.
  This interview is anonymous in the sense that I will not use your name or any other personal identifiers in my master thesis report. However, I will include a transcript of this interview in the appendix to my master thesis and I will describe quotes from this interview in my thesis report. Due to the small team at CET, it is possible that readers familiar with the CET-context can trace your statements back to you. Therefore, I cannot guarantee full anonymity.

  Do you give your consent for recording this interview and using quotes from this interview you in my master thesis?

- *If consent: Start recording & repeat consent on the recording.*

General questions about your transdisciplinary collaboration [8 min]

Could you tell me something about the transdisciplinary collaboration you are involved in?

Follow-up questions (if interviewee doesn't already answer them):

- Could you describe the project that the collaboration belongs to?
- What is the time horizon of this project?
- How is this collaboration contributing to the project?
- Who participates in the collaboration? For example: how many people and what kind of people?
- Could you describe how often the participants meet and how they met?
- What is your motivation to participate in this collaboration?

Questions about your role in this collaboration [15 min]

This part of the interview consists of five main questions.

Could you describe your role(s) in the collaboration?

Follow-up questions (if interviewee doesn't already answer them)

- What are your formal tasks in this collaboration?
- did you end up doing in the collaboration?
- Could you shortly describe a concrete example of how this role played out?
- Does your role change, for instance depending on the circumstances?

I am interested in what your motivation is to adopt this specific role(s). Could you elaborate on that?

Follow-up questions (if interviewee doesn't already answer them)

- Did you choose this role(s) yourself?
  - If Yes: - Did you discuss this choice with anyone?
  - If No: - Who told you to adopt this role?
    - What do you think about being given this role?

I would like to name a few activities that a researcher could hypothetically perform in a transdisciplinary collaboration.
Could you tell me for each activity whether you perform this activity in the collaboration? And if yes, could you shortly describe a personal example of this activity?

- Gathering and analyzing scientific theory and data from interviews, surveys, documents, discourse analysis etc. to produce scientific knowledge related to the topic of the collaboration
- Gathering information about societal processes, for example by reading policy documents, by observing societal events, or by talking to the non-academics in the collaboration
- Presenting scientific knowledge to the other participants
- Re-wording research findings so that the other participants might easier understand the findings
- Looking for or translating scientific insights that you think will be directly useful to the other participant's daily practice
- Linking the other participants in the collaboration to scientists in your network
- Locating and inviting participants to the collaboration

- Organizing meetings (e.g., communication about meeting, organizing location or lunch)
- Leading meetings
- Encouraging that everyone expresses their opinion during meetings
- Encouraging other participants to address local sustainability challenges (also outside this collaboration)
- Voicing your concerns to other participants about current societal processes around sustainability
- Voicing your concerns to other participants about their role in sustainability issues
- Thinking along towards practical solutions for the sustainability challenges of the other participants
- Networking with non-academic people outside this collaboration
- Observing silently how the others collaborate
- Writing fields notes or research diaries about the collaboration process (so not about the content of the research)
- Talking to colleague-researchers about your and their interaction with the other participants
- **Are any activities missing?**

What is your motivation for performing these activities?

Follow-up questions (if interviewee doesn't already answer them)

- Did you choose these activities yourself?
  If Yes: - Did you discuss this choice with anyone?
  If No: - Who told you to perform these activities?
  - What do you think about being assigned these activities?
- Which activities do you prefer and why?

Could you shortly describe whether you encounter any challenges in adopting the role and performing the activities we just discussed?

Questions about the effect of your role on the other participants in the collaboration [12 min]

The final three questions depart from the assumption that participants in a collaboration influence each other. I am curious how you think your role influences the other participants in the collaboration. These final questions are rather open and maybe difficult to answer. Please remember that there is no right or wrong here. I am just curious how you think about the matter.

Could you shortly reflect on how you think your role influences the other participants in the collaboration?

Follow-up questions (if interviewee doesn't already answer them)

- You mentioned that you [perform activity X]. Can you shortly reflect on how that activity might influence the other participants in the collaboration?

One aspect of a transdisciplinary collaboration could be a learning process. Participants to the collaboration could learn from each other. They could for example gain new knowledge and skills. But learning could theoretically also lead to participants changing their behavior, their underlying assumptions or even how they try to control their surroundings.

Could you elaborate what kind of learning processes happen in the collaboration?

Follow-up questions (if interviewee doesn't already answer them)

- Who is learning?
- What is this person learning (knowledge, skills, behavior change, assumption change, change in controlling surroundings)?
- Can you give an example?
- Which learning process do you think is most important?

Could you shortly reflect on how you think your role influence these learning processes?

Follow-up questions (if interviewee doesn't already answer them)

- You mentioned that you [perform activity X]. Can you shortly reflect on how that activity might influence the learning processes in the collaboration?

Closing off the interview [3 min]

- *Thank interviewee for the interview.*
- *Explain that I will organize a **focus group**. Invite the interviewee for the focus group / ask for availability*
- *Explain that I will make a **logbook**. Invite interviewee to fill it out (I will send it via email or give it physically now)*

Interview protocol B (Students)

Interviews for Master thesis of Joran Buwalda about transdisciplinary collaboration

Introduction to the interview [7 min]

- ***Thank interviewee for making time for this interview***
- ***Introduce myself***
- ***Announce topic & structure of interview:***

This interview is for my master thesis. I study Science communication and my research focuses on collaborations between academic researchers and people outside academia. I will refer to these collaborations as 'transdisciplinary collaboration'. As in *trans*cending beyond academia by involving societal actors in the research. I am trying to find out how academics, like you, think about the role of researchers in these kinds of collaborations. With the term 'researchers', I mean academics (students or paid researchers) whose primary job / training it is to do scientific research.

I would like to ask you a few questions about how you think about the collaboration between your students and the societal case owners they do a project for, as well as about the roles your students adopt in these projects.

The questions in this interview are divided in three parts. We will start with some general questions about the student projects. These questions will give me some background information which helps me to understand your answers to the following questions. Next, we will discuss in more detail the role your students have in these collaborations and what your influence as course organizers is on that role. Finally, I would like to zoom out to discuss how you think the student's role affects the interaction with the case owners.

** Interviewees have been selected based on the criterium that they are, have been or are planning to be part of transdisciplinary collaboration.*

- ***Ask consent for recording the interview***.
  This interview is anonymous in the sense that I will not use your name or any other personal identifiers in my master thesis report. However, I will include a transcript of this interview in the appendix to my master thesis and I will describe quotes from this interview in my thesis report. Due to the small team at CET, it is possible that readers familiar with the CET-context can trace your statements back to you. Therefore, I cannot guarantee full anonymity.

  Do you give your consent for recording this interview and using quotes from this interview you in my master thesis?

- *If consent: Start recording & repeat consent on the recording.*

General questions about your transdisciplinary collaboration [8 min]

Could you tell me something about the projects your students are involved in?

Follow-up questions (if interviewee doesn't already answer them):

- Could you describe the course that the projects are part of?
- How are the projects contributing to the course goals?
- Who participates in the collaboration? For example: how many people and what kind of people?
- Could you describe how often the students meet with the societal case owners and how they met?
- What is your motivation to be course organizer?

Questions about your role in this collaboration [15 min]

This part of the interview consists of five main questions.

Could you describe the role of the students in the collaboration?

Follow-up questions (if interviewee doesn't already answer them)

- What are their formal tasks in this collaboration?
- What do they end up doing in the collaboration?
- Could you shortly describe a concrete example of how this role played out?
- *Does their role change, for instance depending on the circumstances?*
- To what degree are the students free to shape this role themselves?
- To what degree do you as course organizers determine their role?

If course organizer sees her/himself as (partially) determining the role of the students:
I am interested in your motivation for asking the students to perform this role. Could you elaborate on this?

I would like to name a few activities that a student could hypothetically perform in a transdisciplinary project.
Could you tell me for each activity whether your students perform this activity in the collaboration? And if yes, could you shortly describe a personal example of this activity?

- Gathering and analyzing scientific theory and data from interviews, surveys, documents, discourse analysis etc. to produce scientific knowledge related to the topic of the collaboration
- Gathering information about societal processes, for example by reading policy documents, by observing societal events, or by talking to the non-academics in the collaboration
- Presenting scientific knowledge to the other participants
- Re-wording research findings so that the other participants might easier understand the findings
- Looking for or translating scientific insights that you think will be directly useful to the other participant's daily practice
- Linking the other participants in the collaboration to scientists in your network
- Locating and inviting participants to the collaboration

- Organizing meetings (e.g., communication about meeting, organizing location or lunch)
- Leading meetings
- Encouraging that everyone expresses their opinion during meetings
- Encouraging other participants to address local sustainability challenges (also outside this collaboration)
- Voicing your concerns to other participants about current societal processes around sustainability
- Voicing your concerns to other participants about their role in sustainability issues
- Thinking along towards practical solutions for the sustainability challenges of the other participants
- Networking with non-academic people outside this collaboration
- Observing silently how the others collaborate
- Writing fields notes or research diaries about the collaboration process (so not about the content of the research)
- Talking to colleague-researchers about your and their interaction with the other participants
- **Are any activities missing?**

To what degree are the students free to choose these activities themselves?
- To what degree do you as course organizers determine these activities?

If course organizer sees her/himself as (partially) determining the role of the students:
What is your motivation for asking the students to perform these activities?

Questions about the effect of your role on the other participants in the collaboration [12 min]

The final three questions depart from the assumption that participants in a collaboration influence each other. I am curious how you think the role of the students influences the other participants in the collaboration. These final questions are rather open and maybe difficult to answer. Please remember that there is no right or wrong here. I am just curious how you think about the matter.

Could you shortly reflect on how you think the students' role influences the collaboration with the case-owners?

Follow-up questions (if interviewee doesn't already answer them)
- You mentioned that the students [perform activity X]. Can you shortly reflect on how that activity might influence the collaboration with the case-owners?

One aspect of a transdisciplinary collaboration could be a learning process. Participants to the collaboration could learn from each other. They could for example gain new knowledge and skills. But learning could theoretically also lead to participants changing their behavior, their underlying assumptions or even how they try to control their surroundings.

Could you elaborate what kind of learning processes happen in the collaboration?

Follow-up questions (if interviewee doesn't already answer them)

- Who is learning?
- What is this person learning (knowledge, skills, behavior change, assumption change, change in controlling surroundings)?
- Can you give an example?
- Which learning process do you think is most important?

Could you shortly reflect on how you think the role of the students influences these learning processes?

Follow-up questions (if interviewee doesn't already answer them)

- You mentioned that the students [perform activity X]. Can you shortly reflect on how that activity might influence the learning processes in the collaboration?

Closing off the interview [3 min]

- *Thank interviewee for the interview.*
- *Explain that I will organize a **focus group**. Invite the interviewee for the focus group / ask for availability*
- *Explain that I will make a **logbook**. Invite interviewee to fill it out (I will send it via email or give it physically now)*

Appendix 3. Overview of structure labels (interview coding)

The interview transcripts were coded. I gave each chunk of text that contained relevant information a structure label. Each label starts with a unique identifier in the form of a (A, B, C…), so I could easily find back each chunk of text in the transcript. The fictional example below gives an illustration.

Fictional interview transcript

Interviewee I give consent for recording.

Interviewer Thank you. Then we will start. How do you feel about cats?

Interviewee I love cats! I think they are very fluffy.

Interviewee How do you feel about dog-people?

Interviewee I hate dog people!

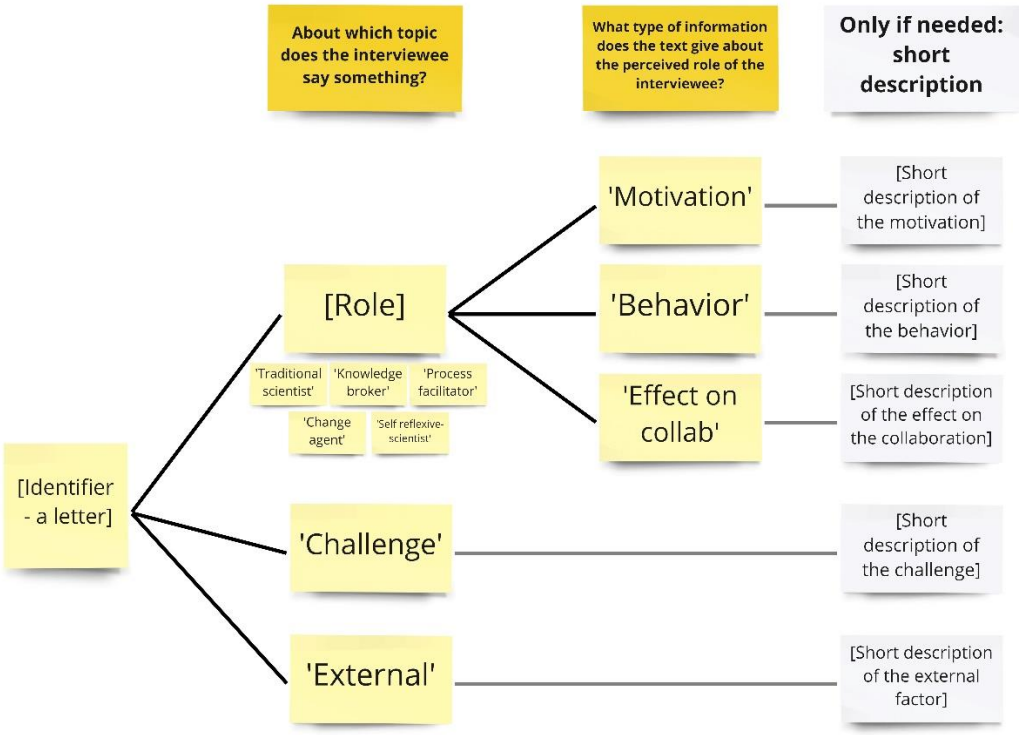
A – Attitude towards cats

B – Attitude towards dog people

The interviews with the PhD-candidates and with the course-coordinators were coded slightly differently, because the course-coordinators were not only asked questions about themselves, but also about their students. The two figures below give a visual overview of how the code labels were constructed.

