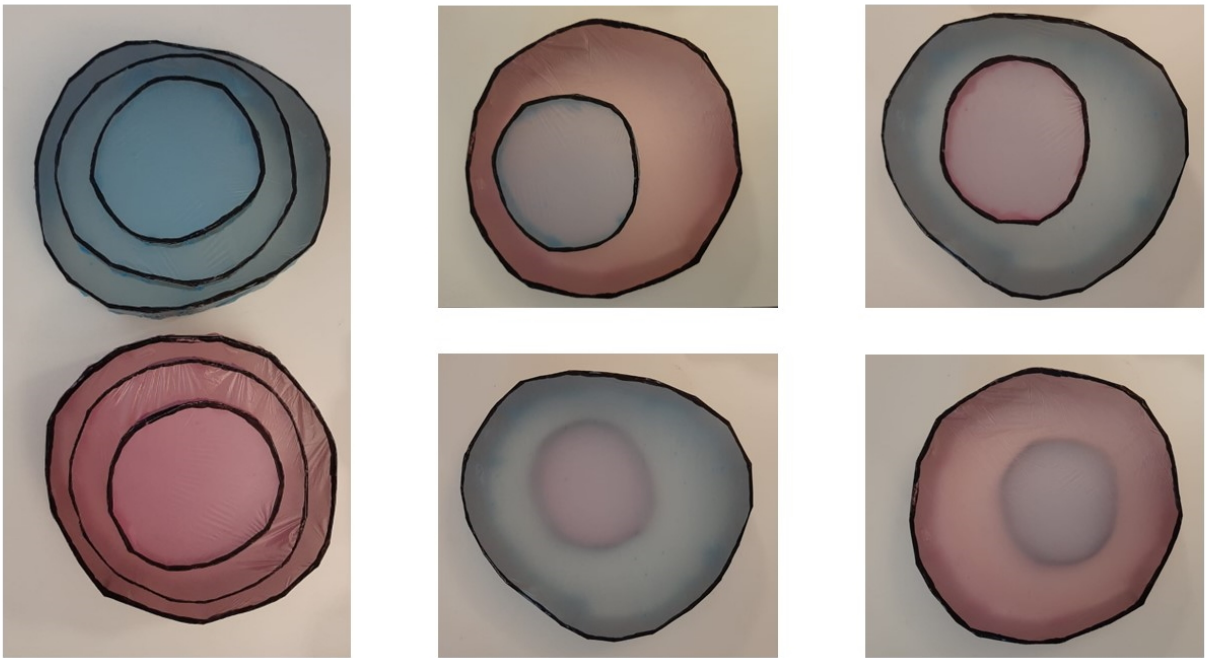
Towards holistic science

Cultivating a mindset suiting inter- and transdisciplinarity

Effie Leijten

Master Thesis



TU Delft

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Cultivating a mindset suiting inter- and transdisciplinarity

by

Effie Leijten

Master Thesis

To obtain the degree of Master of Science,
In the Communication Design for Innovation track of Science Education and Communication,
At the Delft University of Technology,
To be defended publicly on Thursday, November 2, 2023 at 9:00 AM.

Student number:	4477162
Publication date thesis:	October 18, 2023
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An electronic version of this thesis is available at http://repository.tudelft.nl/.

TU Delft

Executive summary

The 21st century is marked by rapid changes, interconnectedness, and uncertainty regarding the future. Complex issues such as climate change pose challenges, yet current scientific approaches predominantly employ reductionism, dissecting intricate problems into isolated components. This 'reductionist' lens limits our ability to comprehend the interdependencies and cascading effects shaping these issues. This thesis addresses the pressing need for scientists to adopt a more 'holistic' perspective on science and embrace inter- and transdisciplinarity in tackling complex 21st century issues, such as climate change. The thesis focuses on the academic discipline of biotechnology and combines insights from 'Science Education and Communication' with 'Life Science and Technology.' It employs a mixed-method, design-based research approach conducted in three phases, guided by the overarching goal of cultivating a 'holistic' mindset suited for inter- and transdisciplinary practice.

Phase 1: Contextual Perceptions and Reflective Practice within the context of a biotechnology research consortium
Phase 1 sets the stage by exploring contextual influences on participants' mindsets regarding inter- and transdisciplinary practice within the academic discipline of biotechnology. This phase involved an in-depth case study focused on a consortium, a specific and localized context within the larger field of biotechnology. The research methodology employed for this phase was primarily qualitative in nature.

To analyze and understand the complex dynamics at play, a theoretical lens was constructed encompassing the Social Identity (Complexity) Theory, the concept of 'Mental Models', the Cognitive Dissonance Theory and theory on Learning Through Reflection. Within this theoretical framework, the mindset is conceptualized as "a collection of individual and collective beliefs".

The most critical findings of Phase 1 revolved around the dynamic nature of contextual shifts observed during reflection processes the case study participants underwent, as evaluated through in-depth coding analysis. These shifts were initiated by the introduction of one of two artworks as unusual contextual triggers, which prompted participants to rethink and reevaluate their perspectives. This underlines the importance of context and how external factors can stimulate reflection, impacting the development of a 'holistic' mindset. Emotions and cognitive dissonance emerged as stimulating factors in these reflective processes with a contextual shift, emphasizing their role as drivers of change in mindsets within the field of biotechnology. Based on these findings, the essence of cultivating a more 'holistic' mindset in this case study's context is encapsulated in the concept of "Re-connecting yourself."

This phase lays the groundwork for understanding how contextual influences shape mindsets and highlights the essential role of reflection, emotions, and cognitive dissonance in the development of a 'holistic' mindset. While the context of Phase 1 was highly specific, the subsequent phases delve into more generalized aspects of inter- and transdisciplinary practice, building upon the insights gained here.

Phase 2: Defining what can induce continuous cultivation of a 'holistic' mindset

Phase 2 focused on defining the factors that can continuously cultivate a 'holistic' mindset within the academic discipline of biotechnology. This phase was informed by an input session with members from a different biotechnology context, broadening the research perspective. The insights from Phase 1 were reevaluated in this phase, and they were combined with insights from additional literature, resulting in three key findings: 1) The importance of preserving individuality while fostering connections within the academic discipline became apparent, emphasizing the need to create a tool that promotes 're-connection' without compromising personal identity; 2) The concept of boundary objects, which facilitate communication across disciplinary boundaries, emerged as a valuable guiding principle for tool design, ensuring it bridges gaps between various perspectives within biotechnology; and 3) Emotions, particularly 'autonomy' and 'relatedness,' were identified as universal triggers for reflective conversations. These insights indicated that tool design should incorporate elements that engage these emotions, promoting meaningful interactions among biotechnology professionals. These insights form the basis for the subsequent stages of tool development.

Phase 3: Tool Design

In the third phase, the "Out of Context!" tool prototype was designed, whose objective is to facilitate the continuous development of a 'holistic' mindset and support interdisciplinary practices among biotechnology professionals. Based on insights from Phases 1 and 2 and an additional input session with members from the different biotechnology context, the tool was designed with the following design criteria in mind: 1) Contextual Relevance, i.e., it addresses the specific needs and challenges faced by academics in the field while preserving individuality and fostering (inter- and transdisciplinary) connections; 2) Facilitation of Creative and Comfortable Discussions, i.e., it facilitates creative and comfortable discussions allowing users to bridge the gap between different perspectives; 3) Integration of Personal Beliefs, i.e., it allows its users to integrate their personal beliefs and experiences in discussions so that contextual factors shaping them are highlighted; 4) Support for Minor Interactions and Individual Use, i.e., support relatively small meetings or personal use; and 5) Establishing a Common Ground, i.e., it helps its users to define and visualize a common ground when reflecting on their mindset.

Conclusion and recommendations

This work offers a unique approach to understanding the transition to inter- and transdisciplinarity, drawing on social constructivism and the experiences of practitioners in the academic discipline of biotechnology. The significance of this research lies in its potential to inform the development of a 'holistic' mindset and the practice of inter- and transdisciplinarity within the biotechnology scientific community. The findings underscore the need for practitioners and researchers to report their experiences and insights regarding the practice of inter- and transdisciplinarity, providing valuable insights into bridging theory and practice. Additionally, the 'Out of Context!' tool's effective implementation and evaluation are vital, as it holds the potential to transform discussions related to the 'holistic' mindset, thereby advancing interdisciplinary practices in the field of biotechnology.

Contents

1

Introduction

The 21st century is marked by rapid changes, interconnectedness, and uncertainty regarding the future (Broo, 2022). At present, the formulation of problems related to complex issues, such as climate change, is challenging. Currently, scientific approaches attempting to tackle these issues are mostly 'reductionist', seeking to dissect intricate problems into isolated components for analysis. For example, (applied) sciences are compartmentalized into ecological, social, economic, and technological factors. However, this 'reductionist' lens limits our ability to comprehend the interdependencies and cascading effects that shape these issues, accompanied by a risk of overlooking the intricate web of interactions among variables and failing to grasp the 'holistic' nature of these issues. For instance, focusing solely on isolated aspects of climate change, such as carbon emissions, without considering the broader socioeconomic context, can lead to ineffective solutions that inadvertently exacerbate other issues.

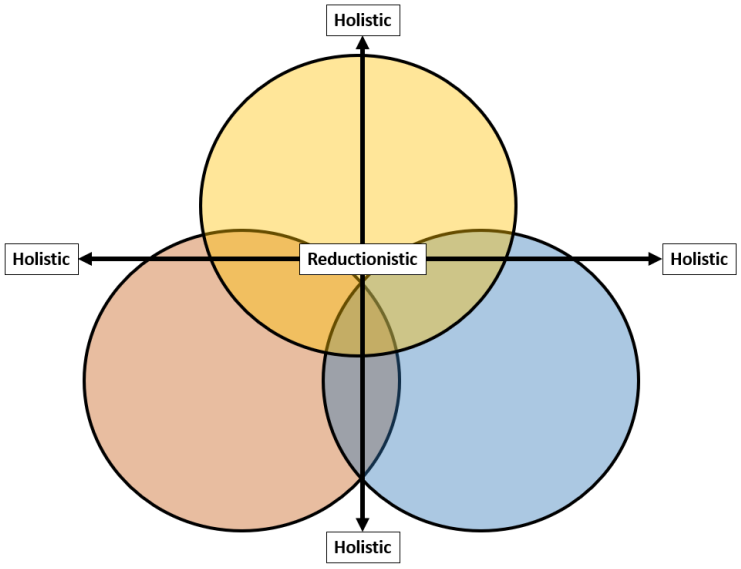


Figure 1.1: **The 'reductionist' versus more 'holistic' scientific perspective.**

In this context, scholars have aptly criticized the current 'reductionist' approach in applied science, labeling it as 'fragmented, 'reductionist, and materialistic', as it is often only shaped by one specific compartmentalized academic discipline (Fonseca Albuquerque Cavalcanti Sigahi and Sznelwar, 2021; Gidley, 2010). For scientists to act more responsibly or ethically related to all complexity outside of their discipline, they recommend a change in scientific inquiry: one related to a 'holistic' view of science and one's responsibility as a scientist (Broo, 2022; da Costa, 2022; Frödin, 2017; Gidley, 2010; Hermes and Rimanoczy, 2018). However, despite the significant efforts that have been undertaken in recent decades to embrace more 'holistic' perspectives, the effectiveness of these endeavors in driving systemic change remains limited (Mckenna et al., 2014).

1.1. A 'holistic' mindset for 'holistic' science

Science meant to contribute to current complex issues, if not all science, is susceptible to socio-cultural values and perceptions of reality. Therefore, to improve current scientific practice, scholars stress that academic participants should respond consciously with self-criticism, self-revision, and self-control (Benedikter et al., 2010). Inspired by this, studies have focused on describing the mindset of individuals who (want to) consistently have this response (Christensen et al., 2021; Noble et al., 2016). This has led to varying concepts of what this 'ideal', 'holistic' mindset should look like.

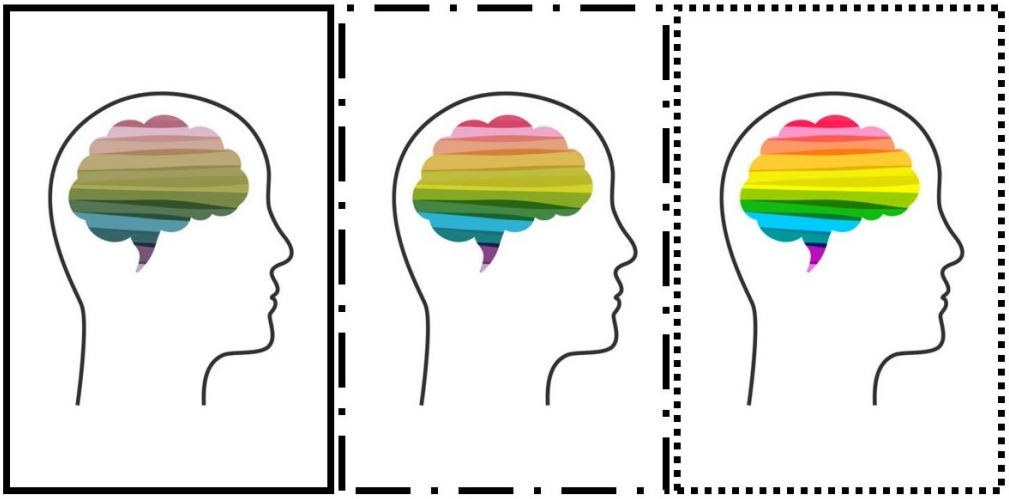


Figure 1.2: **Towards a 'holistic' mindset that acknowledges perceptions to be susceptible to socio-cultural values and perceptions of reality, and supports scientists to transcend current disciplinary or scientific boundaries via inter- and transdisciplinarity.**

In the literature describing this 'holistic' view of science, an interdependence is often acknowledged between exercising this mindset, tackling complex sustainability problems, and (an attempt to have) inter- or transdisciplinary collaborations (Fonseca Albuquerque Cavalcanti Sigahi and Sznelwar, 2021; Gidley, 2010; Max-Neef, 2005). Although different interpretations exist (Max-Neef, 2005), inter- or transdisciplinarity is often defined by one or both of the following aspects: constructive interactions to co-create new knowledge frameworks, and the inclusion of nontraditional stakeholders (Carmen, 2021; Rigolot, 2020). When moving towards inter- and transdisciplinarity, a more 'holistic' mindset is expected to change collaboration norms and practices to those that suit inter- and transdisciplinarity. Vice versa, an improved inter- and transdisciplinary context can help the cultivation or 'practice' of having a more 'holistic' mindset (Kudo et al., 2018).

1.2. Limitations for the cultivation of a 'holistic' mindset

According to the scholarly view of 'holistic' science, it is essential to train individuals to cultivate this 'holistic' mindset and use it in their professional career (Fonseca Albuquerque Cavalcanti Sigahi and Sznelwar, 2021; Hermes and Rimanoczy, 2018). However, a current knowledge gap exists on how to shape scientific (education) environments so that participants internalize this new perspective, i.e., one that envisions that inter- and transdisciplinarity connected to a new mindset is required to solve nowadays complexity (Jacobs and Nienaber, 2011; Kudo et al., 2018). This gap has been largely overlooked by the mainstream academic practice of today (Gidley, 2010; Guimarães et al., 2019). As a consequence, the academic environments remain 'mono-disciplinary'-focused, in which the 'fragmented, reductionist, and materialistic' perspective is extensively trained and connected to collaboration approaches mostly within the discipline itself (Broo, 2022; Fonseca Albuquerque Cavalcanti Sigahi and Sznelwar, 2021; Noble et al., 2016).

Notably, scientific inquiry from this 'reductionist' perspective remains extremely valuable, as problems can be simplified by choosing strategic assumptions. Reflecting on this raises questions like 'Do we really need to train academics of all disciplines to co-develop this 'holistic' view next to the traditional one?' and 'Can we create a subgroup with this co-specialization?'. Currently, the number of disciplinary-broad attempts claiming to set up programs to train individuals in such a co-specialization increases. However, incorporating everything required for this more 'holistic' perspective remains a challenge, as the perspectives remain solely susceptible to the perceptions of individuals participating in these programs. As stated by Gidley (2010),

"While the different disciplines push for what is needed from their own perspectives, very few have the breadth of vision to encompass the wide-ranging sweep of deep change that is required. Yet, perhaps even apparently far-sighted transdisciplinary fields such as futures studies are for the most part looking too close to the ground (pragmatic futures) and/or are too short-term focused (strategic futures)". (Gidley, 2010)

In addition, individual academic participants that are intrinsically motivated to move towards inter- and transdisciplinarity are often limited by their disciplinary context. In essence, based on reported experiences, it is apparent that the predominant emphasis within the current research and education context prioritizes predictable, risk-free practices, highlighting standardized testing and evaluation as indicators of 'strong science' (Christensen et al., 2021). Learning in new, undefined ways with attention to the influence of context is therefore often not worth the time and risk (Christensen et al., 2021; Guimarães et al., 2019). This general preference is reflected in both the science education and the funding preference of grant-giving institutions (Christensen et al., 2021). In addition, according to Böschen et al. (2010), dominating perspectives of nonknowledge are known to differ between scientific disciplines and to cause conflicts and misunderstanding when collaborating inter- or transdisciplinarily. Furthermore, depending on the discipline, existing research (thinking) routines, structures, and networks specific to a discipline are often seen to limit the success in crossing 'disciplinary boundaries' (Böschen et al., 2010; Carmen, 2021). Based on this, one could argue that the current academic, professional environment is generally also not one for participants to individually exercise inter- and transdisciplinarity and cultivate a more 'holistic' mindset suiting complexity. In other words, a second knowledge gap exists in understanding how to both sustain intrinsic motivation within individuals and provide them with the necessary tools to facilitate their movement towards inter- and transdisciplinarity and initiate the required change.

Finally, many argue that the more 'holistic' mindset and inter- and transdisciplinary practice cannot be normatively determined and that instead it must be continuously shaped by the perspectives of its participants (Augsburg, 2014; Thompson et al., 2017). However, for this to happen, participants need to start connecting views from outside disciplinary or scientific boundaries to the complex problem they are tackling and to the mindset they cultivate when doing so. When reflection occurs and participants respond with self-revision, they can initiate a change (Jacobs and Nienaber, 2011; Kudo et al., 2018). Because the limitations of the academic environment play such a significant role in the development of inter- and transdisciplinarity, it is interesting to investigate the role of various academic contexts in more detail. Research aiming to discover how different academic contexts influence the types of collaboration and mindset cultivated by the collaborating participants can be an opportunity to understand how to boost this development. Nevertheless, the actual movement towards inter- and transdisciplinarity needs to be executed by the academics themselves:

"The change is necessary and, in spite of all existing difficulties, it can only come from within the University, through the action and cooperation between enlightened academics" (Max-Neef, 2005)

1.3. The academic discipline of biotechnology

The academic discipline of biotechnology already represents a well-developed branch of various applied sciences that uses living organisms and their derivatives to design processes. However, the discipline has only recently been challenged to integrate into a broader concept of bioeconomy, serving complex societal challenges such as climate change (Carmen, 2021). This comes with new accountability for unknown consequences and risks of implementing modification technologies in day-to-day life, which is increasingly felt by the discipline's participants. However, this newly gained accountability is generally not included in disciplinary practice. In addition, since the discipline focuses on using (adapted) living microorganisms, its participants are inherently connected to an 'objective' and'materialistic' perspective of a 'being'. Phrased differently, biotechnology research efforts continuously explore the 'material' basis of 'existence' or 'identity', defined by genes present (Benedikter et al., 2010). Because of this, the subjective, self-conscious, and non-material dimensions of scientists as 'human beings' are easily overlooked (da Costa, 2022; Frödin, 2017). Based on this, it can be argued that the discipline of biotechnology requires its academic participants to be trained to codevelop the 'holistic' mindset next to the traditional, 'reductionist' one.

1.4. Thesis goal & research questions

This thesis is the result of a Double Degree of two master studies: the master 'Science Education and Communication' with the specialization 'Communication Design for Innovation' (CDI) and the master 'Life Science and Technology' (LST). Both fields are combined by performing social science research and design-based research (CDI), applied in the context of research in biotechnology (LST).

The thesis originates in the normative claim that scientists tackling complex issues need to adapt their perspective on science towards a more 'holistic' one, accompanied by moving towards inter- and transdisciplinarity via continuous reflection (Figure 1.3). However, this thesis evaluates this continuous transition towards inter- and transdisciplinary practice, connected to the cultivation of a more 'holistic' mindset from a social constructivism point of view. From this point of view, the chances of initiating change inherently depend on the social context.

With a specific focus on the context of the academic discipline of biotechnology, this thesis aims to contribute to the transition of academics of the discipline of biotechnology to co-develop a 'holistic' mindset next to 'reductionist' one. It answers the following main research question:

Q: *How can members of the academic discipline of biotechnology be incited to continuously and consciously cultivate a more 'holistic' mindset suiting inter- and transdisciplinarity?*

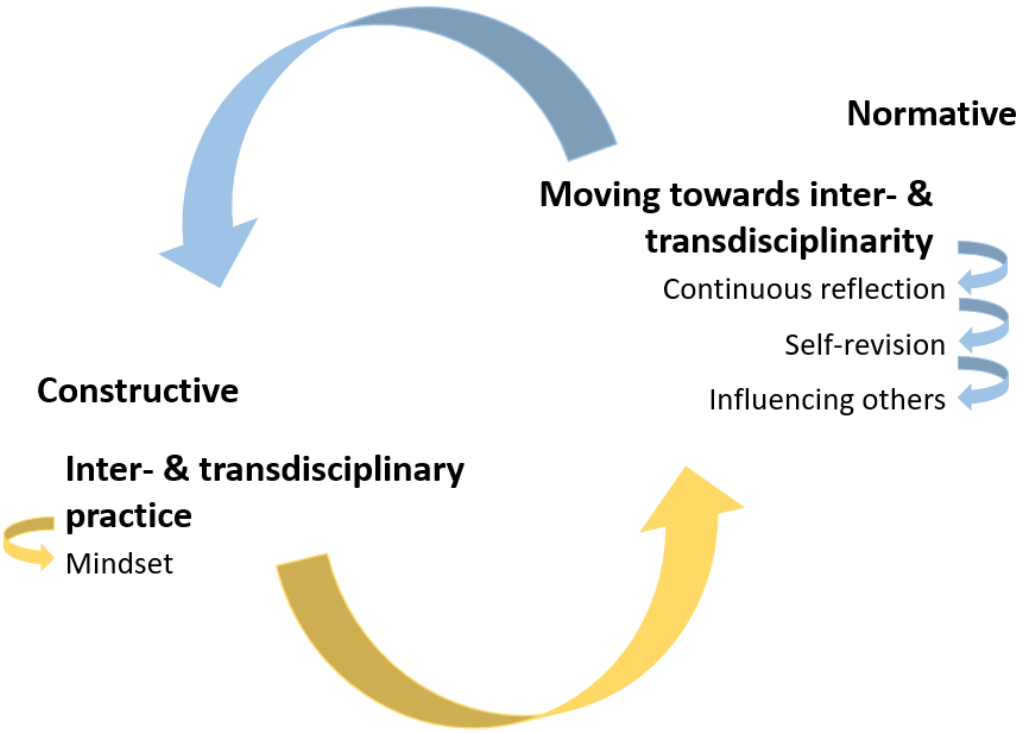


Figure 1.3: **Schematic overview of the starting point of this thesis.** The normative claim for moving towards inter- and transdisicplinarity via continuous reflection is accompanied by a constructivist perspective for shaping this inter- and transdisciplinary practice and, indirectly, the mindset suiting this practice.

To address this overarching question, the research is guided by the following sub-questions:

- **Q1:** *How do contextual perceptions within the academic discipline of biotechnology, as observed in a case study, influence the development of a more 'holistic' mindset suiting inter- and transdisciplinary practices?*
- **Q2:** *According to members of the academic discipline of biotechnology, what can induce the continuous and conscious cultivation of a more 'holistic' mindset?*
- **Q3:** *What tool can be used to support the cultivation of a more 'holistic' mindset of members of the academic discipline of biotechnology?*

1.5. Thesis structure

This thesis follows a phased approach to answer research questions: The chapters in this thesis subsequently focus on research sub-question 1, 2, and 3 (Figure 1.4). However, they are not just isolated sections of research. Instead, they form a coherent narrative in which the answers of previous research sub-question(s) contribute to the research process employed to answer subsequent research sub-questions. The structure unfolds as follows.

In **chapter 2**, the general methodology is introduced. This methodology will further specify the phased approach used to answer all research sub-questions. Thus, this chapter explains the framework used to navigate the research process of this thesis.

Chapter 3 and 4 focus on answering research sub-question 1, i.e., on how contextual perceptions and reflection processes influence the development of a more 'holistic' mindset. **Chapter 3** explores the landscape of the investigated topic, employing an explorative literature study to compose a theoretical framework to define concepts and a view for data analysis that is used to answer research sub-question 1. **Chapter 4** answers research sub-question 1 using a qualitative approach and subsequent data analysis of a specific case study: 'The Towards Zero-Emission Biotechnology Consortium'. This chapter also includes methodology specifics and a discussion of the findings and approach used. **Chapter 5** answers research sub-question 2, focusing on what can incite the continuous and conscious cultivation of a 'holistic' mindset among members of the academic discipline of biotechnology. This chapter includes methodology specifics, a description of the main findings, and a discussion of the findings. **Chapter 6** answers research sub-question 3, by delve into the design of a tool that can support the cultivation of a 'holistic' mindset. This chapter includes methodology specifics, a description of the tool design process, and a discussion of the findings. **Chapter 7** serves as a validation point for tool design. Here, the effectiveness and applicability of the designed tool is tested to evaluate whether the tool answers the main research question - it evaluates whether the tool can be used to incite members of the academic discipline of biotechnology to continuously and consciously cultivate a more 'holistic' mindset suiting inter- and transdisciplinarity.

Chapter 8 discusses the overall research of this thesis. This discussion includes a critical reflection on the findings and approaches used in chapter 5 and 6, and an overall critical reflection on the research performed and the findings of this thesis.

Chapter 9 provides the thesis' conclusion and **chapter 10** describes the outlook regarding future research and tool application. Finally, **chapter 11** provides a personal reflection of the research performed.

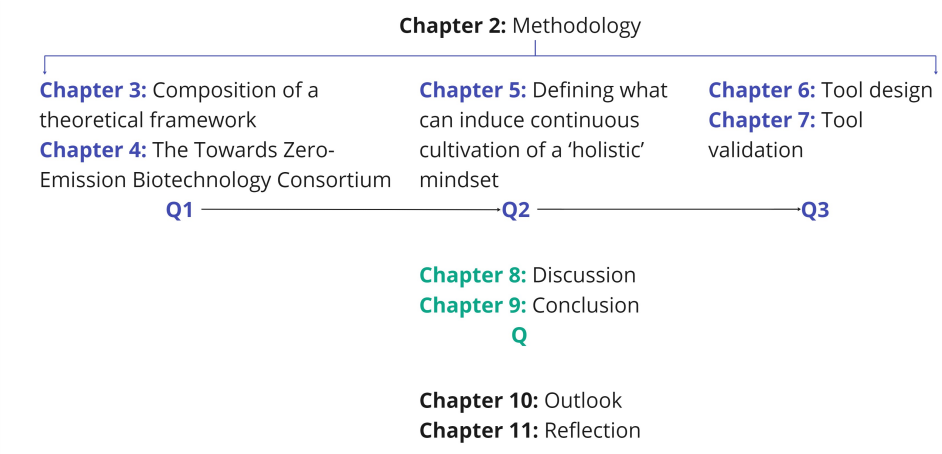


Figure 1.4: **An overview of the thesis structure.** The chapters that contribute to answering a research (sub-)question are depicted above the respective research (sub-)question.

2

Methodology

This chapter explains the general methodology choices made and how theory and practice are combined. Moreover, it explains the way in which these methodology choices support the process of combining the fields of both master programs and how theory and practice contribute to linking both fields in one thesis. However, more detailed description of the methodology and explanations of the choices made are presented in the chapters describing their respective results.

2.1. Design-based research: Triple-diamond model

This section explicates the foundation of the general methodology of this thesis, grounded in design-based research with the use of a mixed-method approach. This approach integrates research methods originating in the social sciences with design methods.

The main research question and the research sub-questions posed in this thesis (Section 1.4) follow a specific progression: first, examining a specific case study context (Q1), then expanding the focus to a broader context (Q2), and finally translating the findings into a practical tool (Q3). To navigate this triple-phased research progression, the 'triple-diamond model' was selected as the methodology framework, encompassing three sequential phases of divergence and convergence (Figure 2.1). The model was previously introduced during the educational program 'Communication Design for Innovation' (CDI) and proved suitable for guiding this research.

Phase 1 utilizes divergent thinking to explore the landscape of the investigated topic, employing literature, theory, and experiences within the context of biotechnology. Subsequently, the process transitions to convergent thinking, combining the insights gathered. The outcomes of this phase are used to address the first research sub-question (Figure 2.1, Section 1.4) and in shaping the foundational essence required to'move towards inter- and transdisciplinarity,' representing the first iteration of the starting point.

The iterations of phases 2 and 3 are used to translate this essence to a bigger context and into a tool (research sub-question 2 and 3, Section 1.4). In **phase 2**, divergent and subsequent convergent thinking is used to gain new input, re-iterate with previous insights, and define the purpose of the tool (captured in a 'Decision Narrative'). In **phase 3**, divergent and convergent thinking is used to design the tool.

In addition to the difference in focus during each loop, this model provides a unique framework to integrate theoretical insights with practical experiences. The upcoming sections explain how this 'triple-diamond model' structure enables the combination of theory and practice at various stages of the research, strengthening the endeavor to address the research sub-questions and subsequently the main research question.

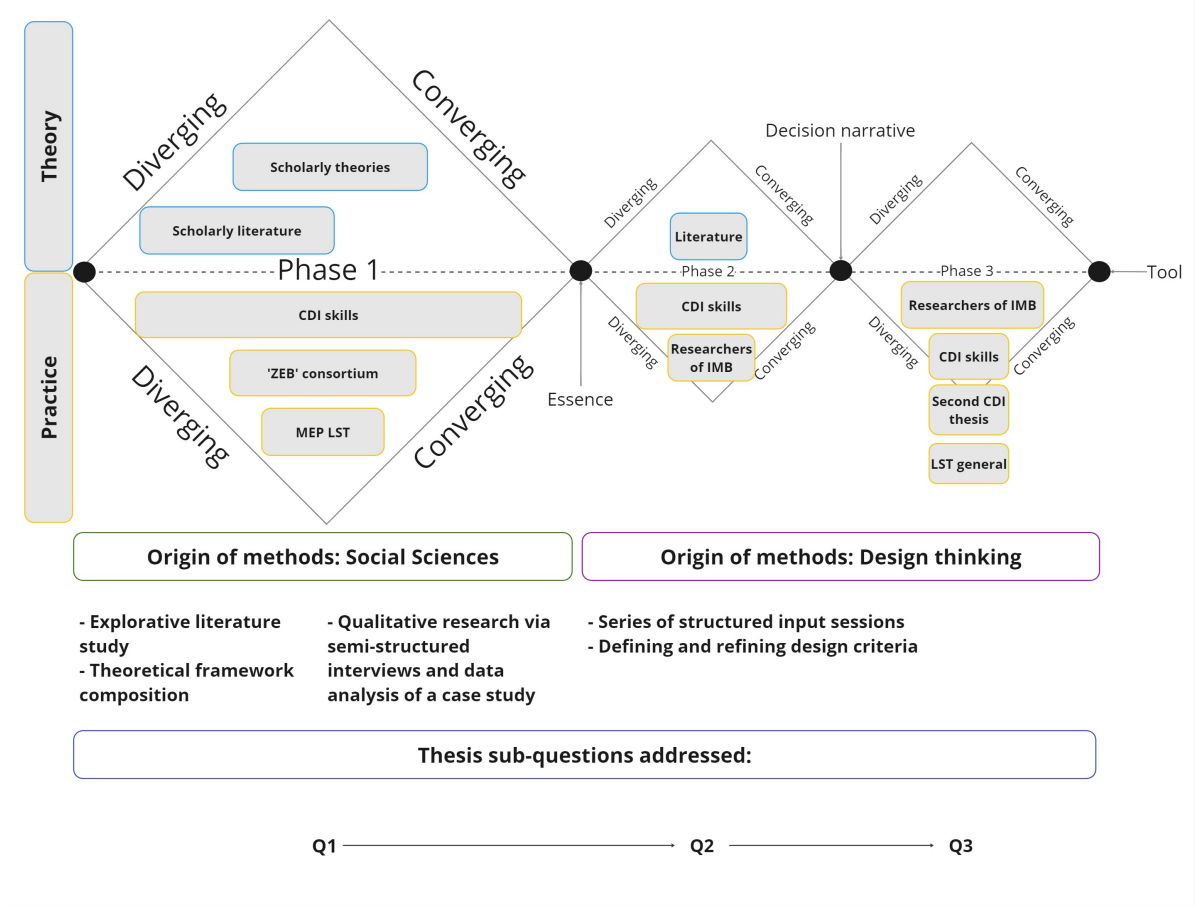


Figure 2.1: **An overview of the 'triple-diamond model' structure followed during the design process of this thesis, visualising the 'research methods', 'thesis sub-questions addressed' and 'source of information processed' for each phase.** Research methods are depicted below the diamonds. Below that, the sub-questions addressed are depicted per phase. The 'type of information processed' is subdivided into 'Practice' (yellow) and 'Theory' (blue). Scholarly theories: Theories as described in scholarly literature; (Scholarly) literature: models and concepts as described in the scholarly literature; CDI skills: skills obtained in the master program 'Science Education and Communication' with the specialization 'Communication Design for Innovation' (CDI); 'ZEB' consortium: experiences from interviewed participants of 'The Towards Zero-Emission Consortium' (TU Delft, related to the technical thesis of LST); MEP LST: experiences obtained when performing research for the technical thesis of the master program 'Life Science and Technology' (LST); Researchers of IMB: experiences from PhD'ers, postdocs and technicians of the research group 'Industrial Microbiology' (IMB) at TU Delft; Second CDI thesis: experiences from a (student) researcher developing a different tool as part of the Double Degree thesis for a similar context ('the academic sub-discipline of nanobiology'); LST general: general experiences obtained from the master program 'Life Science and Technology' (LST).

2.1.1. Theory

Scholarly theory contributed to the research approach of **phase 1** via concepts and definitions obtained from the scholarly literature obtained through exploratory literature studies and through a theoretical framework composed of theories described in the literature that were applicable to the research topic addressed.

In **phase 2**, the practice input acquired through structured input sessions was iteratively refined by incorporating supplementary literature to link it to scholarly (theoretical) views regarding inter- and transdisciplinarity.

2.1.2. Practice

Practice contributed to the research approach of **phase 1** via general CDI skills applied, practical experiences of the case study participants interviewed and personal experiences obtained through research for the technical LST thesis.

'The Towards Zero-Emission Biotechnology Consortium' served as case study for this thesis to answer research sub-question 1. The consortium participants represented various sub-disciplines or 'sections' within the Department of Biotechnology at TU Delft. The collaboration setup of 'ZEB' is based on frequent interactions between primary investigators (PIs) and between PhD students, whom the PIs give direction. In total, nine PIs collaborate with each other. They operate with two objectives:

1. 'Trying to convert resources to products, while minimizing emission or maximizing the utilization of CO2'
2. 'Initiate and strengthen new strategic lines and harvest cross-section synergy.'

This consortium presented itself as a valuable case study for several reasons. The unique composition of the consortium aligns well with the pursuit of inter- and transdisciplinarity. As established earlier, moving towards inter- and transdisciplinarity captures the evolving nature of collaborative practices via continuous reflection. The consortium exemplifies a group of individuals making deliberate efforts to progress from disciplinary silos towards stronger inter- and transdisciplinary engagement.

In **phases 2 and 3**, insights from structured input sessions reflected experiences from both researchers of the group 'Industrial Microbiology' (IMB) (the group supporting the research of the technical thesis of LST) and a (student) researcher developing a different tool as part of the Double Degree thesis for a similar context ('the academic sub-discipline of nanobiology'). Similarly to personal experiences, these insights were used to situate the findings of phase 1 in a broader context and to translate them into tool design. In addition, the inclusion of a student researcher engaged in a parallel Double Degree thesis for a related technical thesis provides an opportunity for cross-disciplinary learning during the tool development approaches.

The technical LST thesis was paused when executing the research steps of phases 2 and 3. However, during these phases, experiences up to that moment from the technical thesis and both master programs contributed to situate insights obtained within broader contexts. This dynamic integration allowed for the informed translation of research findings into applications that resonate with a wider scope, effectively bridging the gap between specific case study insights and their relevance to broader academic and professional contexts.

2.2. Methods

This section describes the choices of methods used when trespassing all phases of the 'triple-diamond model' (Figure 2.1).

The choice of research methods for each phase is intentional and, again, aligns with the distinct nature of the posed research questions. Research sub-question 1 is tailored for qualitative social science research, defining the essence of the problem linked to the thesis's goal, within the confined context of participants of one biotechnology research consortium. Using qualitative methods and data interpretation offers a nuanced understanding of the thesis subject matter. In contrast to this specific context, research sub-question 2 aims to broaden the contextual scope, encompassing a more generalized range of contexts across the 'academic discipline of biotechnology.' In addition, research sub-question 3 introduces a design-oriented inquiry, demanding an approach centered around deliberate design choices. Given this broader context without well-defined boundary conditions, more flexible and adaptive design-based research serves as a more suitable methodology for addressing research sub-questions 2 and 3.

2.2.1. Methods Derived from social sciences

To refine the definitions and points of view of this thesis, including the pivotal 'mindset' concept, an **initial explorative literature study** was selected as the initial divergence methodology. This method ensures a precise definition of the central topic, 'mindset for inter- and transdisciplinarity,' defined as a normative claim according to scholarly perspectives. In addition, a **second explorative literature study** was selected: One that focused on scholarly perspectives on and theories of continuous reflection in the context of inter- and transdisciplinarity.