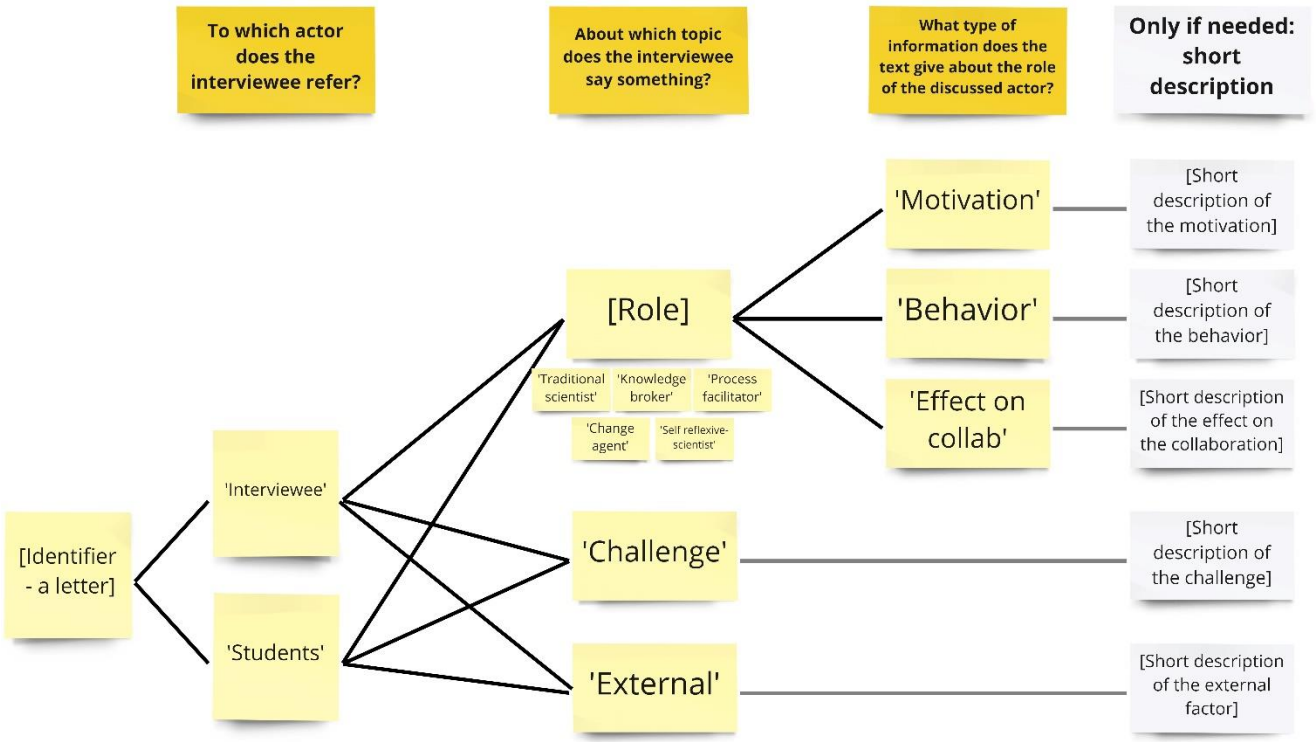
Codes for interviews with PhD-candidates

An example of a code label is: "C – knowledge broker – motivation"



Codes for interviews with course-coordinators

An example of a code label is: “D – students - knowledge broker – behavior”

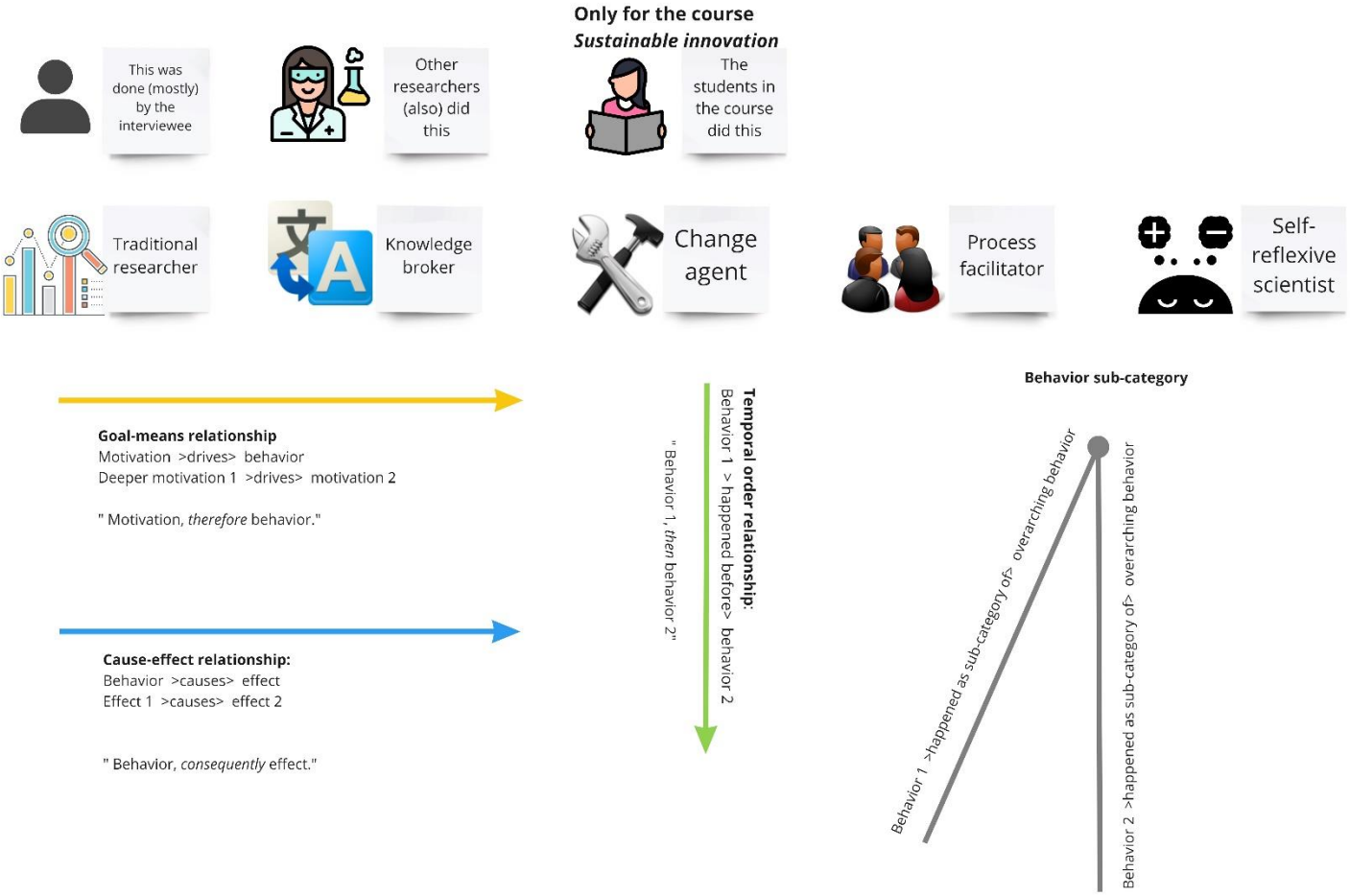


Appendix 4. Mental maps

(I am still looking for a good way to show the mental maps in this Word document. They are too big for one page)

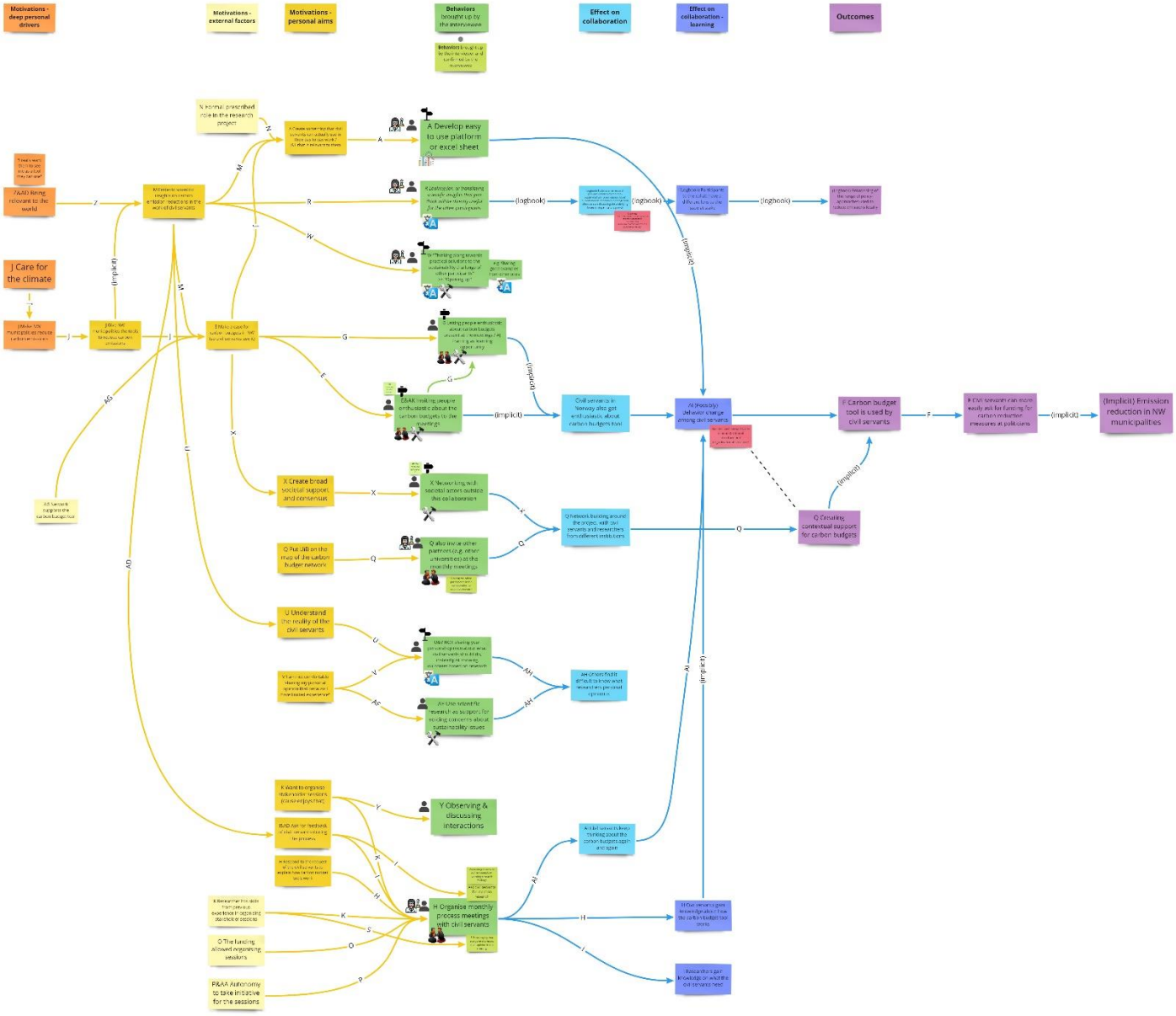
Respondent 8 did not participate in the interview. Therefore, there are 7 mental maps.

Legenda of the mental maps

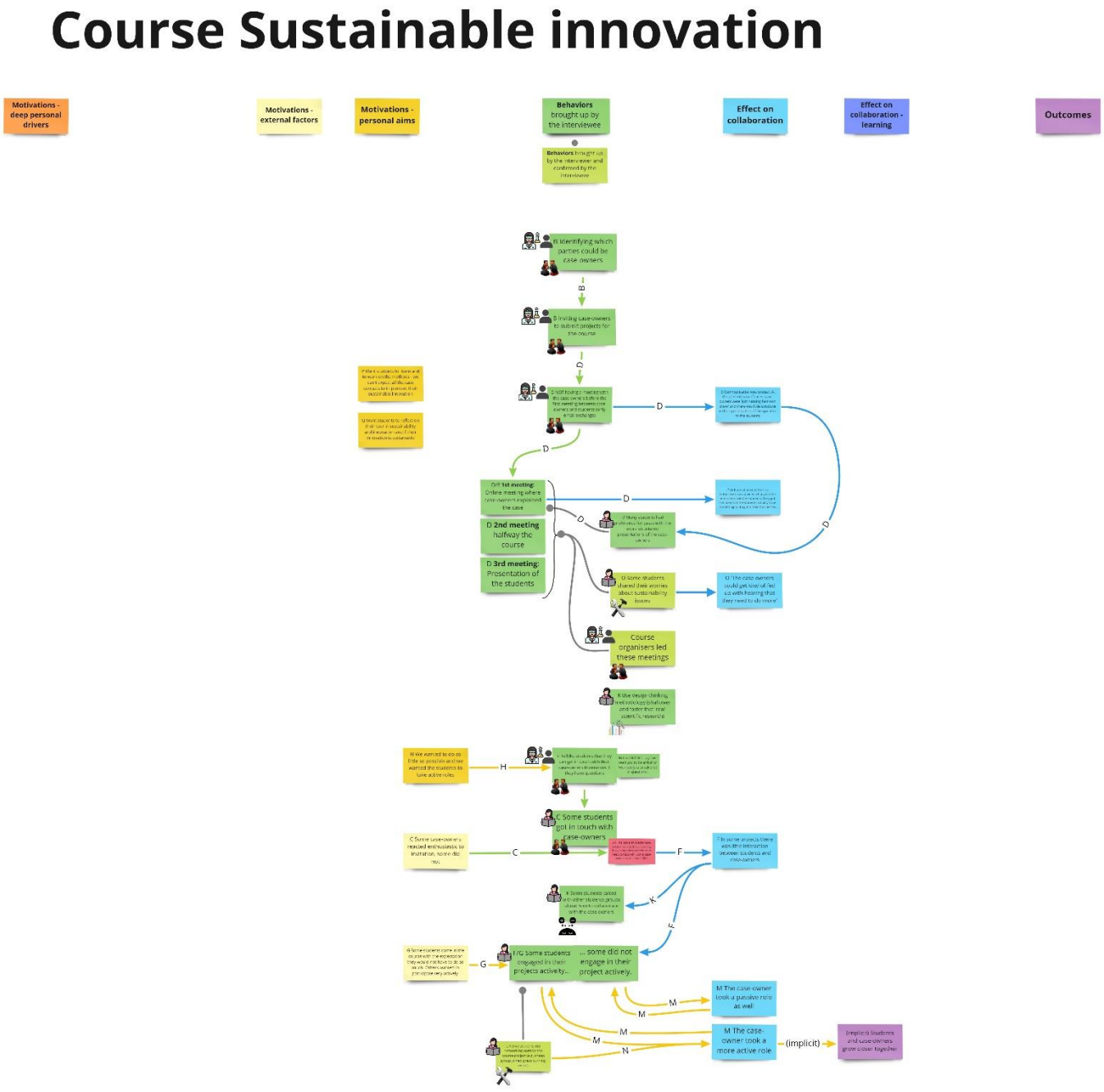


Mental map of respondent 1

Klimabudsjett 2.0

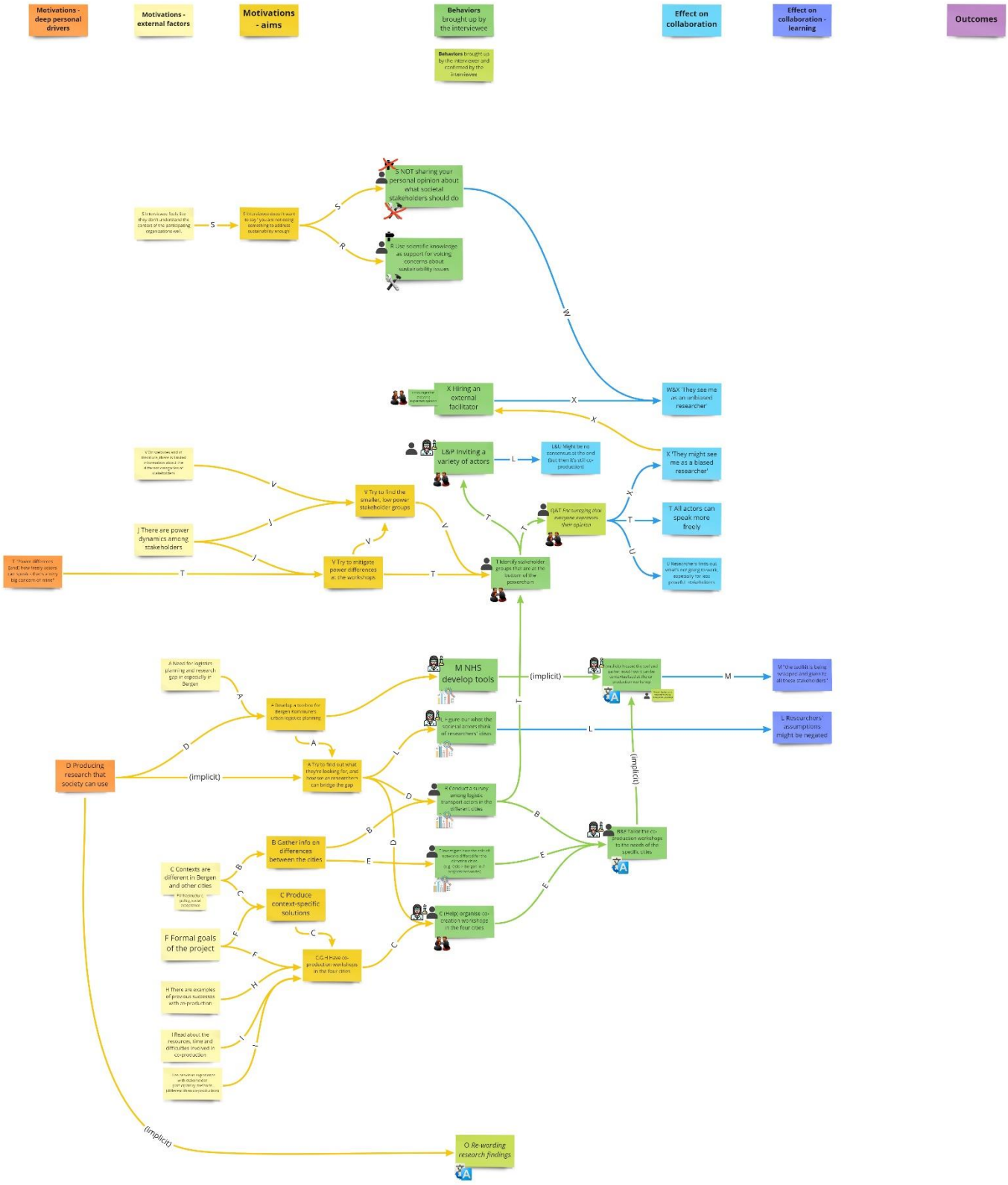


Mental map of respondent 2



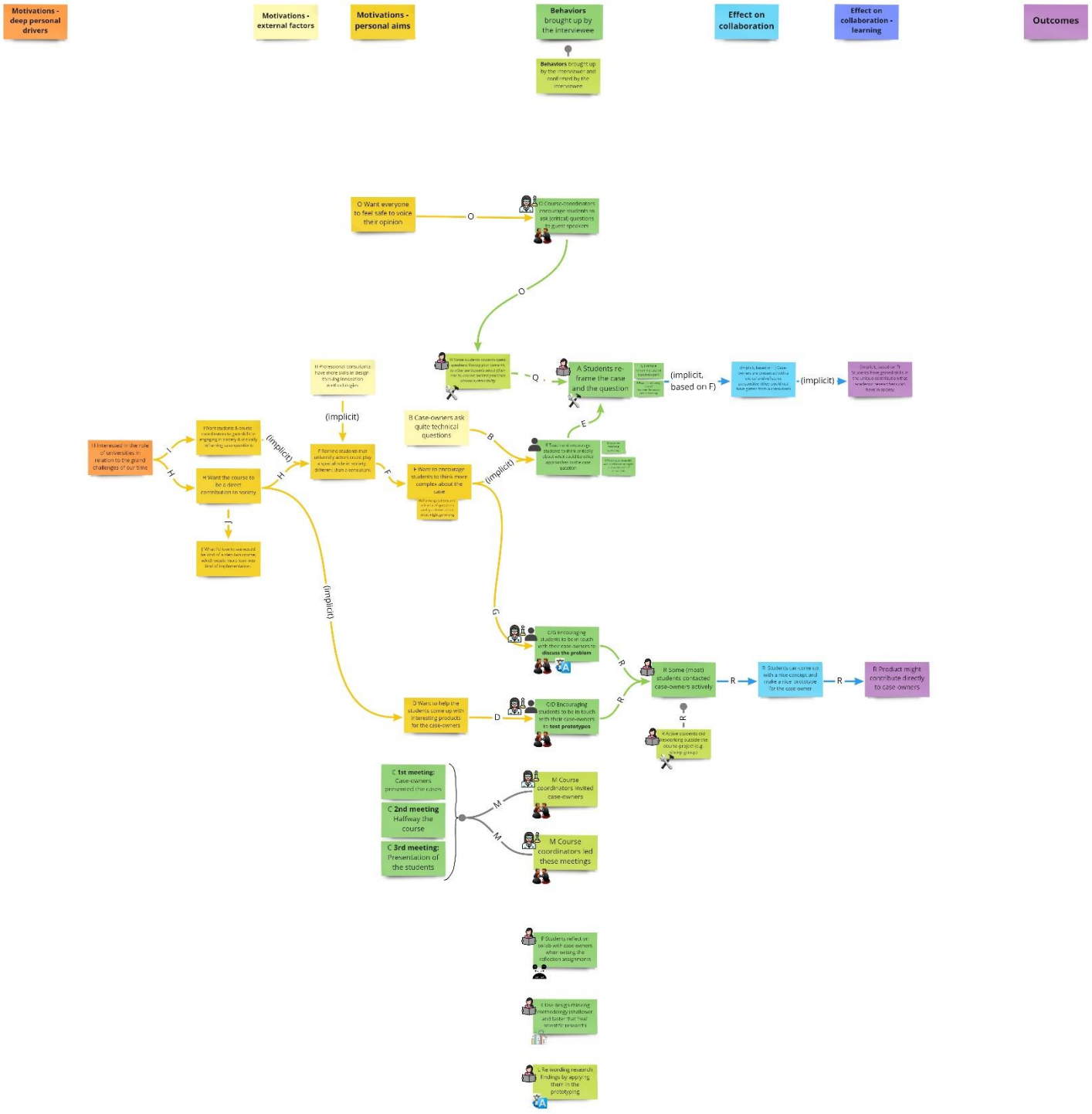
Mental map of respondent 3

Cityfreight

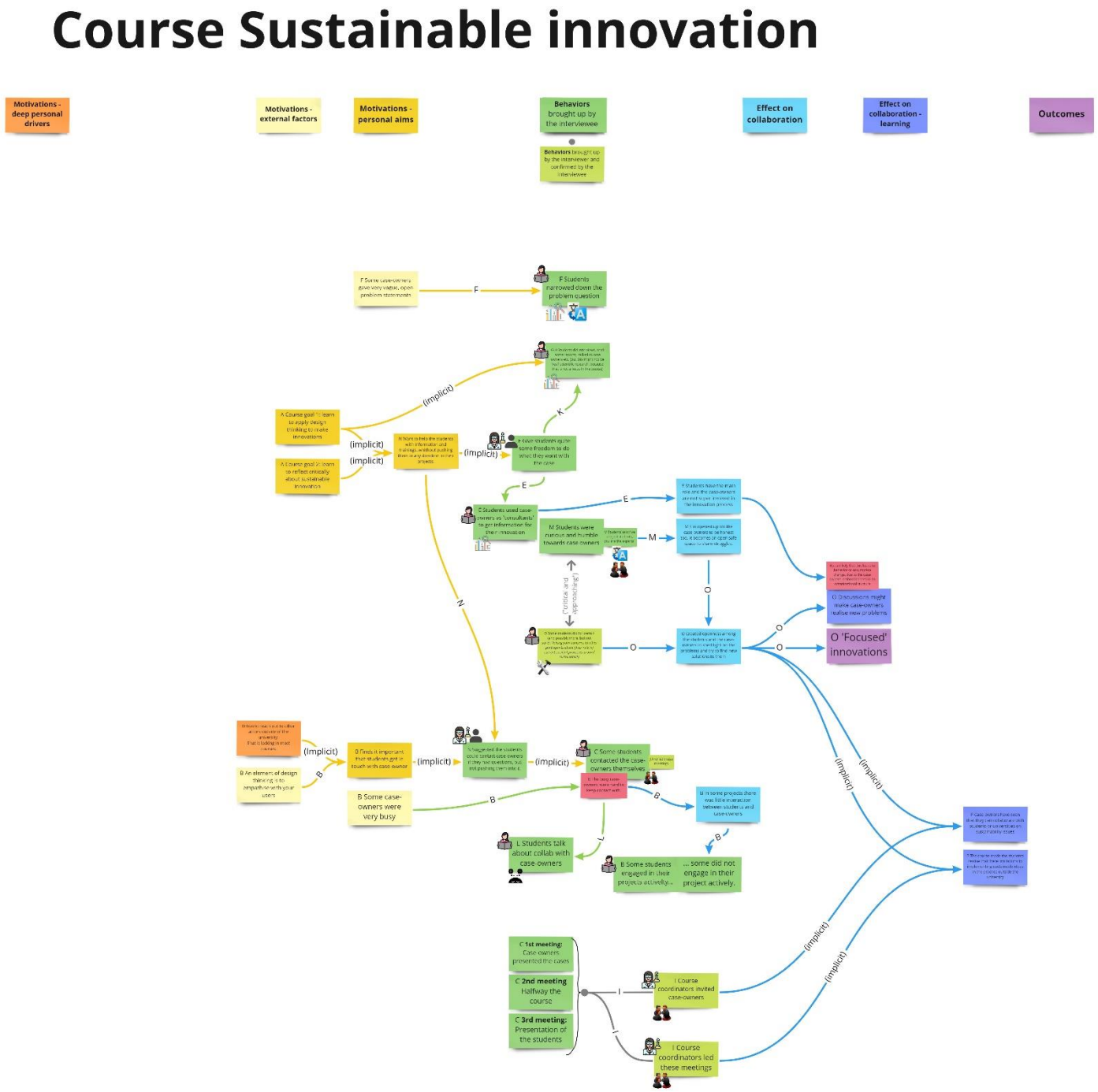


Mental map of respondent 4

Course Sustainable innovation

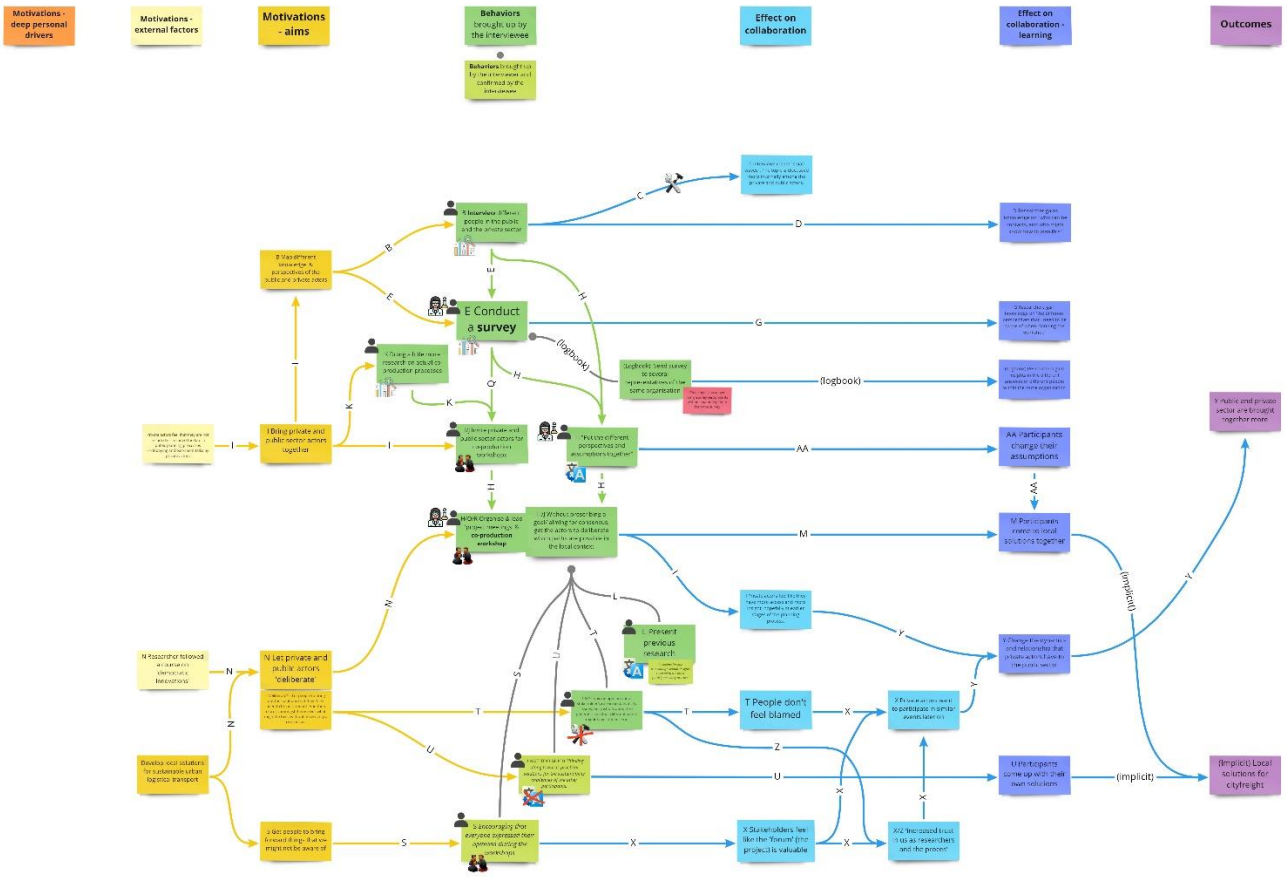


Mental map of respondent 5



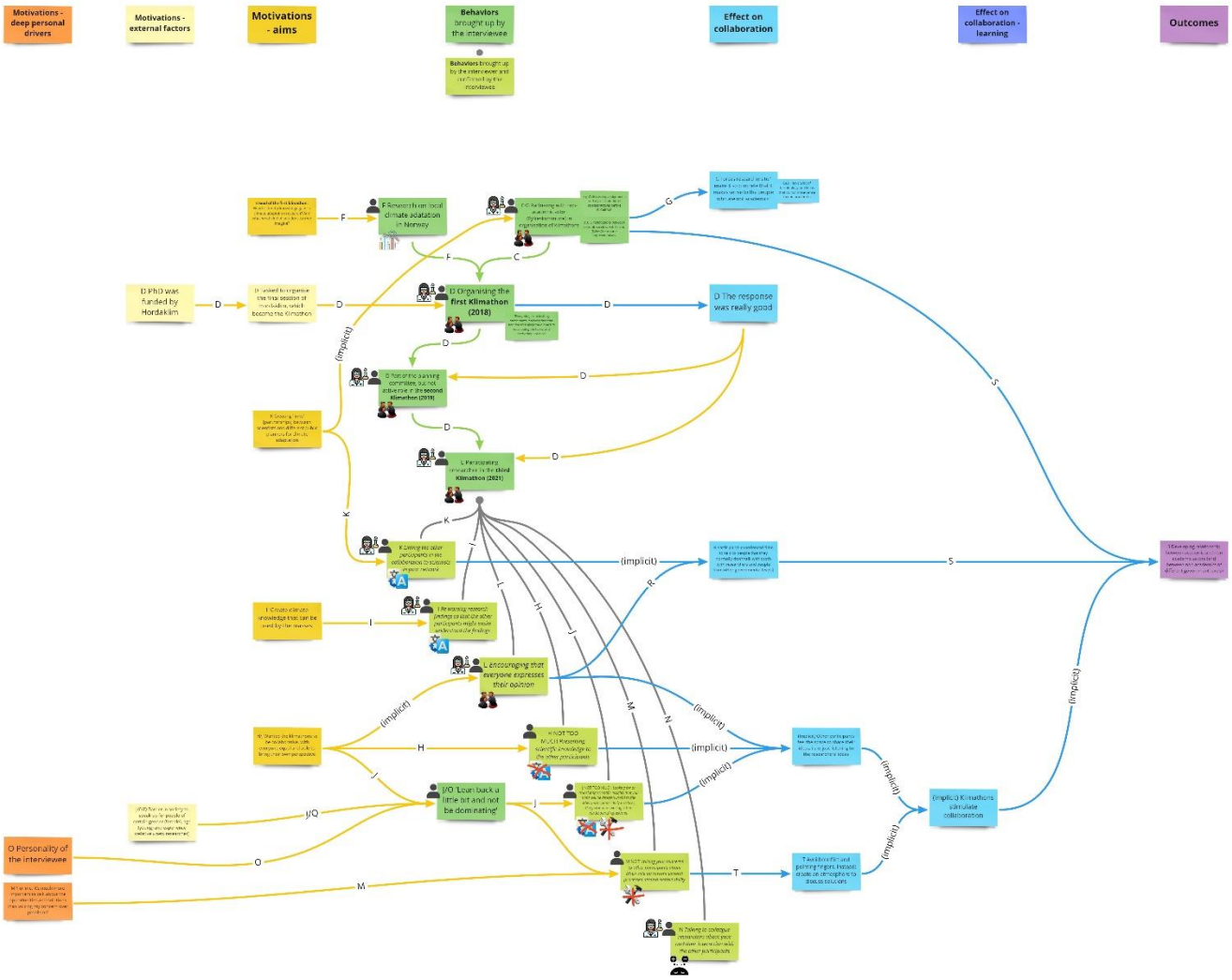
Mental map of respondent 6

Cityfreight



Mental map of respondent 7

Klimathons



Appendix 5. Logbooks

Introduction to the logbooks

Each logbook contained this cover page:

Please read this introduction now (5 min).

Thank you for filling out this logbook! This greatly helps Joran in his master thesis research. The goal of this logbook is to identify how you currently reflect on your transdisciplinary collaboration. So there is no right or wrong!

Please fill in this logbook right after you have been engaged in an activity related to transdisciplinary collaboration.

- *Transdisciplinary collaboration* means interaction between you (as an academic) and non-academics.
- *The activity* could be meeting with societal stakeholders; discussion with a colleague about (the planning of) such a meeting; analysis of stakeholder input (e.g. from a survey); etc.
- *"Right after"* the activity means: on the same day or on the next day, but no later. In this way, your memories are still fresh.

Processing of your entries and privacy

You will be asked to take this logbook to the focus group (date will be announced later). At the focus group, multiple CET-employees will be present, possibly including the director of CET (Håvard). You might be asked to tell what you wrote about in the logbook. You do not have to read the logbook out load.

After the focus group, you will be asked to share your logbook with the researcher (Joran). Joran will not use your name or any other personal identifiers in his master thesis report. However, your logbook might be available in anonymous form to a peer-reviewer on request. Due to the small team at CET, it is possible that readers familiar with the CET-context can trace your statements back to you. Therefore, I cannot guarantee full anonymity.

By filling in this logbook, you give permission for the use of your entries as described above.

Logbook entry respondent 1 (PhD-candidate)

When you have decided to fill in this logbook (right after an activity related to transdisciplinary collaboration, see previous page), please follow the following steps (around 15 min).

Step 1. Briefly describe the activity you were involved in (max 3 sentences)

A workshop with researchers, civil servants, public officials, and NGO workers on the development of subnational carbon budgets. This WS specifically focused on how to address point source emissions from industries, emissions from aviation and shipping, and the statistics for domestic road transport.

Step 2. Check the boxes for the actions you performed during the activity (multiple answers possible)

Left-click on a box and it will be checked.
If your activity involved talking about interaction with societal stakeholders, then check the boxes for the actions you talked about.

☐ Gathering and analyzing scientific theory and data from interviews, surveys, documents, discourse analysis etc. to produce scientific knowledge related to the topic of the collaboration

☐ Gathering (non-scientific) information about societal processes, for example by analysing stakeholder input, reading policy documents, by observing societal events, or by talking to the non-academics in the collaboration

☒ Presenting scientific knowledge to the other participants

☒ Re-wording research findings so that the other participants might easier understand the findings

☒ Looking for or translating scientific insights that you think will be directly useful to the other participant's daily practice

☒ Linking the other participants in the collaboration to scientists in your network

☐ Locating and inviting participants to the collaboration

☐ Organizing meeting (e.g., making agenda, doing communication about meeting, organizing location or lunch)

☐ Leading meeting

☐ Encouraging that everyone expresses their opinion

☐ Encouraging other participants to address local sustainability challenges (also outside this collaboration)

☒ Voicing your concerns to other participants about current societal processes around sustainability

☐ Voicing your concerns to other participants about their role in sustainability issues

☐ Thinking along towards practical solutions for the sustainability challenges of the other participants

☒ Networking with non-academic people outside this collaboration

☐ Observing silently how the others collaborate

☐ Writing fields notes or research diaries about the collaboration process (so not about the content of the research)

☐ Talking to colleague-researchers about your and their interaction with the other participants

☐ Other – specify:

Step 3. Choose one action that you found most challenging or were most unsure about. Describe this action in more detail (max 3 sentences)

Example for the action 're-wording research findings so that the other participants might easier understand the finding': I talked with my supervisor about how we are going to present our research to the civil servants at the upcoming meeting. Maybe we need to avoid jargon? I do not know what terminology they are used to.

In "Looking for or translating scientific insights that you think will be directly useful" i find it particularly challenging to translate the often complex dynamics charted through social science research to other researchers. This often takes more time to dive into the results and their implications and therefore communicating this in a clear and direct way might be a little difficult.

Step 4. Reflect on how this action might affect the collaboration (max 15 sentences, stop if you have taken more than 20 minutes since starting step 1)

Example: What would be the direct effect on the civil servants of avoiding jargon in your presentation? And what would be the effect on your overall collaboration with them?

The direct effect, if successful, could be a broadening of the range of approaches used in policy circles on ways to affect and reduce emissions locally. The different approach provided by socio-cultural does provide a trenchant critic of current models of behaviour change and allows to start discussing the underlying forces driving emissions growth. As such the collaboration would benefit from it as it would provide a different lens to the issue at stake.

But this would be daydreaming to think that that is what the direct effect would be. A successful collaboration would require continuous engagement within a circle of policy makers to affect the way it sees the policy problem.

A danger, when communicated in a clumsy way, is that the collaboration is not seen as relevant nor provide with the knowledge resources relevant for practitioners to carry on their work.

Logbook entry respondent 2 (Course-coordinator)

When you have decided to fill in this logbook (right after an activity related to transdisciplinary collaboration, see previous page), please follow the following steps (around 15 min).

Step 1. Describe the activity you were involved in (max 3 sentences)