To create a theoretical lens for examining the perspectives of the participants and their reflective processes, a **theoretical framework** was composed of applicable theories. To ensure its suitability for addressing the core of the topic, mindset for inter- and transdisciplinarity, this framework was tailored to align with the normative claim and scholarly perspectives identified in the explorative literature study. This framework provides a structure for designing **semi-structured interviews** and **analyzing data**, methods used in the systematic convergent thinking process required to address research sub-question 1 (Section 1.4).

2.2.2. Methods derived from design thinking

As explicated, in **phases 2 and 3**, the methods originated from design-based research. The design approach in these phases involved a series of **structured input sessions**, through which essential insights about the essence, the purpose of the tool and its intended usage were obtained. This approach fosters a collaborative environment that promotes the effective integration of both the personal insights of the researcher(s) and the collective insights of discussion groups.

In **phase 3**, the practice input acquired through structured input sessions revolved around **defining and refining the design criteria** for tool development. These design criteria also served as a framework during the tool validation process.

2.3. The technical thesis

As the research steps executed for this thesis were intertwined with those carried out for the technical thesis of LST ('MEP LST'), personal research experiences within the academic discipline of biotechnology were given a platform to contribute. This integration served to bridge practical experience with the normative claim supported by the literature throughout the research process of **phase 1**. Such an alignment of personal experiences with scholarly perspectives not only enriches the study's depth but also contributes to understanding the specific complexities of the case study. This section describes the technical LST thesis in more detail.

The technical thesis of LST is captured in a project equal to 45 ECTS of work. The project fits in one of the research groups at the Department of Biotechnology of the TU Delft. Consequently, the thesis is done by becoming a temporary group member. In the case of this Double Degree, the technical project had a large focus on laboratory work with microorganisms in the context of industrial applications, fitting into the research group 'Industrial Microbiology' (IMB) (Figure 2.2). Members of IMB include bachelor, master and PhD students, postdocs, experienced technicians, and (assistant) professors. Through structured weekly meetings ('Work discussions'), group members stay up-to-date on all ongoing projects and provide input for new steps. Next to these structured interactions, group members dynamically meet to discuss ongoing science. However, due to the confidentiality of ongoing projects, discussions with members outside IMB are limited.

In the first three months of doing both theses for the Double Degree, all work was being done on the technical thesis of LST. After this, both this thesis and the technical thesis of LST were done part-time. In this way, the experiences of each were given the opportunity to contribute to the project steps of the other.

Figure 2.2: **A group picture taken from all members of the 'Industrial Microbiology' (IMB) research group, Department of Biotechnology, TU Delft.**

Although unusual for LST master theses, the project of the technical thesis of this Double Degree was not directly connected to an ongoing PhD project. Instead, much personal input was granted in choosing the research topic and approach. Due to this freedom on topic and approach, requesting more individualism, proactivity, and 'zooming out' to find connections with ongoing research (both within and outside IMB). By doing so, the project was linked to an ongoing PhD project (and personal coaching) in a more adjacent manner.

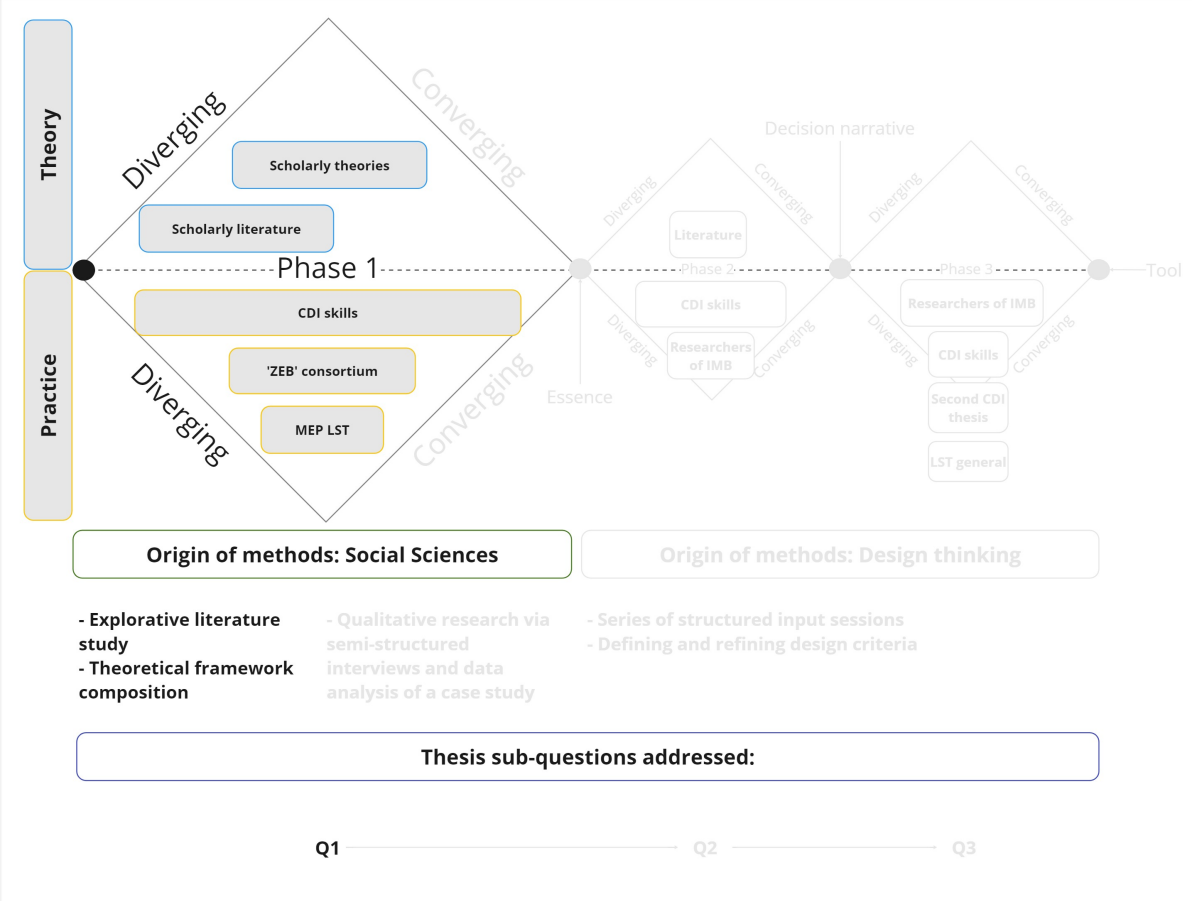
2.3.1. The technical thesis' contribution to this thesis

The personally developed project contributed to biotechnological developments related to the complex sustainability problems of food production and climate change, such as sustainable single-cell protein production and bioethanol production. With this larger picture in mind, the project needed to be demarcated strategically.

The personal experiences of discussing how to do this, inherently linked to discussing funding and publishing goals, contributed to connecting the scholarly literature, theory on reflection, and theoretical framework to the context of the academic discipline of biotechnology. In other words, the personal experiences greatly helped to translate the scholarly theory into practical implications, and vice versa.

3

Composition of a theoretical framework



This chapter delves into the divergent phase of phase 1, a stage dedicated to exploring the intricacies of the topic of research by drawing from established scholarly points of view, concepts, and theories. It employs divergent thinking to navigate the landscape, integrating literature, theory, and contextual experiences within the context of biotechnology. Practical experiences of the technical biotechnology thesis play a pivotal role in interpreting theoretical constructs and literary studies and consequently selecting the views, constructs, and theories used for this thesis.

Importantly, in this phase, the focus is on refining definitions, viewpoints, and theories that will serve as the foundation for our subsequent research. It is not aimed to directly answer research sub-question 1 at this stage, but rather to lay the groundwork for the convergent phase where these refined concepts will be applied in the design of the interview approach.

The chapter proceeds by outlining the interpretation and perspective on ’inter- and transdisciplinarity’, informed by existing literature (Section 3.2). It subsequently elaborates on the chosen standpoint for defining and analyzing ’holistic’ mindsets.

Continuing the discourse, this chapter interconnects the concept of ’continuous reflection’ with the selected interpretations of ’inter- and transdisciplinarity’ and the ’holistic’ mindset (Section 3.3). It does so by integrating scholarly theories, literary interpretation, and practical reflections from the biotechnology technical thesis.

Subsequently, a comprehensive theoretical framework is introduced, tailored to align with the selected conceptual viewpoints that resonate with the biotechnology context (Section 3.4). This theoretical framework finds its place within a model for initiating transformative change through reflection, presenting an initial lens through which to approach the overarching research inquiry, answering the main research question (Q).

Q: *How can members of the academic discipline of biotechnology be incited to continuously and consciously cultivate a more ‘holistic’ mindset suiting inter- and transdisciplinarity?*

3.1. Methods: Literature studies

The methodology selected is motivated by the need to refine the definitions and points of view central to this thesis. In line with this goal, an explorative literature study has been adopted as the initial divergent approach. This choice arises from the need to translate the scholarly critique of the prevailing 'reductionist' scientific practice into the prerequisites necessary to fulfill the normative claim that scientists should cultivate a more 'holistic' perspective on science. An explorative literature study particularly suits this purpose, as it allows for a comprehensive examination of existing scholarly criticisms, theories, and concepts related to the topic of a 'holistic' mindset for inter- and transdisciplinarity.

In the explorative literature search performed to outline the perspective on 'inter- and transdisciplinarity' (Section 3.2) and 'holistic' mindsets (Section 3.2.3), the search engines Web of Science and Scopus were utilized. These searches employed combinations of the following terms as search terms: 'transdisciplinary', 'interdisciplinary', 'mindset', 'consciousness', 'academics', 'discipline', 'biotechnology', 'paradigm', 'sustainability', and 'complexity'. Appendix A shows the summary of the hits obtained by combination of search terms. Based on reading the abstract, the selection for inclusion in this literature overview was based on the following:

- Relative actuality (2000- 2023);
- The fact that inter- and transdisciplinarity was linked to tackling complex issues; and
- The fact that other papers focusing on moving towards inter- and transdisciplinarity cited the work. The judgment of this focus was evaluated by reading the abstracts of the papers.

In the explorative literature search performed to outline the concept and theory of 'continuous reflection' (Section 3.3), the search engines Web of Science and Scopus were used. These searches used combinations of the following terms as search terms: 'transdisciplinary', 'interdisciplinary', 'transformative', 'reflexivity' & 'reflection'. Appendix A shows the summary of the hits obtained by combination of search terms. Based on reading the abstract, the selection for inclusion in this literature overview was based on the following:

- Relative actuality (2000-2023);
- The fact that reflection was linked to (aspects of) inter- and transdisciplinarity; and
- The fact that other papers focusing on moving towards inter- and transdisciplinarity cited the work. The judgment of this focus was evaluated by reading the abstracts of the papers.

In the explorative literature search performed to select theories to consider to compose a theoretical framework (Section 3.4) and place it within a model to initiate transformative change through reflection (Section 3.4.2), the search engines Web of Science and Scopus were uilized. These searches employed combinations of the following terms as search terms: 'mindset', 'constructivism', 'transdisciplinary', 'interdisciplinary', 'contextual', 'perception', and 'theory.' Appendix A shows the summary of the hits obtained by combination of search terms. Based on reading the abstract, the selection for inclusion in this literature overview was based on the following:

- Relative actuality (1990-2023); and
- The fact that the theory was linked to (aspects of) inter- and transdisciplinarity;

When a theory was considered, the decision to include it in a theoretical framework was based on the following:

- Whether the theory was applicable to analyze how perceptions can be contextual;
- Whether the theory could be combined in a framework that assumed reflection could have an impact on these perceptions, via the theory on reflection that resulted from the explorative literature search performed to outline the concept and theory of 'continuous reflection' (Section 3.3); and
- Whether the theory was reported to be possible combined with other theories that resulted from the literature search.

Summary Section 3.1: Methods: Literature studies

Main take-away:

In order to achieve the objectives of Phase 1 of this thesis, three explorative literature studies were performed, each with the following focus:

- The first study focused on refining central definitions and viewpoints in the thesis through an exploration of 'Inter- and Transdisciplinarity' and 'Holistic' Mindsets.
- The second study centered on outlining the concept and theory of 'Continuous Reflection,' a crucial aspect of the research.
- The third study aimed to select relevant theories for the theoretical framework, specifically focusing on 'Mindset,' 'Constructivism,' and 'Contextual Perception' within the context of inter- and transdisciplinarity.

Link with Sections 3.2, 3.3 & 3.4:

- The the scholarly views, theories and concepts described in the upcoming sections are the result of the literature studies described in this section.

3.2. Inter- and transdisciplinarity and a 'holistic' mindset

3.2.1. A need for more inter- and transdisciplinarity

Current social issues are characterized by complexity. They comprise a network of ties and interactions of human and nonhuman events, connected to ambiguity, uncertainty, heterogeneity, and continuous change (Broo, 2022; del Valle García Carreño, 2014; Fonseca Albuquerque Cavalcanti Sigahi and Sznelwar, 2021). This development has led to an increasing call for innovation in society and science's current knowledge production methods (Guimarães et al., 2019). In science, scholars increasingly stress that collaborations planning to solely exchange traditional analyses from 'Cartesian-reductionist-mechanistic' perspectives from various disciplinary expertise areas are insufficient (Fonseca Albuquerque Cavalcanti Sigahi and Sznelwar, 2021).

Collaboration types defined as inter- and transdisciplinarity are increasingly labeled essential to produce more tangible and socially robust, or 'mode 2' knowledge, that is needed in this context (Augsburg, 2014). The main idea of these collaboration types is that both the organization of knowledge production and the output of scientific inquiry trespass the traditional disciplinary boundaries or even scientific practice itself. When solutions to complex issues are seen as the goal of inter- and transdisciplinary collaboration, they are recognized as the result of subjective perception of the creating collaborative group and are therefore recognized as more practical, (yet) 'imperfect' and are up for continuous improvement (Augsburg, 2014; Matthews et al., 2019; Rigolot, 2020).

Within the purview of this thesis, which centers on tackling intricate challenges through a 'holistic' perspective, the pursuit of solutions is also seen as an objective in inter- and transdisciplinary collaboration. Furthermore, based on the personal collaboration experiences of the technical thesis in biotechnology, the collaborative ethos is generally output-driven practices. On the basis of this, this thesis considers the subjective interpretations of biotechnologists of both the solutions themselves and the inter- and transdisciplinary methodologies employed to attain them to be up for continuous improvement.

3.2.2. A continuum towards inter- and transdisciplinarity

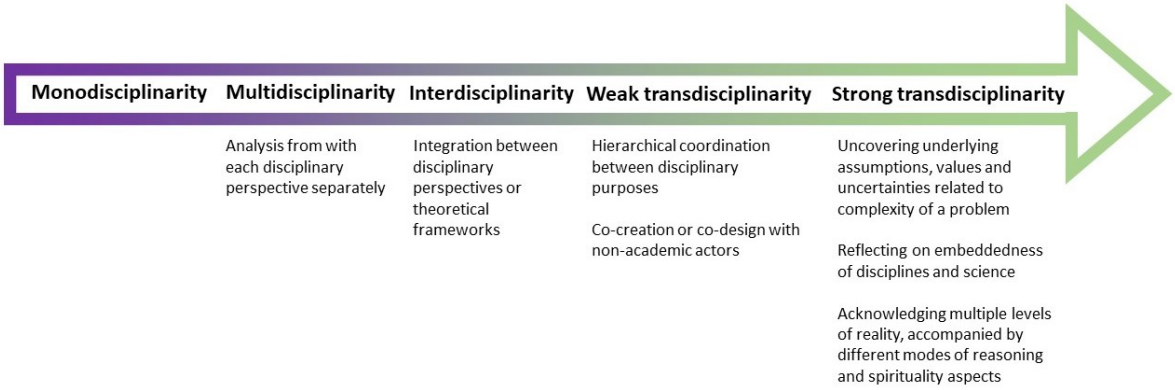


Figure 3.1: **A continuum towards inter- and transdisciplinarity.** Aspects of inter- and transdisciplinarity as defined by scholars are positioned on a continuum moving from 'monodisciplinarity' towards 'strong transdisciplinarity' (Broo, 2022; Bruhn et al., 2022; Christensen et al., 2021; Fonseca Albuquerque Cavalcanti Sigahi and Sznelwar, 2021; Guimarães et al., 2019; Horn et al., 2022; Jacobs and Nienaber, 2011; Klein, 2020; Max-Neef, 2005).

Despite the increasing call for inter- and transdisciplinary practice from both scientific and socio-political communities, no consensus has been established to define these types of collaboration. To provide structure for this thesis, aspects of inter- and transdisciplinarity as defined by scholars are positioned on a continuum moving from 'monodisciplinary' towards 'strong transdisciplinarity' (Figure 3.1). Using this continuum, the scholarly (normative) claim that scientists need to move towards inter- and transdisciplinarity can be understood as moving from 'monodisciplinarity' towards 'strong transdisciplinarity'. In this thesis' view that inter- and transdisciplinary methodology and output are up for continuous improvement, this continuum is used to represent different steps of progressing upward along the continuum.

Steps of progressing upward along the continuum

Whilst some scholars define the concept 'interdisciplinary practice' as scientific inquiry done by academics stemming from different disciplines with the sole prerequisite that they are actively collaborating (Christensen et al., 2021), others specify an additional prerequisite of 'integration' between disciplinary specific knowledge or perspectives (Christensen et al., 2021; Guimarães et al., 2019; Horn et al., 2022). Current conceptualizations of 'transdisciplinarity' include focusing on "coordination between all (disciplines and sub-disciplines as) hierarchical levels", "co-creation of knowledge and co-design of actions with social (non-academic) actors", and approaches that are mutually affective for collaborating participants, uncovering the different underlying aspects such as assumptions and values (Christensen et al., 2021; Fonseca Albuquerque Cavalcanti Sigahi and Sznelwar, 2021; Jacobs and Nienaber, 2011).

In the context of reaching a new view of science, some scholars take their conceptualization of 'transdisciplinarity' even one step further by highlighting the acceptance of different realms of reality instead of the traditional scientific perspective of positivism (Broo, 2022; Bruhn et al., 2022; Jacobs and Nienaber, 2011; Max-Neef, 2005). The well-recognized work of Max-Neef (2005) illustrates this clearly by defining 'strong transdisciplinarity' as:

"…more than a new discipline or super-discipline is, actually, a different manner of seeing the world, more systemic and more holistic." (Max-Neef, 2005)

In order to achieve this, new types of logic that fit societal complexity need to be accessed:

"A bipolar perception, a dynamic tension between opposites. A yin and yang, as suggested by Taoism, in which the yin is analogous to relational thought and the yang to rational thought. In other words, a logic capable of harmonizing reason with intuition and feeling…" (Max-Neef, 2005)

The terms inter- and transdisciplinarity are flexibly used

The concepts of 'inter- and transdisciplinarity' are relatively flexibly used in current scientific work, thereby complicating defining the step of progress and respective mindset suiting each. Compared to the concept of 'interdisciplinarity', the concept of 'transdisciplinarity' is more often linked to effectively dealing with complex research problems and "transcending the narrow scope of disciplinary worldviews" (Broo, 2022; Klein, 2020). However, only using transdisciplinary-focused studies to evaluate transdisciplinarity would lead to relevant findings linked to being overlooked. The evaluation work of an interdisciplinary approach by Christensen et al. (2021) is one example that illustrates this:

"… it is argued that transdisciplinarity is necessary for effective science and societal change, as it can help uncover underlying assumptions in research and practice and develop methodologies for working with uncertainties and disputed values. We, however, argue that this is exactly what we achieved through our interdisciplinary research process, where we truly met each other with curiosity and respect, without losing our anchoring in our respective scientific disciplines." (Christensen et al., 2021)

In literature, conceptualizations such as the one of 'strong transdisciplinarity' of Max-Neef are often complemented by approach-focused definitions of 'inter- and transdisciplinarity' and approaches related to it. On the other hand, work with approach-focused conceptualizations often does not (yet) specify the acceptance or refusal of multiple realities in the scientific world.

Recognizing the multifaceted nature of the concepts of 'interdisciplinarity' and 'transdisciplinarity', it becomes evident that relying solely on one or the other may not fully encapsulate the diverse perspectives of (biotechnology) participants of a social science research inquiry. In this thesis, 'inter- and transdisciplinarity' refers to an inclusive approach that combines interdisciplinary and transdisciplinary perspectives. This term provides a neutral framework for assessing participants' contextual perceptions and their progression along the continuum.

Inter- and transdisciplinarity connected to problem-based or challenge-based learning
The (scientific) practice of inter- and transdisciplinarity to tackle complex issues is often linked to problem-based or challenge-based learning (Christensen et al., 2021). This type of learning is seen as a more 'holistic' perspective for knowledge creation, motivated by curiosity, creativity, and critical thinking and doing. Through intensive collaboration, participants elucidate and question the underlying contextual structures and belief systems. When doing so, reflection can be induced and the idea of the 'ideal' collaborative practice can be altered (Savin-Baden, 2014).

Although problem-based and challenge-based learning has been applied to make science and engineering education more based on tackling current societal issues, the difficulties in implementation and simplification for teaching purposes often make these attempts, again, 'reductionist' (Fonseca Albuquerque Cavalcanti Sigahi and Sznelwar, 2021). As a result, researchers to be are generally not informed about the fact that objectivity and learning in science tackling complexity are context-dependent instead of permanent (Hein, 1991; Rosendahl et al., 2015).

This nuanced interaction between learning theories and real-world implementation underscores a significant gap in general academic understanding of the subjective, context-dependent nature of inter- and transdisciplinarity. Consequently, researching the contextual influences or personal (contextual) beliefs of biotechnology participants becomes a complex endeavor. Based on this, it can be stated that an indirect approach to questioning and data analysis is required: one that is better equipped to capture the subtle yet substantial influence of contextual factors.

3.2.3. Scholarly views on 'holistic' mindsets

Figure 3.2: **A proposed categorization for views on 'holistic' mindsets, as described by scholars, positioned along the continuum towards inter- and transdisciplinarity (Figure 3.1).** Categorizations are based on descriptions found via an explorative literature study (Adolphson, 2004; Benedikter et al., 2010; Broo, 2022; Christensen et al., 2021; Fonseca Albuquerque Cavalcanti Sigahi and Sznelwar, 2021; Gidley, 2010; Guimarães et al., 2019; Hermes and Rimanoczy, 2018; Horn et al., 2022; Jacobs and Nienaber, 2011; Kjellberg and O'rourke, 2018; Kudo et al., 2018; Max-Neef, 2005).

Various scholars have described the mindset change required to make inter- and transdisciplinary collaborations effective. This section describes an overview of the descriptions found by performing an explorative literature study (Section 3.1), and proposes a categorization for views on 'holistic' mindsets as described by scholars that can be positioned along the continuum of inter- and transdisciplinarity (Figure 3.2). Here, it is important to note that these categories are a categorization for views on 'holistic' mindsets and not rigid definitions of mindsets. A certain mindset as described by someone could fit into more than one category, again highlighting the flexibility and diversity of perspectives within the academic discourse.

These categories help connect the continuum of inter- and transdisciplinarity to specific mindsets, showing how a 'holistic' mindset can influence collaborative practices. As stated earlier, when moving towards inter- and transdisciplinarity, a more 'holistic' mindset is expected to change collaboration norms and practices to embrace inter- and transdisciplinarity. Vice versa, an improved inter- and transdisciplinary context can help cultivate or practice a more 'holistic' mindset (Kudo et al., 2018). Thus, in essence, these categories help elucidate the interplay between mindsets and collaborative practices as researchers move towards inter- and transdisciplinarity, aligning with the social constructivism perspective of the thesis (Section 1.4).

The following sections elaborate on all three categories and explain their respective positions along the continuum, providing a deeper understanding of the interaction between mindset and collaborative practices in the context of moving towards inter- and transdisciplinarity.

Category 1: A mindset for conflicting perspectives, values, and assumptions during collaborations

Fitting the conceptualizations of 'inter- and transdisciplinarity' as various disciplinary scientists or actors working together, some scholars describe a more 'holistic' mindset that facilitates these types of collaborations. For example, through a self-reflective learning process within an interdisciplinary group of scholars, Christensen et al. (2021) aimed to identify challenges of academic interdisciplinary capacities and ethos. In their results, they refer to **'a mindset of taking risks'**:

*"Academic researchers are rightfully held by the public, the academic community and themselves to be knowledge experts in various respects, but in order to learn new things, it is imperative to continuously engage in and develop an approach and **a mindset of taking risks** and put yourself up to learning anew in and through challenges."* (Christensen et al., 2021)

Via a case study that addressed how a field-based course can contribute to becoming sustainability experts, Kudo et al. (2018) explained unique learning opportunities to acquire **'interdisciplinary and transdisciplinary mindsets'**:

*"Being interdisciplinary requires researchers to hold multiple disciplinary bases or at least awareness on different ontological and epistemological perspectives when collaborating with others from different academic backgrounds. Such **interdisciplinary-mindset** to acknowledge multiple views to the reality is essential to perform descriptive-analytical skills to examine the complex sustainability challenges…"* (Kudo et al., 2018)

*"… The transdisciplinary idea implies a new mindset that goes beyond the academic and non-academic divide and this requires researchers more efforts than avoiding jargons and rephrasing research outputs. **Transdisciplinary-mindset** entails an entire package of communication with non-academic actors from team formation, planning of joint activities, and actual implementation of projects."* (Kudo et al., 2018)

Focusing on the ability to deal with conflicting disciplinary perspectives, Kjellberg and O'rourke (2018) and Horn et al. (2022) described the need to develop **'a playful attitude of mind'**, characterized by intellectual curiosity, flexibility, and the absence of dogmatism and prejudice, to achieve **'interdisciplinary consciousness'**, which is:

"A kind of know-how exhibited by individuals involved in a group process who can actively empathize with different disciplinary perspectives." (Horn et al., 2022; Kjellberg and O'rourke, 2018)

In conclusion, the descriptions provided by the scholars described coalesce to form the essence of Category 1: A mindset for conflicting perspectives, values, and assumptions during collaborations. These descriptions focus on cultivating a mindset of intellectual curiosity, flexibility, and empathy that facilitates productive interactions in inter- and transdisciplinary contexts. The common thread among them is an emphasis on being open to, aware of, and responsive to existing and well-known conflicting perspectives, values, and assumptions. Based on this, this category is positioned at a relative 'disciplinary' step, where researchers engage with multiple disciplinary bases and work actively to empathize with different perspectives.

Category 2: A mindset that recognizes embeddedness to achieve more ethical solutions to complex issues

In the context of solving complex societal issues, some scholars have described the mindsets required not only to facilitate inter- and transdisciplinary collaborations, but also to optimize the chances of (scientific) innovation results that are 'ethically most correct' when evaluated with a broadened worldview (Fonseca Albuquerque Cavalcanti Sigahi and Sznelwar, 2021; Guimarães et al., 2019). For example, Hermes and Rimanoczy (2018) focused on education tools to develop a **'sustainability mindset'**:

*"The combination of the elements was called **'sustainability mindset'**, defined as a way of thinking and being that results from a broad understanding of the ecosystem's manifestations, from social sensitivity, as well as an introspective focus on one's personal values and higher self, and finds its expression in actions for the greater good of the whole."* (Hermes and Rimanoczy, 2018)

Adolphson (2004) examines a similar **'shift in mindset'** by evaluating the **'biophysical approach'** as a new framework for economic thinking:

*"The **biophysical approach** to economics also supports the notion that an economic system is embedded in a social system. The biophysical approach considers the complete scope of work done for the economic well-being of humans and recognizes that some of that work takes place in nature's economy, independent of human interaction…"* (Adolphson, 2004)

"… The new ethical landscape requires a greater sense of responsibility from market participants, consumers as well as producers. The reward for assuming the additional ethical responsibility is that choices made are more consistent with long-term well-being." (Adolphson, 2004)

In the context of the development of cyber-physical systems as solutions for current societal challenges, Broo (2022) proposes a combination of three mindsets to be able to 'ask the right questions at the right time' during transdisciplinary work for a human-centred and sustainable future:

*"A **systems mindset** replaces reductionism – the belief that everything can be reduced to individual parts – with expansionism – the belief that a system is always a subsystem of some larger system –, and analysis – gaining knowledge of the system by understanding its parts – with synthesis – explaining its role in the larger system of which it is a part. Systems mindset, therefore, requires a shift from disconnections to interconnectedness, from linear to a circular way of thinking, from silos to emergence, from parts to wholes, and from isolation to relationships…"* (Broo, 2022)

*"A **futuristic mindset** uses scenario planning as a tool to carefully craft scenarios that could be important elements in the governance of innovation processes and allows stakeholders to adopt tools for bringing foresight abilities into organizations. These scenarios are considered to be a useful analytical tool for a better understanding of the change as well as the production and distribution of knowledge on change. This is extremely helpful for studying sustainability and complexity and for getting prepared for radical changes…"* (Broo, 2022)

*"A **design mindset** emphasizes observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping, and con-current business analysis, which ultimately influences innovation. This attitude primarily concentrates on understanding the needs and experiences of the user (instead of hypothetical system requirements) as a source of inspiration and insight. Design thinkers have proven to be more innovative because the design mindset is not problem-focused, it is solution-focused and action- oriented towards creating a preferred future."* (Broo, 2022)

In summary, the descriptions offered by the scholars fit in the essence of Category 2: A mindset that recognizes embeddedness to achieve more ethical solutions to complex issues. Within this category, the emphasis is on recognizing the interconnectedness of systems, fostering coordination among diverse hierarchical levels, and expanding boundaries to involve nonacademic actors in ethical decision-making. The mindsets described in this category resonate with the notion of 'weak transdisciplinarity,' where a broader perspective encompassing various disciplinary and sub-disciplinary elements is essential for addressing complex societal issues ethically.

Category 3: A mindset that acknowledges multiple levels of reality to achieve more ethical solutions to complex issues

In line with the 'strong transdisciplinarity' as conceptualized by Max-Neef (2005), some literature touches on how to facilitate the acknowledgement of different realms of reality. When doing so, the current trend towards more inter- and transdisciplinarity is often related at a meta-level to 'a way of being', and defined as the next step in the continuous 'evolution of consciousness' of individuals (Benedikter et al., 2010; da Costa, 2022; Frödin, 2017; Gidley, 2010; Horn et al., 2022; Max-Neef, 2005; Rigolot, 2020). This next step implies that "we are becoming conscious of our evolution and responsible for co-creating it" (Gidley, 2010). In other words, different realms of reality can be subjectively experienced via different states of consciousness.

Up until now, this meta-trend had not received much attention from mainstream academic research on applied consciousness (research on the brain), decision making, and future studies (Gidley, 2010). Benedikter et al. (2010) critique this lack of attention. They describe a new way to achieve 'ethics' based on a continuous search for balance and inclusion of different points of view of consciousness:

"The goal therefore is to more fully appreciate the possible trajectories that lead to these horizons, and to practically and ethically assess the limits and limitations of our actions at the margins of uncertainty. Such a complete account necessitates integrating philosophical, anthropological, sociological and theological (i.e., religious as well as "spiritual") perspectives with those of (geno-, nano-, and neuro-) science, to more fully elucidate the basis of our experiences, cultures, beliefs, and being, and afford better perspective on the possibilities of the future..." (Benedikter et al., 2010)

*"...while inquiries into the nature of being and the issues that arise from this perspective are often ascribed to the "most scientifically valid approach", it remains equally important to weigh any evidence on its overall value relative to what makes information "best" for science, healthcare, public policy, law, society, religion, and human self-understanding and self-determination. We believe that the pursuit of such thorough and balanced reflection can be called, in one word, "ethics". **Ethics**, under the conditions of the present "trans-human(ist)" cultural and civilization transition will no longer remain a pre-determined worldview, but will be defined as the **search for balance and inclusion**."* (Benedikter et al., 2010)

In order to facilitate this inclusion of different (subjective) realities, scholars describe an even more 'holistic' mindset or worldview (Gidley, 2010; Jacobs and Nienaber, 2011; Max-Neef, 2005). To illustrate, Gidley (2010) proposes that a worldview based on scientific materialism requires a **planetary reframing** to reintroduce spaces other than the ones we can physically measure:

"Complex problems require more than piece-meal, fragmented responses and demand a planetary reframing of human relationships with nature and the cosmos…" (Gidley, 2010)

"… The modernist worldview based on scientific materialism has colonized conceptual space with respect to our concepts of space—particularly outer space—by way of its physicalist metaphors drawn from classical physics. Relevant reframings from postformal, integral, and global/planetary perspectives could reintroduce other notions such as inner space to complement outer space, soul/spiritual space to complement physical space, and planetization to complement globalization." (Gidley, 2010)

In conclusion, the descriptions provided in Category 3: A mindset that acknowledges multiple levels of reality to achieve more ethical solutions to complex issues, align with 'strong transdisciplinarity.' This category emphasizes a deep understanding of various realms of reality and their ethical significance.

3.2.4. Conceptualizing the 'mindset'

This section describes varying conceptualizations of the 'mindset' in general used in the literature and explains the conceptualization for ('holistic') mindset used for this thesis.

Conceptualizations of the 'mindset'

Despite the significant amount of research on mindsets, the actual conceptualization of mindset is still debated and often not made explicit. Evaluating these divergent conceptualizations, French (2016) proposes a categorization of three broad streams of conceptualizations of mindset (French, 2016):

- *"The sum total of the activated cognitive procedures"* – from the perspective of the cognitive psychology stream.
- *"A cognitive filter that attends to and influences the totality of cognitive processes with or without an identifiable task"* – from the perspective of social psychology and organizational leadership stream.
- *"An individual or collective belief"* – from the perspective of positive psychology.

Conceptualizing the mindset for this thesis

The scholarly descriptions of the more 'holistic' mindset signal that the mindset represents something that steers a normative attitude or behaviour, suiting inter- and transdisciplinarity (Section 3.2.3). Due to this, the conceptualization of the mindset of this thesis cannot be reduced to a 'value neutral' description of 'The sum total of the activated cognitive procedures'.

In addition, the normative claim of this thesis states a need for continuous cultivation of a 'holistic' mindset to initiate change. To achieve this, not only the mindset must be cultivated by meeting new subjective contexts, but someone's mindset - the perceived normative attitude or behavior - also needs to have its influence on the context. Thus, the conceptualization of mindset of this thesis cannot be reduced to a single filter between cognitive processes that occur inside the mind and the environment outside of the mind. Therefore, the scholarly descriptions of the 'holistic' mindset cannot be aligned with the second conceptualization of the mindset, implying that the mindset serves as a single filter for cognitive processes.

However, the mindset as something that steers a normative attitude or behavior can be interpreted as a contextual perception of one or multiple 'beliefs'. Based on this, for this thesis, the mindset is conceptualized as 'a collection of individual and collective beliefs'.

This conceptualization of the 'holistic' mindset is particularly relevant for interview design and data analysis in qualitative interviews, which will be elaborated on in the next chapter (Chapter 4). In short: The beliefs expressed when discussing the mindset of participants of the case study consortium in relation to their (attempts for) inter- and transdisciplinary practices are considered the mindset suiting inter- and transdisciplinarity according to that participant. Thus, in the data analysis used to answer research sub-question 1, the collection of the beliefs of an individual deduced from discussing the mindset suiting inter- and transdisciplinarity will be considered that person's mindset.

3.2.5. The Social Identity (Complexity) Theory and the Mental Model concept

In this section, the relevance of Social Identity Theory, Social Identity Complexity Theory, and the concept of mental models is explored in the context of understanding the academic mindset within the realm of inter- and transdisciplinarity. Through these perspectives, the contextual origins of an individual's beliefs or collection of beliefs (referred to as their "mindset") can be deduced, and the cognitive connections between these beliefs and other elements can be examined.

The Social Identity Theory

The Social Identity Theory is a theory about group membership. It is based on the assumption that individuals can have multiple selves or identities: cognitive constructs of the self, which are fundamentally relational and self-referential, that answer the question 'who am I?' (Korte, 2007). Identities or selves can be assigned to categories based on the personal perception of the context from which they are derived. Individuals develop these socially derived or social identities as they interact within certain groups.

Individuals develop a social identity through the process of categorization in a particular 'Ingroup', based on its prototypes. Prototypes represent attributes that maximize the distinctiveness of a group as a clearly defined entity (Shelley McKeown et al., 2016). The prototypes of the 'Ingroup' represent not only average similarities between members, but also highlight positive and distinctive characteristics of the 'Ingroup' in relation to the relevant 'Outgroups', accompanied by increased self-esteem (Shelley McKeown et al., 2016). This often leads to increased bias and stereotyping of the respective 'Outgroups'. Moreover, as often not all members of the 'Ingroup' match all prototypes, additional differentiation of the 'Ingroup' can be perceived, based on 'more versus less prototypical members'. When this happens, the least prototypical members are often relatively uninfluential and sometimes even viewed as deviants who potentially threaten the group (Abrams, 2010).

Although hypotheses exist claiming that low self-esteem is a motivational factor for 'Ingroup' differentiation (and biases), empirical evidence is more consistent with the solely general correlation between increased self-esteem and 'Outgroup' bias (Abrams and Hogg, 1988). Therefore, self-categorization is mostly seen as ongoing, dynamic, and context-dependent, without clear motivational causality. The social identity developed is 'expressed' through normative behavior in this context (Shelley McKeown et al., 2016). However, when the context changes, self-categorization can change as well. When this happens, collective normative behaviors previously seen as positive differentiation of the previous social identity can be set in a different light.

Analyzing prototypes or indications of distinctiveness expressed when discussing a social identity can highlight current influences of the context connected to this social identity. Placed in the context of moving towards inter- and transdisciplinary scientific approaches, such expressions can highlight the contextual origin of current normativity in behavior that affects this movement. In addition, when the perceived context of these approaches is changed – for instance, from a 'reductionist' to a more 'holistic' perception – self-categorization, and consequently the personal motivation to act a certain way, can also be changed.