In the session, the students presented their case projects to each other, the student coordinators, the exam committee (the leader of the Collaboratory and an extern committee member) and some of the case owners. The student presents their group projects in 20 minute presentations, followed by 10 minutes with comments and questions from the audience, especially the committee.

Step 2. Check the boxes for the actions the students performed during the activity (multiple answers possible)

Left-click on a box and it will be checked.
If a few students did, but others did not perform the action, then still check the box.
If your activity involved talking about the students' interaction with societal stakeholders, then check the boxes for the actions you talked about.

☒ Gathering and analyzing scientific theory and data from interviews, surveys, documents, discourse analysis etc. to produce scientific knowledge related to the topic of the collaboration

☒ Gathering (non-scientific) information about societal processes, for example by analyzing stakeholder input, reading policy documents, by observing societal events, or by talking to the non-academics in the collaboration

☒ Presenting scientific knowledge to the other participants

☒ Re-wording research findings so that the other participants might easier understand the findings

☐ Looking for or translating scientific insights that you think will be directly useful to the other participant's daily practice

☐ Linking the other participants in the collaboration to scientists in your network

☐ Locating and inviting participants to the collaboration

☐ Organizing meeting (e.g., making agenda, doing communication about meeting, organizing location or lunch)

☐ Leading meeting

☒ Encouraging that everyone expresses their opinion

☐ Encouraging other participants to address local sustainability challenges (also outside this collaboration)

☒ Voicing your concerns to other participants about current societal processes around sustainability

☒ Voicing your concerns to other participants about their role in sustainability issues

☒ Thinking along towards practical solutions for the sustainability challenges of the other participants

☒ Networking with non-academic people outside this collaboration

☒ Observing silently how the others collaborate

☐ Writing fields notes or research diaries about the collaboration process (so not about the content of the research)

☐ Talking to colleague-researchers about your and their interaction with the other participants

☐ Other – specify:

Step 3. Choose one action that made you think most. Describe this action in more detail (max 3 sentences)

Example for the action 're-wording research findings so that the other participants might easier understand the finding': We talked with the students about how to ask for feedback from the case owners. A student asked me whether they had to avoiding scientific jargon when they asked for feedback, because the case owner might not be familiar with the scientific terms. I was not sure about this, as I see advantages and disadvantages of using scientific terms.

"Encouraging that everyone expresses their opinion"

At the end of their presentations, most of the students encouraged the other students and participants to express their opinion, comment on their presentation and as questions. Some gave out paper to get written feedback, other just wanted general feedback at the end.

Step 4. Reflect on how this action might affect the collaboration (max 15 sentences, stop if you have taken more than 20 min since starting step 1)

Example: What would be the direct effect on the case owners if the students avoid jargon in their feedback questions? And what would be the effect on the overall collaboration with them?

This action is absolutely necessary for good collaboration both between the students and their case contacts, and between the students. By encouraging the other participants to express their opinion, the students get feedback from people that might have other point of views, other ways of knowing, other personal experience. To get feedback and being able to take other inputs into consideration and reflect on them will positively affect the collaboration. Sometimes, too much feedback and too many opinions might cause confusion, but to some extent, feedback is absolutely necessary.

Logbook entry respondent 5 (Course-coordinator)

When you have decided to fill in this logbook (right after an activity related to transdisciplinary collaboration, see previous page), please follow the following steps (around 15 min).

Step 1. Describe the activity you were involved in (max 3 sentences)

Case presentations. The students presented their innovation projects for the case owners and the examiners.

Step 2. Check the boxes for the actions the students performed during the activity (multiple answers possible)

Left-click on a box and it will be checked.
If a few students did, but others did not perform the action, then still check the box.
If your activity involved talking about the students' interaction with societal stakeholders, then check the boxes for the actions you talked about.

☐ Gathering and analyzing scientific theory and data from interviews, surveys, documents, discourse analysis etc. to produce scientific knowledge related to the topic of the collaboration

☐ Gathering (non-scientific) information about societal processes, for example by analyzing stakeholder input, reading policy documents, by observing societal events, or by talking to the non-academics in the collaboration

☒ Presenting scientific knowledge to the other participants

☐ Re-wording research findings so that the other participants might easier understand the findings

☐ Looking for or translating scientific insights that you think will be directly useful to the other participant's daily practice

☐ Linking the other participants in the collaboration to scientists in your network

☐ Locating and inviting participants to the collaboration

☐ Organizing meeting (e.g., making agenda, doing communication about meeting, organizing location or lunch)

☒ Leading meeting

☒ Encouraging that everyone expresses their opinion

☐ Encouraging other participants to address local sustainability challenges (also outside this collaboration)

☐ Voicing your concerns to other participants about current societal processes around sustainability

☐ Voicing your concerns to other participants about their role in sustainability issues

☒ Thinking along towards practical solutions for the sustainability challenges of the other participants

☐ Networking with non-academic people outside this collaboration

☐ Observing silently how the others collaborate

☐ Writing fields notes or research diaries about the collaboration process (so not about the content of the research)

☐ Talking to colleague-researchers about your and their interaction with the other participants

☐ Other – specify:

Step 3. Choose one action that made you think most. Describe this action in more detail (max 3 sentences)

Example for the action 're-wording research findings so that the other participants might easier understand the finding': We talked with the students about how to ask for feedback from the case owners. A student asked me whether they had to avoiding scientific jargon when they asked for feedback, because the case owner might not be familiar with the scientific terms. I was not sure about this, as I see advantages and disadvantages of using scientific terms.