Based on this, Social Identity Theory provides a valuable lens through which to study the contextual influences on the mindset of biotechnology academics as they navigate the continuum of inter- and transdisciplinarity. This theory recognizes that biases and positive differentiation stem from specific beliefs influenced by an individual's 'Ingroup' membership, and since this thesis conceives the mindset as a collection of beliefs, it aligns well with the exploration of how social identities shape individuals' mindset within the academic context.

Within the context of 'the academic discipline of biotechnology,' the 'Ingroup' could take various forms, such as a specific research group, a consortium of academics, or even a collaborative team of assistant professors. Similarly, the 'Outgroup' can encompass different entities, including other research groups, external consortia, or individuals from outside the academic sphere. Evaluating beliefs of positive differentiation for the 'Ingroup' or biases against the 'Outgroup' - which are part of one's mindset - sheds light on the boundaries of the group or social context that significantly influences this mindset.

However, as inter and transdisciplinary efforts strive to break down disciplinary boundaries and foster inclusivity, such efforts come with vague and dynamic boundaries. Therefore, the traditional Social Identity Theory may have limitations in fully capturing the contextual elements influencing the mindset and collaboration practices.

The Social Identity Complexity Theory

Most empirical research on social identities and differentiation between groups has been conducted in the context of a single 'Ingroup'-'Outgroup' categorisation. To acknowledge the idea that people can have multiple group identities at the same time, Roccas and Brewer (2002) introduced the concept of 'social identity complexity':

"A new theoretical construct that refers to the nature of subjective representation of multiple 'Ingroup' identities." (Roccas and Brewer, 2002)

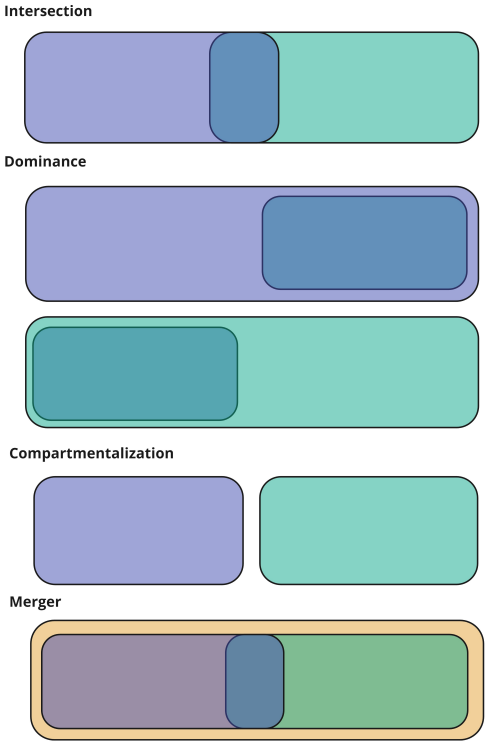


Figure 3.3: **An overview of possible subjective representations of the relation between two 'Ingroups'. (Roccas and Brewer, 2002).** The two 'Ingroups' are depicted in blue and purple. The following different ways in which individuals can reconcile "competing" prototypes of the 'Ingroups' for defining their "overall" social identity are shown: Intersection (focus on the overlap), Dominance (one of the 'Ingroups' is dominant in the "overall" social identity), Compartmentalization (the 'Ingroup' mostly defining the "overall" social identity is context and situation specific), and Merger (both non-convergent 'Ingroup' memberships are simultaneously recognised and embraced in their most inclusive form).

The term 'complexity' in social identity complexity refers to the cognitive process of how a person identifies with multiple 'Ingroups'. Roccas and Brewer claim that perceived overlap in members of the 'Ingroups' plays a role: In the case of a relatively large perceived overlap, the identification process can be reduced to only including overlapping memberships, thus maintaining a relatively simple mental representation of the "overall" social identity. However, as perceived overlap becomes smaller, differentiating between true 'Ingroup' and more 'Outgroup' through prototyping becomes more complex. To cope, Roccas and Brewer suggest different ways in which individuals can reconcile "competing" prototypes for defining their "overall" social identity (Figure 3.3).

As explicated, current inter- and transdisciplinary research approaches can be viewed as 'boundary work' between various academic and social disciplines as either 'Ingroups' or 'Outgroups' (Riesch, 2014). Without this precise categorization, the concept of 'social identity complexity' can help explain the origin of implicit contextual assumptions and beliefs in this 'boundary work'. For instance, individuals involved in addressing climate change may have distinct 'Ingroups' compared to members of the academic discipline of biotechnology. There are hypotheses that state that perceived overlap among members of the 'Ingroups' is negatively related to the inclusiveness of the 'Ingroup', the number of members perceived as part of the "overall" social identity that does not have all relevant prototypes for this "overall" social identity – and tolerance for 'Outgroups'. However, little empirical research has been done to verify this (Brewer and Pierce, 2005; Roccas and Brewer, 2002). Regardless, discussing how different 'Ingroups' are reconciled to one mental representation of the "overall" social identity can offer insights into how the social contexts of these 'Ingroups' affect this "overall" social identity, and the perception of normative behaviors related to it. Thus, the Social Identity Complexity Theory serves as a valuable lens for evaluating the combined influence of diverse social contexts on the academic mindset, particularly in the context of inter- and transdisciplinarity.

Why the Social Identity (Complexity) perspective?
The choice of the Social Identity (Complexity) perspective in this section is justified by the need for an indirect approach to questioning and data analysis. As mentioned in section 3.2.2, researchers are generally not informed about the note that objectivity and learning in science tackling complexity are context-dependent instead of permanent (Hein, 1991; Rosendahl et al., 2015). Consequently, researching contextual influences or personal (contextual) beliefs of biotechnology participants requires an indirect approach to interview question formulation and data analysis. The Social Identity (Complexity) perspective aligns with this requirement, as it can capture the subtle, yet substantial influence of contextual factors, as it explores the nuanced interaction between individual beliefs, social contexts, and mindset within the realm of inter- and transdisciplinarity.

Mental models
The 'mental model' theoretical construct refers to a broader collection of an individual's beliefs and cognitive structures used for understanding and interpreting the world (McNeil, 2015). A mental model encompasses various ideas and schemas that help individuals organize their understanding of specific concepts or topics, such as the functioning of a biological system or the dynamics of a research collaboration. These cognitive frameworks incorporate contextual information and shape expectations, guiding individuals towards contextually appropriate actions.

In contrast, a 'mindset' is more narrowly conceptualized as a very specific set of beliefs that an individual holds, reflecting his or her overarching perspective or stance on only particular issues. Mindsets consist of a focused collection of beliefs and may include attitudes, values, and biases. These beliefs within a mindset often influence an individual's decision-making and behavior within that particular context.

In the context of inter- and transdisciplinary research, understanding someone's mental model offers valuable insights into how academics employ their cognitive structures to approach complex issues, considering the social context and shaping their responses in a contextually appropriate manner. Mental models provide a cognitive framework for dealing with specific topics. Mindsets, on the other hand, represent a narrower set of beliefs within this framework. Examining the overlap and differences between mental models and mindsets can further deepen our understanding of the contexts that cause a specific link in the mental model with certain parts of the mindset.

Why the mental model perspective?
As not all beliefs within an individual's mindset are limited to biases or expressions of positive differentiation, the mental model perspective allows mental models to further elucidate the contextual influences shaping them. In other words, the broader view offered by mental models provides a more comprehensive lens for analyzing the intricacies of how context influences an individual's cognitive framework and, in turn, their mindset.

Summary Section 3.2: Inter- and Transdisciplinarity

Main takeaway:

- Scholars stress the need for more inter- and transdisciplinarity in addressing complex societal issues.
- The definition of inter- and transdisciplinary collaboration types lacks consensus. This thesis positions aspects of these collaborations on a continuum from 'monodisciplinarity' to 'strong transdisciplinarity' (Figure 3.1).
- Various scholars have described a change in mindset required to make inter- and transdisciplinary collaborations effective. Based on an explorative review of the literature, this thesis proposes the following categorization of 'holistic' mindsets as described by scholars:
  - Category 1: A mindset for conflicting perspectives, values, and assumptions during collaborations.
  - Category 2: A mindset that recognizes embeddedness to achieve more ethical solutions to complex issues.
  - Category 3: A mindset that acknowledges multiple levels of reality to achieve more ethical solutions to complex issues.

  These categories help connect the continuum of inter- and transdisciplinarity to specific mindsets, according to the views of scholars.
- This thesis conceptualizes the mindset as "a collection of individual and collective beliefs."
- The proposed view of inter- and transdisciplinarity and categories of 'holistic' mindsets are linked to The Social Identity (Complexity) Theory and the concept of Mental Models.

Link with Section 3.3

- The introduced need to more along the continuum towards inter- and transdisciplinarity whilst cultivating a more 'holistic' mindset is linked to scholarly views and theories on reflection.

3.3. Reflection

3.3.1. Reflection to initiate change

The need to acknowledge the contextual influences in inter- and transdisciplinary science and engineering to solve complex problems has been widely reported in the literature (Popa et al., 2015; Thompson Klein, 2004). Because of this, the concept of reflection on oneself and on attempts to achieve inter- and transdisciplinary practice has become increasingly relevant.

Reflection or reflexivity to achieve inter- and transdisciplinarity?

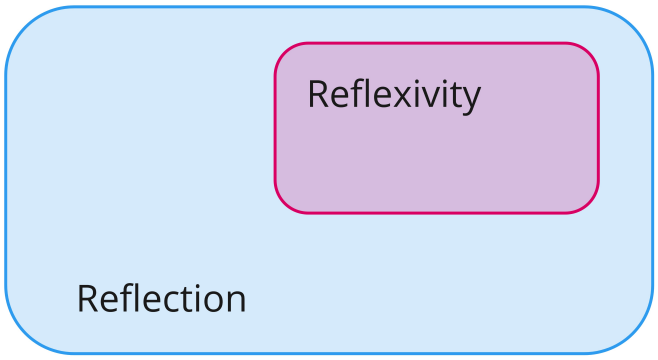


Figure 3.4: **A visualization of the way this thesis views the difference between reflection and reflexivity in the context of inter- and transdisciplinarity.**

Similar to the various coexisting descriptions of inter- and transdisciplinarity and mindsets, the actual interpretation of what type of reflection is required to achieve transdisciplinarity also varies among scholars. Some literary work defines the reflection required, although not always explicit, as reflexivity. Reflection as reflexivity is generally mentioned in relation to phenomena considered in science becoming relevant to individuals due to normative commitments, assumptions, and values, instead of through the 'neutral fact presented' (Popa et al., 2015). Being reflexive is a skill for scrutiny of such influential contextual elements, to achieve a more 'holistic' understanding of the phenomenon studied. It is often referred to as an 'ideal quality or skill' that suitable individuals for inter- and transdisciplinarity possess (Augsburg, 2014; Godemann, 2008):

"In order to be able to accept and understand other perspectives, reflection is required as to one's own perspective." (Godemann, 2008)

Instead of setting reflection equal to reflexivity, other studies assign the reflection required as a more general, loosely defined aspect of inter- and transdisciplinarity, focused on evaluating both the process and the output:

"Generating knowledge was more generally accepted as a process as well as an outcome, as a way of reflecting on a changing world as well as a well-defined body of content." (Brown, 2015)

Incorporating these insights, the thesis recognizes reflexivity as a distinct form of reflective practice, centered on contextual elements such as assumptions and values (Figure 3.4). It should be noted that while reflexivity emphasizes these aspects, certain other reflective practices, although not universally, can also uncover contextual elements and foster a more comprehensive mindset.

In this thesis, **reflection** is defined as "the ability to reflect on knowledge integration processes and the ability to take on new ideas" (based on Godemann, 2008). **Reflexivity** is "the ability to reflect on knowledge integration processes, particularly focusing on contextual elements such as assumptions and values".

Reports of reflective practice to achieve inter- and transdisciplinarity
In the context of the development of inter- and transdisciplinary practices, reflective practice and self-reflexivity have also been applied in grounded work by practitioners and researchers from the life sciences, social sciences and the humanities, including reflection-based intersubjective, participatory, and subjective approaches (Binder et al., 2015). For instance, Bruhn et al. (2022), proposing that continuous reflection and self-revision can be achieved via connecting unusual views dynamically to existing networks of academic participants, offer a different approach to learning via reflection: They present an interactive visualization tool that helps transdisciplinary researchers applying their practice in a context of sustainability to integrate aspects around mindsets and inner transformation (Bruhn et al., 2022). The study stresses the requirement of non-normativity in purposes and definitions:

"We do not pursue a clear plan with the platform. Rather, we see it as a catalyst for our research field creating conditions for further emergence. Simultaneously, these visualizations offer us continuous reflections about our own field as it is emerging." (Bruhn et al., 2022)

This resonates with the thesis's perspective, embracing the concept that engaging in reflective practice serves as a pivotal driver for progressing along the continuum towards inter- and transdisciplinarity (Section 3.2.2), thereby concurrently cultivating the development of a 'holistic' mindset.

3.3.2. Theory on learning through reflection

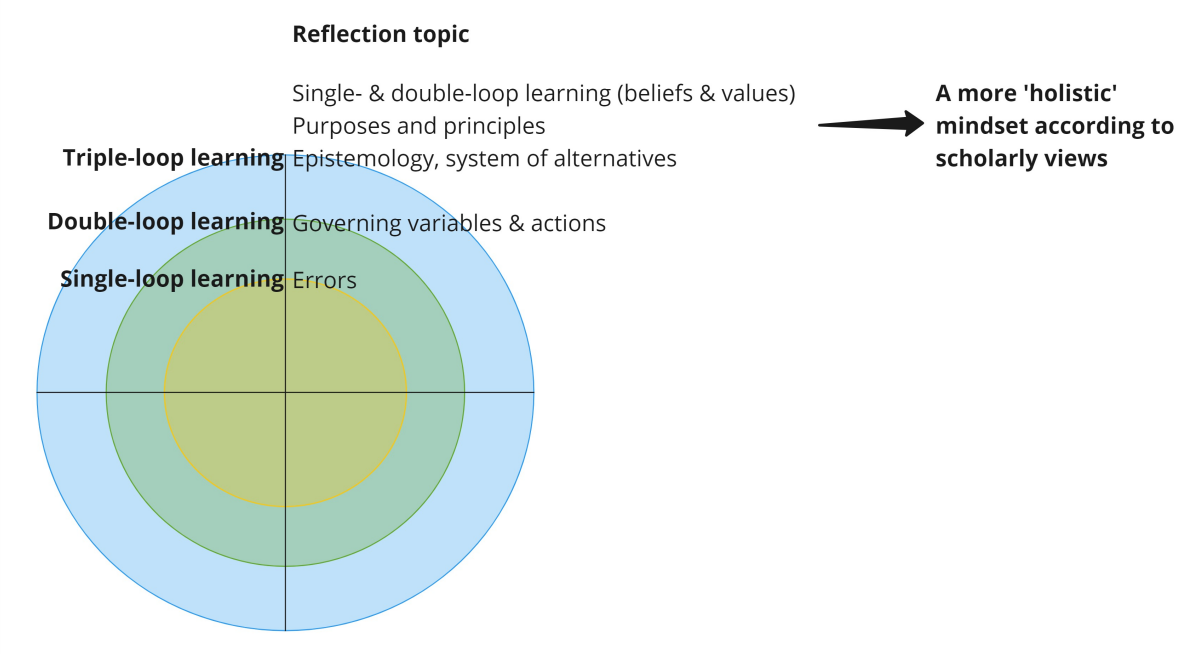


Figure 3.5: **Schematic overview of the classification levels or 'loops of learning through reflection in the context of moving towards inter- and transdisciplinarity.**

Reflective practice can be linked to theory on 'learning through reflection'. Learning through reflection linked to initiating change has been extensively described in the organizational learning literature. Many conceptualizations define various classification levels or 'loops' of learning through reflection (Figure 3.5). Based on the review of Tosey (2011), the classifications of single-, double-, and triple-loop learning are described.

Reflection in **single-loop learning** is about:

"…detecting an error and subsequently correcting it without questioning or altering the underlying variables of the system." (Tosey et al., 2012)

It occurs without questioning the underlying influential contextual elements.

Reflection in **double-loop learning** is about:

"…correcting mismatches by first examining and altering the governing variables, and then the actions." (Tosey et al., 2012)

It occurs when certain beliefs and values dependent on the context are questioned, but the system of the context itself remains the same.

Reflection in **triple-loop learning** has been conceptualized in three different ways. When defined as:

"Reflexivity about processes of learning at either single- or double-loop levels" (Tosey et al., 2012),

It can be related to the indicated need for reflexivity to achieve inter- and transdisciplinarity. The conceptualization matches the reflection required to cultivate a mindset assigned to the first category of 'holistic' mindsets as described by scholars: 'A mindset for conflicting perspectives, values, and assumptions during collaborations'.

A reflection process can be assigned to this conceptualization of triple-loop learning through reflection when someone modifies their learning strategies based on a (sudden) realization of how contextual elements influence (and limit) learning through reflection of single- or double-loop processes. This could be achieved by combining insights obtained from single- and double-loop learning through reflection, performed in different (separate) collaboration contexts. It results in a new understanding that promotes collaboration by embracing diverse perspectives, values, and assumptions within the learning context.

The second triple-loop learning conceptualization,

"Learning through reflection on a level that is beyond, and considered by proponents to be superior to, single-loop and double-loop learning in that it concerns underlying purposes and principles" (Tosey et al., 2012),

Can be connected to the cultivation of a mindset assigned to the second category of 'holistic' mindsets as described by scholars: 'A mindset that recognizes embeddedness to achieve more ethical solutions to complex issues'. It is about developing new principles or changing the embedded system and its values and assumptions connected to it.

A reflection process can be assigned to the second conceptualization when someone engages in introspection to uncover fundamental purposes and principles and when it results in a perceptual shift. It results in new insights that recognize the embeddedness of the system of analysis.

The third and final triple-loop learning conceptualization,

"A change of epistemology, or a corrective change in the system of sets of alternatives from which choice is made" (Tosey et al., 2012),

Touches upon the meta-trend in the 'evolution of consciousness'. It is said not to be achieved through solely conscious, instrumental means, but leaves a role for the unconscious and aesthetic. Therefore, it can be connected to the cultivation of a mindset assigned to the third category of 'holistic' mindsets as described by scholars: 'A mindset that acknowledges multiple levels of reality to achieve more ethical solutions to complex issues', suiting Max-Neef's conceptualization of 'strong transdisciplinarity' (Max-Neef, 2005). This triple-loop learning conceptualization is often referred to as 'transformational learning' (Jones, 2009).

A reflection process can be assigned to the third conceptualization, where someone undergoes reflection that prompts an insight into acknowledging more levels of reality related to solving a complex issue.

Only via triple-loop learning, a mindset can become (even) more 'holistic'
For this thesis, based on scholarly views on 'holistic' mindsets, only triple-loop learning through reflection is linked to a cultivation process of a certain mindset at a certain point in the transition towards inter- and transdisciplinarity. Thus, via triple-loop learning, a mindset can become (even) more 'holistic' (Figure 3.5).

Notably, discussions about which 'loops' should be accessed when learning through reflection are often normative, implying that achieving single- and double-loop learning is not as good as triple-loop learning (Roper and Pettit, 2002). As indicated, this thesis also links the cultivation process to make mindsets more 'holistic' to reflection in this 'superior loop'. However, this does not imply that single- and double-loop learning through reflection is not needed for the cultivation process of the mindset suiting inter- and transdisciplinarity. After all, to properly reflect on a mindset via triple-loop learning, shallow errors (single-loop) and errors in underlying context-dependent values and beliefs (double-loop) must be corrected first.

The influence of social context
Also in the development of reflective practice, the social context of participants practicing it has a significant influence. While educational experts are increasingly promoting reflection education as an essential component of academic professional development, effective implementation in curriculum remains a great challenge (van Braak et al., 2022). Although 'best practices' are documented, effective approaches to teaching reflection will always depend on various context-specific goals, strategies, and situational aspects of students who learn to reflect. Furthermore, despite the increasing acknowledgment of reflective practice in (inter- and transdisciplinary) science, the underlying contextual elements that affect the perception of 'scientific reliability' are barely the focus. Instead, scientists reflect on 'social legitimacy', which is seen as a distinct requirement that must be pursued and often traded against the decisions made by normative 'objective' reliability (Popa et al., 2015). Thus, the social context of scientists (to be) has an under-acknowledged impact on their knowledge generation.

In the context of reflection on the process and the output of scientific practice, the effect of learning through reflection on an individual is dependent on both personal experiences and professional experiences within research collaboration dynamics on interpersonal, research group, organizational level and disciplinary level (Frödin, 2017). For self-revision to begin, the presented triggers must be both relatable and conflicting with the underlying beliefs and assumptions, triggering the participant to become aware of new connections related to their personal and professional role and responsibilities within the larger system (Adolphson, 2004; Hermes and Rimanoczy, 2018; Horn et al., 2022). However, triggers that are too conflicting with personal beliefs or beliefs shared at influential levels can cause too much discomfort, causing participants to neglect observed differences (Hermes and Rimanoczy, 2018; Horn et al., 2022).

For a new view to have its influence in initiating change, both the reflection process and the desired action to take must be connected to all levels and the degree of embeddedness of the participant in each of them (Frödin, 2017; Guimarães et al., 2019). Limiting or supporting characteristics can be identified for each level, and alterations can be made. When this happens, science can be practiced according to the current agreement of guidelines, while participants are supported to be open to new views, continuously reflect and speak up for further improvements (Broo, 2022). Thus, defining mindsets and collaborations required via learning through reflection is context-specific and continuously shaped by participants' heterogeneity and interactions (Augsburg, 2014).

3.3.3. The Cognitive Dissonance Theory

The role of creativity and emotions

When evaluating the current revolution towards inter- and transdisciplinarity in collaboration and knowledge creation, literature also suggests a revolution in the praxis of learning through reflection. Our interpretations of the world, updated through continuous reflection, are often based on rationality and 'reductionism' (Lozano, 2014). In order to sustain a continuous 'holistic' improvement of these interpretations, scholars propose that learning through reflection needs to happen via both cognitive and affective processes, initiated by a certain trigger (Burga et al., 2017; Shrivastava, 2010).

According to Lozano (2014), accepting abstract thinking and creativity in organizational learning (through loops of reflection) can be useful to regain awareness of more 'holistic' characteristics. When practicing this type of thinking, anomalies in phenomena that challenge the current status quo of interpretations can be recognized (Lozano, 2014). As creativity often involves deep feelings, it can be argued that individual creativity links 'synergistically' the cognitive and the affective. In this way, rationality and science meet emotions and art (Solomon, 2013).

The role of creativity and emotions in reflective practice can also be recognized in some of the existing scholarly descriptions of the more 'holistic' mindset (da Costa, 2022; Hermes and Rimanoczy, 2018; Horn et al., 2022). For example, Horn et al. (2021), when developing a "playful intervention to stimulate the development of 'interdisciplinary consciousness'", found that reflection interventions contributed to enhancing interdisciplinary consciousness by also sparking affective critical reflection (Horn et al., 2022). Furthermore, in the model suggested by Hermes and Romanoczy (2018) to achieve a 'sustainability mindset', deep learning is suggested that addresses the learner's intellect, emotions, and values (Hermes and Rimanoczy, 2018). In their empirical findings, they describe the importance of experiencing 'cognitive dissonance' during the observed sequence of this more 'holistic' type of learning through reflection:

*"A **sequence** was also noted that started with realizing the seriousness of certain social or environmental aspects, but not just as distant facts: the leaders reflected on what their personal contribution was to those problems. This created moments of introspection and revision of their paradigms, with an emotional experience of **cognitive dissonance**: they realized that while they were ethical individuals, their actions (or their organization's actions) had questionable impacts on stakeholders they never had thought of. The tension became a stressor, and they spontaneously sought to get into action to 'repair' the damage, to address the problems that had become visible for them."* (Hermes and Rimanoczy, 2018)

The Cognitive Dissonance Theory

The Cognitive Dissonance Theory, as described by Festinger (1957), states that when individuals experience a discrepancy between their beliefs or attitudes and their actions, they are motivated to reduce this cognitive dissonance. To alleviate the discomfort arising from this inconsistency, individuals can change their beliefs, modify their actions, or alter their perception of their actions to align with their existing beliefs.

In the context of learning through reflection, this theory offers a lens to link learning through reflection to a changed mindset (i.e., a set of beliefs): When an unusual trigger causes individuals to confront inconsistencies between their existing mindsets or collaborative practices and new perspectives or information, cognitive dissonance may arise. This dissonance can act as a catalyst for change, prompting individuals to reevaluate and adjust their mindset or actions to achieve alignment and reduce discomfort.

However, as stated, the cognitive dissonance theory proposes a third outcome: As observed in the sequence described by Hermes and Rimanoczy (2018), excessive or overwhelming dissonance can lead individuals to change their perception rather than their beliefs or actions. When this is the case, no learning through reflection has occurred.

Summary Section 3.3: Reflection

Main take-away:

- Based on scholarly views, the continuous cultivation of a mindset suiting a 'holistic' view of science can be connected to reflection-induced change, by:
  - Including general reflective practice on inter- and transdisciplinarity, of which reflexivity is a part.
  - Using the theory of single-, double-, and triple-loop learning through reflection. Although reflection needs to happen via all 'loops', only through triple-loop learning through reflection can a mindset become more 'holistic' (Figure 3.3.2).
  - Assigning a role of creativity and emotions in the praxis of reflection.
  - Recognizing the role of cognitive dissonance as a lens to explain the occurrence, processes, and outcomes of reflection in changing mindsets or collaborative practices.
- The development of reflective practice is significantly influenced by the social context of participants. The effective implementation of reflection education in academic curricula remains challenging due to context-specific goals, strategies, and situational aspects of students.

Link with Section 3.4:

- The insights regarding the view on inter- and transdisciplinarity, scholarly (normative) views on 'holistic' mindsets, and theory on reflection are processed in a theoretical framework.

3.4. Theoretical framework

This section presents a comprehensive theoretical framework designed to analyze individual perceptions among biotechnology academics, contextual influences, and potential changes therein, facilitated by types of learning through reflection. The framework serves as the backbone for addressing research sub-question 1:

Q1: *How do contextual perceptions within the academic discipline of biotechnology, as observed in a case study, influence the development of a more 'holistic' mindset suiting inter- and transdisciplinary practices?*

At the core of this framework are key theories and concepts that help deduce specific contextual influences of someone's mindset. **Social Identity Theory** and **Social Identity Complexity Theory** provide valuable insights into how individuals perceive themselves within specific 'Ingroups', which in turn influences their 'social identity' and the beliefs associated with these groups. These beliefs can manifest as biases towards 'Outgroups' and positive differentiation for 'Ingroups'.

Mental models serve as cognitive frameworks that help individuals make sense of their experiences in relation to inter- and transdisciplinarity. These models contain interconnected beliefs and encompass both normative beliefs influenced by specific 'Ingroups' and general beliefs influenced by overall 'social identity'.

Cognitive Dissonance Theory is central to evaluating the reflection processes in the proposed framework. It is based on the idea that unusual contextual elements serve as triggers that cause cognitive dissonance. This dissonance can lead to one of three outcomes: a change in perception of inter- and transdisciplinary practices (a change in perception of actions), a change in the practices themselves (a change in actions), or a change in mindset (a change in beliefs). Learning through reflection primarily occurs in the latter two outcomes, particularly emphasizing triple-loop learning for cultivating a more 'holistic' mindset. **Learning through reflection** occurs primarily in the latter two outcomes, particularly emphasizing triple-loop learning to cultivate a more 'holistic' mindset.

In essence, the **theoretical framework** is constructed by integrating these theories and concepts. It enables us to indirectly examine how the contextual influences, 'Ingroup context(s),' 'contextual reference(s),' and 'creative trigger(s)', indirectly influence an individual's mindset.

Within this framework, mental models are conceptualized as schematic organizations of ideas related meaningfully to inter- and transdisciplinarity. Here, a person's mindset concerning inter- and transdisciplinarity is considered a subset of their mental model, comprising a set of interconnected beliefs. Among these beliefs, some express positive differentiation for 'Ingroups' or reveal biases towards 'Outgroups', whilst some express general, normative beliefs influenced by specific 'Ingroup(s)' combined in an overall 'social identity'.

The link between individual identity, social identities and mental models can be explained by the idea of the self as cognitive schema, which is a sort of implicit identity. This schema contains fixed core concepts and fluid concepts that allow individuals to adapt their identity according to a social context. Together with the individual core, social identities can be seen as a social-cognitive schema for normative behavior within this 'Ingroup' (Korte, 2007). When relevant in the context of scientific inquiry, these social cognitive schemas are part of the mental model accessed, providing structure so that 'appropriate' (normative) actions can be simulated.

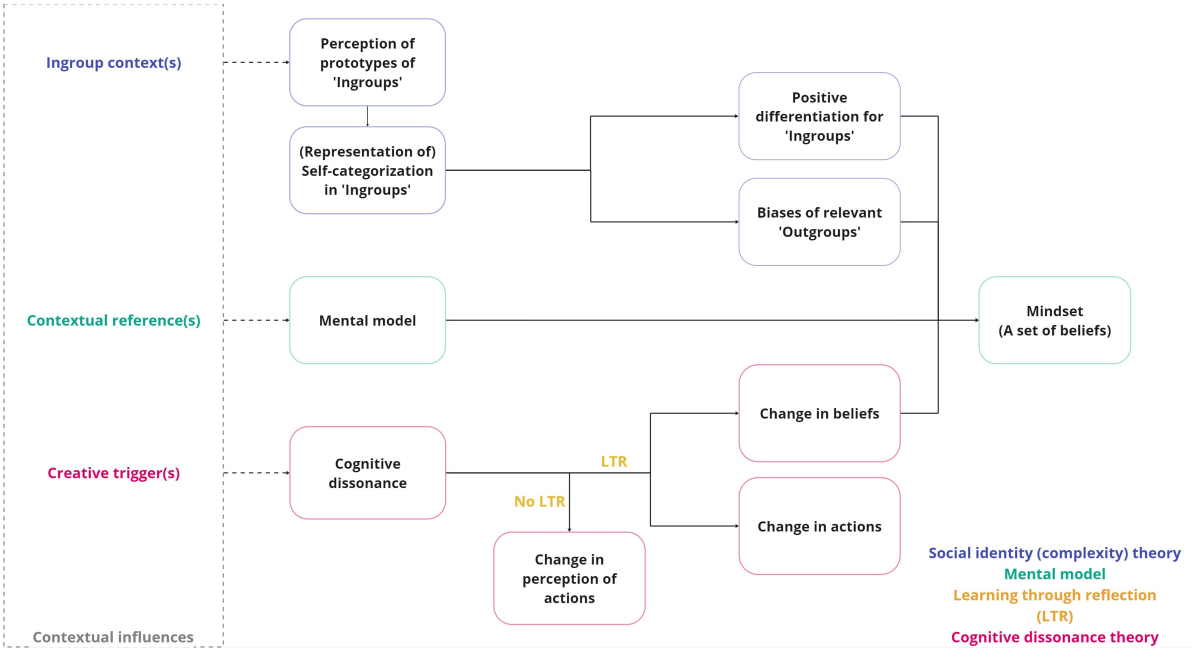


Figure 3.6: **Schematic representation of the theoretical framework of this thesis.** The framework integrates elements from Social Identity Theory, the theoretical concept of mental models, learning through reflection, and Cognitive Dissonance Theory, each depicted in distinct colors. The influence of contextual elements is indicated by dotted lines.

When moving towards inter- and transdisciplinarity, scholars often state that traditional 'reductionist mental models' need to be questioned and evaluated through learning through reflection (Section 3.3.2) (Lozano, 2014). When single-loop and double-loop learning happens, research practices or contextual governing variables are reviewed, respectively, whilst maintaining the mental model as is. However, when triple-loop learning occurs, the mental model is revised (Jones, 2009). Interpreted as reflexivity in inter- and transdisciplinarity (Section 3.3.1), learning about mental models of different disciplines and stakeholder groups can give a more 'holistic' picture of underlying beliefs and social reasoning, as Otto-Banaszak et al. (2011) argued for understanding different perceptions of stakeholders that are adapting to climate change. Interpreted from the perspective of the mindset that matches a broadened worldview ensuring that (scientific) innovation outcomes are 'ethically most correct', challenging a mental model can highlight subjective perceptions of simple causal relationships structured in the assumed independent embedded system. Or, as Adolphson (2004) writes about revision in mental models needed to get to the 'biophysical perspective':

"The appeal of such models is that they are neat and clean and easy to understand. The drawback is that they do not represent much of what is happening in the real system. The model assumes simple causal relationships, but in reality we have intricate webs of interacting variables. The model assumes an independent system, but in reality we have nesting set of subsystems at multiple levels, with interaction between the subsystems." (Adolphson, 2004)

3.4.1. A framework to deduce contextual influences

A part of the introduced framework can be used to deduce contextual influences that affect the (development of) a more 'holistic' mindset in the context of inter- and transdisciplinary practices. Contextual perceptions that influence how participants view their mindset with regard to inter- and transdisciplinarity can be derived through an examination of mental models. These mental models are closely intertwined with social identity (complexity) theories, the complexities of the issues being addressed, and perceptions of current or desired inter- and transdisciplinary approaches.

Within this framework, beliefs expressed during discussions about the mindset are considered mindset-specific beliefs. When these beliefs indicate a bias favoring an 'Outgroup' or expressing positive differentiation for an 'Ingroup', it becomes evident that contextual influences are at play. Moreover, by exploring how a participant perceives the relationship between two 'Ingroups' (The Social Identity Complexity Perspective), the 'Ingroups' impact on all mindset-specific beliefs can be further specified.

To further deduce the influence of identified contextual factors on specific beliefs within the mindset, a schema connecting all beliefs with beliefs with identified contextual references. Thus, this perspective allows us to discern the broader impact of contextual influences on mindset-specific beliefs within the context of inter- and transdisciplinary practices.

3.4.2. A framework shaping a model for initiating change

Building upon the insights gained from the contextual social identity and mental model perspectives, as well as the observed sequence by Hermes and Romanoczy (2018) in their study on achieving a 'sustainability mindset' through reflection (Hermes and Rimanoczy, 2018), a model for initiating change via reflection is proposed in the context of this thesis. This model serves as a theoretical framework for understanding the process through which reflection-induced change can lead to the development of 'holistic' mindsets within interdisciplinary scientific endeavors (Figure 3.7).

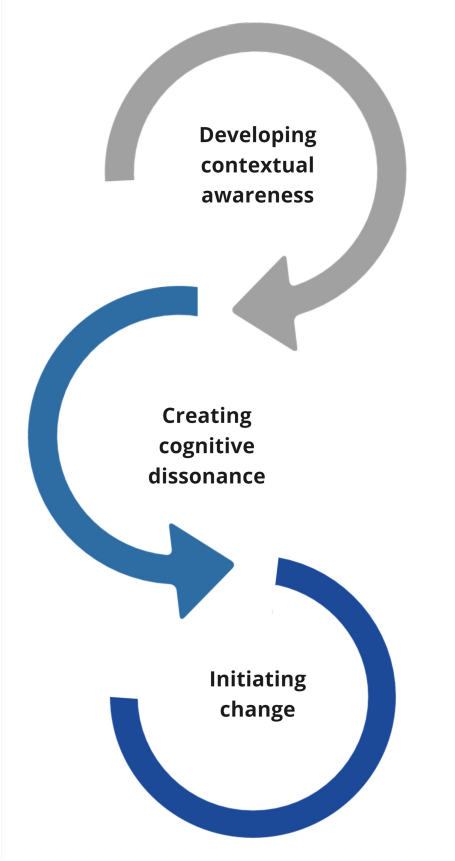


Figure 3.7: **A Model for Initiating Change via Reflection.** This adapted model incorporates elements from Hermes and Rimanoczy, 2018 and integrates them with the contextual social identity and mental model perspectives discussed in this theoretical framework.

The model's dynamic sequence captures the intricate interplay between creativity, social identity dynamics, mental models, and reflective learning, offering a comprehensive approach to the evolution of mindsets.

Step 1: Developing Contextual Awareness
The model begins with the crucial step of developing contextual awareness through creative triggers. Creative triggers are catalysts that prompt individuals to view their context from different angles, illuminating subjectivity and contextual nuances. These triggers can be artistic expressions, interdisciplinary collaborations, or unexpected perspectives that challenge ingrained assumptions. Creative triggers stimulate the exploration of one's social identity within a broader context, fostering a deeper understanding of how personal beliefs and social groups influence perception.

Step 2: Creating Cognitive Dissonance
The model progresses to the step of creating cognitive dissonance. Individuals engage in critical evaluation of their mental models, unraveling assumptions and acknowledging cognitive biases. By creating cognitive dissonance, individuals pave the way for transformative reflection, enabling them to embrace alternative viewpoints and recognize the potential limitations of 'reductionist' thinking.

Step 3: Initiating Change
With increased contextual awareness and experienced cognitive dissonance, the model advances to the phase of initiating change. Reflective learning becomes the conduit through which individuals bridge the gap between their existing mindset and the 'holistic' mindset required for inter- and transdisciplinarity. Focused on this thesis topic, i.e. the cultivation of a 'holistic' mindset, the change needed is a change in mindset. Importantly, this evolved mindset is not only individually transformative, but is also shared within the academic context. By actively promoting and sharing this 'holistic' mindset, individuals create potential new triggers (as in Step 1) for others, thus perpetuating a cycle of transformative change.

The proposed model, comprising Developing Contextual Awareness through creative triggers, Creating Cognitive Dissonance, and Initiating Change by cultivating and sharing new mindsets, encapsulates the intricate interplay of creativity, social identity, mental models, and reflective learning within inter- and transdisciplinarity. By encompassing these stages, the model offers a holistic framework that guides the transformation of mindsets (along the continuum of inter- and transdisciplinarity), fostering 'holistic' and ethically informed approaches to complex problem solving.

In summary, this model represents the view of how contextual influences, such as creative triggers, can initiate reflection processes that target contextual perceptions. It therefore contributes to answering the second part of research sub-question 1 by providing a structured framework for designing interviews aimed at inducing reflection and evaluating how the reflection process can influence the development of a more 'holistic' mindset.

Summary Section 3.4: Theoretical Framework

Main take-away:

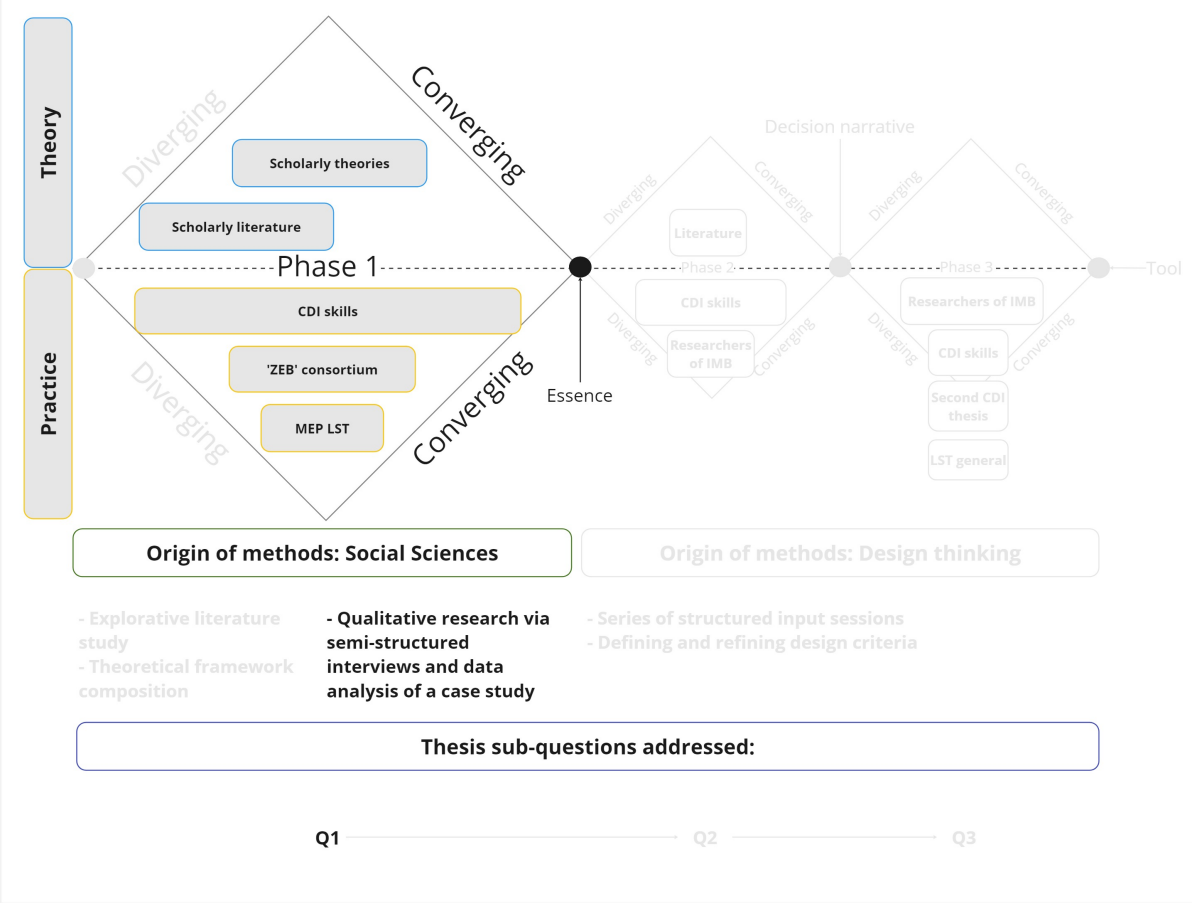
- This section introduces a theoretical framework incorporating the Social Identity (Complexity) Theory, the concept of Mental Models, the Cognitive Dissonance Theory and theory on Learning Through Reflection to analyze individual perceptions, contextual influences, and changes resulting from reflection triggered by contextual influences.
- This section also presents a model for initiating change through reflection, which is derived from the theoretical framework. This model outlines the dynamic process of developing contextual awareness, creating cognitive dissonance, and initiating change, offering a comprehensive approach to the evolution of mindsets in the context of inter- and transdisciplinarity.

Link with Chapter 4:

- The insights regarding the view on inter- and transdisciplinarity, scholarly (normative) views on 'holistic' mindsets, theory on reflection, together with the composed theoretical framework are used in the interview design and data analysis to answer research subquestion 1 (Q1).

4

The Towards Zero-Emission Biotechnology Consortium



This chapter delves into the convergent phase of Phase 1, a stage dedicated to a systematic convergent thinking process in which views, constructs, and theories of the divergent thinking stage together with experiences of the technical LST thesis are utilized for a semi-structured qualitative interview design with a case study suiting the normative claim to move along the continuum for inter- and transdisciplinarity. Subsequently, data analysis of the interviews held is used to address research sub-question 1 (Q1):

Q1: *How do contextual perceptions within the academic discipline of biotechnology, as observed in a case study, influence the development of a more 'holistic' mindset suiting inter- and transdisciplinary practices?*

As mentioned, 'The Towards Zero-Emission Biotechnology Consortium' (the 'ZEB' consortium) served as a case study to answer this research sub-question. The consortium participants represented various subdisciplines or sections within the Department of Biotechnology at TU Delft. The collaboration setup of 'ZEB' is based on frequent interactions between primary investigators (PIs) and between PhD students, whom the PIs give direction. In total, nine PIs collaborate with each other. They operate with two objectives:

1. 'Trying to convert resources to products, while minimizing emission or maximizing the utilization of CO2'
2. 'Initiate and strengthen new strategic lines and harvest cross-section synergy.'

As explained (Section 2.1.2), the consortium exemplifies a group of individuals who make deliberate efforts to progress from disciplinary silos to stronger inter- and transdisciplinary engagement. Research sub-question 1 (Q1), divided into two specific sub-questions tailored to this case study, is answered in this chapter:

Q1a: *What contextual perceptions influence how research participants of 'The Towards Zero-Emission Biotechnology Consortium' view their mindset suiting inter- and transdisciplinary practices?*

Q1b: *What characteristics can be deduced from the reflection of the research participants in 'The Towards Zero-Emission Biotechnology Consortium' that resulted in a more 'holistic' mindset?*

The chapter proceeds by outlining how views, constructs, and theories of the divergent thinking stage together with experiences of the technical LST thesis are captured in an interview design. Then, the concept of a ('holistic') mindset is operationalized, and a systematic analysis approach of the interview data is explained. Finally, the interview findings that answer research sub-question 1 (Q1), specifically divided into sub-questions Q1a and Q1b, are described and discussed in both the context of methodology used and in context of the main research question:

Q: *How can members of the academic discipline of biotechnology be incited to continuously and consciously cultivate a more 'holistic' mindset suiting inter- and transdisciplinarity?*

4.1. Methodology

As established in chapter 2, the selection of research methodologies for each phase is deliberate and aligns with the unique nature of the research questions posed. Specifically, research sub-question 1 (Q1a & Q1b) are tailored for qualitative social science research. This tailored approach serves to elucidate the core of the issue tied to the thesis's objective, within the specific context of participants from a biotechnology research consortium (the 'ZEB' consortium). Through these methodologies, an intricate comprehension of the subject matter of the thesis is achieved.

4.1.1. Semi-structured interviews

The selection of semi-structured qualitative interviews as the primary research method for this design-based research phase is rooted in their alignment with the theoretical framework constructed to address the research sub-questions 1 (Q1).

Q1: *How do contextual perceptions within the academic discipline of biotechnology, as observed in a case study, influence the development of a more 'holistic' mindset suiting inter- and transdisciplinary practices?*

As introduced (Section 3.4), the theoretical construct 'mental model' represents a cognitive structure that individuals form to meaningfully relate a set of ideas obtained through interactions with their environment (McNeil, 2015). This construct is shaped by contextual references and personal qualitative interpretations, encapsulating the 'personal mind' (Reynolds et al., 1996). The choice of semi-structured interviews is suited to this due to their capacity to systematically evaluate a person's mental model, by inquiring about perceptions of the complex challenges addressed by the consortium and the approaches and mindsets linked to this: By posing consistent questions to each participant concerning perceptions of the issue tackled by the consortium, the perceptions of inter- and transdisciplinarity, the participants' perceptions of their social identity complexity, and their understanding of the relevant mindset, semi-structured interviews offer a way to systematically construct a 'mental model representations' for each participant. These representations mirror the participants' cognitive arrangements in which interconnected ideas are endowed with meaning. Importantly, the semi-structured format allows for follow-up queries, affording the researcher the flexibility to delve deeper into the nuanced relationships among these interconnected ideas. Therefore, this approach cultivates a comprehensive understanding of participants' mental models and provides invaluable insights into their contextual perceptions.

Next to the composed theoretical framework, a model for initiating change through reflection was introduced (Section 3.4.2). As explained, this model offers a theoretical foundation for understanding the transformative process for the cultivation of a more 'holistic' mindset facilitated by reflection. At its core, this model emphasizes the systematic examination of participants' mindsets and other parts of their mental models, as they are a crucial element in the reflection process. By employing creative triggers, individuals can initiate reflection and the effect of this reflection can be analyzed methodically using their original mindsets and mental models as reference points.

Participants & Interview Settings

Seven out of the nine primary investigators (PIs) actively participated in the semi-structured qualitative interviews conducted for this research. These interviews were organized in settings designed to promote insightful conversations suitable for elucidating the mental models of the participants.

Physical Interviews: The majority of interviews were conducted in a carefully selected physical setting, specifically chosen to ensure a neutral and comfortable environment for the participants. Physical interviews were scheduled in advance and held in dedicated rooms within the academic facilities of TU Delft. These interview spaces were equipped with suitable audio (and video) recording equipment (using a laptop and Microsoft Teams).

Virtual Interview: One interview was conducted online using Microsoft Teams. Both audio and video from the online meeting were recorded.

Duration: Each interview session had a standardized duration, with all interviews lasting approximately one hour. This consistency in the duration of the interview ensured that each participant had a similar opportunity to share their perspectives and insights.

Ethical Considerations: To protect the privacy of the participants and minimize the potential risks associated with the interview process, a data management plan and informed consent forms were developed. These ethical protocols received formal approval from the Human Research Ethics Committee of the University of Delft.

Informed Consent: Prior to each interview, participants received detailed information about the purpose of the study, the interview process, and the handling of their data. All participants willingly signed the informed consent form, highlighting their voluntary participation in the interviews.

Recording and Data Management: With the participants' explicit approval, interviews were recorded to capture audio and video, or only audio, based on individual preferences. These recordings were preserved and later anonymized in the format of interview transcripts to protect the identities of the participants and ensure confidentiality. All original recordings were securely deleted one month after the interview completion.

Role of the Interviewer: During the interviews, the interviewer maintained a neutral and nondirective role. The interview protocol was adhered to, ensuring consistency and enabling a comprehensive exploration of the perspectives of the participants. To minimize any potential influence on participants' responses, follow-up questions were posed using open-ended prompts such as 'can you elaborate on that?' or 'how so?'. These open-ended inquiries were intentionally used to avoid steering the interview in any particular direction. The interviewer's primary aim was to facilitate a comfortable and open space for participants to express their perceptions and reasoning without any external interference, thus allowing for an unfiltered capture of their reasoning for the concepts questioned.

4.1.2. Interview protocol

In alignment with the theoretical framework and its central theoretical concept, the mental model, the interview protocol is structured into three distinct parts, each serving a specific research purpose (Figure 4.1). The complete interview protocol can be found in Appendix B.

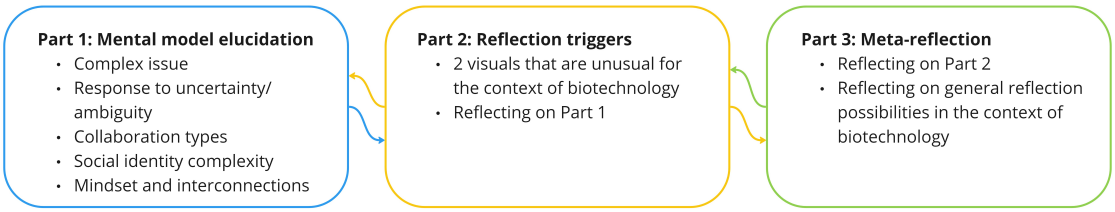


Figure 4.1: **A schematic overview of the interview protocol used to interview participants of a case study ('The Towards Zero-Emission Biotechnology Consortium').**

Part 1: Mental model elucidation

The first section of the interview protocol (Part 1) serves to operationalize the theoretical framework, particularly the concept of the mental model, within the context of the participants' experiences in 'The Towards Zero-Emission Biotechnology Consortium'. The objective of this section is to explore the cognitive structure of the participants, which encompasses their perceptions and beliefs concerning the **complex issue** they are addressing, their **responses to uncertainty /ambiguity**, their perspectives on inter- and transdisciplinarity (**collaboration types**) in their context, their subjective representations of specific social groups (**social identity complexity**), and their mindset (**mindset and interconnections**).

Complex issue: This operationalization process starts by seeking the participant's perspective on the issue they are addressing within the consortium. The aim is to understand how participants mentally structure and interpret the challenges they face.

Response to uncertainty / ambiguity: Then, participants are also invited to articulate their responses to uncertainty, providing insights into their cognitive processes when confronted with ambiguous or unfamiliar situations, i.e. situations that are common in the context of inter- and transdisciplinary practices.

Collaboration types: In alignment with the theoretical framework (Section 3.4), participants are questioned about their views on inter- and transdisciplinarity, as depicted on the continuum. They are asked to what extent they agree with statements grounded in scholarly perspectives (Section 3.2.2). This approach allows data analysis of this thesis to connect their practical experiences and viewpoints with theoretical constructs. Subsequent follow-up questions are designed to prompt participants to provide contextual references and explanations for their views on inter- and transdisciplinarity.

Social identity complexity: To deduce contextual influences originating from specific 'Ingroups,' participants are encouraged to select subjective representations of two ingroups: 'the academic discipline of biotechnology' and 'the group aiming to address the issue.' They are then asked to explain why they chose these representations. Follow-up questions provide participants with the opportunity to further specify these abstract 'Ingroups' and add more, if relevant, to their mental model.

Mindset and interconnections: Since the mindset is perceived as an integral component of the mental model, participants are asked to describe their mindsets and elucidate how these mindsets relate to the topics discussed earlier in the interview. This comprehensive approach helps to evaluate whether everything discussed, including contextual influences from references or 'Ingroups', has any bearing on their mindset.
All-together, this part is instrumental in answering the research sub-question 1a (Q1a).

Q1a: *What contextual perceptions influence how research participants of 'The Towards Zero-Emission Biotechnology Consortium' view their mindset suiting inter- and transdisciplinary practices?*

Part 2: Reflection triggers

The second part of the interview protocol (Part 2) is centered around the concept of triggering reflection through visual prompts. These prompts are intentionally selected on the basis of personal experiences of conducting the technical LST thesis.

2 visuals that are unusual for the context of biotechnology: The selection of Visual 1 and Visual 2 as reflection triggers in the interview protocol is grounded in the theoretical framework and scholarly literature, particularly the model presented by Hermes and Rimanoczy (2018) to achieve a'sustainability mindset.' As mentioned above, this model emphasizes 'deep learning,' which involves addressing the learner's intellect, emotions, and values. A key component of this transformative learning process is the induction of 'cognitive dissonance,' a phenomenon in which individuals experience a misalignment or discomfort between their existing perceptions and new information or stimuli.

Given that art is an unusual contextual influence within the academic field of biotechnology, the selected artworks are designed to stimulate the necessary cognitive dissonance without overwhelming the participants. To ensure the balance, the selected visuals maintain relevance to biotechnology while introducing elements that challenge participants' existing perceptions. Here, it is important to note that the reasons for visual selection are not strict selection criteria but rather aspects of relevance, selected by the author, a member of the academic discipline of biotechnology.

Based on this reasoning, the inclusion of these visual triggers aims to initiate a reflection process that aligns with research sub-question 1b:

Q1b: *What characteristics can be deduced from the reflection of the research participants in 'The Towards Zero-Emission Biotechnology Consortium' that resulted in a more 'holistic' mindset?*

The subsequent descriptions of Visual 1 and Visual 2 provide insight into the relevance assigned to biotechnology.

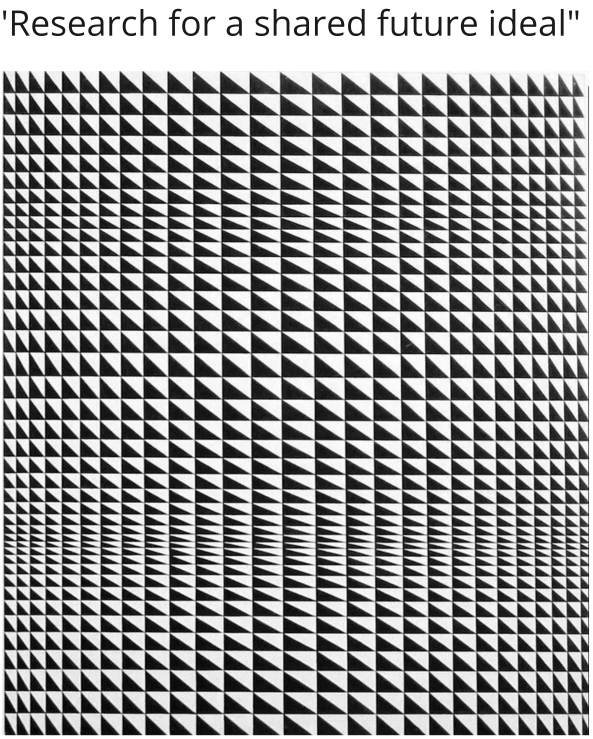


Figure 4.2: **Visual 1 as the first trigger for Part 2 of the interviews.** The visual is composed by combining the artwork 'Straight curve' created by Bridget Riley with the sentence 'research for a shared future ideal'.

Visual 1 (Figure 4.2) was composed by combining the artwork 'Straight curve' created by Bridget Riley with the sentence 'research for a shared future ideal'. The artwork was selected as it could be related to the following research experiences for the technical thesis of the Life Science and Technology (LST) master:

- **Main message versus sub-contexts in information flow:** The artwork's intricate patterns and curves may symbolize the intricate interplay between overarching biotechnology research objectives (tackling complexity) and the smaller objectives found in sub-contexts of biotechnology research groups.
- **Working on your own islands:** The visual may resonate with the idea of researchers working independently, each on their unique 'islands' of expertise, which is a characteristic of many research endeavors.
- **Reduced expert view:** The visual can represent the narrowing of one's perspective when focusing deeply on a particular aspect of research, potentially at the expense of the broader expert view.
- **Setting boundary conditions and controlling the environment within:** The visual's structured 'boxed' elements could be analogous to the researcher's task of defining and controlling experimental conditions within the laboratory setting.
- **Screening for growth (reversed growth curves):** The visual's curves might prompt considerations of growth curves, which are often used in biological research to monitor the growth of cells or organisms.

- **Repetitive work in the lab:** The repetitive nature of the visual's elements can parallel the repetitive tasks and experiments commonly encountered in laboratory work.
- **Being dependent on visualizing equipment and software to study cells (Optical illusion):** The visual's potential optical illusion aspect could symbolize the reliance on advanced equipment and visualization techniques to study cells and biological phenomena.

Figure 4.3: **Visual 2 as the second trigger for Part 2 of the interviews.** The visual is composed by combining the artwork 'Laboratory life' created by Suzanne Anker with the sentence 'responsibility and expertise for the ecosystem'.

Visual 2 (Figure 4.3) was composed by combining the artwork 'Laboratory life' created by Suzanne Anker with the sentence 'responsibility and expertise for the ecosystem'. The artwork was selected as it could be related to the following research experiences for the technical thesis of the Life Science and Technology (LST) master:

- **Controlled versus uncontrolled environmental conditions:** The visual may evoke contemplation about the controlled and artificial laboratory environments in contrast to the complex and often uncontrolled conditions of the natural ecosystem.
- **Aesthetics of nature versus development to protect nature:** It can prompt considerations about the balance between appreciating the aesthetics of the natural world and the need for nonaesthetic scientific research and development to protect and preserve the ecosystem.
- **Fundamental research versus implementation:** The imagery of the artwork may symbolize the distinction between fundamental research conducted in controlled settings and the practical implementation of scientific findings to address real-world ecological challenges.
- **Being enclosed from society:** The visual can evoke thoughts about the sense of enclosure that researchers sometimes experience when deeply immersed in laboratory work, potentially isolated from broader societal concerns.

Reflecting on Part 1: After presenting the participants with the two visuals that are unconventional in their professional context, participants are then asked to re-evaluate their mental models, including their mindset, considering the impact of these triggers. Specifically, they are asked to assess whether their perceptions of the concepts previously explored in Part 1 have evolved or changed.

Part 3: Meta-reflection
Reflecting on Part 2: The third part of the interviews is designed to initiate meta-reflection by asking participants if they experienced any form of reflection during Part 2. Specifically, participants are asked whether their reflection was triggered by the artworks presented in Part 2 or by the emotions evoked when viewing those artworks. Depending on the participants' responses, follow-up questions are posed to explore the reasons behind the occurrence or absence of reflection.

Reflecting on general reflection possibilities in the context of biotechnology: At the end of the interview, general questions are introduced to investigate contextual factors that typically influence the occurrence of reflection within the academic discipline of biotechnology. These inquiries aim to identify the contextual characteristics within the 'academic discipline of biotechnology' that either facilitate or hinder the type of reflection observed or not observed in the earlier parts of the interview.

Together with Part 2, this section addresses research sub-question 1b (Q1b):

Q1b: *What characteristics can be deduced from the reflection of the research participants in 'The Towards Zero-Emission Biotechnology Consortium' that resulted in a more 'holistic' mindset?*

4.1.3. Data analysis
This section describes the systematic analysis of the data of the transcripts of semi-structured qualitative interviews. All interview transcripts and the applied first cycle coding are accessible via this hyperlink.

First cycle coding
With the use of the software ATLAS.ti, interview transcripts were initially coded with in vivo, concept, emotion, magnitude, attribute and values coding. Here, values codes were subdivided into beliefs (B), values (V), and attitudes (A) and annotated whether being expressed explicitly or implicitly. As summarized in Appendix C, attribute and magnitude coding was done systematically.

Second cycle coding to answer research sub-question 1a
As explained, Part 1 of the interviews seeks to understand the contextual perceptions that influence how research participants view their mindset concerning inter- and transdisciplinary practices. To answer research sub-question 1a (Q1a),

Q1a: *What contextual perceptions influence how research participants of 'The Towards Zero-Emission Biotechnology Consortium' view their mindset suiting inter- and transdisciplinary practices?*,

second cycle coding in the mapping format was applied to generate representations of the participants' mental models concerning the concepts discussed ('**mental model elucidation**'). Via this mapping process, the contexts (un)consciously referenced during the participants' reasoning become visible. In a second mapping process, the participants' **perceptions on inter- and transdisciplinarity** (for which they described a suitable mindset) were categorized based on their response to the collaboration statements given. Then, based on the participants' answers on how they envisioned the social identity complexity of the two social groups 'the academic discipline of biotechnology' and 'the group trying to tackle the issue', contextual influences shaping a part of their mental model were deduced ('**deducing contextual influences**'. Finally, based on the participants' descriptions of their mindset to suit their collaborative practice, **beliefs were assigned** to be mindset specific or non-mindset specific, and, if possible, assigned to one of the proposed categories for 'holistic' mindsets as described by scholars (Section 3.2.3).

1) Mental model elucidation: In research that examines or elucidates mental models, it is generally assumed that actual mental models are inaccessible to the researcher (McNeil, 2015). However, representations of mental models or 'expressed mental models' can be made. 'Fuzzy cognitive mapping', a type of concept mapping, can be used to construct such representations (Barbrook-Johnson and Penn, 2022; Elpiniki I. Papageorgiou, 2014).

Fuzzy cognitive maps are “networks of factors and their causal connections” (Figure 4.4). They are especially suitable in participatory, collaborative contexts to capture a mental model of a system (Barbrook-Johnson and Penn, 2022). Fuzzy cognitive mapping has been used in literature with a great variety of concepts mapped and mapping procedures, providing flexibility for this research of inter- and transdisciplinary mindset, but also respective disadvantages such as difficulties in comparing the findings with the literature (Elpiniki I. Papageorgiou, 2014).

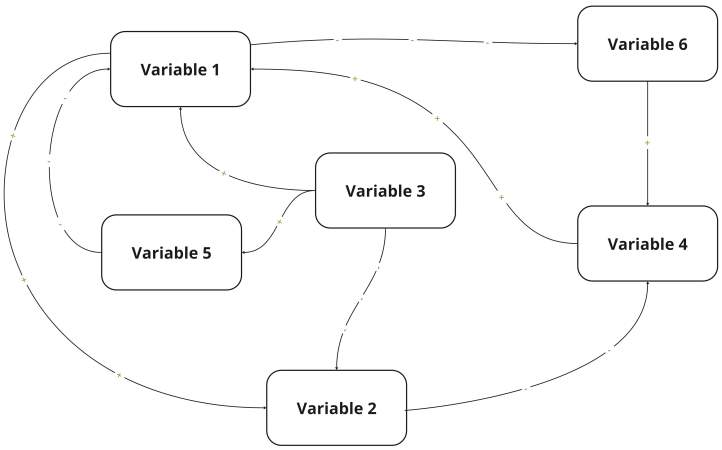


Figure 4.4: **An example of a Fuzzy Cognitive Map.** Green and red arrows represent positive and negative causal relationships, respectively.

In line with this, the data analysis of this thesis was based on a (fuzzy cognitive) mapping process: Using the online software of Miro, in vivo, concept and values codes of Part 1 of each interview were mapped based on the causal reasoning of each participant. Figure D.2 provides a summary of this systematic fuzzy cognitive mapping process. The following is a description of each step of the mapping process.

1a) Theming code groups and causal relations in reasoning: Interview transcript codes from various sections, including A) the complex issue, B) response to uncertainty/ambiguity, C) collaboration types, D) social identity complexity, and E) mindset and interconnections (Section 4.1.2), were organized thematically. These thematic groups emerged during the analysis when rereading the transcripts and grouping codes that were expressed to have a connection. The causal relationships within these thematic groups were drawn based on what the participants explicitly mentioned when they described how one theme influenced or was influenced by another. For example, when a participant spoke about how his response to uncertainty (B) was influenced by his perceptions of collaboration types (C), a causal relationship was established. In cases where causal relations were not explicitly mentioned but were apparent through the reasoning of the participants, dotted lines were used to represent these relations. Here, it is important to note that the dotted lines were drawn on the basis of the researcher’s interpretation.

1b) Simplifying: To simplify the map, themes that had fewer than three causal connections to other themes and isolated feedback loops with only a few reasoning steps were removed. After doing so, themes with high similarities were merged. This step ensured that the map remained focused on the most significant and interconnected themes, avoiding unnecessary complexity and redundancy.

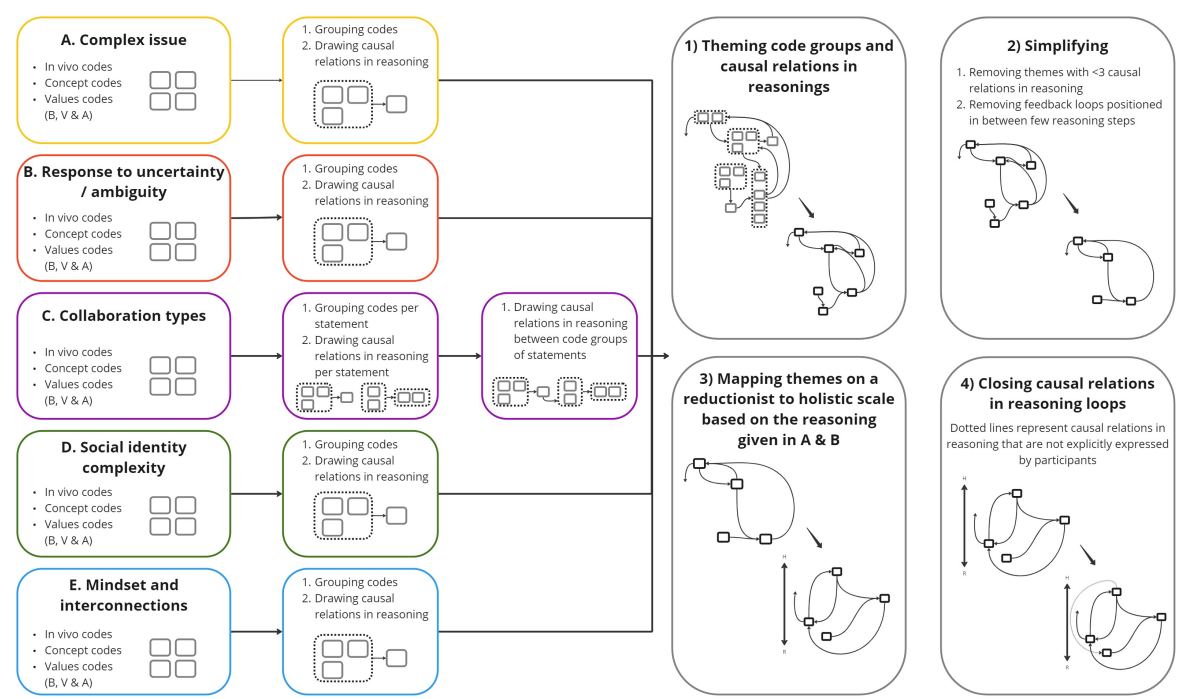


Figure 4.5: **An overview of the systematic process for mapping first cycle codes of Part 1 of the interviews to create a mental model representation in which the variables are positioned on a 'holistic' (complex system) to 'reductionist' (reduced system) scale.**

1c) Mapping themes on a reductionist to holistic scale based on the reasoning given in A & B: Themes were then placed on a spectrum ranging from reductionist to holistic based on their alignment with the participants' reasoning about A) complex issues and B) responses to uncertainty/ambiguity. The positioning of themes was made by the researcher based on the interpretation of participants' explanations, with the following reasoning: the themes were positioned based on the explicit reasoning of participants regarding the bigger problem and ways to tackle it versus the smaller, more concretely described subproblems and ways to address them, as well as any related aspects. In this context, the bigger problem was considered the most holistic, whereas the smaller, more concretely defined problems were considered more reductionistic. To compare the positioning of themes between different participants, the researcher analyzed the themes' commonalities. When determining the position of themes on the spectrum, direct quotes are used to provide transparency and allow readers to evaluate the researcher's judgment.

1d) Closing causal relations in reasoning loops: Finally, dotted lines were used to represent "obvious" causal relations in reasoning that could not be explicitly expressed by participants in the interview transcript. This step helps to ensure that the map accurately reflects the complete causal reasoning process. Again, it is important to note that these dotted lines were drawn based on the researcher's interpretation.

The example presented in Appendix D presents interview transcript segments related to sections A) the complex issue and B) response to uncertainty/ambiguity, along with the thematically grouped and mapped codes for only these sections (Step 1a) and the reductionist to holistic reasoning steps derived from this transcript (Step 1c).

2) Perception of inter- and transdisciplinarity: Through the experiences of the technical LST thesis, it has been observed that individuals in the field of biotechnology face difficulty articulating their collaborative practices in terms of inter- and transdisciplinarity independently. The purpose of this second analysis step was to gain deeper insights into participants' mental models of inter- and transdisciplinarity, specifically by assessing their perceptions through the evaluation of attributes as described by scholars. These attributes were previously positioned along a continuum, moving upward toward inter- and transdisciplinarity (Section 3.2.2, Figure 3.1).

Using the software of ATLAS.ti, participants were grouped according to to what extent they agreed with the inter- and transdisciplinary attributes as suggested by scholars (attribute and magnitude coding), and both concept and in vivo coding describing their argument. All participants were grouped according to their level of agreement with the statement itself, as expressed and confirmed in the interview. Concept and in vivo coding were used to map their perception for the current situation and/or for the future or ideal situation in terms of the amount of collaborations happening in the consortium they based their (dis)agreement. Appendix D presents an example of this data analysis step.

3) Deducing contextual influences: This step aimed to identify and understand the 'Ingroup context(s)' affecting specific beliefs expressed and 'contextual reference(s)' expressed that influence the participant's mental model. These contextual references are related to the social identity complexity and mental model components of this thesis' theoretical framework and are deduced through an examination of participants' chosen subjective representations regarding the relationship between two key 'Ingroups', 'the academic discipline of biotechnology' and 'the group trying to tackle the issue'.

The goal here is to understand how these contextual influences impact the mental models of the participants, which were previously placed on a scale from reductionist to holistic in Step 1. This analysis relied on attribute coding for the categorization of chosen subjective representations and on in vivo coding to elucidate the underlying explanations.

To interpret these contextual influences, the reasoning steps articulated by the participants in sections A) and B), which had guided the positioning of themes on the reductionist to holistic scale in Step 1, were referred to. While the researcher's interpretation plays a role in this analysis step, it is grounded in the in vivo codes extracted from the participants' responses. For transparency, direct quotes are included when presenting findings in this thesis.

The example presented in Appendix D presents interview transcript segments related to section D) Social identity complexity, and the contextual elements that were deduced from this and linked to holistic to reductionist reasoning steps derived from step 1.

4) Assigning mindset-specific beliefs: This section details the operationalization of a mindset conducive to inter- and transdisciplinarity. This operationalization involves the assignment of mindset-specific beliefs, contextualized by their representation of biases towards an 'Outgroup', positive differentiation for an 'Ingroup', or a clear association with the context. The process is anchored in the social identity complexity representation chosen by participants and their provided explanations for these representations.

Mindset operationalization: As described, the data analysis of the interviews held focuses on analyzing the mindset perceived by the participants as "a collection of individual and collective beliefs" (Section 3.2.4). To evaluate contextual influences shaping the mindset, beliefs were assigned to one of three categories (based on the composed theoretical framework, Section 3.4) - positive differentiation, bias, and normativity - and the respective 'Ingroup', 'Outgroup' or general context (Section 4.1.3).

Belief: A belief is conceptualized as a mental attitude or state toward a particular proposition (Campbell, 1950), expressed in a particular context. A belief is operationalized according to the following: In all interview transcriptions, a belief was coded (values coding) each time a participant expressed a particular proposition in combination with an expressed personal attitude or state towards favoring or disfavoring this proposition (explicit or implicit).

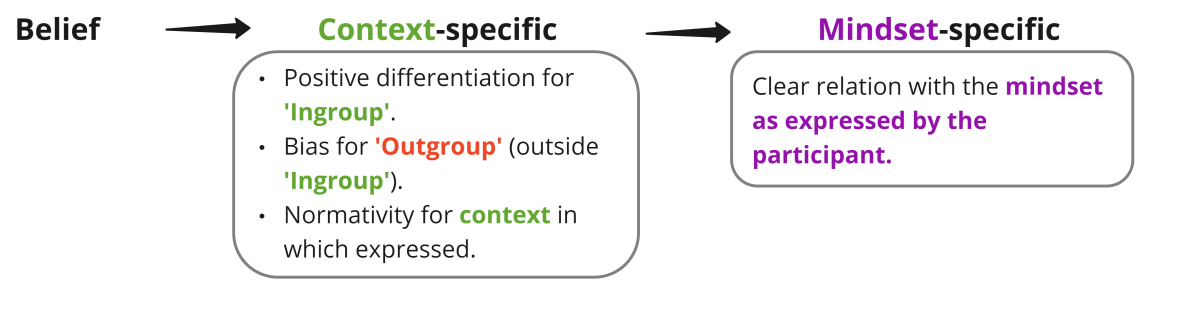


Figure 4.6: **An overview of the operationalization steps used to define what type of beliefs, expressed in what type of context (context-specific) are part of the mindset, i.e. "a collection of individual and collective beliefs" (mindset-specific).** First, all coded beliefs were made context-specific by assigning them to one of three categories - positive differentiation, bias or normativity - and the respective 'Ingroup', 'Outgroup' or general context. From this collection of context-specific beliefs, beliefs were assigned to be mindset-specific when a clear relation with the mindset as expressed by the participant could be observed in the systematic data analysis (Section 4.1.3).

Context-specific belief: A context-specific belief that indicates positive differentiation is conceptualized as a belief that indicates how the group present in this social context ('Ingroup') differentiates positively from relevant groups not present in this social context ('Outgroups'). It is operationalized according to the following: The coded beliefs were evaluated in combination with in vivo and concept codes of the participant's verbal expression. The beliefs were subdivided into this type when a positive differentiation was observed for an 'Ingroup'.

A context-specific belief that indicates a bias is conceptualized as a belief that indicates how a relevant group that is not present in this social context ('Outgroup') negatively differentiates itself from groups that are present in this social context ('Ingroups'). It is operationalized according to the following: The coded beliefs were evaluated in combination with in vivo and concept codes of the participant's verbal expression. When a bias for an 'Outgroup' was observed, beliefs were subdivided into this type of belief.

A context-specific belief that indicates normativity is conceptualized as a belief perceived as general for the context in which it is expressed. It is operationalized according to the following: The coded beliefs were evaluated in combination with in vivo and concept codes of the participant's verbal expression. When no positive differentiation for an 'Ingroup' or bias for an 'Outgroup' was observed, beliefs were subdivided into this type of belief.

Mindset-specific belief: A mindset-specific belief is conceptualized as a context-specific belief (indicating positive differentiation, bias, or normativity) that the participant acknowledges to be part of or shape the current mindset of the participant. It is operationalized according to the following: Context-specific beliefs indicating positive differentiation, bias or normativity assigned to the respective 'Ingroup', 'Outgroup', or context were evaluated in combination with in vivo, concept, and (remaining) values codes that are specific for the interview parts where the mindset was discussed. Beliefs were subdivided into this type when a clear relationship was observed.