'Thinking along towards practical solutions for the sustainability challenges of the other participants ': Some of the students got feedback on their presentation during the session. There was a good conversation between the case owners and the students and a wish to find solutions together. It was also an open space for constructive critique.

Step 4. Reflect on how this action might affect the collaboration (max 15 sentences, stop if you have taken more than 20 min since starting step 1)

Example: What would be the direct effect on the case owners if the students avoid jargon in their feedback questions? And what would be the effect on the overall collaboration with them?

Several of the groups are in dialogue with their case owner to realize their projects. I believe this demonstrate a successful relationship between the students and the case owners. They have together worked to find a common solution but also to redefine a broad societal challenge. Further, the students have not just cooperated with their case owners, but they have also reached out to other relevant actors. Several of the students reflected in their presentations on how it was important to see the problem from a different point of view but also that interactions with different actors framed and shaped both their problem definition and solution. I believe, and hope, that the course have thought the students the value of feedback and interaction with different actors.

Logbook entry respondent 6 (PhD-candidate)

When you have decided to fill in this logbook (right after an activity related to transdisciplinary collaboration, see previous page), please follow the following steps (around 15 min).

Step 1. Briefly describe the activity you were involved in (max 3 sentences)

I have been gathering respondants for my stakeholder survey.

Step 2. Check the boxes for the actions you performed during the activity (multiple answers possible)

Left-click on a box and it will be checked.
If your activity involved talking about interaction with societal stakeholders, then check the boxes for the actions you talked about.

☐ Gathering and analyzing scientific theory and data from interviews, surveys, documents, discourse analysis etc. to produce scientific knowledge related to the topic of the collaboration

☐ Gathering (non-scientific) information about societal processes, for example by analysing stakeholder input, reading policy documents, by observing societal events, or by talking to the non-academics in the collaboration

☐ Presenting scientific knowledge to the other participants

☐ Re-wording research findings so that the other participants might easier understand the findings

☐ Looking for or translating scientific insights that you think will be directly useful to the other participant's daily practice

☐ Linking the other participants in the collaboration to scientists in your network

☒ Locating and inviting participants to the collaboration

☐ Organizing meeting (e.g., making agenda, doing communication about meeting, organizing location or lunch)

☐ Leading meeting

☐ Encouraging that everyone expresses their opinion

☐ Encouraging other participants to address local sustainability challenges (also outside this collaboration)

☐ Voicing your concerns to other participants about current societal processes around sustainability

☐ Voicing your concerns to other participants about their role in sustainability issues

☐ Thinking along towards practical solutions for the sustainability challenges of the other participants

☐ Networking with non-academic people outside this collaboration

☐ Observing silently how the others collaborate

☐ Writing fields notes or research diaries about the collaboration process (so not about the content of the research)

☐ Talking to colleague-researchers about your and their interaction with the other participants

☐ Other – specify:

Step 3. Choose one action that you found most challenging or were most unsure about. Describe this action in more detail (max 3 sentences)

Example for the action 're-wording research findings so that the other participants might easier understand the finding': I talked with my supervisor about how we are going to present our research to the civil servants at the upcoming meeting. Maybe we need to avoid jargon? I do not know what terminology they are used to.

I am seeking to spread my survey amongst individuals in the private sector, including through interest organisations. One of my challenges is which organisations to choose, and whether these have overlapping memberships. I do not want to 'spam' people with my survey invitation if this decreased the possibility that they will answer it.

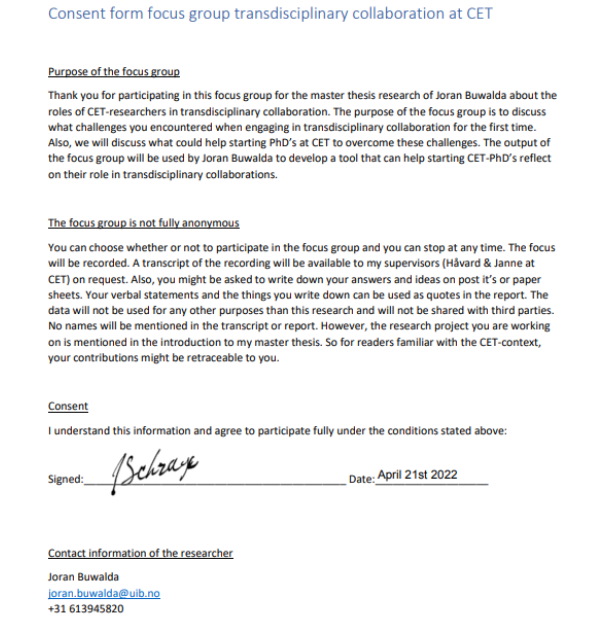
Step 4. Reflect on how this action might affect the collaboration (max 15 sentences, stop if you have taken more than 20 minutes since starting step 1)

Example: What would be the direct effect on the civil servants of avoiding jargon in your presentation? And what would be the effect on your overall collaboration with them?

I have considered that some organisations will have different representatives, meaning that despite the same business being represented in more than one organisation, it is not the same individuals who are representing them. This means it may be more fruitful to send my survey to several organisations, as in this way it is reaching different individuals. Even if they work in the same place, it could then be possible to look for differences in their answers. Also, some individuals may answer from their position and others from their personal engagement in the topic of my survey.

Appendix 6. Consent forms for the focus groups and test session

Consent forms of the participants to the focus groups



Consent form focus group transdisciplinary collaboration at CET

Purpose of the focus group

Thank you for participating in this focus group for the master thesis research of Joran Buwalda about the roles of CET-researchers in transdisciplinary collaboration. The purpose of the focus group is to discuss what challenges you encountered when engaging in transdisciplinary collaboration for the first time. Also, we will discuss what could help starting PhD's at CET to overcome these challenges. The output of the focus group will be used by Joran Buwalda to develop a tool that can help starting CET-PhD's reflect on their role in transdisciplinary collaborations.

The focus group is not fully anonymous

You can choose whether or not to participate in the focus group and you can stop at any time. The focus will be recorded. A transcript of the recording will be available to my supervisors (Håvard & Janne at CET) on request. Also, you might be asked to write down your answers and ideas on post it's or paper sheets. Your verbal statements and the things you write down can be used as quotes in the report. The data will not be used for any other purposes than this research and will not be shared with third parties. No names will be mentioned in the transcript or report. However, the research project you are working on is mentioned in the introduction to my master thesis. So for readers familiar with the CET-context, your contributions might be retraceable to you.

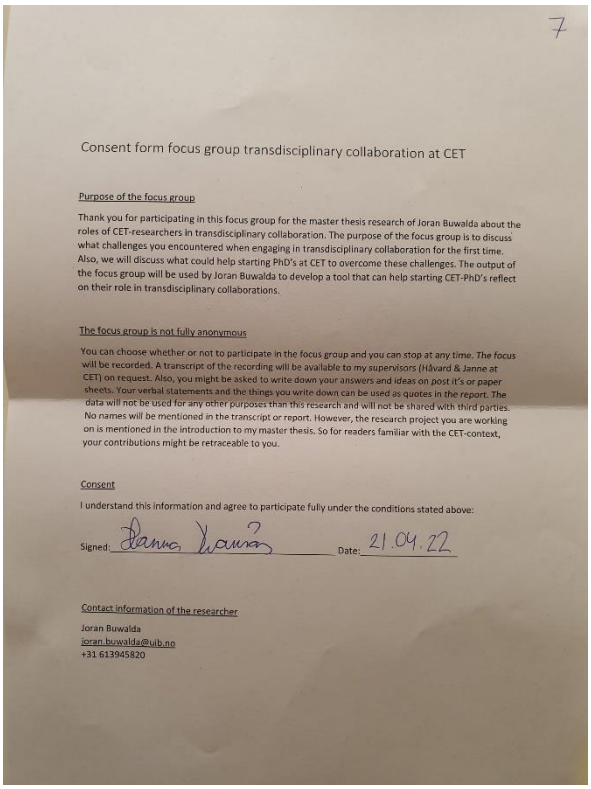
Consent

I understand this information and agree to participate fully under the conditions stated above:

Signed: JSchrage Date: April 21st 2022

Contact information of the researcher

Joran Buwalda
joran.buwalda@uib.no
+31 613945820



7

Consent form focus group transdisciplinary collaboration at CET

Purpose of the focus group

Thank you for participating in this focus group for the master thesis research of Joran Buwalda about the roles of CET-researchers in transdisciplinary collaboration. The purpose of the focus group is to discuss what challenges you encountered when engaging in transdisciplinary collaboration for the first time. Also, we will discuss what could help starting PhD's at CET to overcome these challenges. The output of the focus group will be used by Joran Buwalda to develop a tool that can help starting CET-PhD's reflect on their role in transdisciplinary collaborations.

The focus group is not fully anonymous

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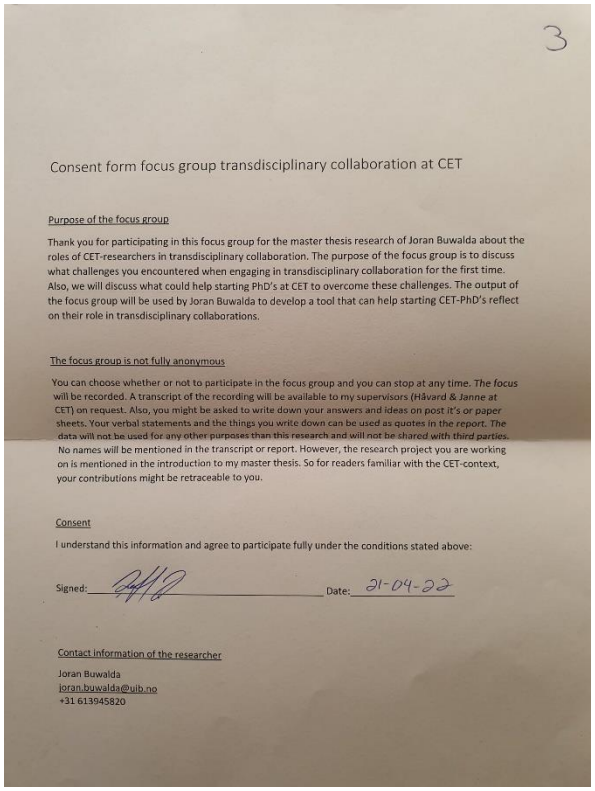
Consent

I understand this information and agree to participate fully under the conditions stated above:

Signed: Janne Kaurs Date: 21.04.22

Contact information of the researcher

Joran Buwalda
joran.buwalda@uib.no
+31 613945820



3

Consent form focus group transdisciplinary collaboration at CET

Purpose of the focus group

Thank you for participating in this focus group for the master thesis research of Joran Buwalda about the roles of CET-researchers in transdisciplinary collaboration. The purpose of the focus group is to discuss what challenges you encountered when engaging in transdisciplinary collaboration for the first time. Also, we will discuss what could help starting PhD's at CET to overcome these challenges. The output of the focus group will be used by Joran Buwalda to develop a tool that can help starting CET-PhD's reflect on their role in transdisciplinary collaborations.

The focus group is not fully anonymous

You can choose whether or not to participate in the focus group and you can stop at any time. The focus will be recorded. A transcript of the recording will be available to my supervisors (Håvard & Janne at CET) on request. Also, you might be asked to write down your answers and ideas on post it's or paper sheets. Your verbal statements and the things you write down can be used as quotes in the report. The data will not be used for any other purposes than this research and will not be shared with third parties. No names will be mentioned in the transcript or report. However, the research project you are working on is mentioned in the introduction to my master thesis. So for readers familiar with the CET-context, your contributions might be retraceable to you.

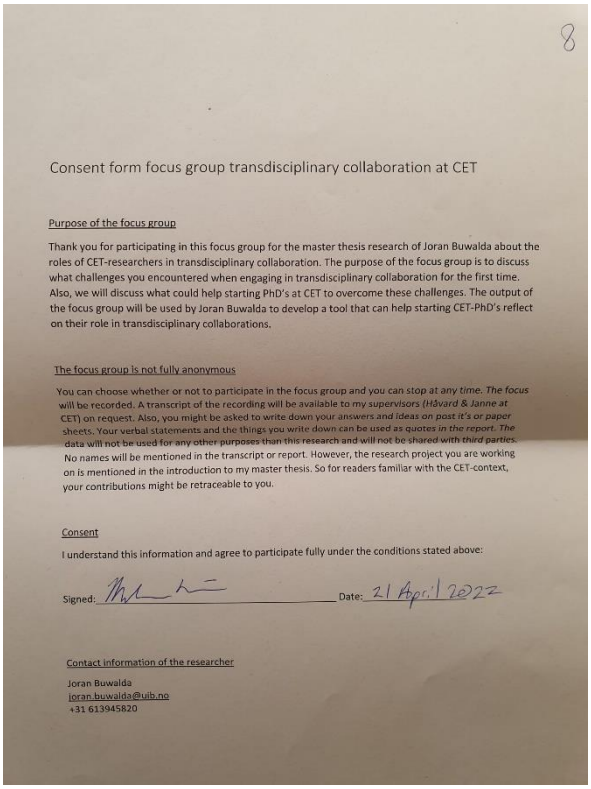
Consent

I understand this information and agree to participate fully under the conditions stated above:

Signed: Date: 21-04-22

Contact information of the researcher

Joran Buwalda
joran.buwalda@uib.no
+31 613945820



8

Consent form focus group transdisciplinary collaboration at CET

Purpose of the focus group

Thank you for participating in this focus group for the master thesis research of Joran Buwalda about the roles of CET-researchers in transdisciplinary collaboration. The purpose of the focus group is to discuss what challenges you encountered when engaging in transdisciplinary collaboration for the first time. Also, we will discuss what could help starting PhD's at CET to overcome these challenges. The output of the focus group will be used by Joran Buwalda to develop a tool that can help starting CET-PhD's reflect on their role in transdisciplinary collaborations.