This operationalization process culminates in a **final second cycle coding data analysis step**, as illustrated in Figure 4.7. First, all values codes that were beliefs (both explicit and implicit) were assigned to one of three categories - positive differentiation, bias and normativity - and the respective 'Ingroup', 'Outgroup' or general context. From these context-specific beliefs, the beliefs that were a part of the mindset were deduced from in vivo, concept, and values codes of this mapping that were specific for the interview parts where the mindset was discussed.

Within this step, the relationships between mindset-specific beliefs and their respective contexts are examined in connection with the contextual elements derived from Step 3, which focused on the social identity complexity representation. This approach enables the comprehensive analysis of contextual factors that influence the participants' expressions of the mindset conducive to inter- and transdisciplinarity.

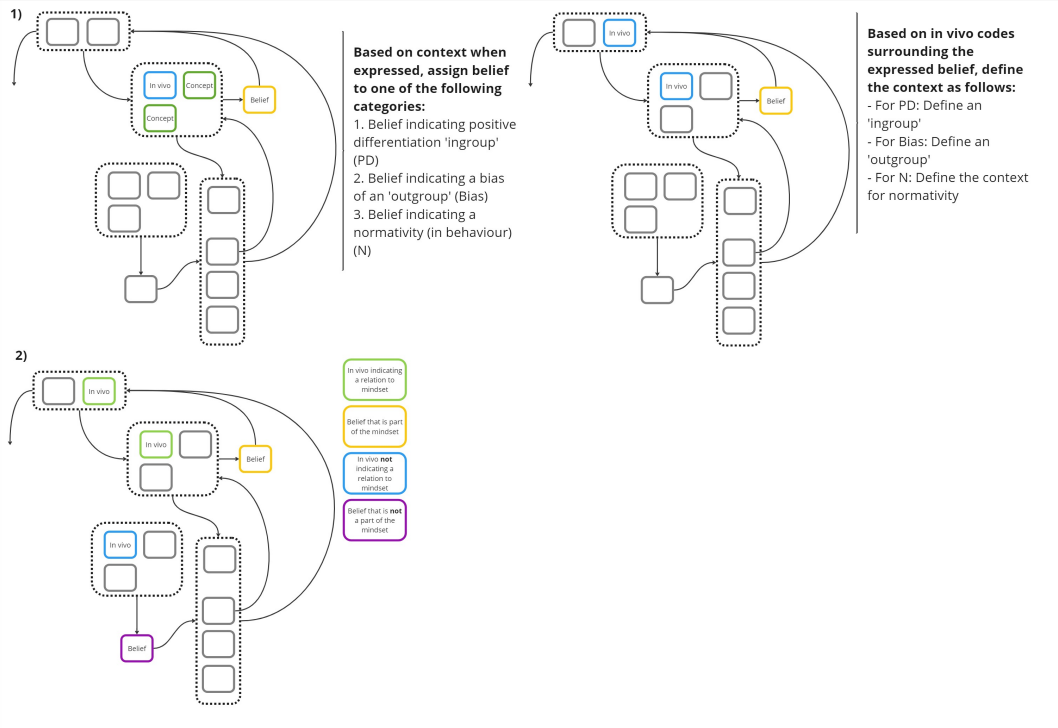


Figure 4.7: **Overview of the systematic process of 1) assigning values codes that were beliefs to one be context-specific beliefs based on the social identity (complexity) theory - via positive differentiation, bias and normativity - and 2) assigning context-specific beliefs to be mindset-specific or non-mindset-specific.** Assigning was done using the themed code groups and causal relationships in reasoning (step 1, Figure D.2).

Second cycle coding to answer research sub-question 1b

In line with the thesis's perspective that only triple-loop learning through reflection fosters the development of a more 'holistic' mindset, research sub-question 1b (Q1b),

Q1b: *What characteristics can be deduced from the reflection of the research participants in 'The Towards Zero-Emission Biotechnology Consortium' that resulted in a more 'holistic' mindset?*,

was addressed through a focused analysis. The analysis in this step is first focused on the assessment of whether participants experienced reflection and if this reflection led to any changes in their mindset.

1. **Option 1: No Reflection.** This option is assigned when participants expressed that they did not engage in any reflective processes during their participation.
2. **Option 2: Reflection but No Changed Mindset.** This category is used when participants acknowledged that they reflected, but this reflection did not result in changes to their existing mindset.
3. **Option 3: Reflection Causing a Changed Mindset.** Participants fall into this category when their reflections led to alterations in their existing mindset or beliefs.

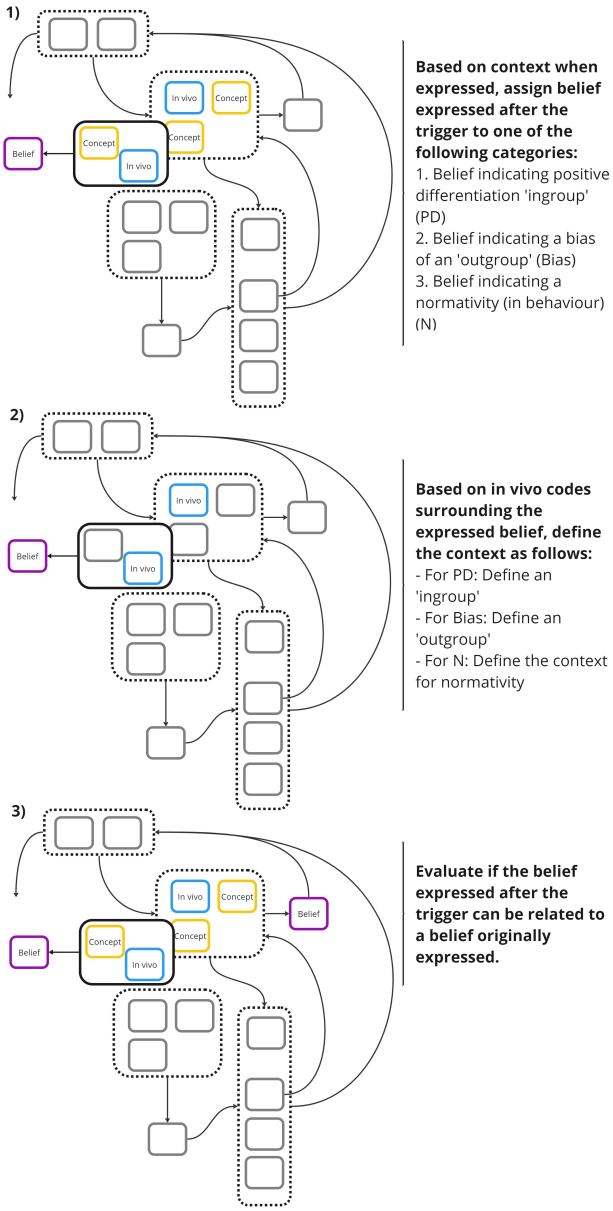


Figure 4.8: **An overview of the systematic process for mapping first cycle codes specific for Part 2 of the interview on top of the Fuzzy Cognitive Map in which the variables are positioned on a 'holistic' (complex system) to 'reductionist' (reduced system) scale (Figure D.2), and how values codes that were beliefs were assigned to one of three categories - positive differentiation, bias and normativity - and the respective 'Ingroup', 'Outgroup' or general context.** Assigning was done using the themed code groups and causal relationships in reasoning (step 1, Figure D.2).

Then, using the online software of Miro, in vivo, concept and value codes and the causal reasoning of each participant from Part 2 of each interview were mapped on top of the maps of Part 1 (Figure 4.8). Similarly to the mental model elucidation process to answer research sub-question 1a (Q1a), all values codes that were beliefs (both explicit and implicit) were assigned to one of three categories, positive differentiation, bias, and normativity, and the respective 'Ingroup', 'Outgroup' or general context. Subsequently, the contextual influences on mindset-specific beliefs, both changed and unchanged, were assessed by examining how these beliefs could be connected to the contextual influences that were deduced during step 1c), as derived from the comprehensive mapping of participants' responses in Part 1 of the interviews (similar to Steps 1 and 3 of the second cycle coding to answer research sub-question 1a).

Finally, second cycle coding was used to theme emotions experienced by participants when exposed to these triggers and their subsequent impact on the reflection process. Other than that, this research sub-question was addressed by directly examining the 'triple loop learning' participants' responses to the posed question.

Summary Section 4.1: Methodology

Methodology Overview:
Semi-structured interviews followed by a systematic data analysis were chosen as methodology for the convergent part of Phase 1.

Interview Design:
The interview protocol is divided into three key parts:

- The first part, Mental Model Elucidation, focuses on extracting and categorizing participants' beliefs, shaping their mindset.
- The second part, Reflection Triggers, introduces stimuli designed to prompt reflection in the context of biotechnology.
- The third part, Meta-Reflection, involves probing participants about the potential reflection process they underwent.

Data Analysis per Interview Part:

- To answer research sub-question 1a (Q1a): Mental Model Elucidation and deducing contextual influences of the mindset involve a systematic process of coding and mapping to do the following with beliefs expressed by participants in the first part of the interview:
  - Categorizing them as context-specific and mindset-specific
  - Examining their relationships with social identity complexity representations or other contextual references
  - Evaluating these contextual influences in relation to mindset-specific beliefs
- To answer research sub-question 1b (Q1b): Data analysis focuses on the second and third part of the interview. Based on the second part,
  - It employs classifying participants' reflections into categories 'No Reflection', 'Reflection but No Changed Mindset', or 'Reflection Causing a Changed Mindset'; and
  - Categorizing beliefs expressed and deducing their contextual influences in a similar way to the data analysis process for answering research sub-question 1a (Q1a).

  Based on the second and third parts,
  - It employs evaluating the emotions experienced by participants during reflection triggers; and
  - Analyzing the participant's answers of directly addressing the reflection processes they underwent.

Link with Section 4.2:

- The methodologies and interview structure detailed in this chapter form the bedrock of the findings discussed in the following section.

4.2. Findings

In this section, the findings relevant to the two research sub-questions (Q1a & Q1b) are presented. The section starts by describing the fuzzy cognitive maps that visually represent the mental models of participants concerning inter- and transdisciplinarity in the context of their consortium and how their mindsets are aligned with these models. These mental models are derived from the systematic second cycle coding process outlined in Step 1.

Subsequently, qualitative observations are described, comparing participants' holistic to reductionist reasoning steps, the contextual influences deduced in Step 3 of the data analysis, and their responses to various interview questions.

Finally, this section is rounded off by describing the mindset-specific beliefs found and the contextual influences that affect them.

The section then transitions to the findings relevant to addressing research sub-question 1b. In this part, the reflection processes experienced by all participants are described and categorized into three distinct options: No Reflection, Reflection but No Changed Mindset, and Reflection Causing a Changed Mindset. Then, the emotions expressed by the participants when encountering triggers are described. Finally, the contextual influences found that either facilitate or hinder the reflection process are described, as reported by participants for whom it was observed that after reflection, different contextual influences affected their beliefs or actions.

4.2.1. Research sub-question 1a

Fuzzy cognitive maps representing the participants' mental models

Via Fuzzy Cognitive Mapping (Section 4.1.3), individual mental models of participants were represented. When doing so, variables were mapped on the same 'holistic' (complex system) to 'reductionist' (reduced system) scale as the steps for tackling the issue that was indicated by each participant (Figure 4.16). 'Ingroups' or contexts and beliefs that are part of the mindset were deduced. This section introduces all representations of the individual mental models of all participants. Each time, the main causal reasoning and the role of mindset are summarized, as described by the participant.

Participant 1 (Figure 4.9) acknowledged that the complex issue was big and urgent. As many people are concerned about the problem, more scientists with expertise will be able to investigate various potential solutions proposed in society. Collaborations between sections of 'ZEB' are considered extremely effective as they represent many of the potential solutions in the more 'holistic' system and more integrated 'holistic' solutions. Only through expertise can it be decided which integrated solutions will work: a success or a breakthrough. To implement solutions and make a positive impact, scientists need to explain to all people concerned with the problem what the right approach is.

Participant 1 described the mindset as:

"A set of ideas and opinions. The… That you can express to other peers and you feel aligned with what their… On what their set of ideas and opinions is."

Connected to the mental model, the mindset described represents all beliefs that indicate that the issue is an urgency that must be solved through expertise, specifically the collaborations between the sections of 'ZEB'.

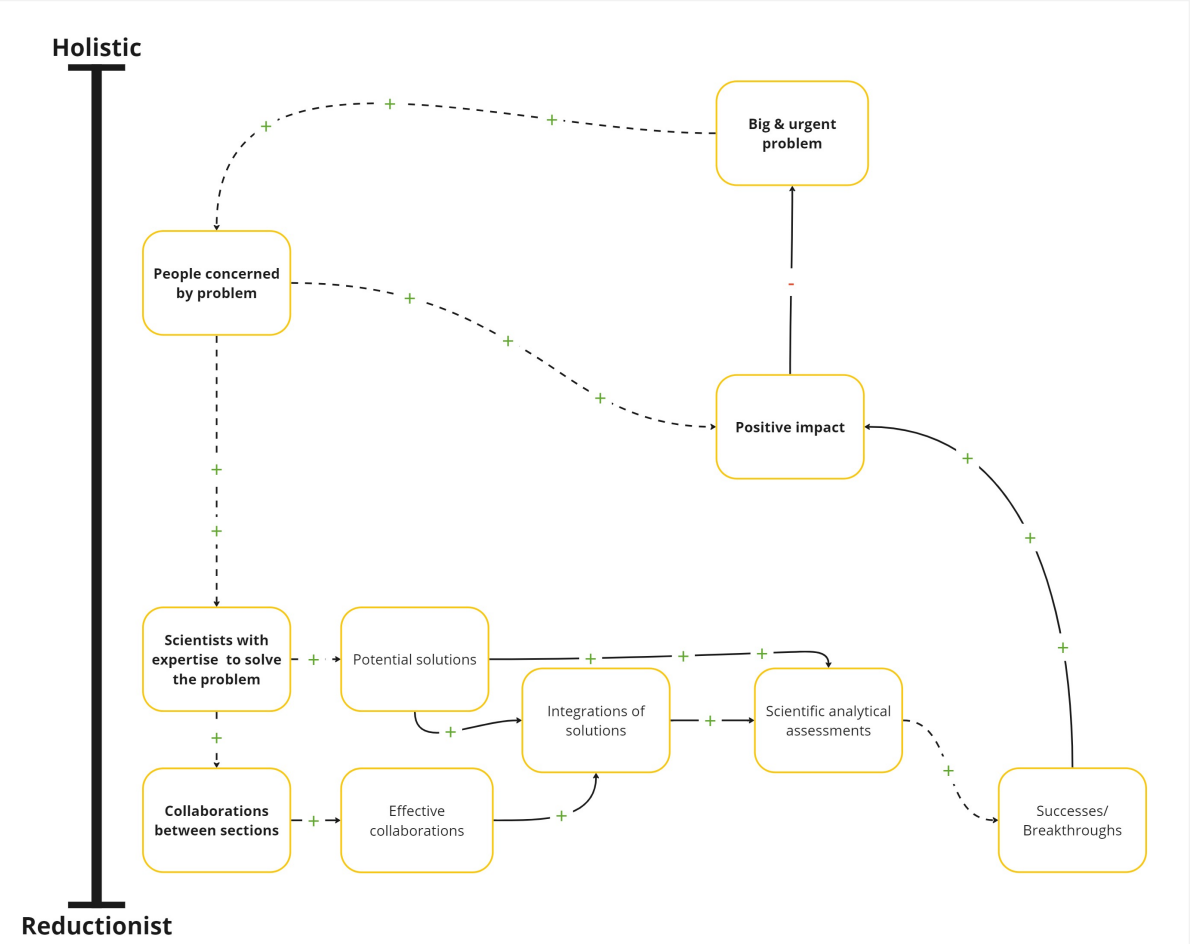


Figure 4.9: **Mental model representation of participant 1 (deduced from Part 1 of the interviews).** The representation was constructed via Fuzzy Cognitive mapping of in vivo, concept and values codes (Section 4.1.3). Variables (stated in yellow squares) are positioned on a 'holistic' (complex system) to 'reductionist' (reduced, embedded system) scale according to reasoning steps depicted in Figure 4.16, and connected the contexts depicted in Figure 4.17. Arrows with green '+ signs' and red '- signs' represent positive and negative causal relations between the variables, respectively.

Participant 2 (Figure 4.10) described the complex issue as a general increase CO_2 in the atmosphere. To tackle it, all perspectives on solutions of the people concerned by the problem are required. The work of academics with expertise matters as it represents a smaller diversity of (integrated) solutions. In this model, interactions with the more diverse group active in, the more 'holistic', complex step, are essential to solve it, but not happening at the moment.

Participant 2 described the mindset as:

"The framework that you use to put things that happen in your surroundings, kind of, in a certain perspective."

Connected to the mental model, the mindset described represents a collection of all beliefs that were indicated to influence the participant's viewpoint on the uncertainty to deal with the problem. This point of view is placed on a positive to negative spectrum. The work of academics makes the viewpoint more positive, whereas the bigger diversity in the more 'holistic', complex system makes it more negative.

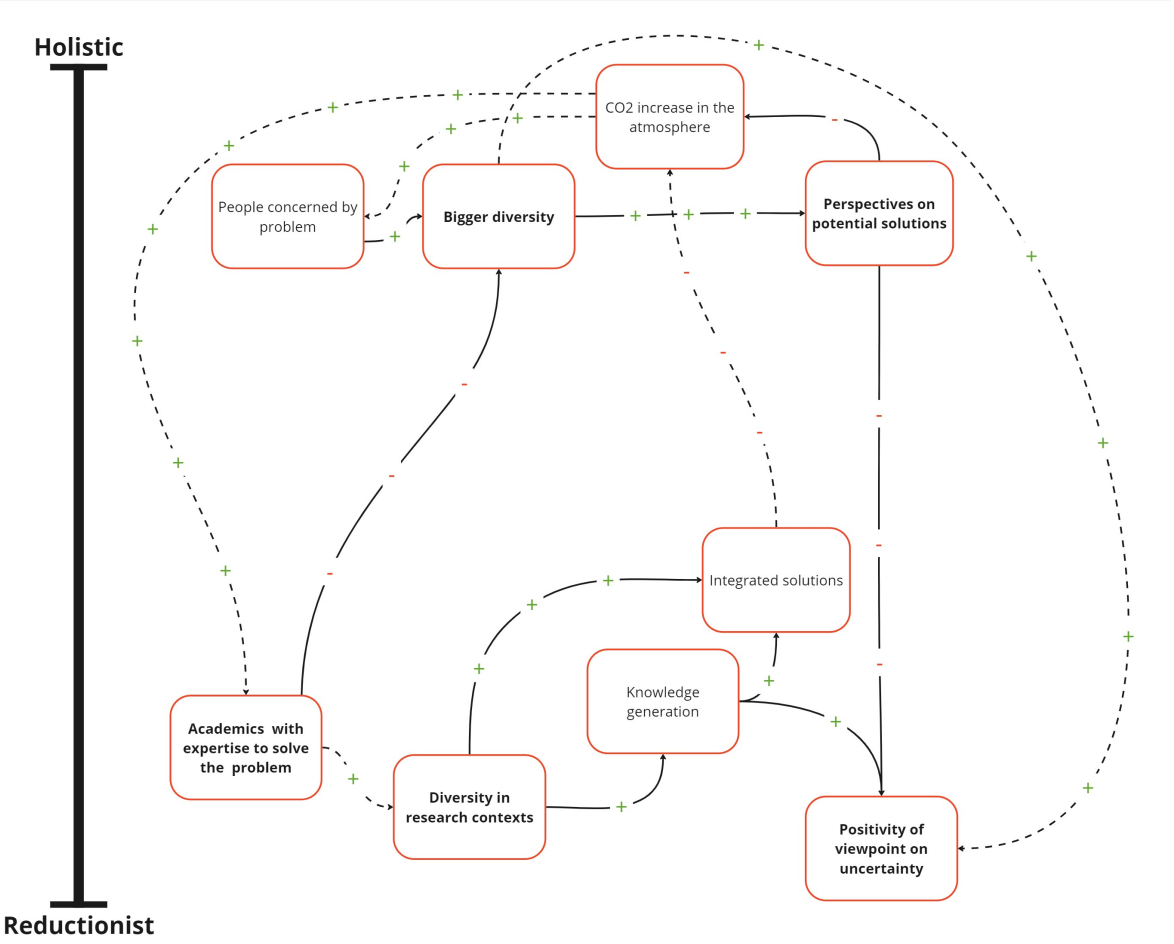


Figure 4.10: **Mental model representation of participant 2 (deduced from Part 1 of the interviews).** The representation was constructed via Fuzzy Cognitive Mapping of in vivo, concept and values codes (Section 4.1.3). Variables (stated in red squares) are positioned on a 'holistic' (complex system) to 'reductionist' (reduced, embedded system) scale according to reasoning steps depicted in Figure 4.16, and connected the contexts depicted in Figure 4.17. Arrows with green '+ signs' and red '- signs' represent positive and negative causal relations between the variables, respectively.

Participant 3 (Figure 4.11) described the issue as the current traditional production processes and linked the challenge of tackling it to various types of complexity, both of the development and implementation of technical solutions. In this model, technically educated people concerned with the problem are equipped to reduce different types of complexity. By collaborating both between and outside the sections of 'ZEB', technical solutions can be rightly integrated to reduce overall complexity. Here, the perspectives of laypeople further increase the complexity of the development and implementation of technical solutions.

Participant 3 related mindset to ambition and motivation:

"Actually, [I am a] very motivated person… to develop the technology I've been developing… And to me, that's part of the solution of the bigger problem. Uh, so my mindset has been always about making an impact… For society, for research, for science…"

Connected to the mental model, the mindset described represents a collection of all beliefs expressed in relation to the work of participant 3, in order to have an impact by reducing traditional production processes.

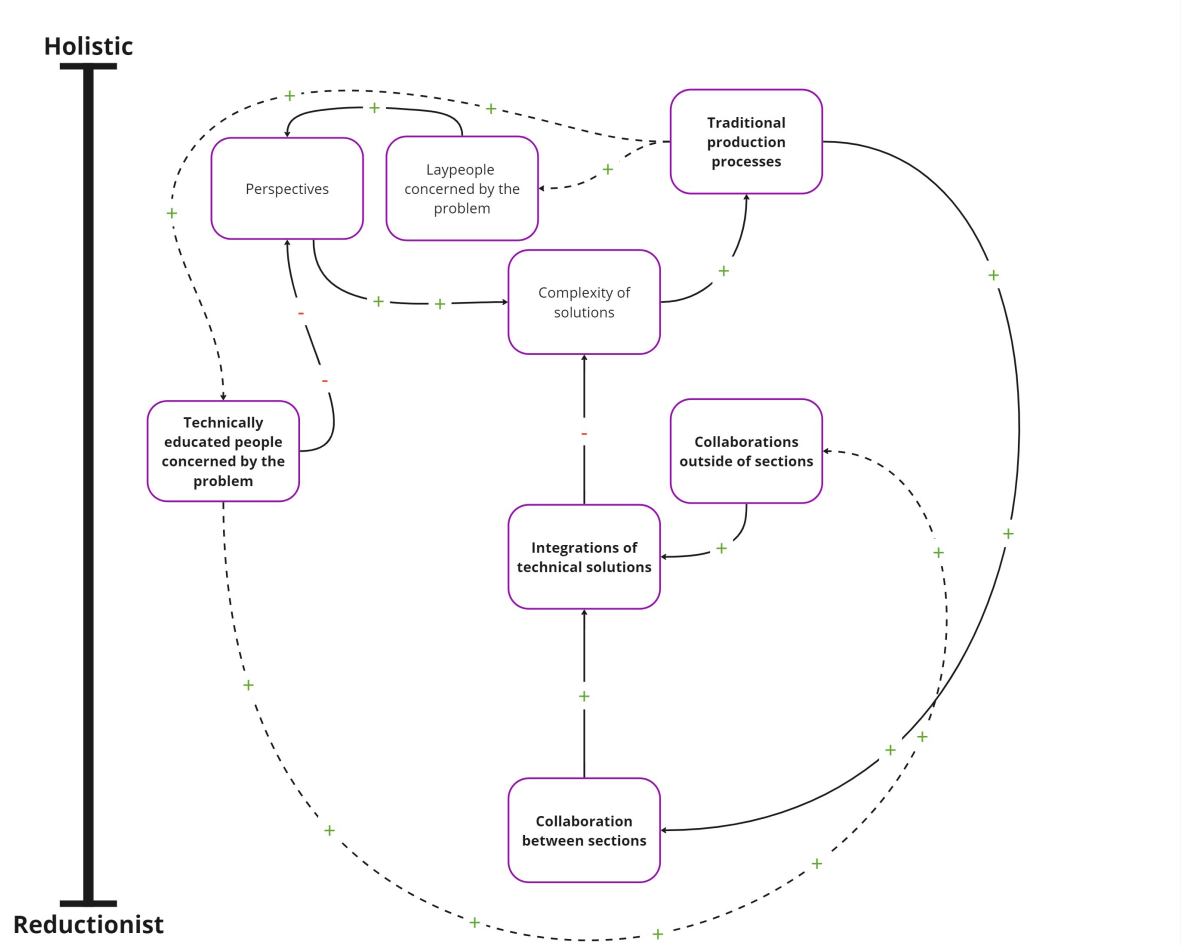


Figure 4.11: **Mental model representation of participant 3 (deduced from Part 1 of the interviews).** The representation was constructed via Fuzzy Cognitive Mapping of in vivo, concept and values codes (Section 4.1.3). Variables (stated in purple squares) are positioned on a 'holistic' (complex system) to 'reductionist' (reduced, embedded system) scale according to reasoning steps depicted in Figure 4.16, and connected to the contexts depicted in Figure 4.17. Arrows with green '+ signs' and red '- signs' represent positive and negative causal relations between the variables, respectively.

Participant 4 (Figure 4.12) envisioned the issue as any waste that is put in the environment, along with the consequences of doing so. The complexity of solving the complex issue is primarily related to the diversity of approaches in a reduced 'academic discipline of biotechnology' system. As the industry is the main group that tries to address the issue, the group has a big say on how approaches to this more reduced research level will be implemented. Interaction with industry occurs when there is a certainty of success at the academic level. When this is the case, the uncertainty of the research stops, the collaborations between the section of 'ZEB' are reduced, and concrete deliverables are passed on to the industry. On the other hand, collaborations between the section of 'ZEB' and fundamental research are essential to achieve a scientific breakthrough.

Participant 4 described the mindset as:

> *"How you're thinking about something in a certain point in time."*

Connected to the mental model, the mindset described represents a collection of all beliefs indicating how participant 4 thought about the appropriate approach to tackle the complex issue at the moment of the interview. As participant 4 expressed a high certainty of success for the current project, collaborations with industry were considered most relevant. However, participant 4 expressed that for projects within 'ZEB' that are at a different stage, collaborations between sections were the most important.

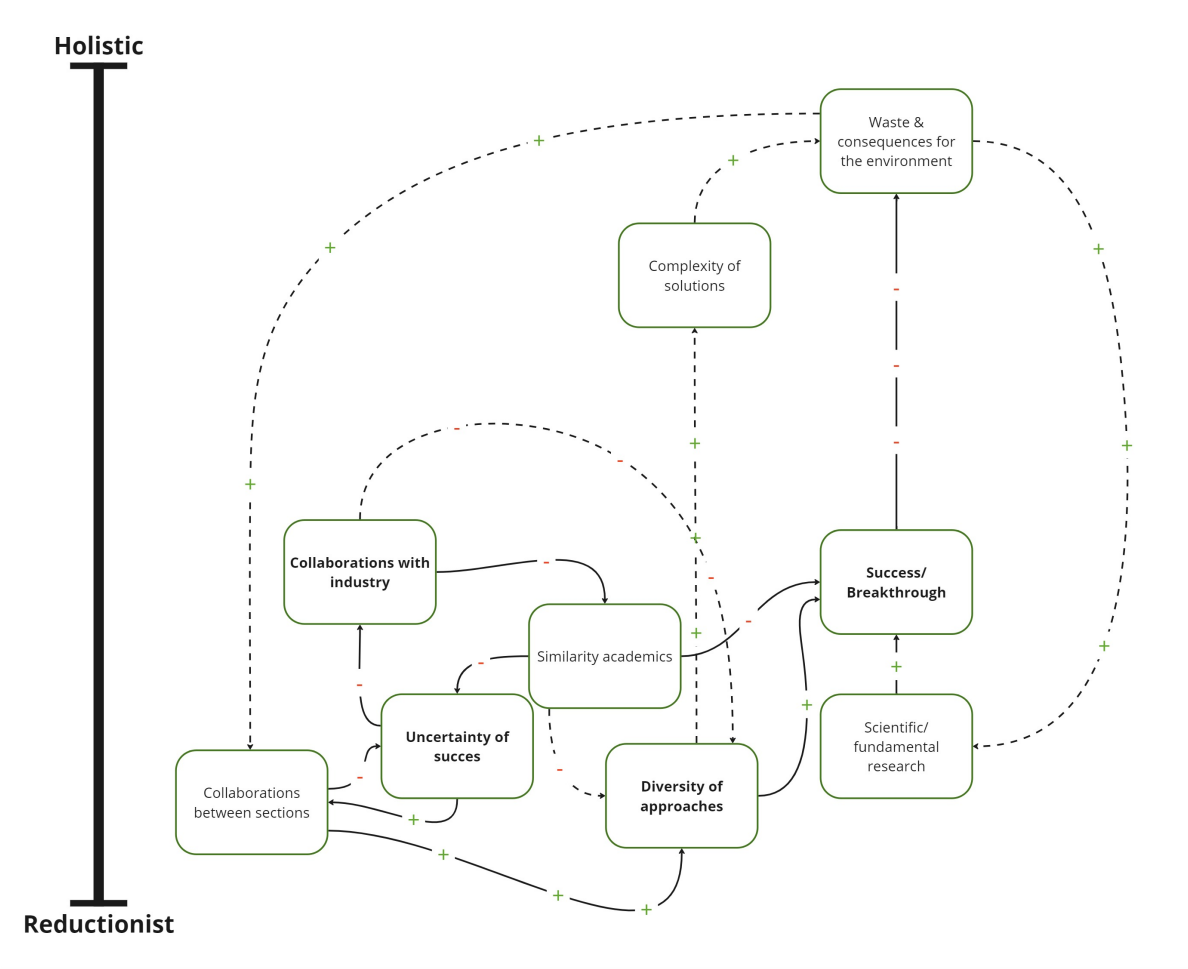


Figure 4.12: **Mental model representation of participant 4 (deduced from Part 1 of the interviews).** The representation was constructed via Fuzzy Cognitive Mapping of in vivo, concept and values codes (Section 4.1.3). Variables (stated in dark green squares) are positioned on a 'holistic' (complex system) to 'reductionist' (reduced, embedded system) scale according to reasoning steps depicted in Figure 4.16, and connected the contexts depicted in Figure 4.17. Arrows with green '+ signs' and red '- signs' represent positive and negative causal relations between the variables, respectively.

Participant 5 (Figure 4.13) described the issue as waste, harmful gas, and the negative consequences that are connected to it. Scientific-technological innovations are needed to solve it at a 'holistic', complex step. Subsequently, collaborations are required to align these innovations with social complexity. In these higher collaborations, all perspectives should be considered equally important. In so doing, they need to be integrated into a consistent whole. In this model, the collaborations between the sections of 'ZEB' represent a more reduced, embedded system in the 'the scientific development of technical innovations' system. Here, the strategic setup of the collaborations will result in the integration of results and the widening of perspectives of the participants of 'ZEB'. In this scientific and technical system, widening a technical perspective is especially important, as it will result in more technical perspectives that steer technological innovations.

Participant 5 described the mindset as:

"The way you see a given issue, and the… The ways you… The ways you think are necessary to approach it and solve the issue, right? The mindset related to a particular equation."

Connected to the mental model, the mindset described represents a collection of all beliefs indicating the equation of participant 5 to solve this issue, both in the embedded system of 'ZEB' or 'the scientific development of technical innovations', and in the more 'holistic' system.

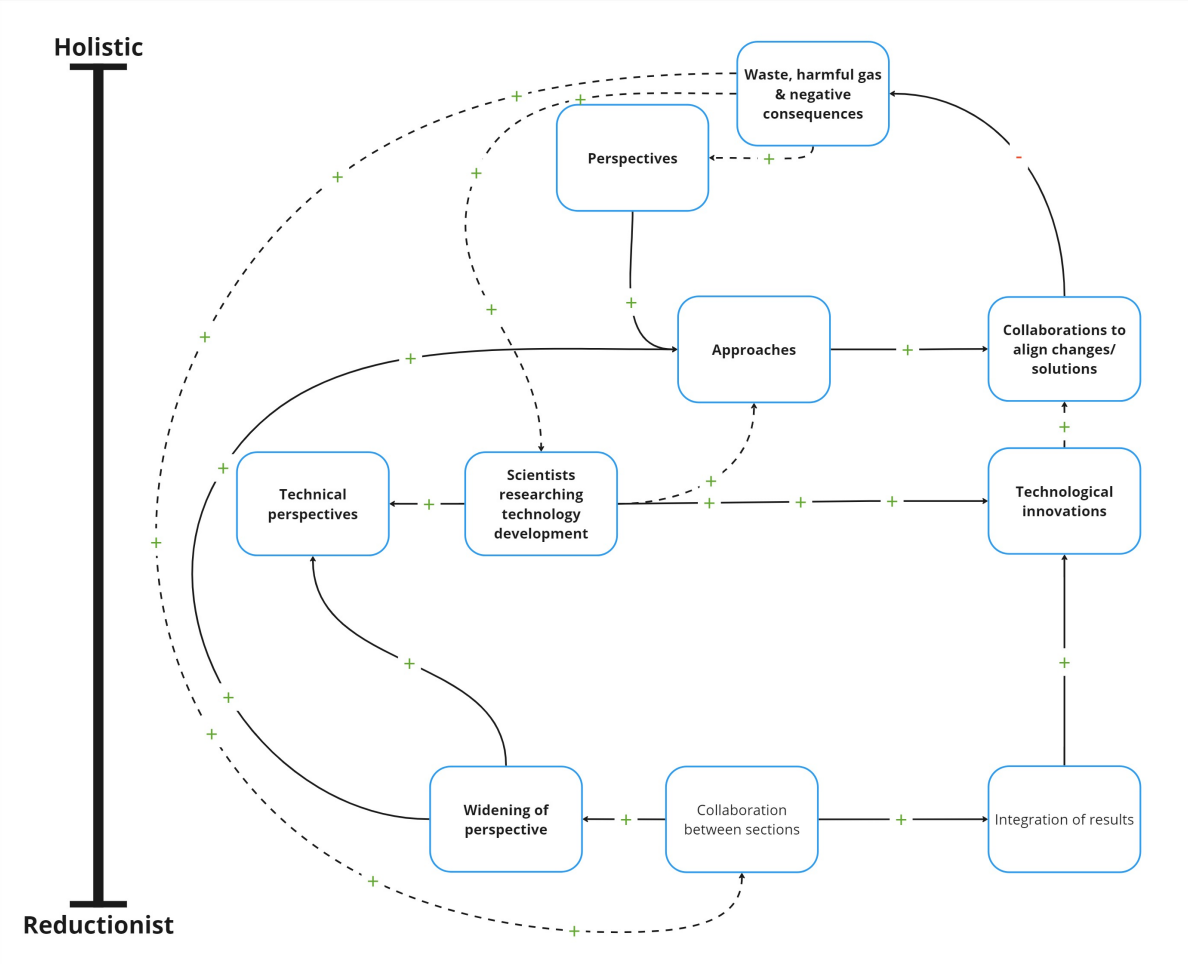


Figure 4.13: **Mental model representation of participant 5 (deduced from Part 1 of the interviews).** The representation was constructed via Fuzzy Cognitive Mapping of in vivo, concept and values codes (Section 4.1.3). Variables (stated in light blue squares) are positioned on a 'holistic' (complex system) to 'reductionist' (reduced, embedded system) scale according to reasoning steps depicted in Figure 4.16, and connected the contexts depicted in Figure 4.17. Arrows with green '+ signs' and red '- signs' represent positive and negative causal relations between the variables, respectively.

Participant 6 (Figure 4.14) envisioned the issue as 'emissions' in general. Reducing emissions is done through the implementation of 'impactful solutions' for more sustainable production processes and technologies. In order to integrate potential solutions so that they encompass entire production processes, scientific complementary expertise and collaborations at this technical, embedded level are required. To determine which of these potential solutions can have an impact, a sufficient level of understanding of both this reduced technical level and the more 'holistic' ('big picture') complex system must be translated into sound analytical assessments. To acquire a sufficient understanding of the 'big picture', collaborations are also required at the less-reduced 'implementation' step.

Participant 6 related the mindset to:

"The way of thinking… It is related to my values and the actions that I can take, based on… The information that I have from the world in general, scientific and non-scientific."

Connected to the mental model, the mindset described represents a collection of all beliefs linked to the main role of participant 6 in 'ZEB', which was determining which potential solutions can become 'impactful solutions'.