The focus group is not fully anonymous

You can choose whether or not to participate in the focus group and you can stop at any time. The focus will be recorded. A transcript of the recording will be available to my supervisors (Håvard & Janne at CET) on request. Also, you might be asked to write down your answers and ideas on post it's or paper sheets. Your verbal statements and the things you write down can be used as quotes in the report. The data will not be used for any other purposes than this research and will not be shared with third parties. No names will be mentioned in the transcript or report. However, the research project you are working on is mentioned in the introduction to my master thesis. So for readers familiar with the CET-context, your contributions might be retraceable to you.

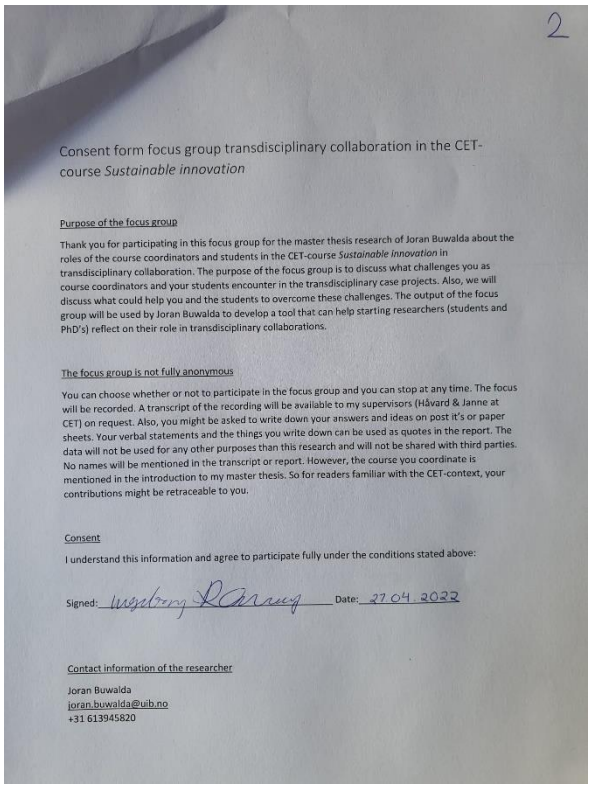
Consent

I understand this information and agree to participate fully under the conditions stated above:

Signed: Date: 21 April 2022

Contact information of the researcher

Joran Buwalda
joran.buwalda@uib.no
+31 613945820



2

Consent form focus group transdisciplinary collaboration in the CET-course *Sustainable innovation*

Purpose of the focus group

Thank you for participating in this focus group for the master thesis research of Joran Buwalda about the roles of the course coordinators and students in the CET-course *Sustainable innovation* in transdisciplinary collaboration. The purpose of the focus group is to discuss what challenges you as course coordinators and your students encounter in the transdisciplinary case projects. Also, we will discuss what could help you and the students to overcome these challenges. The output of the focus group will be used by Joran Buwalda to develop a tool that can help starting researchers (students and PhD's) reflect on their role in transdisciplinary collaborations.

The focus group is not fully anonymous

You can choose whether or not to participate in the focus group and you can stop at any time. The focus will be recorded. A transcript of the recording will be available to my supervisors (Håvard & Janne at CET) on request. Also, you might be asked to write down your answers and ideas on post it's or paper sheets. Your verbal statements and the things you write down can be used as quotes in the report. The data will not be used for any other purposes than this research and will not be shared with third parties. No names will be mentioned in the transcript or report. However, the course you coordinate is mentioned in the introduction to my master thesis. So for readers familiar with the CET-context, your contributions might be retraceable to you.

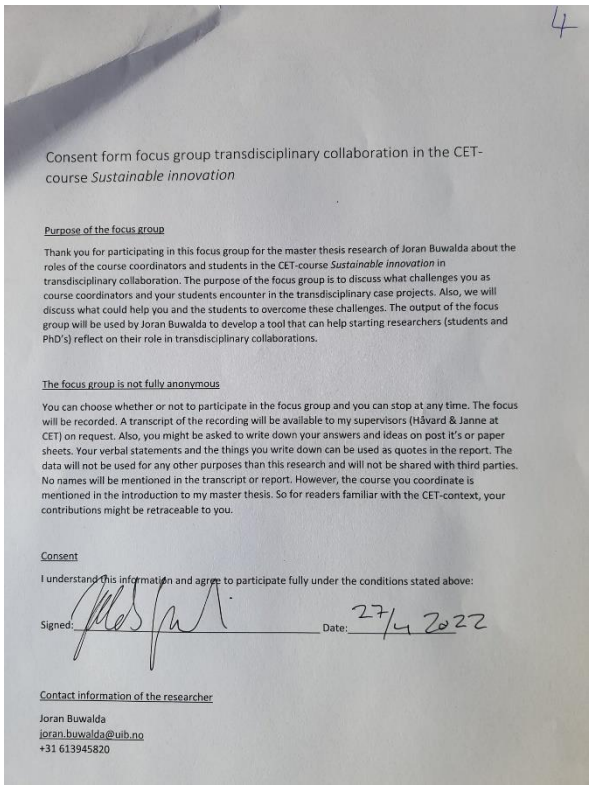
Consent

I understand this information and agree to participate fully under the conditions stated above:

Signed: _____ Date: 27.04.2022

Contact information of the researcher

Joran Buwalda
joran.buwalda@uib.no
+31 613945820



4

Consent form focus group transdisciplinary collaboration in the CET-course *Sustainable innovation*

Purpose of the focus group

Thank you for participating in this focus group for the master thesis research of Joran Buwalda about the roles of the course coordinators and students in the CET-course *Sustainable innovation* in transdisciplinary collaboration. The purpose of the focus group is to discuss what challenges you as course coordinators and your students encounter in the transdisciplinary case projects. Also, we will discuss what could help you and the students to overcome these challenges. The output of the focus group will be used by Joran Buwalda to develop a tool that can help starting researchers (students and PhD's) reflect on their role in transdisciplinary collaborations.

The focus group is not fully anonymous

You can choose whether or not to participate in the focus group and you can stop at any time. The focus will be recorded. A transcript of the recording will be available to my supervisors (Håvard & Janne at CET) on request. Also, you might be asked to write down your answers and ideas on post it's or paper sheets. Your verbal statements and the things you write down can be used as quotes in the report. The data will not be used for any other purposes than this research and will not be shared with third parties. No names will be mentioned in the transcript or report. However, the course you coordinate is mentioned in the introduction to my master thesis. So for readers familiar with the CET-context, your contributions might be retraceable to you.

Consent

I understand this information and agree to participate fully under the conditions stated above:

Signed: _____ Date: 27/4 2022

Contact information of the researcher

Joran Buwalda
joran.buwalda@uib.no
+31 613945820

Consent forms of the participants to the prototype evaluation sessions

Note: at the time of these session, they were still called 'input sessions'. That is why the consent forms below refer to 'input sessions'.

Consent form input session about transdisciplinary collaboration at CET

Purpose of the input session
Thank you for participating in this input session for the master thesis research of Joran Buwalda about the roles of CET-researchers in transdisciplinary collaboration. The purpose of the input session is to discuss and evaluate two prototype reflection tools that I developed for CET-researchers.

Data collection during the input session
You can choose whether or not to participate in the input session and you can stop at any time. The session will not be recorded in any way. Joran writes comments during the session based on your input. Your comments will not be used for any other purposes than this research and will be added in the appendix of the master thesis in anonymous form. No names are mentioned in the master thesis report. However, if you are a CET-researcher, it is mentioned in the report which research project or student-course you are working on. So for readers familiar with the CET-context, your contributions might be retraceable to you. If you are a CDI student, your participation in this session is fully anonymous.

Consent
I understand this information and agree to participate fully under the conditions stated above:

Signature: K. Joosten Date: 1-6-2022

Contact information of the researcher
Joran Buwalda
joran.buwalda@uib.no
+31 613945820

Consent form input session about transdisciplinary collaboration at CET

Purpose of the input session
Thank you for participating in this input session for the master thesis research of Joran Buwalda about the roles of CET-researchers in transdisciplinary collaboration. The purpose of the input session is to discuss and evaluate two prototype reflection tools that I developed for CET-researchers.

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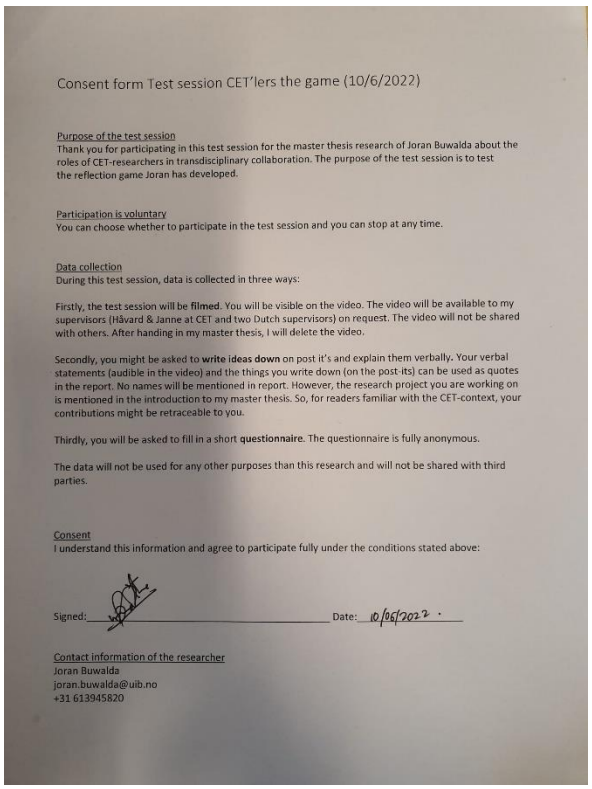
Consent
I understand this information and agree to participate fully under the conditions stated above:

Signature: _____ Date: 1-6-2022

Contact information of the researcher
Joran Buwalda
joran.buwalda@uib.no
+31 613945820

Consent forms of the participants to the test session



Consent form Test session CET'lers the game (10/6/2022)

Purpose of the test session
Thank you for participating in this test session for the master thesis research of Joran Buwalda about the roles of CET-researchers in transdisciplinary collaboration. The purpose of the test session is to test the reflection game Joran has developed.

Participation is voluntary
You can choose whether to participate in the test session and you can stop at any time.

Data collection
During this test session, data is collected in three ways:

Firstly, the test session will be **filmed**. You will be visible on the video. The video will be available to my supervisors (Håvard & Janne at CET and two Dutch supervisors) on request. The video will not be shared with others. After handing in my master thesis, I will delete the video.

Secondly, you might be asked to **write ideas down** on post it's and explain them verbally. Your verbal statements (audible in the video) and the things you write down (on the post-its) can be used as quotes in the report. No names will be mentioned in report. However, the research project you are working on is mentioned in the introduction to my master thesis. So, for readers familiar with the CET-context, your contributions might be retraceable to you.

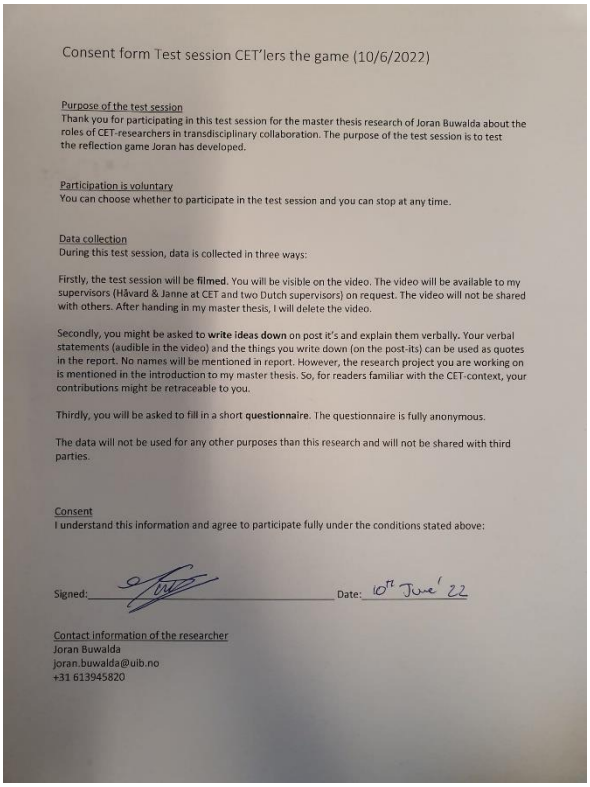
Thirdly, you will be asked to fill in a short **questionnaire**. The questionnaire is fully anonymous.

The data will not be used for any other purposes than this research and will not be shared with third parties.

Consent
I understand this information and agree to participate fully under the conditions stated above:

Signed: _____ Date: 10/06/2022

Contact information of the researcher
Joran Buwalda
joran.buwalda@uib.no
+31 613945820



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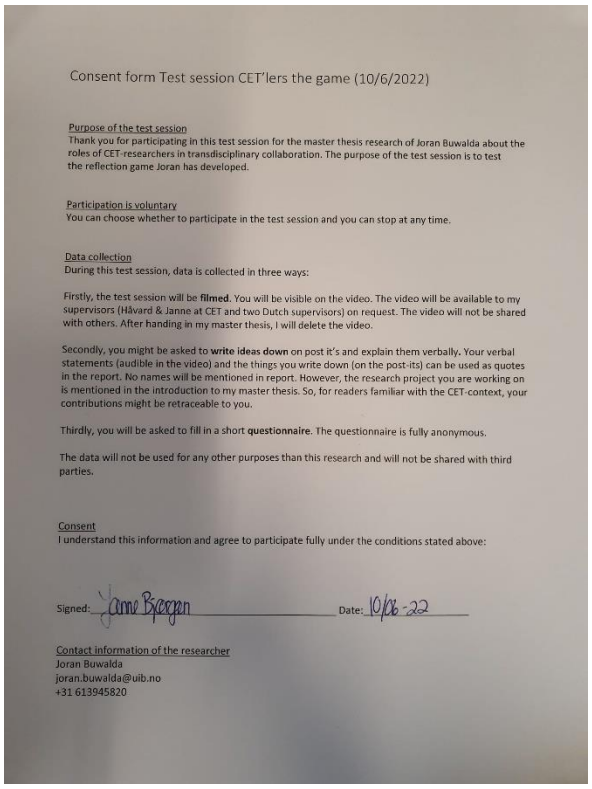
Thirdly, you will be asked to fill in a short **questionnaire**. The questionnaire is fully anonymous.

The data will not be used for any other purposes than this research and will not be shared with third parties.

Consent
I understand this information and agree to participate fully under the conditions stated above:

Signed: _____ Date: 10th June '22

Contact information of the researcher
Joran Buwalda
joran.buwalda@uib.no
+31 613945820



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The data will not be used for any other purposes than this research and will not be shared with third parties.

Consent
I understand this information and agree to participate fully under the conditions stated above:

Signed: Anne Bjørgen Date: 10/06-22

Contact information of the researcher
Joran Buwalda
joran.buwalda@uib.no
+31 613945820

Appendix 7. Decision narratives

Decision narrative – students

These are a few pages from a fictional diary of a student who follows the course Sustainable innovation at the University in Bergen.

Dear diary

No, that sounds lame. Let me erase that.

Maybe I should just start writing. It is quite a while since I wrote in this diary. I am also a bit stressed. I have to choose electives for the second semester of my second year in my bachelor. I have to choose my electives for the next semester. I am very interested in sustainability, and I want to contribute to solving these issues. But most of the courses here are so academic and so theoretical. Also honestly, I am just very busy next semester so maybe the best is to take a course that does not have a too demanding exam. I will think about it a bit more.

I enrolled for the course Sustainable innovation. I do not really know what to expect from it. This is going to be quite chill. Only 10 sessions and no exam. But I read something about a case project. I'm not so sure about that. I mean I think it's cool we actually do a project for a real company, but I don't really get what we're supposed to do yet. But I guess I'll learn more about that first session of the course. We'll see.

This is so cool! We had the first session today. Instead of a boring course introduction we had a really good discussion. It was about how we as students can make a contribution to solving climate change. This is exactly what I have been thinking about lot. Most courses in universities, they're just so theoretical and not really about how it works in society. I really like that in this course they're not just teaching us how to apply our knowledge, but they let us experiment with how 'to be researchers' that can do something in society. I thought I was the only one who really thought about this. But it turned out most of the others did too. At the end of the session the course coordinator, who is a student too, said: 'I hope that after this course you see that you don't have to work at a consultancy agency, at an NGO or be an activist to transform society. You can do that right from the university.' I feel like this course is sort of a playing ground for that maybe. Where we can experiment with ways in which we can have impact on society. I really want to start now!

It was the second course session today. I am in a team now. In our team we discussed which role division we should have. But we started with a discussion a bit deeper in a sense – about the topic of last week: how do we want to have impact on society? And how can we make sure that the impact is the unique, so that we don't copy the work that consultants for example are already doing. It was quite hard topic to discuss about. I had not really thought about it that way yet. In the end most of us

agreed that we can use our interdisciplinary background, because we are all from different studies, to integrate knowledge in a way that others might not be able to and translate that to what the case owner would need. I am really fascinated by this idea that the theoretical knowledge from the university just doesn't work like just communicating that to society - you need to translate it before it can be used right? Someone else in my group was more about: we need to be critical. There are so many people in society who just follow whichever frame is most popular or they just do what politicians say. She thought that students can be critical because they have the most recent academic knowledge. So they can negate ideas of the case-owners? I understood why he said that but thought that should not be the biggest focus of the project at first, because it is more important to create a partnership, to create trust and to make sure that you really understand the other so you can translate the knowledge for them. We need to understand how they look at it for that. And not be critical which just causes them not to say anything anymore. But in the end, we agreed that maybe we can do both. We could start with trust and understanding and maybe later on we could sort of divide roles as a good cop bad cop kind of situation. So I would be the one most responsible for creating trust and mutual understanding, and she, a bit later on, the one to be most responsible for constructive critical conversations. And another one liked to be more like our secretary and be the first contact point for the case-owners and the one planning meetings. I think we have an okay role division now.

One of the things I don't really understand yet is how we're going to get a grade for this. We're sort of giving direction to our own process now. But what do the teachers want to see for a good grade? It's a bit vague actually. I asked this to the course-coordinator. She gave a nice reply, I think. She let me tell a bit about the discussion we had just had. And then she showed me that that discussion related to three of the course goals already. I never really look at those, but now the course goals sort of make sense to me. It's really about this interacting about society, and critically assessing how you can make innovations for society.

We were also warned that it can be quite hard to get in touch with the case-owners because they're just so busy. That was a bit of a bummer, because I think we really have to speak to them a lot to really get a good partnership. But now we have discussed this, I am really motivated to get in touch with them. We also asked the course-coordinators if they had tips on how we could both create a relationship of trust and understanding (as I wanted) and more that critical thing (as my group-member wanted). And our secretary – he is really good at writing short emails. So I think we'll manage if we just persist.

Oh god, I never did a project like this before. I'm just very happy that first conversation with the case owner will be together with the whole team. But I am actually really excited about this. Yea.

Decision narrative – starting PhD's

These are a few pages from a fictional diary of a new PhD-candidate at the Center for Climate and Energy transformation at the University in Bergen.

YES! I got the PhD-position! I don't know what I would have done with my life if I had not gotten this PhD-position. I will travel to Norway in three weeks. I have been there before, on exchange during my bachelor. I followed the course *Sustainable innovation* at CET then. That is how I got in touch with the people at CET. But that I would get a PhD there – wow.

I leave in two days. I can't help these thoughts just building in my head. Will they like me as a colleague? Will I be able to make friends? I am also a bit scared for the transdisciplinary collaboration in my PhD. I think it is very important that we collaborate with society to make knowledge more relevant, but I have hardly done this before and as a foreigner who doesn't speak Norwegian, I can imagine it will be hard. I feel like I am an expert on the topic of my PhD, but this transdisciplinary stuff is new to me.

I had my first day at CET today. It was much more chill than I had expected. Nora helped me install at my desk and she was so helpful. Havard came up to me and we had a nice chat. We agreed I would just take today to unpack all my stuff and we would talk tomorrow about the first things for the PhD. I also met many of my colleagues at lunch today. They were really kind. At the end of the lunch break about half of the CET-researchers were left. Turned out these were precisely the CET researchers who were involved in transdisciplinary research. So we talked about that. They all offered to think along and to help if I wanted that. It really felt like a bit of a community. They asked me why I wanted to do transdisciplinary research. I hadn't really thought of it like that yet – it was just part of the PhD-position. But they insisted: why did *I* want to do it? I was ashamed that I didn't really have a clear answer, other than: 'I think it is good to collaborate with people in society.' So they said: think about it.

I had a really good conversation today. I was talking with two of the PhD-candidates who are involved in transdisciplinary collaboration. I had thought a bit about their question: why did *I* want to do a transdisciplinary PhD? So my starting point is that I think it is good to collaborate with people in society. But why do I think that? Well, first of all, I think it makes our research better, because we can involve perspectives in the research that we could otherwise not involve. So we have more knowledge input, so to say. Second of all, it also benefits society, because we can make sure that the research was are doing and the tools we are producing are actually relevant to society by co-producing them with people from society. Their input can help us to adapt the knowledge to what they need specifically in their context. We did this in the course *Sustainable innovation* during my bachelor exchange, when we developed an innovation for a societal case-owner. The other two PhD-candidates agreed, but they also saw other reasons you could engage in transdisciplinary collaboration. For example, your aim could be to facilitate equal deliberation processes between actors. So then it isn't even really about producing new knowledge but more about getting people

together who previously didn't talk with each other, so they can share and combine their already existing knowledge.

'But then why do you need researchers?' I asked. 'If they just share the knowledge they already have?'

The other PhD-candidates laughed: 'Maybe the societal actors become the "researchers" and we become more like "facilitators".'

I couldn't really imagine what this would look like, so I asked them to elaborate. 'Well,' one said, 'for example you could do stakeholder analyses to identify which actors are relevant for the topic of your PhD. You invite them and put them into mixed groups. You frame the whole session as a "discussion forum" and prepare specific assignments form them to work on, so they are forced to share their ideas. Without you as a scientist actually presenting that much of your knowledge and research findings.'

Another PhD-candidate chipped in: 'And there are more collaborative exercised like that. For example collaborative systems mapping. But a challenge can be to facilitate the discussion so that everyone feels like they can contribute, despite power differences among the participants.'

'But that sounds quite hard!' I exclaimed in some horror. 'I have no experience with facilitating discussion like that. Is this what I have to do in my PhD?'

They laughed. 'Not necessarily. You can do the type of transdisciplinary research you think is important in your project. You will talk about that with you supervisor – Havard is your supervisor, right?'

Another responded: 'As long as you know what your objective is for the transdisciplinary collaboration, and why you find that important. And as long as you choose a form that suits your objective, but also one that you are comfortable with and have the skills for. I mean, if facilitating those complex discussions is not your thing right now, then don't go for that. Or do it together with someone who is very experienced.'

Another added: 'And communicate your objective very clearly. It is crucial that everyone in the collaboration shares their expectations. But then you first need to know very clearly what your own expectations are – why you are in this, so to say.'

They told me which PhD-candidates have experience with which types of transdisciplinary collaboration and encouraged me to ask for help. I have a lot to think about now. Why do I really want to do this, and then what is my objective? What form of collaboration suits that goal? Which activities should we then perform in the collaboration? And do I actually have the skills for that? It's not just thinking about what the research plan describes, but also a lot more thinking about my own motivations and skills. Yea I really need to think about this. But in this it is actually quite cool. I feel like I can determine how we will organize this now. That gives a good feeling. And at least I'll be super prepared for my first conversation with Havard about this.

Appendix 8. Two prototypes

Prototype 1: Your unique contribution

[First version, before validation in the prototype evaluation sessions]

You want to do transdisciplinary collaboration? Cool! But do your collaboration partners also want to work with *you*?

Convince your colleagues and societal stakeholders that you are worth investing their time in! Sell to your potential collaboration partners why you can make a unique contribution.

This reflection tool mimics a job interview setting: An application committee member asks you (the applicant) *why* you want to engage in transdisciplinary collaboration and *what* you can contribute to that collaboration. You can make the *why* concrete by putting forward 'motivation cards'. You can make the *what* concrete by putting forward 'skill cards'. You will reflect on how your motivation and skills can come into play when you are faced by different real-life transdisciplinary challenges (described on 'challenge cards'). The application committee member helps you by asking you reflection questions that are written on 'reflection cards'.

Preparation

- The game is played in duo's One is an 'applicant', the other is a 'committee member'.
- The applicant chooses one motivation card and three skill cards (skills related to the five researcher-roles) that are closest to their real motivation and skills.
- The committee member has a deck of challenge cards (related to the challenge identified I this master thesis).

Gameplay

1. The committee member draws 3 challenge cards.

2. The applicant must choose 1 of these challenge cards and put 1 motivation and 1 skill card from their own pile next to it.

3. The committee member can draw a reflection card with a question to ask the applicant. The question relates to the connection between motivation / skill and the challenge.

4. The committee member and the applicant determine together if they think the fit between motivation/sill and task is good. They can move the motivation/skill to one of the other tasks, or draw new cards, untill they are satisfied.

Prototype 2: CET'lers THE GAME

[First version, before validation in the prototype evaluation sessions]

You want to transform society? Cool! But how are you going to conquer the lands outside the ivory towers of your social sciences castle?

Plan your campaign and CET'le in society!

In this board-game, you pick a character. Examples of characters are: the mad professor (reflective scientist), the respected king (process facilitator) and the charming rebel leader (change agent). Each character comes with three actions they can put into action during the game. Besides picking a character, you also pick an 'objective': what kind of impact do you want to have in society? The game is played on a board. As the team moves around the board together, they are faced by challenges, which are based on real-life transdisciplinary challenges. Each player determines which of their actions they want to put into use to address the challenges and achieve their personal impact-goals. The player who gets closest to their personal impact goal wins the game.

Preparation

- The tool is played as a game by 3-5 people. If 6 people or more are present, two games can be played in parallel. The tool is not meant for individual use or use in duo's.
- Each player chooses an objective from the pile of objective cards: what kind of impact do you want to have on society?
- Next, you get to choose one personality
    - the mad professor, who comes with genius theories… but sometimes people have trouble understanding the professor (reflective scientist)
    - the … (knowlegde broker)
    - the respected king who never shares their own opinion, but facilitates the collaboration between others (process facilitator)
    - the charming rebel leader who is always openly critical (change agent)
    - the silent spy who reflects on what is happening around them (self-reflexive scientist).

Each personality comes with three core qualities cards (skills related to the five researcher-roles).
E.g. the mad professor can generate scientific insights, analyze actor networks in society and invite societal actors to CET lunches.
E.g. the rebel leader can critically reframe the assumptions of a powerful societal stakeholder, network with societal stakeholders and bluntly tell that they think societal actors should do

Gameplay

The game is played on a board. The team moves around the board together. So there is one pawn for the whole team.

1. Roll the dice & walk the corresponding number of steps on the board

2. Follow the instruction in the field the pawn has ended up on. The odd fields (field 1,3,5 etc...) contains an instruction like: 'There is no funding for transdisciplinary collaboration – go three steps back.' When landing on such a field, follow the instruction and restart at step 1. The even fields contain the instruction: 'Draw a challenge card'. When landing on such a field, continue to step 3.

3. Take the top card from the deck of challenge cards. Someone reads the challenge out load. *The challenge relates to a situation described in one of the interviews or focus groups but is translated to a medieval fantasy context.*

4. Each player individually looks at their objective and the action cards of their character. They each choose one action card to put into action to address the challenge. Place objective card and the chosen action card face up in front of you.

5. The team now looks at all action cards that have been put forward by the multiple players. This is how the team addresses the challenge. But wait – everyone had a *different* objective. With this combination of actions put forward – who gets closest to their objective? The game facilitator leads a discussion on this. The team must come to a consensus. The winner gets 1 point.

The round ends. Restart at step 1.

Continue untill team reaches the finish or decides they are done playing. The player with most points wins.

Appendix 9. Comments made during the prototype evaluation sessions

Reactions to the **decision narrative about students**:

- “Like that in the narrative, the student reflects on transdisciplinary collaboration in multiple course sessions, so it is a recurring theme in the course. Already try to do that in the course, partly successful.”
- “The thoughts about grading were interesting. I think the reaction of the course-coordinator in the narrative was quite smart. Made it more concrete what was expected of student.”
- “Useful to reflect on why you engage in transdisciplinary collaboration before thinking about what skills you need for that and role division etc.”

Reactions to the **decision narrative about PhD-candidates:**

- “Is the reflection tool to be used during or after this story?”
- “It ends with the main character saying: ‘I really need to think about this’. So the reflection still has to happen?”
- “I think what you are trying to say is that unasked questions also lead to new relevant questions not coming up. PhD-candidates already have questions about their role in collaboration and the challenges they face. But before thinking about that, you want them to ask themselves a set of deeper questions – about why they engage in collaboration. Because without first reflecting on these deeper questions, the thinking that roles and challenges is too limited.”
- “I don’t really see the iterative nature of reflection in your decision narrative. I think that is important.”