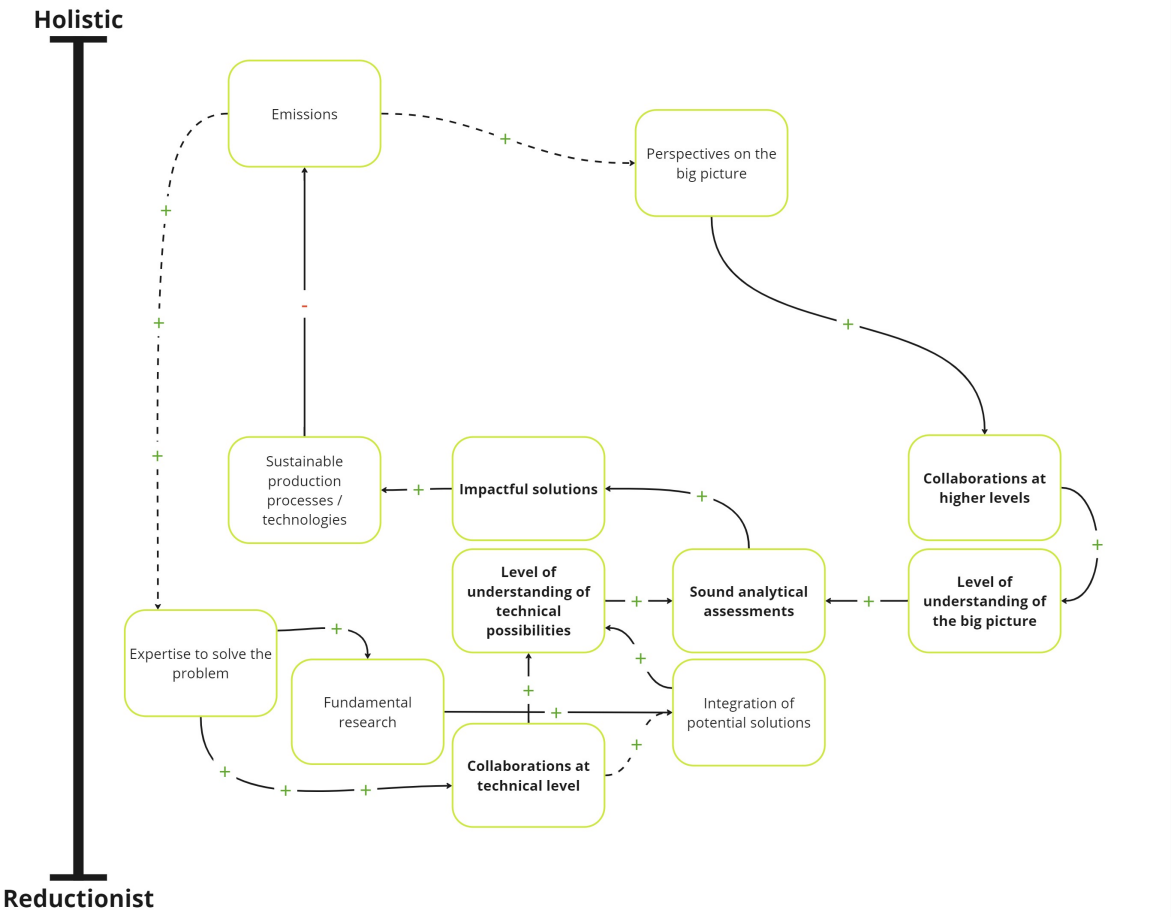


Figure 4.14: **Mental model representation of participant 6 (deduced from Part 1 of the interviews)** The representation was constructed via Fuzzy Cognitive Mapping of in vivo, concept and values codes (Section 4.1.3). Variables (stated in light green squares) are positioned on a 'holistic' (complex system) to 'reductionist' (reduced, embedded system) scale according to reasoning steps depicted in Figure 4.16, and connected the contexts depicted in Figure 4.17. Arrows with green '+ signs' and red '- signs' represent positive and negative causal relations between the variables, respectively.

Participant 7 (Figure 4.15) described the complex issue as CO_2 emissions and the negative consequences associated with it. To solve it, sustainable production processes must be implemented. Within the embedded system of production processes, current unsustainable production processes inspire technical people to look for alternatives. In the more reduced applied research system, the number of perspectives on these alternatives is reduced via analytical (impact) assessments. The project of participant 7 within 'ZEB' offers innovation progress and subsequent information for these assessments. To progress in this personal project, collaborations need to be searched for with other approaches that have a logical connection to this approach. Although participant 7 did acknowledge that all those concerned with the problem in the most 'holistic' system can also offer perspectives on alternatives, extreme and unrealistic approaches were indicated to not contribute to innovation progress in the more reduced system of 'ZEB'. According to participant 7, social resistance in the more 'holistic' system can prevent 'impactful solutions' for production processes from being implemented.

Participant 7 described the mindset as:

"The way you address the things that you encounter in day-to-day life… Well… And also, the longer term life, of course. But… How do you respond to situations? What kind of action do you take? How do you address other people and interact with them?"

Connected to the mental model, the mindset described represents a collection of the beliefs of all participants 7 indicating how to respond to perspectives on potential solutions.

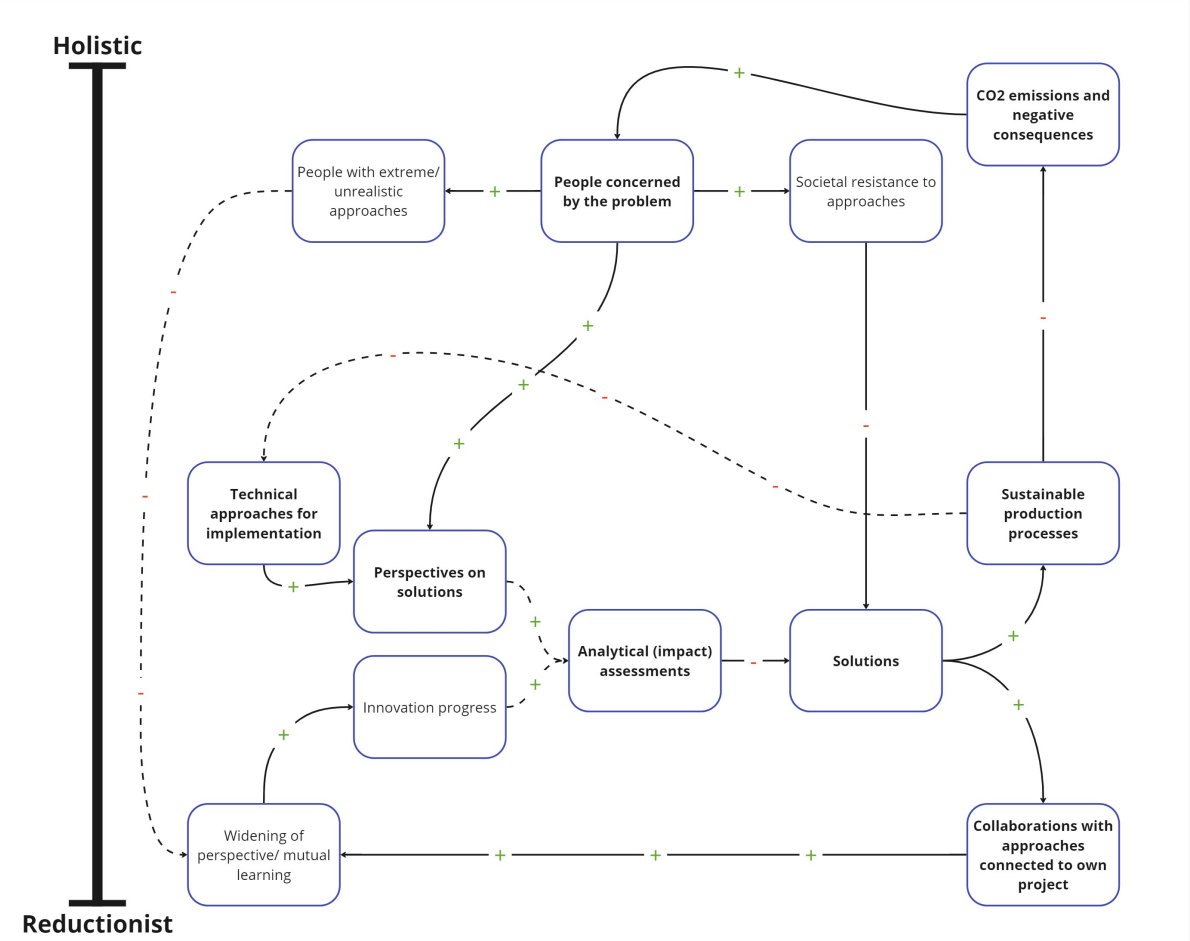


Figure 4.15: **Mental model representation of participant 7 (deduced from Part 1 of the interviews).** The representation was constructed via Fuzzy Cognitive Mapping of in vivo, concept and values codes (Section 4.1.3). Variables (stated in dark blue squares) are positioned on a 'holistic' (complex system) to 'reductionist' (reduced, embedded system) scale according to reasoning steps depicted in Figure 4.16, and connected the contexts depicted in Figure 4.17. Arrows with green '+ signs' and red '- signs' represent positive and negative causal relations between the variables, respectively.

Elucidating 'holistic' versus 'reductionist' steps in the participants reasoning concerning the consortium's issue to solve

In this section, various qualitative observations are presented, expanding upon the mental model representations introduced previously. These observations encompass a comparison of participants' reasoning, spanning from 'holistic' to 'reductionist' steps, the contextual influences deduced in step 3, and their responses to various interview questions.

As a reminder, the spectrum of 'holistic' to 'reductionist' reasoning steps was established based on the alignment with the participants' explanations regarding complex issues and responses to uncertainty/ambiguity (Section 4.1.3, Step 1c, Figure 4.16): the steps for tackling the issue indicated by each participant were positioned on a 'holistic' (complex system) to 'reductionist' (reduced system) scale. These steps represent embedded systems that participants acknowledge when relating the overall issue to the role of the 'academic discipline of biotechnology' and 'ZEB' in solving it. Figure 4.16 shows these steps in relation to the issue description. To ensure clarity and transparency, the placement of themes along this spectrum is supported by the researcher's interpretation and incorporates direct quotes from the participants' interviews.

When discussing the issue for which one of the objectives of the 'ZEB' consortium is,

'Trying to convert resources to products, while minimising emission or maximizing the utilisation of CO_2',

serves as a solution, all participants explicitly expressed the issue to be complex, and various description of the issue were given.

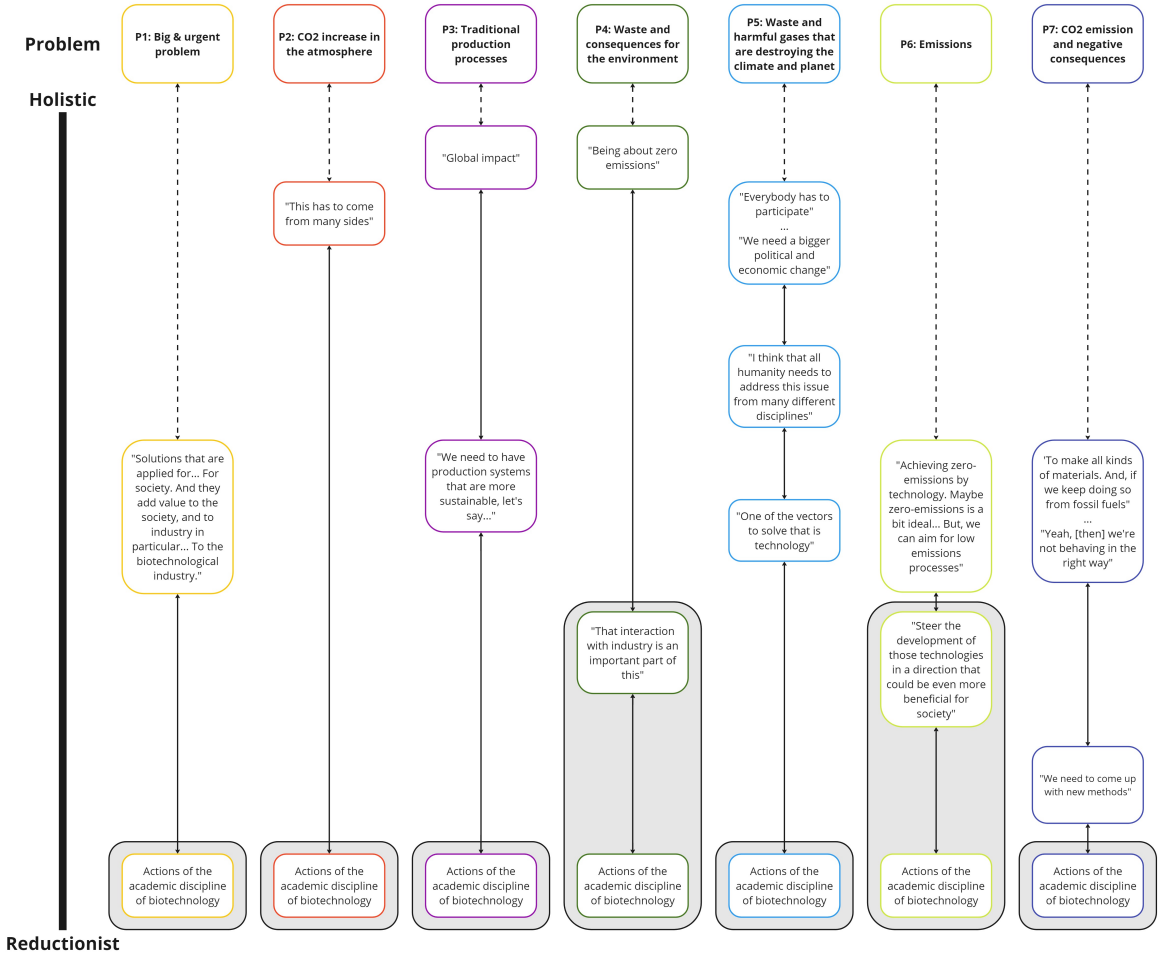


Figure 4.16: **The problem description and steps for tackling the problem indicated by each participant of 'ZEB' positioned on a 'holistic' (complex system) to 'reductionist' (reduced system) scale.** Problem descriptions are depicted above the scale. 'Actions of the academic discipline of biotechnology' are situated in the most reduced system. Quotes from each participant represent the steps between these two systems. The grey area highlights the steps in which the 'ZEB' has a role, as expressed by each participant.

It was observed that many of the participants acknowledged the role of (industrial) production systems (Participants 1, 3 and 7) or the role of transferring research knowledge to industrial partners (participant 4) as an important step. Others referred to the role of technology (Participants 5 and 6).

Q4: To what extent do you think this issue is complex, or, in other words, that it is interconnected with many things?

Participant 4: *"... And, presently, that wastage is being… Trying to be addressed by the industry, but… It's a difficult thing to address, you know… They're putting energy into it. And, in that context, we're putting rather energy into [it] to see if other things can be gained from it. And, hopefully, someone reaches a conclusion… That's amicable and works out. Hopefully, for our project, hopefully there's too few pairs of terms. We're chasing the amount waste we've done to the environment. There's the point of the scheme… So, in interacting with industry. That's been… The message that we've had is that interaction with industry is an important part of this."*

Notably, only two participants (participants 2 and 5) expressed a more 'holistic' step(s) in which people outside of the industry or the technology step had an active role in tackling the issue.

Q4: To what extent do you think this issue is complex, or, in other words, that it is interconnected with many things?

Participant 2: *"Very, very complex. Yes, yeah. I also don't think there is one solution to it. This has to be coming from many sides. But, I think… I mean there are a lot of different… It's… I think it will be hard to name something that it's not intertwined with, right? I mean… It's intertwined with us, like with our footprint, with our daily lives, with what we eat, with how many children we get, with our welfare, with… I mean it's with… How we travel, how we work, and basically everything."*

Q6: How do you generally respond to uncertainties or ambiguity related to an issue?

Participant 5: *"... Honestly, I do believe that developing clean technologies is essential, but not sufficient. I do think that we need a bigger political and economic change if we need… If we want to solve this problem."*

For most of the participants, the role of 'ZEB' was related to the relatively reduced system 'the academic discipline of biotechnology'. However, participants 4 and 6 expressed that transferring research knowledge into a larger system was also an important part of 'ZEB'.

Linking steps to 'Ingroups'

This section describes observations after performing step 3 of the data analysis (Section 4.1.3), connections are established between participants' reasoning steps positioned along a spectrum from 'holistic' to 'reductionist' in Step 1 (Figure 4.16) and their subjective representations of the relationship between two central social 'Ingroups'— 'the academic discipline of biotechnology' and 'the group trying to tackle the issue'.

As indicated, this analytical step aims to elucidate the 'Ingroup contexts' that impact specific beliefs and the 'contextual references' that shape the mental models of the participants (Figure 4.17). These contextual influences relate to the social identity complexity and mental model components outlined in the theoretical framework of this thesis. As noted, while this analysis involves some degree of researcher interpretation, it is grounded in in vivo codes extracted from the participants' responses. To ensure transparency, direct quotes are given when presenting the findings.

All participants confirmed their membership in both 'Ingroups,' 'the academic discipline of biotechnology' and 'the group trying to tackle the issue.' Furthermore, they unanimously endorsed the notion that (future) inter- and transdisciplinary practices should align with scholarly attributes captured in the first two statements given when discussing the collaboration types (Section 4.1.2, Appendix B).

- Collaborations set up for 'ZEB' do not only happen within disciplines or sub-disciplines.
- Collaborations set up for 'ZEB' occur between members from different disciplines, with each member analyzing the issue from the perspective of their individual discipline.

However, for the remaining statements, answers varied among participants, showing inconsistencies and a lack of alignment with the scholarly continuum (Section 3.2.2). For example, some respondents agreed with statements higher on the continuum while disagreeing with statements lower on it.

What follows is a description of the qualitative observations made in this context:

Participants with a representation in which 'the group trying to tackle the issue' was **dominant** (participants 1 and 3) expressed 'the academic discipline of biotechnology' to be an embedded group offering a unique solution, which was not dependent on solutions outside of this 'Ingroup'. For these participants, both 'Ingroups' were connected, as the implementation of this solution was carried out by 'the group trying to tackle the issue'.

Participant 1: *"... at the end, we are tackling a climate change problem that concerns all, the society. And, I think biotechnologists are just one part of the society, with some tools to try to resolve it. But, they are concerned in the same way as the rest of the society."*

Participant 3: *"We have a common problem and '[Group] A' is one part of the possible solution that is part of the bigger pool of solutions… And that's how I see it."*

In contrast, participants who chose the subjective representation **'intersection'** (Participants 4, 6 and 7) or **'merger'** (participant 5) expressed that the solutions offered by 'the academic discipline of biotechnology' depended on the other group. Participants who expressed that, in addition to the system of 'the academic discipline of biotechnology', transferring research knowledge into a wider system was also an important part of 'ZEB' (participants 4 and 6) envisioned the intersection as a means of transferring this information from 'the academic discipline of biotechnology' to the other 'Ingroup'.

Participant 4: *"Yeah, that's where I'm at. I'm already crossing over into industry. I'm making those kinds of contacts."*

The remaining participants envisioned the intersection as an overlap in perspectives or expertise between both 'Ingroups'.

Participant 7: *"I think that there's substantial overlap between… Well… Belonging to this work group ['Group A'] let's say, and more… [Belonging to] the social purpose group… In that, what I try to achieve in 'Group A' has a strong connection with 'Group B'. And also, the… Items picked up in '[Group] B'… The signals… The commentary picked up in '[Group] B' affects how I act in '[Group] A'. So, there is definitely a mutual benefit, which I think is best represented by having a certain overlap. On the other hand, there are things in '[Group] A' that are… Yeah… Not necessarily tied to '[Group] B', and vice versa. So, in that sense, I would not overlap them completely..."*

Only participant 2 expressed to see both groups somewhat disconnected from each other, in a **'situation and context-dependent'** manner:

Participant 2: *"In some way, I can see it like this. So, when I'm doing my work, I see myself mainly as a biologist. And then, the… But, when I'm in the supermarket and I buy organic food… Then, I don't do that because I'm a biologist. Maybe, I should even not do it as a biologist, because it also has disadvantages. But… Then, I'm doing it more from... Well, I try to do something. Everyone should try something. This is what I try. You never know if what you're doing is the best or not."*

In line with this, when discussing one of the statements that represented a common attribute of inter- and transdisciplinarity indicated by scholars – 'co-creation and co-design with non-academic actors' – participant 2 was the only participant who did not agree that this was happening or needed to happen ideally (Figure 4.18). In this specific reasoning, industrial collaboration partners were seen as members of 'the academic discipline of biotechnology' and therefore disconnected from 'the group trying to tackle the issue'.

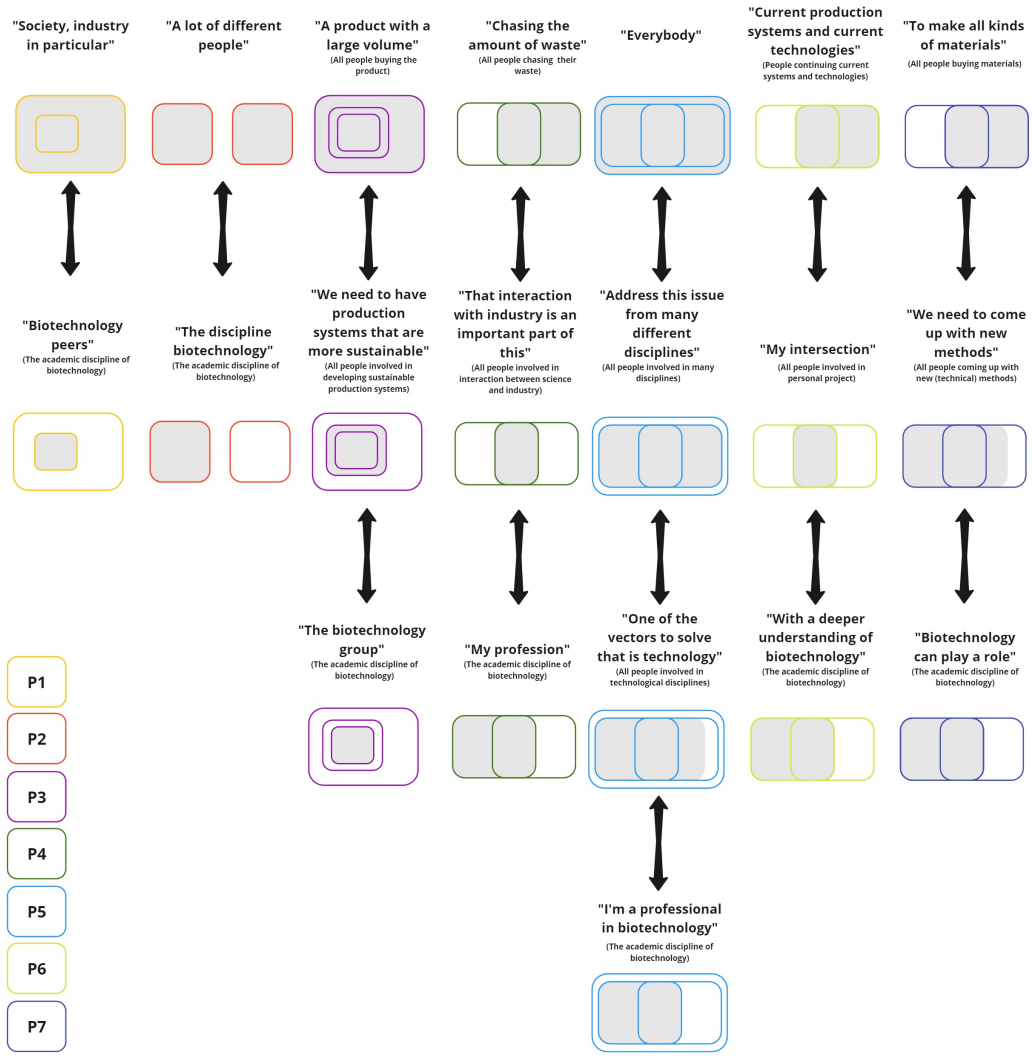


Figure 4.17: **Contextual influences connected to the steps for tackling the problem indicated by each participant of 'ZEB' positioned on a 'holistic' (complex system) to 'reductionist' (reduced system) scale (Figure 4.16).** The subjective representations represent the relations between the participants' memberships of two social 'Ingroups' ('the academic discipline of biotechnology' and 'the group trying to tackle the issue'), and are based on the Social identity complexity theory (Section 3.4). The 'Ingroups' or social contexts expressed for each step are represented by the grey area marked in the subjective representations and quotes.

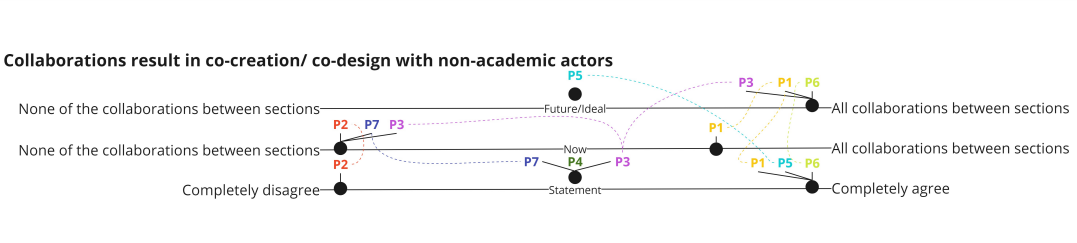


Figure 4.18: **Overview of to what extent participants agreed with the statement 'Collaborations set up for 'ZEB' result in co-creation or co-design together with non-academic actors', and on what they based their argumentation.** The 'statement' scale shows the level of agreement based on magnitude coding (Section 4.1.3); the 'Now' scale is applicable for participants that based their argumentation for (dis)agreeing on their perception of current collaborations (attribute coding). The 'Future/Ideal' scale is applicable for participants that based their argumentation for (dis)agreeing on their expectation for future collaborations or how they envision ideal collaborations.

In light of the theoretical lens employed in this thesis, it becomes evident that the participants who selected 'dominant' and 'intersection' representations primarily emphasized industrial or technological contexts and 'Ingroups' in shaping their mental models. This preference suggests that these contexts significantly influence their perspectives on the issue and practices of the consortium.

Conversely, participants who selected 'merger' and 'context and situation specific' representations demonstrated a recognition of the role of individuals outside the realm of technology in addressing the issue. Through the theoretical framework's perspective, this implies that 'Ingroups' or contexts beyond the boundaries of technology exert influence over their mental models.

Estimated similarity between both 'Ingroups'

To understand how participants looked at the distinctiveness of 'the academic discipline of biotechnology' in relation to 'the group trying to tackle the issue', they were asked to evaluate to what extent both groups were similar. All participants acknowledged that the second group was much larger and, in that sense, different from the first group. In addition to this aspect, perceived (dis)similarity varied greatly.

However, when evaluating the answers given in relation to contextual references deduced, it was observed that participants that perceived similarity between both groups (Participants 1 and 4) referred in their explanation to more 'reductionist' systems and contexts deduced from their reasoning (Figure 4.19). In contrast, it was observed that participants that perceived dissimilarity between both groups (Participants 2, 5, 6 and 7) referred in their explanation to more 'holistic' systems and contexts deduced from their reasoning. Participant 3, who referred to both, was not sure how to answer.

Participant 3: *"As I said, like… Then group… This problem would be the same as [for] 'Group A' ['the academic discipline of biotechnology'], so in that sense, it's similar. But then 'Group A' would use a biotechnology approach to [solve] the problem."*

Participants 5 and 2, who both articulated that 'the academic discipline of biotechnology' and 'the group trying to tackle the issue' were dissimilar, consistently referred to holistic systems when explaining their perceptions. This alignment suggests that the contextual influences affecting their mental models, originating from realms beyond technology or industry, are inherently distinct from their own academic research context. On the other hand, participants 6 and 7, both selecting the 'intersection' representation, also referred to 'holistic' systems in their explanations. This implies that they acknowledged the existence of these external contexts, but did not fully integrate them into their reasoning processes for addressing the consortium's challenge.

Participant 7: *"Because 'Group B' is so much bigger. [It] covers a whole… Well… section of people… All of society would be working towards the same goal… At least, all stakeholders there, and… So, I think they're very dissimilar...*

... And there, I do think that for me, at this moment, 'Group B' is too diverse and too broad to really say there's an integrated vision, and I weigh all those things equally important [in that]. There are definitely people that I would associate with 'Group B', because we have [a] similar purpose… But, [people] that are so different in how you would address things that I would say, in that sense, I do not give equal value to them. Well… Equal value…? I do not give equal credence to their approach."

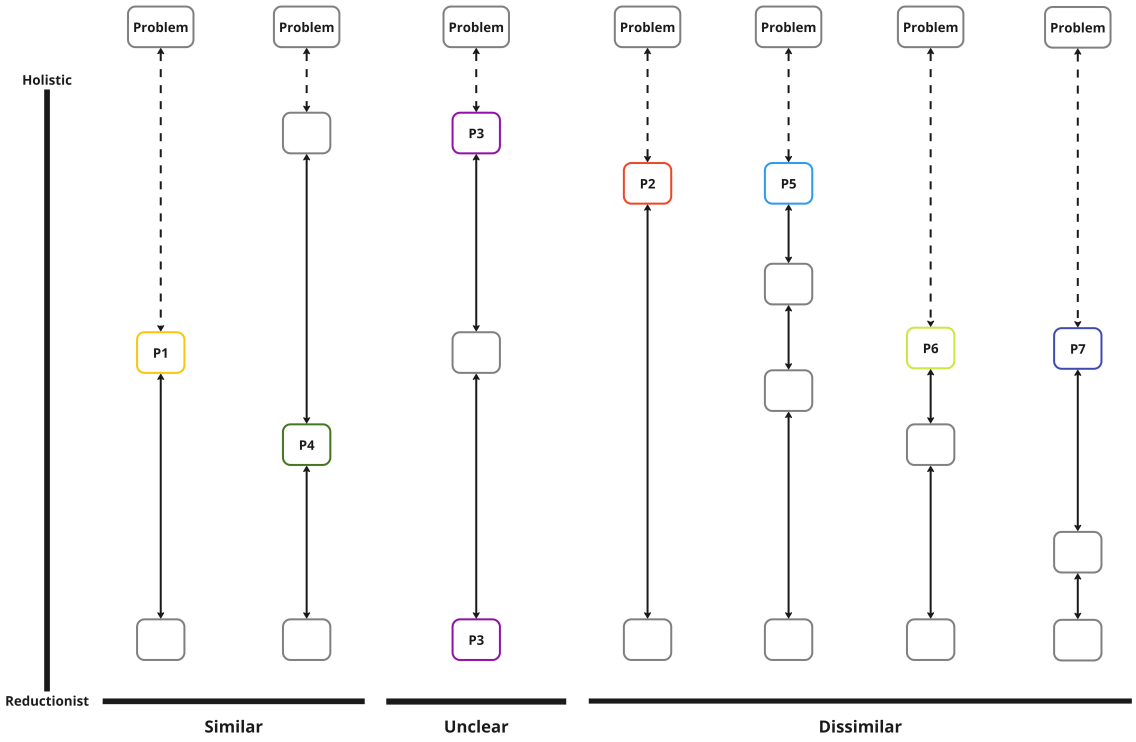


Figure 4.19: **Perceived (Dis)similarity and Contextual Influences:** This figure showcases the participants' perceptions of the similarity between 'the academic discipline of biotechnology' and 'the group trying to tackle the issue.' The boxes along the vertical scale represent the reasoning steps initially introduced in Figure 4.16, which span from 'holistic' to 'reductionist.' Color-coded boxes indicate the contextual references invoked by participants in their explanations, and arrows connect reasoning steps to these references. Participants are grouped based on whether their perceptions of both 'Ingroups' were similar, dissimilar, or whether they were unsure about their perception of (dis)similarity. This visualization provides a summary of how contextual influences impact participants' evaluations of (dis)similarity between the 'Ingroups.'

Participants' response to uncertainty and ambiguity

Given the inherent connection between complex issues and uncertainty as well as ambiguity, participants from 'ZEB' were asked about their general responses to these challenges. In alignment with the various 'holistic' to 'reductionist' steps for addressing the issue expressed by participants (as illustrated in Figure 4.16), the responses of the participants varied depending on the specific contexts for which these responses were considered appropriate. During fuzzy cognitive mapping analysis, the researcher observed that participants' articulated responses to uncertainty and ambiguity could be broadly classified along an analytical versus a social spectrum (Figure 4.20). The categories 'analytical response' and 'social response' emerged as a result of the data analysis process, where themes related to responses to uncertainty and ambiguity could be clearly associated with either analytical or social dimensions. The presentation of these findings on the participants' responses to uncertainty and ambiguity is relevant, as it sheds light on the dynamic relationship between individuals' cognitive approaches and the contexts in which they operate.

When evaluating the answers given in relation to the deduced 'Ingroup contexts' that had influence, it was observed that five participants expressed an analytical response to uncertainty or ambiguity in the contexts of the more 'reductionist' steps. In a context related to more 'holistic' steps and thus larger 'Ingroup contexts', the only two participants who assigned an active role to people outside of the industry or technology (participants 2 and 5, Figure 4.16) expressed that they have a social response to uncertainty and ambiguity.

Participant 5: *"Here, in science, we use the scientific method, and it's a very precise way to remove uncertainty, right? But, there's issues where it… Where you… It's hard, basically. For instance, in policy, right? There's different policies that you can implement, and it boils down to ideology, right? It boils down to ideas… And different people can see [that] differently. So, that's another type of uncertainty, right? And that requires political discussion."*

In contrast, the response to uncertainty or ambiguity of the remaining participants in the more 'holistic' contexts (participants 4, 6 and 7) was very analytical.

Participant 7: *"Of course, when it comes to an implementation… Yeah… Then, you do have to weigh in, what's the potential gain versus the potential loss that you make. And, that's the approach I would take. And, in that particular case, it's often just comparing the 'financials'. Of course, you would like to take a broader perspective than that as well… Also, on the societal and then… What the climate impact, for example, [is]. But, in the end, for me… Yes, it would be a cost-benefit calculation…"*

Thus, the participants who assigned an active role to individuals outside of the industry or technology and held subjective representations of both 'Ingroups' categorized as 'context and situation specific' or 'merger' expressed to adopt a social response when facing uncertainty and ambiguity in interdisciplinary contexts.

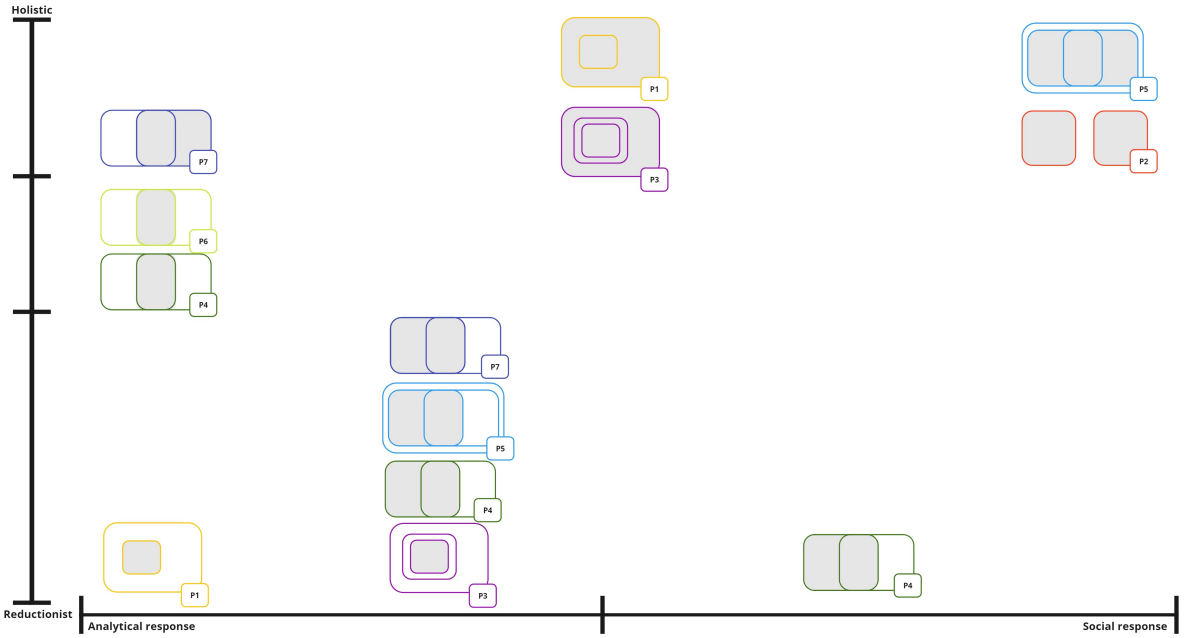


Figure 4.20: **Overview of an emerged categorization of participants' responses to uncertainty or ambiguity, mapped on an analytical versus social spectrum (horizontal) and on a vertical 'holistic' (complex system) to 'reductionist' (reduced system) scale indicating steps for tackling the 'holistic' problem expressed by participants (Figure 4.16).** For each participant, 'Ingroup contexts' that were deduced to influence the answer given are indicated in grey in the subjective representations of the relations between the two social 'Ingroups' 1) 'the academic discipline of biotechnology' and 2) 'the group trying to tackle the issue', based on the Social identity complexity theory (Section 3.4).

When discussing an important aspect of 'strong transdisciplinarity' as conceptualized by Max-Neef (2005) – 'acknowledging multiple levels of reality, accompanied by different modes of reasoning and spirituality aspects' (Section 3.2.2) – participants with an analytical response to uncertainty or ambiguity in a more 'holistic' context (participants 4, 6 and 7) also disagreed on the role of spirituality aspects in the collaboration of 'ZEB' (Figure 4.21). Notably, participant 2 agreed that there was a role for spirituality aspects, but only in terms of intuition, and not in terms of shared feelings.