Reactions to the **essence**:

- “I like the essence. Unique role in society is precisely what I often think about. And nice way to make ‘why you engage in collaboration’ concrete”
- “This makes me think of what I saw in my internship: policymakers are often focused on the final goal and the implementation, while researchers are more focused on the research process itself. So when they exchange expectations, there is a mismatch. So the researchers need to think about: why am I doing this? And communicate that.”
- “Cynevin model is new – could you send it after this session?”

Reactions to **prototype 1: Your unique contribution**. The respondent saw the potential value of the prototype. But thought that, before the prototype would deliver on that value, it needed to change in tone to be less intimidating and competitive and needed further development.

- "The setting of a job interview with an 'applicant' and a 'committee' sounds intimidating. I would not find this a comfortable tool to engage with."
- "The terms 'applicant' and 'committee' create power distance, which I rather felt you wanted to avoid? It also gives a sense of competition. The decision narrative was more about helping each other and learning from each other, than proving yourself to others."
- "I think it should be more about convincing yourself that you can have a unique contribution, than convincing others of this."
- "The cards with motivations, skills and tasks are a smart way to create concrete handles for reflection on what you can contribute and why you want to do collaboration."
- "Not clear what the *tasks* are. Are these situation students would encounter in the course, or challenges they could face? What level of complexity vs specificity should these tasks have?"
- "Clear that skills relate to the five roles. But in the real world, you have a lot of skills. And things that are not your superpowers, you might still be able to do. So it might be problematic to choose just 1,2,3 cards with skills."
- "What insights can you extract from each step? What can be talk about further later? Add debriefing questions after each step? Or make facilitators guide to let facilitator help the players extract insights?"
- "Game mechanics not clear enough yet."
- "Idea: With regards to the *motivation cards*: how can we solve a challenging task while remaining true to our motivations?"
- "Idea: you could also turn the roles around. So applicant and committee member change roles. It would be cool to help my professor reflect on his contribution in transdisciplinary collaboration."
- "Idea: You could make the roles equal. Both have to convince each other of their contribution. They stand in the room facing each other. Every time one of them makes a strong argument, they make a step forward. See where they meet – person who made most steps has the best fit between skills/motivations and task. This does maintain or even strengthen the competitive element, though."

Reactions to **prototype 2: CET'lers the game.** The respondent showed more enthusiasm here, although they also said more had to be clarified. Comments:

- "This sounds exciting. Fun. And think you can get a lot of reflection out of this."
- "I can see you are much more enthusiastic about this one, Joran. You are smiling while you are telling about it. And the whole thing is worked out in more detail. This is a concept. The previous prototype was an idea."
- "Nice that it is more of a group reflection."
- "This feels much less competitive than the previous one. You work together here."
- "Avoid characters being gendered."
- "'Mad professor' sounds negative, while 'charming rebel leader' sounds positive. Can you both make them positive?"

- “Change agent not necessarily always openly critical. Change agent can use the ‘language of power’ without critically assessing that language, to create movement. And reflective scientist can be critical too.”
- “The game is too complicated. Can you simplify it? Suggestions: 1) Take out the medieval theme. It pulls attention away from what you actually want to do: stimulate reflection. The people who use the tool will be interested in the topic of transdisciplinary collaboration anyway. 2) Have only a few skills cards, not too many. 3) Explain the game super clearly, step by step.”
- “How can you make sure that all players have an equal contribution in the discussions? For example, will new PhD-candidates speak up just as much as the experiences PhD-candidates?”
- “How to facilitate that the players can extract insights from the game?”
- “This could be cool if you have the time to build it properly. Maybe build on existing game mechanics. Existing character-based role-playing games? Can also use ideas from ‘red and black pen’”
- “Idea: Can you involve external stakeholders in the game? In challenges – for example boss of big oil company comes to you and asks…”
- “Idea: You could make multiple roads on the game board, to show there is not something like ‘the path’ in transdisciplinary collaboration. Should not become more complicated than it is though.”

Comparison between the two prototypes

Arguments mentioned for prototype 1:

- More centered around reflective conversation
- Easier to extract insights from the use of the tool
- Easier to understand how to play

Arguments mentioned for prototype 2:

- More collaboration, ability to play it in a bigger team to stimulate group reflection
- More playful and to some people definitely more fun
- Less intimidating and less competitive
- Joran is more enthusiastic about it

Appendix 10. Raw data of the test session

Comments on post-its

The test participants could post post-its where they found the game instruction or game cards unclear. They wrote four comments on post-its:

- "Team? Who's in the team?" (posted on the game instructions, section *The game in short*)

The term "team" caused confusion. One test participant got the impression that the game was played in multiple teams simultaneously. I clarified that all the players together form one "team" and that the game both has a cooperation element (in your "team") and a competition element ("individual"). This must be explained more clearly in the game instructions.

- "It'd be fun to have a timer", with a drawing of an hourglass (posted on the game instructions, section *Gameplay – step 2*)

The test participant suggested this to time the 5-minute discussion in the game.

- "Action cards are a little too vague?" (posted on the game instructions, section *Gameplay – step 4*)

This post-it spurred a further discussion about changes in the game, see section 9.4.3.

- "So what if action cards do not fit with the situation card? Or you want to do something else than the action card?" (posted on an action card)

This post-it spurred a further discussion about changes in the game, see section 9.4.3.

Questionnaire raw data

N = 3
Anonymous questionnaire
Possible answers: 1 = strongly disagree | 2 = disagree | 3 = neutral | 4 = agree | 5 = strongly agree

I felt like the situation cards in the game were:	**Answers**
Realistic	4 3 4
Relevant to situations I encounter in real-life	4 4 4
I felt like the action cards in the game were:	
Realistic	3 4 3
Relevant to the transdisciplinary collaboration I engage in	4 3 4
I felt like the guiding question cards in the game:	
Were helpful	1 4 2
Made me think about the same topic in a different way	1 3 3
I gained new insights on:	
Which contributions I can make in transdisciplinary settings	3 4 2
Why I have a preference for certain contributions in transdisciplinary settings	3 5 3
Why others have a preference for certain contributions in transdisciplinary settings	4 5 4
Which actions I can perform in transdisciplinary collaborations	4 4 5
Why I have a preference for certain actions in transdisciplinary collaborations	3 4 3
Why others have a preference for certain actions in transdisciplinary settings	3 5 4
How multiple people can combine their actions to achieve a desired contribution	4 3 4
How my actions affect the outcome of a transdisciplinary collaboration activity	3 3 3
Some final statements:	
The game provided a structure for the discussion about contributions and actions	4 4 5
It was easy for me to understand the rules of the game	4 4 4
It cost me little time to understand the rules of the game	4 5 4
It was easy for me to play the game	2 5 4
Each game round went fast enough to keep me engaged	4 5 5

Transcript of the discussion about the game

This is the transcript of the video that was taken of the test session. I transcribed only the parts of the video where relevant input was generated in a verbal way. For instance when the test participants asked questions about how the game works, made comments about the game, or did suggestions how to improve the game. I did not transcribe the normal game play.

I aligned the numbering of the test participants with the numbering of the respondents to my research:

Participants to the test session	**Was this participant also a respondent in the case-study?**
Participant 1	Yes: respondent 1
Participant 2	No.
Participant 3	Yes: respondent 3

00:00 *The participants start reading the rules of the game.*

1:48 *The moderator breaks the silence.*

Moderator I see you are writing a post-it. Can I answer your question?

Participant 1 Sure. My question is – you mention the team here. The team is us as a group?

Moderator Yes.

Participant 3 So ideally, it's supposed to be multiple teams, or?

Moderator You work together as one team.

Participant 1 So we are all at CET working, like dealing with a situation and we all have different action cards that we have to resolve that situation.

Moderator "We all at CET" is then the people playing the game.

Participant 2 So it is both cooperation and competition?

Moderator That's it!

The participants continue reading the game rules.

Moderator Is that question on the post-it a question you would like an answer to now, before we can move on?

Participant 1 No, it's just - you said that there was like this specific amount of time we should be resolving these things in. Would be cool to have such an hourglass thing.

4:45 *The participants start playing the game.*

10:31 *When the participants are choosing an action card to help achieve the unique contribution (step 3), they mention that this is hard.*

Participant 1 This is difficult.

Participant 3 What if you don't have a card that you believe is good enough?

Moderator What do you think when reading the instructions?

Participant 3 The action that will “best” help you.

Participant 2 It is hard. I think I would do none of these. I would do something else.

Participant 3 I know!

Participant 2 Al right okay I have one.

All participants put down an action card and the game continues.

19:58 *When round 1 ends, the moderator halts the game.*

Moderator Are there any more questions? I saw you writing a bit on a post it. It that something you want to share?

Participant 2 What if the action cards do not quite fit with the situation or the contribution card? Because I felt like the actions cards I got were like: yeah that's not exactly what I would do. And then I would like - and what if you want to do something else than the action cards you have?

Moderator Did you share this feeling?

Participant 3 Yea. My action cards were a little too vague, like open to interpretation like especially if you're trying to convince why your card should be chosen.

Participant 1 I like mine. *All participants laugh*

Participant 3 The situation cards are very specific and to tackle these your action cards are much broader, I felt. So you can either make the situation also a little bit broader or maybe the action cards a little more specific.

Moderator And participant 2, do you also have a suggestion how to address what's on your post-it?

Participant 2 Not that I wrote down, but maybe it should be - of course that would sort of ruin the part that you want to know which action card is whose, but maybe you can have like a wild card. An extra one. Yeah, like something completely different. Which means that you show your opinion but then you also get the opportunity of arguing for another way.

Participant 3 Yeah, that's nice. Like how we have a fourth one, which is just blank and then you do with that whatever you want to do.

Participant 2 Yeah, like that. Like let's say that this just game goes for like four rounds and you only use it once.

Participant 1 So like a joker. Yeah, so I was thinking that you would put one on top. Just to make it a bit more clear on who put which one. So to have one plus card.

Participant 2 Yeah, my thought was just to make this part of it like special. You shouldn't be able to just use it whenever you feel like it. You should be like: okay if I use it now, I can't use it for three next rounds.

Participant 2 So yeah, and my other thought now at the end of this round was that - I don't want to pick a new situation card. I want to continue with this situation. Sort of okay now we done that, what can we do next?

Participant 3 It's a problem for those of us who think about transdisciplinary situations a lot.

Participant 2 I just felt like: I don't want to leave this story.

24:00 *The participants start playing a second round of the game.*

29:47 *When choosing a unique contribution, the participants deliberately broke the game rules by choosing two contributions instead of 1, because they thought this would make the game better.*

Participant 2 What if we sort of add "use the situation as a case study for fragmented governance processes", comma, to "enhance knowledge exchange".

Participant 3 Yea, I think 2 needs to be embedded in 3.

Participant 1 Thank you for the rules, but we're going to change them.

Participant 2 So we agree on two and a half?

Participant 1 Yea. Can we do that?

Moderator Not according to the rules. But you are playing. So play it like you want to play it.

The players start looking at their action cards (step 3).

Participant 3 If I put the same card forward as last round, everyone will know it is my card. That is something you need to consider [aimed at the moderator].

Participant 1 Yes. And in the second round, you already know what your cards are before looking at the situation. So it can influence the discussion about the situation.

Moderator Do you like that?

Participant 1 I don't know. I think it's better if everyone draws new cards.

Participant 2 Yea, everyone draws new cards.

Participant 3 Or we put everything back in the deck, and you get exactly the same number back as in the current game rules. Otherwise nobody wins.

Participant 2. Yes.

Moderator Timewise I suggest you continue playing.

33.38 *The participants continue the game.*

40:34 *When round 2 ends, the moderator stops the game.*

Moderator We will close off with a short questionnaire soon. But before that, I would like to ask you two general questions. One question is – I put in this game that your action card has to be chosen and the others don't know which card is your. I was wondering – what does that do to how you feel in the game? What does that do to the vibe?

Participant 3 I did not think of defending my action cards. I thought about what is best for the situation. So I put down what I thought would be best for the situation.

Participant 2 To me, that you have to defend your own card actually makes it a bit more exciting. But at the same time it gets you trying to argue for your own card even though you actually don't think it is the best one.

Participant 3 Yea. I agree. It is a tension between the common good and your own individual take on that.

Moderator I put that tension in there on purpose. Because I thought you can choose what you think is best. But maybe you learn more by being forced to defend something which you don't necessarily think it right. That you learn new arguments for something you didn't agree with. Do you think that works at all?

Participant 3 But I don't understand the purpose of that. Because you say we work in transdisciplinary settings. And then we have to fix our ways and actions to their situation. So we need to change our actions and try to see how they benefit the situation, right? I understand it as a game – but I don't necessarily understand the objective of that.

Participant 2 It could also be an interesting discussion to argue about why you don't think your card is the best one when it comes to roles and things like that. For example, I chose this because it was the best I had, but I really don't think we should go with this.

Participant 1 In a way, the cards are the skills that we have as academics. And this is the situation. And because academia can be a difficult context to find funding, write papers. So that this kind of situation is coming up, means that you have to make your approach relevant. I see it a bit like that, that you have to find ways to frame your research that it is relevant to those transdisciplinary situations.

Moderator Thanks. Final question. You wrote on a post-it that you could refresh the cards. So after a round you could get the same number of action cards, so the winning still works, but you refresh them from the pile. And you also said earlier: I would want to go on with the same situation. So a question to all three of you: How do you think the game would be if you change action cards but not change situation?

Participant 3 I think that would be interesting actually. To see what specific roles you would need to combat a situation. That would realistically speaking – you would have action points to reach your objective.

Participant 1 Could you repeat the question?

Moderator Imagine we would change the game from what it is now. So instead of changing situation we would keep the same situation each round. And instead of keeping the same action, we get new actions every round.

Participant 2 So we could build on the first actions, so it's like "what's next". Which role, what should we do next?

Participant 1 I like having new situation. But also having new actions cards. And having the situation before the action cards. Because I think I would be drawn to a situation based on the action cards I have. If I would not have that, I would rather say: "This number 2 really excites me personally." Then you realize: "Ah, I don't have the right action cards for it." So if you know your actions cards it becomes a bit more strategic and it takes some of the fun away, I think.

Moderator Cool. Shall we end off with the survey? And then we are done.