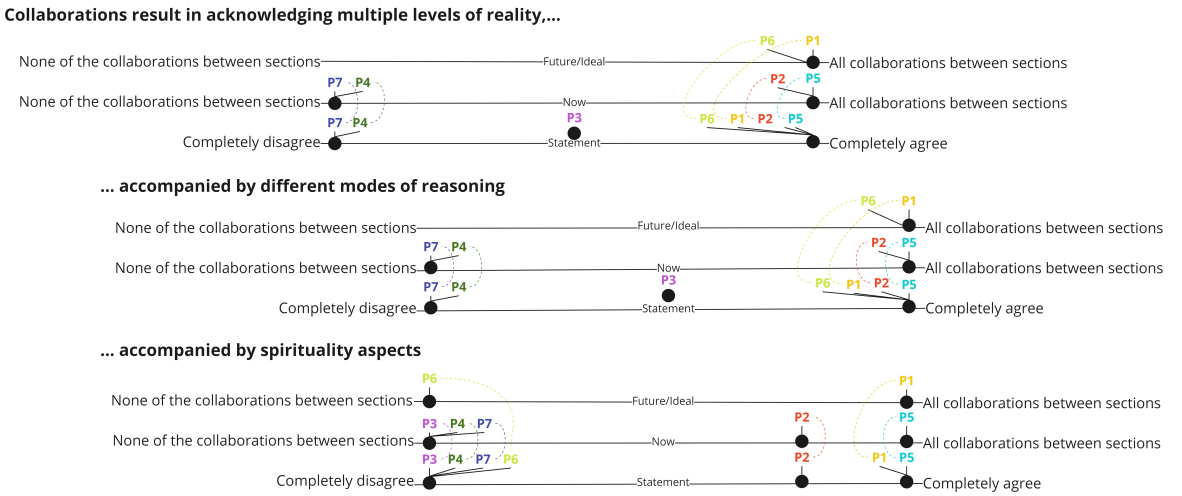


Figure 4.21: **Overview of to what extent participants agreed with the statement 'Collaborations set up for 'ZEB' result in participants acknowledging multiple levels of reality, accompanied by different modes of reasoning and spirituality aspects such as feeling and intuition', and on what they based their argumentation.** Analysis of the level of agreement was done by analysing the level of agreement of the following separately: 1) Collaborations result in acknowledging multiple levels of reality; 2) Acknowledging multiple realities in collaborations is accompanied by different modes of reasoning; 3) Acknowledging multiple realities in collaborations is accompanied by spirituality aspects. For each, the 'statement' scale shows the level of agreement based on magnitude coding (Section 4.1.3). The 'Now' scale is applicable for participants that based their argumentation for (dis)agreeing on their perception of current collaborations (attribute coding). The 'Future/Ideal' scale is applicable for participants that based their argumentation on their expectation for future collaborations or how they envision ideal collaborations.

Uniqueness of issue description

When participants were asked about the uniqueness of their issue description, five of them indicated that their descriptions were part of a broader diversity of issue descriptions. To investigate the contexts in which this perception of diversity was grounded, a fuzzy cognitive mapping approach was employed, similar to the methodology used to explore participants' responses to uncertainty and ambiguity. This approach involved mapping the codes specific to the question of uniqueness against the in vivo and concept codes used to define the 'holistic' and subsequent 'reductionist' steps to address the issue (as presented in Figure 4.16) and the associated contextual influences (Figure 4.17). Through this mapping process, the notion of diversity, as referred to by participants, was linked to specific contexts, as illustrated in Figure 4.22.

The categorization of 'part of diversity issue descriptions' and 'general issue description' was directly informed by magnitude coding related to Question 5 (Q5): "Do you think that other people trying to come up with a solution define the problem the same way as you do?" The coding encompassed three values: 'high,' 'medium,' and 'low'. However, the code 'medium' was not applied to any of the transcripts.

Notably, the two participants that expressed more 'holistic' step(s) in which people outside the industry or technology step had an active role in tackling the issue (participants 2 and 5) referred to the context linked to these respective 'holistic' steps when describing the uniqueness of their issue description. Most of the remaining participants referred to a context linked to more 'reductionist' steps when describing the uniqueness of their issue description. Participant 7, however, did introduce a new, more 'holistic' context when describing the uniqueness of the given issue description, whilst acknowledging the complications that this context brings:

Participant 7: *"I think there's a lot of different perspectives you can take… And, that's also what you see if you… Well… Go to any random demonstration… Or go to any discussion on what exactly the problem and the solution is. You will see a lot of difference in both how people state the problem and in how people state potential solutions for it…*

"…So, there's an entire spectrum of things there… Which is not easy to navigate as well."

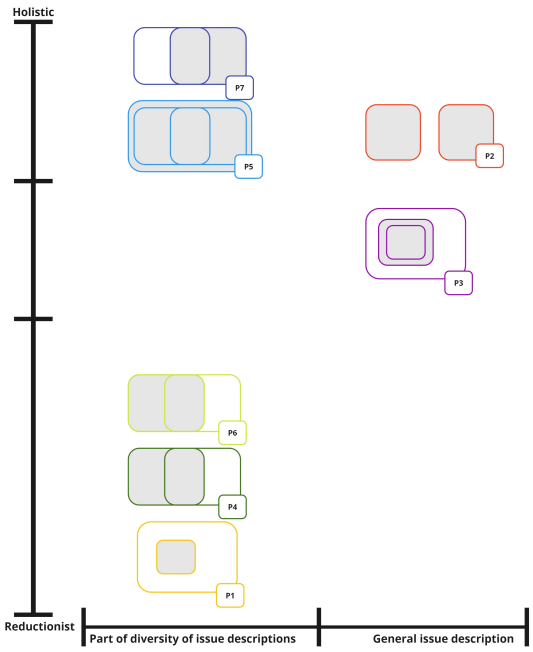


Figure 4.22: **Overview of how participants perceived the uniqueness of their issue description, assigned to 'Part of diversity of issue descriptions' or 'General issue description' analysis categories, and mapped on a vertical 'holistic' (complex system) to 'reductionist' (reduced system) scale indicating steps for tackling the 'holistic' problem expressed by participants (Figure 4.16).** For each participant, 'Ingroups' or contexts linked to the system expressed are indicated in grey in the subjective representations of the relations between the two social 'Ingroups' 1) 'the academic discipline of biotechnology' and 2) 'the group trying to tackle the issue', based on the Social identity complexity theory (Section 3.4).

Mindset-specific beliefs and the contextual influences

Throughout this findings section, the examination of participants' mental models, their holistic to reductionist reasoning steps, contextual influences and the correlation between responses to various interview questions has been the focus. Now, an investigation will be conducted to understand how participants' mindset-specific beliefs are shaped by contextual influences, addressing research sub-question 1a.

Linking beliefs to different contextual influences can highlight the difference in meaning between beliefs that initially seem similar. The different contexts of participants 3 and 5 - academic versus societal - when expressing the belief '(Bio)technology is essential, but not sufficient' serves as an example to illustrate this:

Participant 3: *"And yeah, I also collaborate with a lot of other people at TU Delft that are not seen [as the] biotechnology group…"*

"…to me, I very much collaborate with '[Group] B' as well. So again, I think it's very similar to what I just said. It's… Biotechnology is a tiny group. I need much more than biotechnologies to be able to help me develop the technology I'm working on."

Participant 5: *"Honestly, I do believe that developing clean technologies is essential, but not sufficient. I do think that we need a bigger political and economic change if we need… If we want to solve this problem."*

For each participant, mindset-specific beliefs expressed in relation to a deduced context (Section 4.1.3) were listed and categorized into the following categories: a belief indicating positive differentiation of an 'Ingroup', a belief indicating bias for an 'Outgroup', a general belief relating to normativity expressed in relation to the specific context (Section 4.1.3, Figure 4.7). Appendix E shows the proportion of mindset-specific beliefs.

Most mindset-specific beliefs that indicate **positive differentiation** of an 'Ingroup' were expressed when referring to 'ZEB' or a subgroup of 'ZEB' as the 'Ingroup context'. Here, it was observed that the participants who expressed that the transfer of research knowledge into a wider system was also an important part of 'ZEB' (participants 4 and 6, Figure 4.16), expressed beliefs indicating positive differentiation with a subgroup of 'ZEB' as the context of the 'Ingroup': the group involved in their projects. As explained, these participants envisioned this subgroup as an **'intersecting'** bridge for passing on knowledge from the 'academic discipline of biotechnology' to the broader technical implementation social contexts. Thus, the positive differentiation expressed for this subgroup reveals that these smaller groups within 'ZEB' have an influence on how these participants view sharing knowledge outside the consortium.

Participant 4: *"Because my project is very much at a different stage [compared] to a lot of other projects. And so because I'm moving forward and that direction quite fast, we've already got some very concrete deliverables on hand...*

... And, a lot of people in the 'ZEB' sort of things can't really help me with that… Because of the nature of the cake… It's not through not wanting to. It's just they can't really do much for me right now."

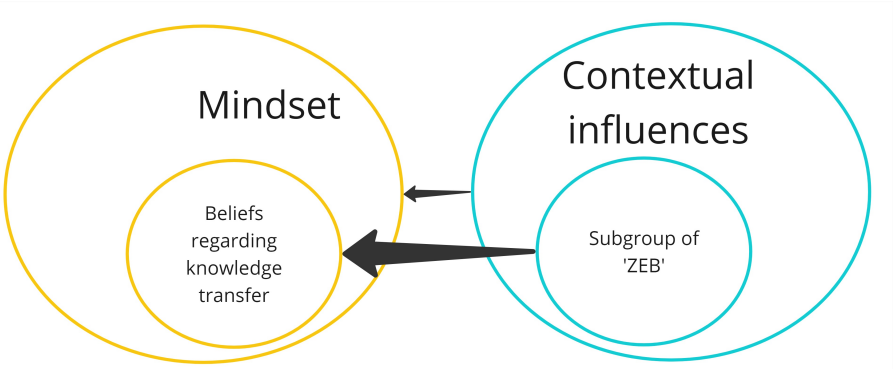


Figure 4.23: **A schematic representation of the contextual influence of the subgroup of 'ZEB' for mindset-specific beliefs of participant 4 and 6 regarding knowledge transfer.**

Out of all mindset-specific beliefs expressed, the mindset-specific beliefs indicating a **bias** were expressed in relation to an 'Outgroup' in a more 'holistic' system. In line with the observed positive differentiation of the more embedded subgroup of 'ZEB', participant 4 also expressed mindset-specific beliefs indicating biases for 'Outgroups' in more reduced systems: 'members of industry' and 'academics/members of biotechnology'.

Participant 4: *"It's up to us to show to industry that they can get a return on their investment… Because that's what they care about…"*

Only two participants (participants 6 and 7), who perceived ‘the academic discipline of biotechnology’ and ‘the group trying to tackle the issue’ as dissimilar, expressed mindset-specific beliefs related to preferring rationality over feeling-based approaches. These participants acknowledged the existence of external contexts outside of the technical environments, but did not fully integrate them into their reasoning processes to address the challenge of the consortium. This indicates that for these participants, contextual influences from inside technical environments have an impact on mindset-specific beliefs regarding how to use rationality and feelings when tackling complex issues.

Participant 7: *”I think [that] my mindset is rather analytical… Factual… [About] trying to see ‘okay, these are the facts… This is what we can conclude from it… There’s a problem… Let’s see what we can do with that’. So, for me, that’s means that the problem as I view it is mostly in the 1st place a technical one. Which also means that sometimes… Yes… Social resistance towards solutions or towards acknowledging the problem, for me, are… Well… I need to really try to take the other person’s perspectives there… It’s not a natural perspective for me to sometimes have this kind of commentaries. So yeah, it’s not so much feeling oriented. It’s rather factual.”*

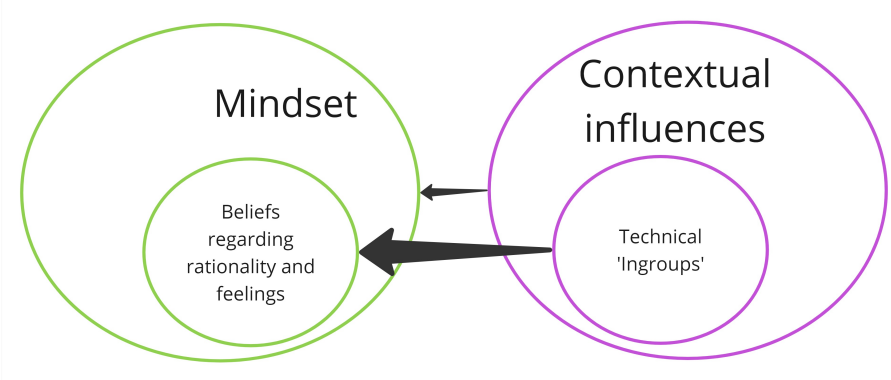


Figure 4.24: **A schematic representation of the contextual influence of technical social groups for mindset-specific beliefs of participant 6 and 7 regarding whether to use rationality and/or feelings to tackle the consortium’s issue.**

The mindset-specific beliefs that related to **normativity** were mostly expressed in relation to the most ’holistic’ system. Participants 5 and 6, who perceived the need to include all perspectives in their approach, indicated normativity to inclusivity. This aligns with their tendency to acknowledge the existence of external contexts and diverse perspectives (as discussed earlier). In contrast, participant 7 expressed beliefs indicating normativity to not include all perspectives, which corresponds to their preference for a more analytical and factual mindset, focusing primarily on technical aspects.

Additionally, in the more reduced ‘academic industrial’ system, the mindset-specific beliefs of participants 4, 6, and 7 indicated a focus on collaboration outcomes. They emphasized which perspectives should be included to avoid complications when integrating various points of view into established solutions within the technical environment. This preference for outcome-oriented collaboration aligns with their inclination toward analytical thinking and suggests that contextual influences within technical environments shape their mindset-specific beliefs regarding collaboration and problem solving.

Participant 7: *"The first thing is that in the collaborations that I seek out… They should be logically connected to the work that I'm doing myself. When it comes to completely other things, I think there's people that are much more expert than I am. So, let them do that part. For the rest… It does involve that I want to check [the following]: Is something the sensible approach to begin with? If you just look at the technical details, I wouldn't take an approach that says 'Well… This feels like it could contribute'. [Instead], let's first do some numbers and let's see if it makes sense to do something before do it… Yeah… And, that also makes me a bit averse, maybe, to sort of the 'green washing' type of collaboration, so to say. Uhmm. Yeah. How would you describe that..? Well… Maybe, I'll already did [describe it]. Things that look very nice conceptually, but when you look a bit deeper, it's [like] 'okay, this is not going to work because the numbers aren't checking out'. I would try to avoid that."*

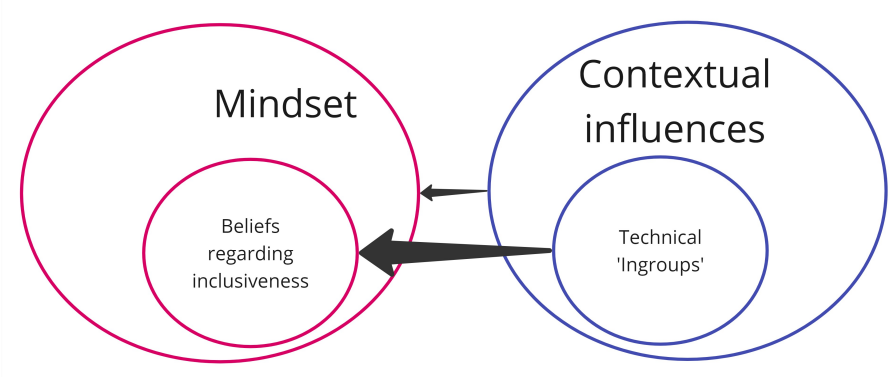


Figure 4.25: **A schematic representation of the contextual influence of the technical social context for mindset-specific beliefs of participant 4, 6 and 7 regarding inclusiveness in collaborations.**

4.2.2. Research sub-question 1b

In line with the thesis's perspective that only triple-loop learning through reflection fosters the development of a more 'holistic' mindset, research sub-question 1b (Q1b),

Q1b: *What characteristics can be deduced from the reflection of the research participants in 'The Towards Zero-Emission Biotechnology Consortium' that resulted in a more 'holistic' mindset?*,

is addressed through a focused analysis. This analysis initially focuses on assessing whether participants experienced reflection and if this reflection led to any changes in their mindset. Then, emotions expressed by participants upon encountering triggers are described. Finally, the contextual influences found that either facilitate or hinder the reflection process are described, as reported by participants who indicated that their mindset changed due to reflection.

Describing the participants' reflection processes

In this part, the reflection processes experienced by all participants are described. As indicated, in the interviews, the artworks represented potential contextual influences for the mental models (and mindsets) of the participants. To evaluate how these contextual influences can affect reflection, participants' reflection processes were assigned to one of three options of type of reaction (No Reflection, Reflection but No Changed Mindset, and Reflection Causing a Changed Mindset).

Then, participants' in vivo, concept, and values codes, along with their causal reasoning from Part 2 of each interview, were mapped onto the fuzzy cognitive maps created during Part 1. This process allowed an assessment of how beliefs could be assigned to one of three categories: positive differentiation, bias, and normativity. These beliefs were associated with respective 'Ingroup', 'Outgroup' or general context, revealing potential new contextual influences on mindset-specific beliefs gained after reflection.

Figure 4.26 shows the overview of the type of reaction participants expressed to have for every trigger. All participants expressed that reflection took place during Part 2 of the interviews. Therefore, none of the participants were assigned to the 'No Reflection' option.

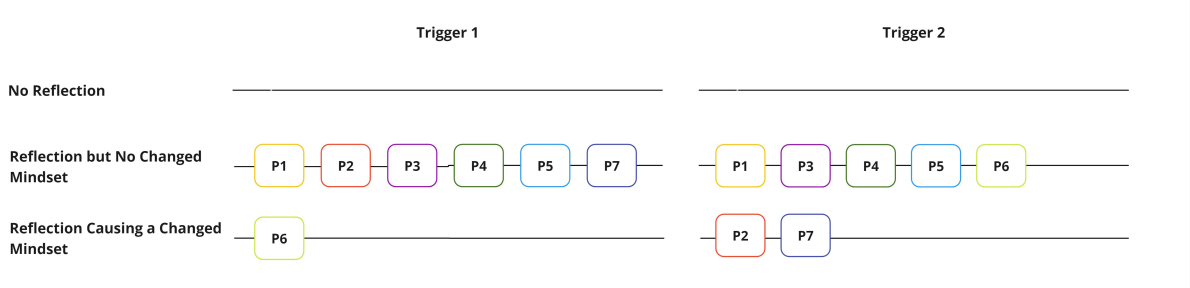


Figure 4.26: **An overview of the reflection per participant per trigger (Part 2 & 3 of the interviews, Section 4.1.2), indicating which participants expressed to have had one of three reactions after seeing each trigger.** For each trigger, it is indicated for which participants being exposed to the trigger resulted in 'No Reflection', 'Reflection but No Changed Mindset', or 'Reflection Causing a Changed Mindset'.

Participants Assigned to 'Reflection but No Changed Mindset' for both triggers

For both triggers, most participants were assigned to the 'Reflection but No Changed Mindset' option (participant 1, 2, 3, 4, 5 & 7 for trigger 1, and participant 1, 3, 4, 5 & 6 for trigger 2).

Notably, after seeing trigger 1, participants 4 and 7 expressed previously stated mindset-specific beliefs in relation to a 'holistic' system, thereby relating the trigger to more 'holistic' contextual influences. After reflecting on these beliefs, they proposed a correction for which actions needed to be taken: 'We should let the collaboration setup grow organically' and 'We need to correct our mindset to this collaborative environment'.

Interestingly, although the correction of participant 7 focused on the desired mindset to tackle the issue, participant 7 did not link this correction to the mindset in the reduced context of 'ZEB', thus indicating a cognitive dissonance resolved by changing the perception of the consortium's actions rather than changing the actions or beliefs.

Participant 7 (Trigger 1): *"If we look at the people that are in 'ZEB', they're more or less on one of the converging lines [of the artwork]. They have not only shared goal but also a relatively similar idea of how to get there. So, in that sense, I don't think my mindset needs to be completely different in how to deal with that. I don't have any feeling of any of the other projects, like 'oh, this is so completely different from what I would do… Or, this doesn't make sense at all at this point…' So, there... I don't see any reason for a change."*

Moreover, for participant 4, the reflection process revealed that his personal mindset was distinctly different from the mindset suited to the context of the consortium. Specifically, the mindset-specific beliefs expressed by participant 4 during the reflection induced by the second trigger could not be subdivided into mindset-specific beliefs that were already expressed in Part 1 of the interviews. Consequently, no correction in mindset was proposed, as participant 4 considered their beliefs to be already a part of their personal mindset and values, although not completely congruent with the consortium's shared mindset.

Participant 4 (Trigger 2): *"I think my personal project is very much directed towards, actually, solving the ecosystem problem. I'm taking… I'm taking waste [people] threw out in the environment. I'm trying to not make that a waste product anymore. I'm trying to make it a valuated product so that we don't throw it back in, waste back, in the environment. So, I think that my project is 'bang on' in this description. In fact, it was designed for this description. It was very much thought about it. Yeah. Yeah. No, I had every intention of linking these two specifically to an ecosystem."*

For participant 5, the reflection process induced dissonance that resulted in a change in their actions, specifically the action of advocating for the inclusion of partners from various social backgrounds. The dissonance stemmed from a more 'holistic' contextual trigger that highlighted the limitations of a solely technology-driven approach to solving the problem. This acknowledgment that a 'holistic' approach is necessary led to a change in participant 5's course of action, emphasizing the importance of including partners from other sectors in 'ZEB'.

Participant 5 (Trigger 2): *"This represents one view, that is pretty common, I think… That we are going to solve the problem just through technology development..."*

"…[This view gives me] a bit of an anger. Because, I think it's a naive view, right? It's a naive view to think that within this system we can actually solve this problem…"

"… I would advocate to include partners from other sides of society… You know… Outside of science and technology development into 'ZEB'."

All mindset-specific beliefs expressed by the remaining participants for whom reflection did not change their mindset could be subdivided in mindset-specific beliefs that were already expressed in Part 1 of the interview. Additionally, the contextual influences affecting these beliefs remained unchanged compared to those deduced after analyzing Part 1 of the interviews.

Participants assigned to 'Reflection Causing a Changed Mindset'

After seeing trigger 1, participant 6 did propose a correction focused on the mindset in relation to the reduced 'ZEB' context, but only by expressing earlier stated, mindset-specific beliefs in this same context. After evaluating the mindset-specific belief 'it is important to understand the impact of technologies on society', a correction was proposed to improve the mindset with a broader technological understanding:

Participant 6 (Trigger 1): *"[It] would be nice to have an even deeper understanding of the fundamentals… Of the different technologies and tools… "*

"... So, based on the figure, probably, having a higher resolution in the level of understanding of those technologies."

Mindset-specific beliefs expressed by participant 7 during reflection induced by the second trigger were subdivided into mindset-specific beliefs that were already expressed in Part 1 of the interviews and resulted in new mindset-specific beliefs that altered underlying principles of the more reduced systems. These beliefs were expressed in relation to a 'holistic' system by acknowledging a useful tension between naturalists and scientists or engineers:

Participant 7 (Trigger 2): *"The first thing I see here is a bit of that tension between, say, the naturalists and the scientists, engineers… By projecting these two layers on top of each other, creating a very chaotic picture… Which… On one hand, signals [that] you can let them go hand in hand. You can use your scientific mindset and all your engineering skills and stuff you can do in the lab to be more responsible about how we use the ecosystem. But, it can also be interpreted as… We lose track of naturalness, and we put everything in engineering… And, there's really a tension between the two and a conflict between the two… So, I think in that sense, it tries to… Well… Maybe… Make these two perspectives clash and think about how you see things. And then, for me, I have been more of the scientist-slash engineering mindset, I would say. Use the science to take your responsibility in how the ecosystem develops in the future. But, I can also recognize that, to others, it might have a more dystopian meaning."*

Subsequently, reflection resulted in a belief that altered principles of the 'academic/ discipline of biotechnology' context, followed by altered principles in the 'sub-group of 'ZEB'' context and a proposed correction of the mindset: 'I have to constantly connect my analytical mindset to assess my work related to the bigger goal'.

Mindset-specific beliefs expressed by participant 2 during reflection induced by both triggers were subdivided into mindset-specific beliefs that were already expressed in Part 1 of the interviews and resulted in new mindset-specific beliefs that indicated a change in epistemology. Reflection by participant 2 focused first on mindset-specific beliefs expressed in relation to a 'holistic' system. For the second trigger, this was accompanied by the focus on a mindset-specific belief expressed in an embedded context, 'subgroup of 'ZEB'.

As described, participant 2 expressed his desire to see these contexts and 'Ingroups' linked to them somewhat disconnected from each other, in a situation and context-dependent manner. Furthermore, when discussing the collaboration aspects of 'ZEB', participant 2 agreed that multiple levels of reality were acknowledged, accompanied by different modes of reasoning and intuition, but not by feelings. When connecting the emotion induced by both reflection triggers, participant 2 acknowledged the influence of intuition and feelings to be much broader, and affecting the mindset at a more meta-level of consciousness:

Participant 2 (trigger 1): *"I get **annoyed**… Because I think… And, I thought about that. I think that's because of this word 'ideal'. So, it may… It's... I don't know. It's just… This is somehow how people always want us to sell our work. And, [that] it should be perfect and [that] we should save the world… And all this ideals… So, maybe I'm… Maybe my mindset is not optimistic, kind of, enough to, kind of, relate to that..."*

"...that's also what I see when people are really, really, kind of, really intensely believe in something… And, this is really their ideal. Then, I think, they are… Kind of their whole lives… Everything, at least seems, mapped on top of each other, towards this one ideal. So, actually, that… With me, it's more separated somehow… I don't know. But, it's maybe more intuition, [which] matches a bit with kind of the annoying [or] annoyance that I have here."

Participant 2 (trigger 2): *"This **energetic feeling**, or something like that, makes me feel more connected as a person also to my work. And, that's a bit what this represents, I think, also for me… That it's not, kind of, in 'I'm kind of a maybe different person in the supermarket than at my job'. But here, it feels more like… And, that's maybe more because I feel more of this energy, and positive vibes make me feel more… Possibly also kind of personally, at a personal level, involved in my work."*

Triggers and the context they represent

Within the context of participants' reflection processes, it is notable that although all participants reported engaging in reflective activities, distinct outcomes emerged for a select few. Participant 5, when exposed to trigger 2, experienced a switch in contextual influence, transitioning from a more 'holistic' perspective to a reductionist one, which prompted a consequential shift in action, notably advocating for the inclusion of partners from diverse societal backgrounds. On the contrary, participants 2 (in response to both triggers) and 7 (trigger 2) underwent a switch in contextual influence, causing them to reevaluate their mindsets. This change in mindset was marked by a broader understanding of technological and societal implications (participant 6) and a nuanced perspective on the relationship between naturalistic and scientific engineering principles (participant 7). These instances underscore that despite all participants acknowledging the reflective process, for these select individuals, the transition between 'holistic' and reductionist worldviews served as a triggering catalyst, leading to tangible changes in mindset and action, ultimately affecting their engagement with the subject matter.

In all these switching cases, the second trigger was involved. In these cases, the artwork induced reflection on mindset-specific beliefs in relation to the 'societal/general/daily life system.' Subsequently, the reflection on these beliefs was connected to more reduced, embedded contexts, which made the beliefs in these contexts change. In Parts 2 and 3 of the interviews, most of the participants confirmed that the 'holistic' and reduced contexts indicated in this reflection matched the participants' interpretations of the artwork's different 'layers.' In other words, they confirmed that the layers of the artwork represented experiences from both within and outside the 'academic system.' Furthermore, participants who experienced a change in their mindset or actions after the switch in contextual influences acknowledged that their reflection was indeed induced by the art, as shown in Figure 4.27.

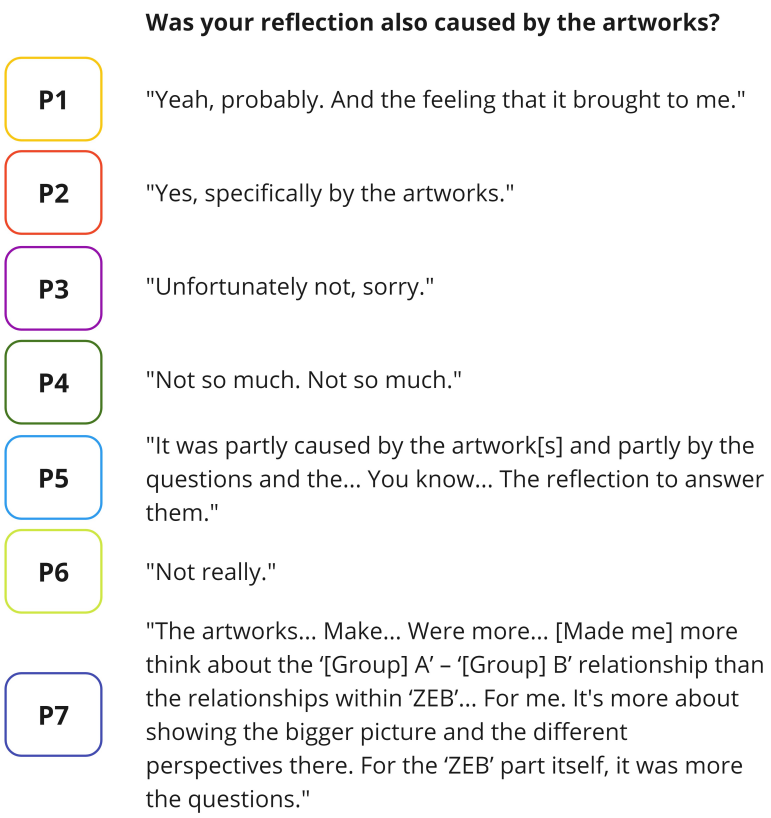


Figure 4.27: **Overview of participants' answers when asked 'Was your reflection also caused by the artworks?'.**

The triggers and emotions

Upon evaluation of the emotions expressed and coded through in vivo codes in Part 2 of each interview, it was observed that the participants that confirmed reflection was caused by the artworks also expressed they felt certain emotions when looking at the artworks, both positive and negative (Figure 4.28). Participant 6 was the only participant who did not confirm that reflection was caused by the artworks, but with an emotion code in the interview parts discussing one of the triggers (artwork 2). In particular, the respective emotion '(being) overwhelmed' was the only emotion implicitly expressed. All other emotions were explicitly mentioned by the participants in Part 2 of the interviews.

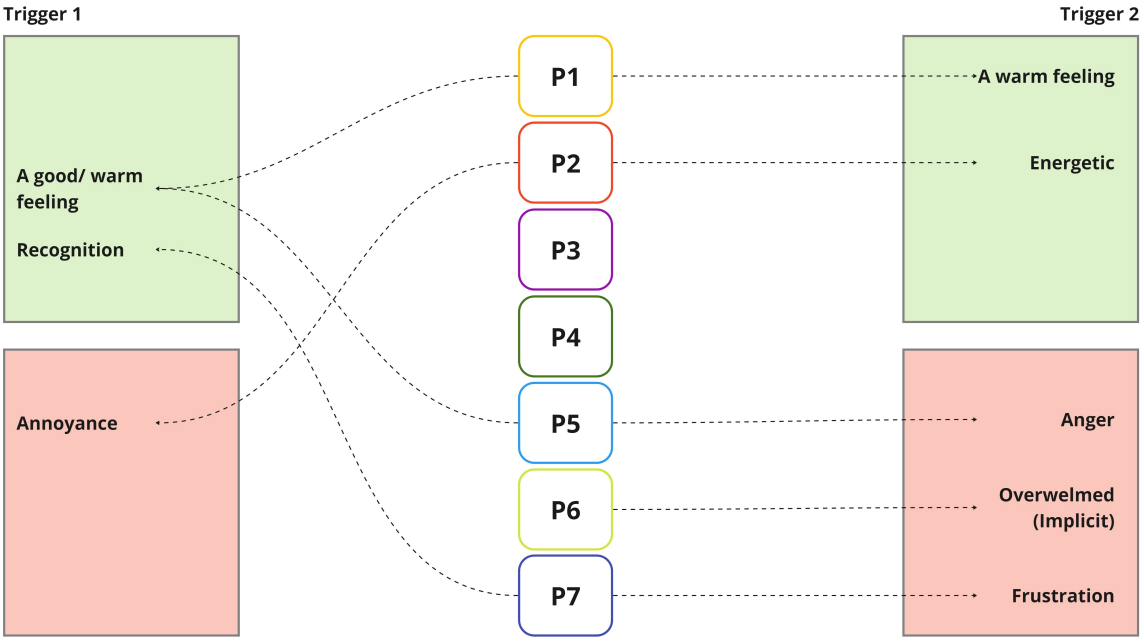


Figure 4.28: **Overview of positive and negative emotions experienced by participants as expressed for each reflection trigger in Part 2 of the interviews.** Emotions per participant are depicted in words connected with the respective participant via a line. When no emotion (and line) were shown for a participant-trigger combination, no emotion was expressed. Positive emotions are positioned in a green square; negative emotions are positioned in a red square.

Academic Contextual Constraints on Contextual Switching during Reflection

When discussing the general reflection possibilities and contextual influences of the 'academic discipline of biotechnology,' participants who experienced a switch in contextual influences (participants 2, 5, and 7) provided more detailed insights into why this context typically limits the type of reflection induced by the artworks. For instance, participant 5 indicated that most academics focus solely on the complexity of science, and therefore lack a more global, 'holistic' view of the issues they are working on:

Participant 5: *"I think that, very often, academics lack a more global view of issues and just focus on the science… Which is complex enough… But, the reality is even more complex..."*

"…any technology can be very beneficial or very dangerous, depending on how we use it. And, that's… And, I think scientists have a responsibility, right? It's like [when] Albert Einstein was developing the atomic bomb. And, when he realized… You know… He was like 'hey, we have a responsibility in this. It's not… We're not just developing the technical solution, and we can't just… Just isolate and… You know… That happens with everything, right? With everything we do, we really need to broaden the scope and look [at] it from… Zoom out, right? Look at how it embeds into the wider context."

Participant 7 added that having this more global view is generally not accompanied by a change in collaboration approaches:

Participant 7: *"I do reflect more on the aspect of the societal contribution. Or… [On] 'how can I tie my research into my lectures?', or something like that. The mindset for direct collaborations? Maybe not so much, no. It's sort of a thing that's goes more or less organically, like, 'hey, I like your work, you like mine… Let's talk… Let's see what we can do."*

According to participant 7, (the mindset for) collaboration is mainly affected by the commercial value of research output and the risks of losing intellectual property when collaborating from a global point of view:

Participant 7: *"'How do I want to interact with this person?' is in the end [for me]: 'what are the facts?'. Will I already tell my idea bluntly? [Will I] say "hey, this is what I want to do… I don't have this expertise… Let's… Do you want to get on board?"? With the risk of that person running away with it… With a risk of this person thinking "hey, this has commercial value. I am going to patent this and… bad luck for you". Or, I might [be] very secretive. But, with the risk that nothing gets off the ground in the first place, because I never really make it attractive to work with. So, that has a big impact on how you will conduct a research, and it's very much related to your mindset, I think."*

Finally, participant 2 realized that although feelings are part of science and reflection, the biotechnology environment is generally not one in which this is discussed:

Participant 2: *"I mean, if things do not work, I… At least I automatically start to reflect. And then, often, it's about feelings, because you are irritated by someone or by a process..."*

"... So, I think… I think everyone reflects in themselves, kind of, but I think not a lot of reflection is kind of shared. And, I think the reflection can become more powerful if it's also shared between people. But, let's say… If we kind of keep it [a] simpler formulation… Sharing feelings is not something that's very common, at least in my biotechnological environment."

Summary Section 4.2: Findings

Main take-away:
Research sub-question 1a (Q1a),

Q1a: *What contextual perceptions influence how research participants of 'The Towards Zero-Emission Biotechnology Consortium' view their mindset suiting inter- and transdisciplinary practices?*,

Is answered with the following main findings:

- All participants confirmed their membership in both 'Ingroups,' 'the academic discipline of biotechnology' and 'the group trying to tackle the issue.' For participants who selected the 'dominant' representation (participants 1 & 3), the first 'Ingroup' was seen as an embedded group offering a unique solution, which was not dependent on solutions outside of this group.
- Most of the participants (participants 1, 3, 4, 5, 6 & 7) acknowledged the role of (industrial) production systems, the role of transferring research knowledge to industrial partners, or the role of technology itself as an important 'holistic' to 'reductionist' reasoning step in how to solve the issue of the consortium. Here, participants who selected 'dominant' (participants 1 & 3) and 'intersection' (participants 4, 6 & 7) representations of both 'Ingroups' primarily emphasized industrial or technological contexts and 'Ingroups' shaping their mental models. Conversely, participants who selected 'merger' (participant 5) and 'context and situation specific' (participant 2) representations demonstrated a recognition of the role of individuals outside the realm of technology in addressing the issue.
- For most of the participants, the role of 'ZEB' was related to the relatively reduced 'the academic discipline of biotechnology' context. However, for two participants (participant 4 & 6), transferring research knowledge into a larger context was also seen as a part of 'ZEB'. Both selected the 'intersection' representation and envisioned this intersection as a means for this knowledge transfer.
- All participants unanimously endorsed the notion that (future) inter- and transdisciplinary practices should align with scholarly attributes captured in the first two statements given when discussing the collaboration types ("collaborations do not only happen within disciplines or sub-disciplines" and "collaborations occur between members from different disciplines, with each member analyzing the issue from the perspective of their individual discipline). However, for the remaining statements, the answers varied among the participants.
- Participants who perceived the 'Ingroups' 'the academic discipline of biotechnology' and 'the group trying to tackle the issue' to be similar (participants 1 & 4) referred in their explanation to more 'reductionist' systems and contexts deduced from their reasoning. In contrast, participants who perceived both 'Ingroups' to be dissimilar (participants 2, 5, 6 & 7) referred in their explanation to more 'holistic' systems and contexts deduced from their reasoning.
- When classifying the responses of the participants to uncertainty and ambiguity along an analytical versus social spectrum, it was observed that only the two participants who assigned an active role to people outside the industry or technology (participants 2 & 5) expressed an analytical response in the context related to more 'holistic' steps to tackle the problem. The remaining responses in relation to this 'holistic' context (of participants 4, 6 & 7) were very analytical. These latter participants also disagreed with the notion that spiritual aspects play a role in the collaboration of the consortium.
- The two participants who expressed more 'holistic' step(s) in which people outside the industry or technology had an active role in tackling the issue (participants 2 & 5) referred to the context linked to these respective 'holsitic' step(s) when describing the uniqueness of the issue. Most of the remaining participants referred to a context linked to more 'reductionist' steps when doing so.

Summary Section 4.2: Findings

Main takeaway (continuation):

- Participants 4 and 6, within the 'ZEB' consortium, expressed mindset-specific beliefs related to knowledge transfer. They highlighted the importance of a smaller subgroup within 'ZEB' as an 'intersecting' bridge for passing on knowledge to external contexts, thus influencing their beliefs about knowledge transfer.
- Participants 6 and 7, who perceived the 'academic discipline of biotechnology' and 'the group trying to tackle the issue' as distinct, expressed mindset-specific beliefs favoring rationality over feelings. These participants integrated external contexts to a lesser extent in their reasoning, indicating that contextual influences within technical environments shaped their rationality-oriented mindset.
- Participants 4, 6, and 7, operating within a more reduced 'academic industrial' system, emphasized the importance of collaboration outcomes and which perspectives should be included. Their mindset-specific beliefs were influenced by the technical context, with a focus on outcome-oriented collaboration and problem solving.

Research sub-question 1b (Q1b),

Q1b: *What characteristics can be deduced from the reflection of the research participants in 'The Towards Zero-Emission Biotechnology Consortium' that resulted in a more 'holistic' mindset?*,

Is answered with the following main findings:

- Visual 2 triggered shifts in contextual influences for participants 2, 5, and 7, resulting in changes in actions or mindsets.
- These participants confirmed that the artwork layers represented various 'holistic' and reduced contexts.
- It was observed that participants (except participant 6) who confirmed that reflection was caused by the artworks also expressed that they felt certain emotions when looking at the artworks, both positive and negative.

Link with Section 4.3:

- The findings described in this section are discussed in section 4.3.

4.3. Discussion

4.3.1. Reflecting on the findings

Research sub-question 1a,

Q1a: *What contextual perceptions influence how research participants of 'The Towards Zero-Emission Biotechnology Consortium' view their mindset suiting inter- and transdisciplinary practices?*,

was answered through semi-structured qualitative interviews and subsequent data analysis.

Technical implementation contextual influences

As discussed earlier, social identity complexity theory revolves around the cognitive process through which individuals identify with multiple 'Ingroups' that possess similar or 'competing' prototypes. Subjective representations used in interview questions offer insights into the different ways individuals reconcile these 'competing' prototypes to construct their overall social identity (Roccas and Brewer, 2002).

Moving from the theoretical framework to the findings, when assessing the various 'steps for tackling the issue' as articulated by participants and positioning them on a 'holistic' (complex system) to 'reductionist' (reduced system) scale, it becomes evident that most participants (participants 1, 3, 4, 6, and 7) recognized the pivotal role of the technical implementation within 'ZEB.' This implementation involves collaborations with industrial partners, general production, or general technology. The alignment with the 'implementation Ingroup' contexts, albeit varying among these participants, indicates the significance of technological aspects in shaping their mental models.

Moreover, from a social identity complexity perspective, these findings hint at a clear division in how participants evaluated 'competing' prototypes between 'the academic discipline of biotechnology' and 'the technical implementation group'. Here, six participants reconciled 'competing' prototypes by envisioning the actions of 'the academic discipline of biotechnology' as a direct part of their identity and the actions of the 'technical implementation group' as an indirect part of their identity. On the basis of this, one could speculate that their experiences in the context of this 'technical implementation' (collaborations with industry) might have a relatively lesser impact compared to their direct experiences within 'the academic discipline of biotechnology.' Considering the potential implications of this division in social identity complexity, it might suggest that participants who primarily align their identity with 'the academic discipline of biotechnology' could potentially wield significant influence in shaping the consortium's direction and its approach to interdisciplinary practices.

Participants 1, 3, 4, 6, and 7, who selected 'dominant' and 'intersection' representations, primarily emphasized industrial or technological contexts and 'Ingroups' in shaping their mental models. This preference suggests that these contexts significantly influence their perspectives on the issue and practices of the consortium. Additionally, their alignment with the 'implementation Ingroup' and the absence of people from outside the realm of technology in their holistic to reductionist reasoning steps reinforce the impact of these technical contexts on their views and attitudes.

The integration of contextual influences from outside of technological environments and mindset-specific beliefs for inclusiveness

Conversely, participants who selected 'merger' and 'context and situation specific' representations (participant 2 and 5) demonstrated a recognition of the role of individuals outside the realm of technology in addressing the issue. Through the perspective of the theoretical framework of this thesis, this implies that 'Ingroups' or contexts beyond the boundaries of technology exert influence over their mental models. When discussing the participant's response to uncertainty and ambiguity, the same participants expressed their social response to uncertainty and ambiguity when in the more 'holistic' context related to this step. Furthermore, when describing the uniqueness of their issue description, the same participants and a third participant referred to the contexts related to these 'holistic' steps, while the remaining participants referred to more 'reductionist' contexts.

Additionally, as indicated, the same participants who selected the 'merger' and 'context and situation specific' representations articulated that 'the academic discipline of biotechnology' and 'the group trying to tackle the issue' were dissimilar. They referred to 'holistic' systems when explaining this perception of dissimilarity. This alignment suggests that the contextual influences affecting their mental models, originating from realms beyond technology or industry, are inherently distinct from their own academic research context.

On the other hand, two participants who selected the representation of the 'intersection' also referred to 'holistic' systems in their explanations. Both participants expressed mindset-specific beliefs related to preferring rationality over feeling-based approaches, and one of them expressed beliefs indicating normativity for not including all perspectives. In the more reduced system, three participants (including the two referred to above) expressed mindset-specific beliefs that indicated a focus on outcome-oriented collaboration.

Based on this, it can be said that these participants acknowledged the existence of external contexts outside of the technical environments but did not fully integrate them into their reasoning processes to address the challenge of the consortium. This indicates that for these participants, contextual influences from inside technical environments have an impact on mindset-specific beliefs regarding how to use rationality and feelings when tackling complex issues. Because of this, contextual influences from inside technical environments have an impact on beliefs regarding inclusiveness in a way that only rational approaches are accepted.

When examined through the lens of social identity theory, these findings suggest the presence of shared prototypes among participants, potentially linked to a preference for rationality as a problem-solving approach. This inclination towards rationality may also be associated with a limited inclusiveness prototype, where rationality-driven decision making could lead to excluding alternative perspectives. These prototypes, ingrained within their social identity, could influence their perceptions and behaviors within their attempt to collaborate in an inter- and transdisciplinary manner.

Contextual influences on mindset-specific beliefs concerning knowledge transfer

Examining the contextual influences shaping participants' mindset-specific beliefs, it was observed that the participants that expressed that transferring research knowledge into a wider system was also an important part of 'ZEB' expressed beliefs indicating positive differentiation with a subgroup of 'ZEB' as the 'Ingroup': the group involved in their projects. Both these participants selected the subjective representation 'intersection' when discussing the two 'Ingroups' in the interviews and related this to transferring knowledge of 'the research context' to 'the technical implementation context', which was perceived as something unique for their projects. The positive differentiation expressed for this subgroup reveals that these smaller groups within 'ZEB' have an influence on how these participants view sharing knowledge outside the consortium. A participant also expressed mindset-specific beliefs indicating biases for the 'Outgroups' 'industry' and 'academics/biotechnology'. From a social identity perspective, these findings suggest that, for these participants, experiences in the contexts of their projects are more influential than experiences in the general context of 'the academic discipline of biotechnology'.

In the context of moving towards inter- and transdisciplinarity, scholars relate to the need to 'co-create or co-design with nonacademic actors', including (industrial) partners for 'technical implementation'. Notably, as indicated by one participant in Part 3 of the interviews (meta-reflection), the risks of losing intellectual property can be a limiting influence of the 'academic discipline of biotechnology context' to reflect on the mindset. Interestingly, De Maeijer et al. (2018) linked this influence to interactions between industrial partners and academics to understand their influence on the roles and identities of participants (De Maeijer et al., 2018). Using a linguistic ethnography approach, they evaluated contextual routines and the (a)symmetry in the allowed distribution of the participants engaging in interactions. The framework they use to this connects to the main findings related to knowledge transfer discussed in this section: they evaluate 'secrecy' versus 'openness' (pre-preparedness to share and receive information) in relation to fluid and fixed (assumed) identities. They state that 'secrecy' elements such as intellectual property often go hand in hand with a collaboration dynamic of 'keeping face', i.e. to prevent 'face-threats', identity aspects such as values and beliefs are not shared). However, their results indicate a power shift initiated by 'leading individuals': one with more 'openness' and in which "academics and 'industrials' jointly (re)determine the course of the project and academics no longer solely bear the burden of technological uncertainty" (De Maeijer et al., 2018).

When linked to the findings discussed in this section, the smaller influence of the academic disciplinary context on the mindset-specific beliefs of the two participants who value knowledge transfer could indicate a similar shift towards 'openness'. On the other hand, the mindset-specific beliefs expressed that indicate biases for 'Outgroups' industry and 'academics / biotechnology' suggest a tendency to stereotype and additional 'Ingroup' differentiation (increased self-esteem) for the participant's project, which indicates the opposite of openness for sharing identity aspects.

To answer **research sub-question 1b**,

Q1b: *What characteristics can be deduced from the reflection of the research participants in 'The Towards Zero-Emission Biotechnology Consortium' that resulted in a more 'holistic' mindset?*,

The model for initiating change, rooted in the theoretical framework of this thesis, was used as the lens through which the reflections of the participants influenced their mindset-specific beliefs. To do so, a detailed analysis of the interviews was conducted, categorizing each participant's reflection process into one of the following reactions: option 1 (No Reflection), option 2 (Reflection but No Changed Mindset), and option 3 (Reflection Causing a Changed Mindset).

A shift in contextual influences and the Role of Reflection Triggers

When analysing the participants' perceptions of inter- and transdisciplinarity evaluated in Part 1 of the interviews (Step 2 of data analysis to answer Q1a, Section 4.1.3), it became evident that the scholarly continuum, as positioned along the theoretical framework, did not consistently align with the participants' views within 'The Towards Zero-Emission Biotechnology Consortium'. While the first two statements regarding collaborations within disciplines or across different disciplines met unanimous agreement, participants' responses to the subsequent statements displayed notable inconsistencies. Such disparities indicate a divergence between the theoretical continuum and the contextual perceptions within this specific case study.

However, a noteworthy shift in contextual influences was observed among participants who experienced a recognition of embeddedness during Part 2 of the interviews. This recognition of embeddedness in interdisciplinary and transdisciplinary contexts closely parallels the scholarly view of a 'shift in mindset' towards recognizing interconnectedness and fostering coordination among diverse hierarchical levels. For instance, this process of acknowledging embeddedness aligns closely with the concept of 'deep learning,' encompassing intellectual, emotional, and values-based dimensions, which serves as a cornerstone for initiating transformative change within the framework of this study (Hermes and Rimanoczy, 2018). This recognition of embeddedness within the participants' responses hints at the applicability of the scholarly perspective on mindset to this case study. Specific to this case study, this implies that the development of a more 'holistic' mindset, rooted in recognizing embeddedness, acted as a catalyst for the cultivation of a 'holistic' perspective.

Here, it is essential to revisit the influence of the reflection triggers used during the interviews, as they played a crucial role in influencing participants to engage in reflection that transcended their immediate technological context. As described, all instances of this shift towards recognizing embeddedness were at least partially induced by the second artwork serving as a reflection trigger. Participants confirmed that the layers of this artwork represented experiences from both within and outside the 'academic system.' This observation underscores the significant role played by the choice of the artwork as a trigger, encouraging participants to consider contexts beyond technology during their reflections. Consequently, regardless of their social identity complexity representation, all three participants experiencing this contextual shift acknowledged the existence of external contexts as they transitioned from 'holistic' to 'reductionist' approaches when addressing the consortium's challenge.

A shift in contextual influences accompanied by both cognitive and affective processes
As explained, some scholarly literature that focuses on moving towards inter- and transdisciplinarity suggests a revolution in the praxis of learning through reflection: one in which instead of solely cognitive processes (rationality), also affective processes have a role (Burga et al., 2017; Lozano, 2014; Shrivastava, 2010). Interestingly, all participants who experienced such a contextual shift during their reflection acknowledged that the triggers indeed induced their reflection. Additionally, it was observed that these participants also expressed that they felt certain emotions when looking at triggers. These findings confirm the importance of affective processes and creativity, specifically for reflection, to cultivate a more 'holistic' mindset.

In line with this influence of experience emotion, the concept of 'cognitive dissonance' served as a central part of this thesis' theoretical framework used as a lens to study the participants' reflection processes. Through the interview analysis, it was observed that experiencing such dissonance indeed caused one of three reactions of participants when triggered with the artworks: a change in perception of action, a change in action, or a change in (mindset-specific) belief. The phenomenon of experiencing 'cognitive dissonance' when participants recognized their role and embeddedness in a new manner was also reported by Hermes and Romanoczy (2018), and involves reflecting on one's contribution to addressing complex issues in novel ways. As reported by Hermes and Romanoczy (2018), this reflection often leads to the surfacing of frustrations, the recognition of differences within interdisciplinary groups, and a heightened awareness of the need to align one's mindset with the overarching goals. It is plausible that this phenomenon could also be observed in the reflections of other participants, such as Participants 2 and 7. To illustrate this, here are excerpts from Participant 7's reflections, providing a glimpse into this process:

Participant 7 (About the emotion experienced): *"I think it does signal that I have frustrations with certain members of 'Group B'…"*

Participant 7 (About the role of others in the 'holistic'): *"..[However],it does emphasise that it's, even though they have, maybe, a similar purpose in the end, it's so different, that you can't really identify with them, in many aspects..."*

Participant 7 (Reflecting on own role): *'...it's easy to just focus on the technical aspects and park these other things for later. So… Maybe, make sure and keep in check with yourself that your mindset is also oriented towards the goal, and not only towards things that you're doing along the way."*

4.3.2. Reflecting on methods and data analysis

In this phase of the study, qualitative data was collected through semi-structured interviews, which provided valuable insights into the mindsets of the participants and their connection to various aspects of 'ZEB.' The interview design was tailored to encourage participants to discuss their beliefs in relation to 'ZEB,' potentially leading to a stronger emphasis on positive differentiation for 'ZEB' as an 'Ingroup.' However, it is essential to acknowledge that the interview structure also included discussions on the relationship between 'ZEB' and other 'Ingroups,' such as 'the academic discipline of biotechnology' and 'the group trying to tackle the issue.' These discussions provided opportunities for participants to link their mindsets to more 'holistic' perspectives concerning the problem at hand. Although the interview setup may have influenced the focus on different 'Ingroups,' the data analysis aimed to explore mindset-specific beliefs qualitatively, rather than quantifying the ratio of focus on specific 'Ingroups.' This approach allowed for a deeper understanding of the participants' mindset-related beliefs.

A critical evaluation of the theoretical framework used in this study is warranted to assess its effectiveness in guiding research. The framework incorporated the Social Identity (Complexity) Theory and the concept of 'mental models' to analyze the interview findings. However, several important considerations need to be addressed. First, it is essential to recognize that the framework assumes that contextual influences are not adequately recognized by current academics. This assumption was not explicitly checked during the interviews. Second, the centrality of The Social Identity Complexity Theory in this research is notable. The Social Identity Complexity Theory is a relatively young theory that may not have been widely applied in research. Despite this, it played a central role in this study, with the assumption that an individual is influenced by multiple social identities. Finally, while the exploratory review of the literature confirmed the compatibility of the chosen theories within the framework, a systematic review was not conducted to validate the general consensus on the fit of these theories.

These critical points raise questions about the suitability of the theoretical framework and potential limitations it may introduce into the research process. To enhance future studies, it is advisable to consider research setups that allow for the evaluation of both direct and indirect responses to contextual influences, providing a more comprehensive understanding of their impact on participants' mindsets. Additionally, given the foundational role of the theoretical framework in this phase's data analysis, future research efforts could benefit from conducting a broader or systematic literature review to validate and refine the chosen theoretical framework.

A third critical aspect of the data analysis of this study is the role of personal interpretation in the research process. Qualitative data analysis involved multiple steps, including coding, mapping, and categorizing beliefs as context-specific or mindset-specific. All these steps were carried out by a single researcher, introducing the possibility of personal bias and interpretation. Additionally, the elucidation of mental models was performed through Fuzzy Cognitive Mapping, a method that, when used with specific algorithms to generate group mental models, reduces the influence of researcher interpretation. However, the decision was made to focus on individual mental models and utilize a more qualitative approach to elucidate them through Fuzzy Cognitive Mapping. This choice was driven by the research's emphasis on individual reflection on various professional and private contexts and how these contexts shape mindsets.

Acknowledging the potential influence of personal interpretation is essential to understanding the limitations of the study and underscores the need for transparency in the research process. These considerations should serve as a foundation for future research endeavors, prompting researchers to explore strategies for minimizing personal bias and improving consistency of analysis, such as intercoder reliability, i.e., where researchers or analysts independently code, interpret, or analyze the same data set, and to make explicit their interpretive choices throughout the research process.

4.3.3. Reflecting on validity and generalizability

Regarding generalizability, the findings of this study may present challenges in terms of generalizability due to its small sample size of seven participants and its focus on the specific context of the 'Towards Zero-Emission Biotechnology Consortium.' However, the study contributes to transferability by providing a comprehensive understanding of mindset development within interdisciplinary and transdisciplinary contexts. Although the direct transfer of findings to other contexts might be limited, research methodologies, as well as the application of the theoretical framework, can serve as a valuable foundation for similar studies in diverse interdisciplinary and transdisciplinary domains.

In terms of validity, it is important to acknowledge potential challenges stemming from researchers' interpretation during qualitative data analysis. The data analysis process, which included coding, mapping, and categorizing beliefs, may introduce an element of personal interpretation and subjectivity. However, the external validity of the study remains a priority, ensuring that the research is as applicable as possible to other settings and contexts. The transparency of the research process, including detailed descriptions of the methodologies used and the specific context of the 'Towards Zero-Emission Biotechnology Consortium,' aims to facilitate external validity by allowing other researchers to assess the applicability of the findings to their own cases. This methodological transparency contributes to the credibility of the study's conclusions and reinforces the potential for external validity in similar interdisciplinary and transdisciplinary environments.

Summary Section 4.3: Discussion

Main take-away:
The following points of discussion are most relevant regarding the findings that answer research sub-question 1a (Q1a),

Q1a: *What contextual perceptions influence how research participants of 'The Towards Zero-Emission Biotechnology Consortium' view their mindset suiting inter- and transdisciplinary practices?*:

- **Role of Technical Implementation:** Most participants recognized the pivotal role of technical implementation within 'The Towards Zero-Emission Biotechnology Consortium.' From a social identity perspective, this indicates that technological aspects significantly influence their mental models.
- **Speculation on Social Identity Complexity:** Speculation based on the social identity complexity lens reveals competing prototypes between 'the academic discipline of biotechnology' and 'the technical implementation group.' Participants reconciled these competing prototypes in distinct ways, suggesting that those primarily aligning with 'the academic discipline of biotechnology' may have more influence in shaping the consortium's direction.
- **Contrasting Groups and Beliefs of Inclusiveness:** Participants with different social identity complexity representations demonstrated varying beliefs regarding inclusiveness. Some acknowledged external contexts outside of technology, while others preferred rationality over feelings-based approaches, which influenced their inclusiveness beliefs. The social identity complexity lens suggests that these preferences may influence perceptions and behaviors in inter- and transdisciplinary collaboration.
- **Preferences for Rationality and Lack of Influence from Outside Contexts:** Some participants preferred rationality over feelings-based approaches and did not fully integrate external contexts outside of technology into their reasoning processes. The social identity lens speculates that these preferences might result in limited inclusiveness and impact mindset-specific beliefs.
- **Knowledge Transfer and Openness:** Literature suggests the importance of 'openness' in inter- and transdisciplinary collaboration, as it can lead to a shift in power dynamics and influence participants' perceptions. Participants who valued knowledge transfer expressed openness, while those who had biases against 'Outgroups' indicated the opposite of openness for sharing identity aspects.

The following points of discussion are most relevant regarding the findings that answer research sub-question 1b (Q1b),

Q1b: *What characteristics can be deduced from the reflection of the research participants in 'The Towards Zero-Emission Biotechnology Consortium' that resulted in a more 'holistic' mindset?*:

- **Misalignment with Scholarly Continuum:** The scholarly continuum, as positioned along the theoretical framework, did not consistently align with the participants' views within 'The Towards Zero-Emission Biotechnology Consortium.' While some statements met unanimous agreement, disparities emerged regarding subsequent statements, indicating a divergence between the theoretical continuum and participants' contextual perceptions.

- **Shift in Contextual Influences and 'Deep Learning':** A significant shift in contextual influences was observed among participants, particularly during Part 2 of the interviews. This shift closely parallels the 'deep learning' concept, which involves recognizing embeddedness in interdisciplinary and transdisciplinary contexts and aligning with the 'shift in mindset' towards recognizing interconnectedness. This shift in contextual influences acted as a catalyst for cultivating a 'holistic' mindset and aligns with the origin of the model for initiating change described in literature.
- **Influence of Reflection Triggers:** However, the influence of reflection triggers used during interviews played a crucial role in inducing participants to engage in reflection that transcended their immediate technological context. The choice of artwork as a reflection trigger encouraged participants to consider contexts beyond technology during their reflections.
- **Cognitive-Affective Reflection and Cognitive Dissonance:** A relevant takeaway from this discussion is the importance of cognitive-affective reflection in cultivating a holistic mindset. This was emphasized in the context of literature, particularly with regard to the need to incorporate affective processes for transformative change. The concept of 'cognitive dissonance' played a central role in the discussion, highlighting that this phenomenon often leads to a shift in mindset and a heightened awareness of the need to align one's mindset with overarching goals.

Finally, the following general points of discussion are relevant:

- **Role of Qualitative Data Analysis:** The qualitative data analysis process, including coding, mapping, and categorizing beliefs, was utilized to explore mindset-specific beliefs qualitatively. While the research design encouraged the participants to discuss their beliefs, it also introduced the possibility of personal bias and interpretation during data analysis. Transparency and the recognition of potential personal interpretation were highlighted as important considerations to improve the quality of future research.
- **Effectiveness of Theoretical Framework:** The effectiveness of the chosen theoretical framework, which incorporated the Social Identity (Complexity) Theory and 'mental models,' was discussed. The framework assumed that contextual influences are not adequately recognized by current academics and focused on the role of multiple social identities. However, the potential limitations and assumptions of the framework were acknowledged, emphasizing the importance of future research to validate and refine the chosen theoretical framework through broader literature reviews.
- **Generalizability and Validity:** The section addressed generalizability and validity concerns. The small sample size of seven participants and the specific focus on 'The Towards Zero-Emission Biotechnology Consortium' could pose challenges in terms of generalizability. However, the study aimed to contribute to transferability by providing insights that can be applied to similar interdisciplinary and transdisciplinary contexts. Validity concerns were related to potential personal interpretation during qualitative data analysis. The section emphasized the need for transparency in the research process and encouraged future researchers to explore strategies to minimize personal bias and improve consistency in analysis.

Link with Section 4.4:

- Section 4.4 describes the conclusion of Phase 1 based on the findings (Section 4.2) and the points of discussion described in this section.

4.4. Conclusion

Phase 1 of the study aimed to answer research sub-question 1,

Q1: *How do contextual perceptions within the academic discipline of biotechnology, as observed in a case study, influence the development of a more 'holistic' mindset suiting inter- and transdisciplinary practices?*

To answer research sub-question 1a:

Q1a: *What contextual perceptions influence how research participants of 'The Towards Zero-Emission Biotechnology Consortium' view their mindset suiting inter- and transdisciplinary practices?*,

A theoretical lens consisting of the Social Identity (Complexity) Theory and the concept of mental models was used. Participants exhibited various mindsets, which were influenced by 'social identity (complexity)', with some participants prioritizing technological contexts, while others recognized influences from outside technology. The influence of 'Ingroups' on mindset-specific beliefs and attitudes towards inclusiveness varied between participants. Additionally, the academic disciplinary context had different levels of influence on the mindset-specific beliefs of the participants about knowledge transfer.

To answer research sub-question 1b,

Q1b: *What characteristics can be deduced from the reflection of the research participants in 'The Towards Zero-Emission Biotechnology Consortium' that resulted in a more 'holistic' mindset?*,

A model for initiating change was used linking a reflection process initiated by a creative trigger as contextual influence to previous contextual perceptions deduced to answer Q1a. Here, a shift in contextual influences was found to be induced by a specific reflection trigger (the second artwork), which led to changed ('holistic') mindset or action in the context of inter- and transdisciplinary practice. Participants experienced cognitive dissonance and emotional responses during this shift. This second artwork prompted participants to recognize contexts outside of technology, affecting mindset-specific beliefs about embeddedness.

4.4.1. Essence: Re-connecting yourself

Starting from the normative claim that scientists tackling complex issues need to adapt their perspective on science towards a more 'holistic' one, accompanied by moving towards inter- and transdisciplinarity via continuous reflection, phase 1 of this thesis aimed to find an essence of what it means to do this. Based on the findings discussed, the following essence was defined by the researcher herself for what it means for academics of the discipline of biotechnology to cultivate a more 'holistic' mindset via continuous reflection, accompanied by moving towards inter- and transdisciplinarity:

"Re-connecting yourself"

On the one hand, this essence refers to the interview finding that acknowledging embeddedness, triggered by mindset-specific beliefs that are related to the most 'holistic' contexts of the participants in their professional inter- and transdisciplinary approaches, can further cultivate a 'holistic' mindset via reflection. On the other hand, this essence refers to reconnecting with various aspects of yourself, both cognitive and affective, thereby improving the praxis of reflection. As reflecting on a 'holistic' mindset needs to be continuously done, this essence also refers to the social process of connecting with more and more different people and reflecting upon each other's (mindset-specific) beliefs.

Summary Section 4.4: Conclusion

Main take-away:
Starting from the normative claim that scientists tackling complex issues need to adapt their perspective on science towards a more 'holistic' one, accompanied by moving towards inter- and transdisciplinarity via continuous reflection, phase 1 of this thesis is concluded by an essence of what it means to do this as defined by the researcher herself:

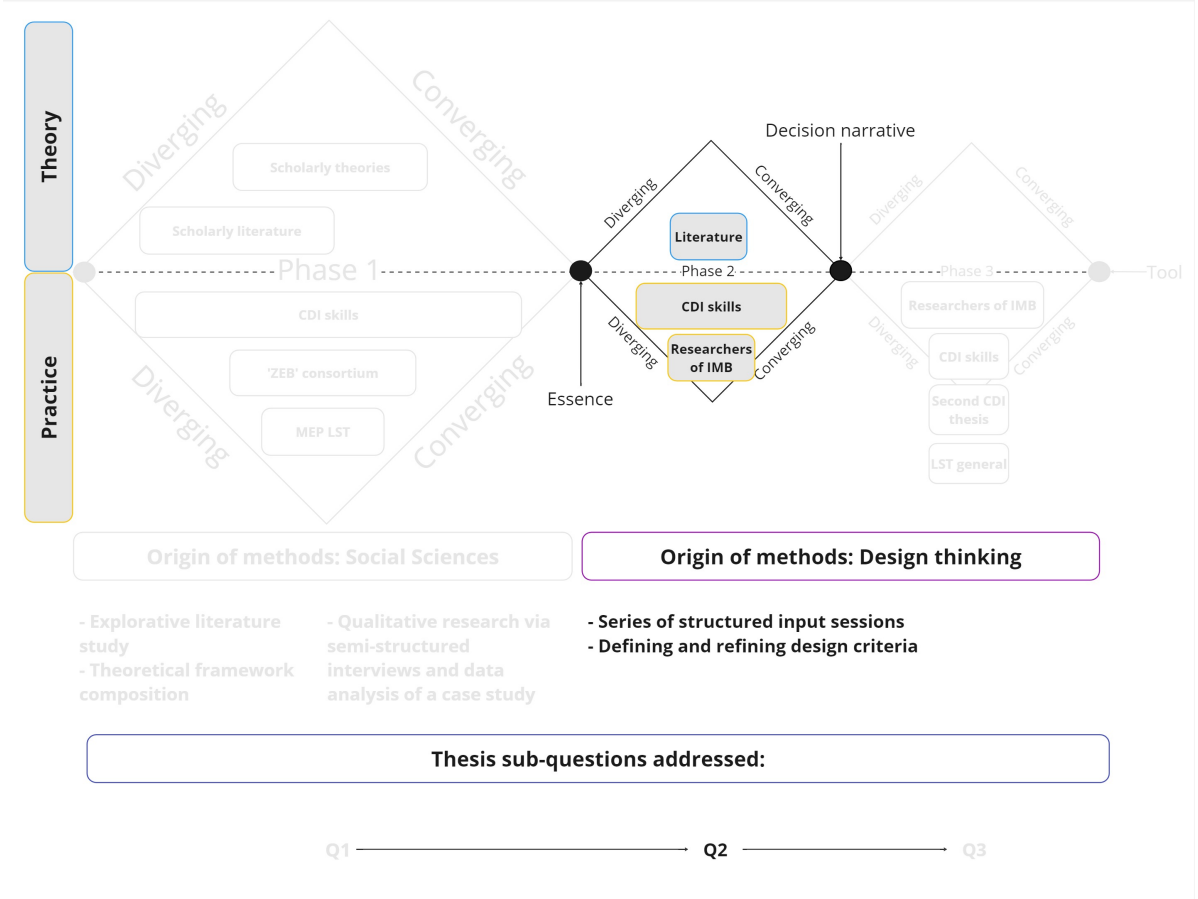
"Re-connecting yourself"

Link with Chapter 5:

- In the next chapter describing the Phase 2, divergent and convergent thinking was carried out to further specify what this essence means in this broader context of the academic discipline of biotechnology and re-iterate these new insights with insights of Phase 1 and the insights previously reported in literature.

5

Defining what can induce continuous cultivation of a ‘holistic’ mindset



This chapter describes the progression of this thesis' research, marking the process of Phase 2: divergent and subsequent convergent thinking to gain new input, reiterate with previous insights and additional literature, and define the purpose of the tool. Rooted in the principles laid out in prior chapters, the focus now turns to how motivation can be stimulated within members of the academic discipline of biotechnology, fostering a 'holistic' mindset suiting to inter- and transdisciplinarity.

In this phase, a new research sub-question is introduced, broadening the scope beyond the consortium context examined in Phase 1:

Q2: *According to members of the academic discipline of biotechnology, what can induce the continuous and conscious cultivation of a more 'holistic' mindset?*

This inquiry thus extends into the broader realm of biotechnology, seeking to reveal catalysts that can nurture the cultivation of a 'holistic' mindset. It serves as the cornerstone of this thesis' research, laying the groundwork for the subsequent phase where the final research sub-question will be addressed:

Q3: *What tool can be used to support the cultivation of a more 'holistic' mindset of members of the academic discipline of biotechnology?*

All-together, this phase contributes to answering the main research question:

Q: *How can members of the academic discipline of biotechnology be incited to continuously and consciously cultivate a more 'holistic' mindset suiting inter- and transdisciplinarity?*

5.1. Methods: Input session and literature study

The selected methodology for this phase is based on its suitability to **diverge** on what the essence meant in the broader context of the academic discipline of biotechnology and subsequently converge by (re)iterating the insights with the insights of phase 1 and the insights previously reported in the literature. In alignment with this aim, a multifaceted approach was employed, one that begins with an input session followed by an explorative literature study.

To **diverge**, an input session was organized with members (PhD'ers, Postdocs, and experienced technicians) of the 'Industrial Microbiology' (IMB) group. The session lasted one hour and took place in a real-life setting, in a neutral meeting room at the TU Delft. Participants were invited by email and informed that their participation constituted consent for handwritten notes to be taken from their input, but no direct quotes were recorded. Four participants were selected for this input session based on their availability and their expressed interest in contributing to the broader exploration of holistic science.

During this session, the researcher's role assumed an active facilitative stance, characterized by the use of nondirective probing questions to encourage thoughtful reflection and discourse and taking intensive notes.

During the input session, members were briefly introduced to the starting point of this thesis: the normative claim that scientists tackling complex issues need to adapt their perspective on science towards a more 'holistic' one, accompanied by moving towards inter- and transdisciplinarity via continuous reflection. The introduction to the topic and the essence was facilitated using three PowerPoint slides. Then, an elaborate discussion was held to discuss the members' various interpretations of the essence and how they envisioned the approach or actions to achieve this.

To define the purpose of the tool, **convergent thinking** was carried out by reiterating the insights of the input session with previous insights from phase 1 and literature. For this re-iteration, an additional explorative literature search was conducted using the search engines Web of Science and Scopus, and by using combinations of the following terms as search terms: 'interdisciplinarity', 'transdisciplinarity', 'emotion', 'language', 'similarity', 'diversity' 'context'. On reading the abstract, the selection for inclusion in this review of the literature was based on the following.

- Actuality (2000-2023);
- The fact that it could be linked to insights of phase 1 and insights of the input session; and
- The fact that other papers focusing on moving towards inter- and transdisciplinarity cited the work. The judgment of this focus was evaluated by reading the abstracts of the papers.

5.2. Findings of the input session

The main insights that resulted from the input session are described based on the following themes:

Theme 1: Re-connecting yourself with different research contexts
Some members interpreted the essence as re-connecting themselves with different research contexts. Here, a connection was made between research contexts and the stage of personal development in a scientific career: the longer someone had developed in the academic context, the bigger the ability to re-connect with different research contexts. Thus, connecting was mainly done via experience, knowledge, and expertise related to the area to connect with. In this discussion, it was highlighted that young scientists can sometimes be stubborn because they connect an aspect of their mindset to only certain specific experiences.

Theme 2: Re-connecting yourself with different people
Some members interpreted the essence as re-connecting themselves with a wider variety of people and, subsequently, their personalities and mindset. Here, members agreed that re-connecting meant 'recognising yourself in the other', which all members linked to 'having had the same experiences'. It was noted that researchers in the same research group, or to some extent amongst all members of 'the academic discipline of biotechnology', 'having had the same experiences' often meant 'knowing what it is like to perform experiments in the laboratory'. In this context, re-connecting with someone with a positive and output-driven mindset can be done by recognizing yourself in lab work that immediately resulted in publishable results. In contrast, re-connecting with someone with a very negative and 'experimental' mindset can be done by recognizing yourself or your equipment constantly 'failing' in the lab.

Regarding re-connecting with academics of other disciplines or even with people working outside of academia, members of the session expressed that it was much harder to find 'a similar experience'. In this context, members agreed that various assumptions could sometimes help the conversation (i.e. finding a connection or parallel by assuming to have a similar experience somewhere in life), but sometimes also limited the dialogue. It was noted that biotechnologists generally assume themselves as experts who need to send a specific (connecting) message. Being experts, they often assume that they not only have sufficient knowledge related to science, but also know enough to understand what type of knowledge these 'different people' need to have. This led to the realization that, in these cases, listening to people's values, interests, and ideas is extremely valuable to create a mutual understanding, but it is often forgotten.

Theme 3: Re-connecting has limits
Some members expressed that this re-connection needs to have its limits: there always needs to be 'some part of yourself that is distinctive for who you are', and there always will be parts of others with which you cannot relate. However, they did acknowledge that having these differences in work ethic, mindset, or attitude during collaborations can create tension and cause collaborating partners to feel uncomfortable. Remarkably, all members of the input session agreed that when dealing with these tensions, searching for a more 'holistic', abstract similarity, or factor creating 'coherence' made dealing with such tensions more comfortable.

Theme 4: Re-connecting with different aspects of yourself, other than rationality
Some members interpreted the essence as re-connecting themselves with different aspects of themselves, such as ambition, daily experiences and feelings, and creed. Here, it was noted that people in academia are often very much 'inside their heads', dealing with rationality. Because of this, they often forget to 'embody their thoughts' or link what is theoretically possible to how they and the people in their surroundings are feeling at that moment. Therefore, participants in the input session confirmed that feelings are generally not shared in relation to project goals or collaboration evaluations.

Theme 5: Re-connecting on a meta-level, on how reflection is affected by its context
Finally, some members started to reflect on how their academic environment affected their reflection. Here, one PhD'er mentioned that reflection was often done by evaluating the progress made with the coaching (assistant) professor. When doing this, topics such as well-being and emotions felt are being discussed, however, in a relatively pragmatic manner (changing schedules for more rest, going to an outsourced training, etc.) and not linked to the scientific practice evaluated.

5.3. A re-iteration with literature and previous insights

Re-connecting yourself with different research contexts and people related to the theoretical framework and knowledge transfer from research to implementation

The input session interpretation of re-connecting yourself as re-connecting with different research contexts, an ability gained through personal development during a scientific career (theme 1), can be easily connected to the theoretical framework as composed for this thesis (Section 3.4). As a mental model occurs when individuals interact with their environment, in order to manipulate the obtained experiences mentally and consequently update cognitive simulations that belong to similar experiences (Adolphson, 2004; Seel, 2001), a mental model is shaped by contextual experiences and personal qualitative interpretations (Reynolds et al., 1996). Here, a later stage in the scientific career can be seen as having had more experience in the context of 'the academic discipline of biotechnology', and, therefore, more 'accurate' simulations for similar experiences. The input session interpretation of re-connecting yourself as recognizing yourself in others based on similar experiences can also be connected to the concept of 'mental models' updated with various experiences.

This interpretation of re-connecting yourself as recognizing yourself in others based on 'having had similar experiences' (theme 2) can also be evaluated from a social identity complexity perspective (Section 3.4). The note that, when finding 'similar experiences' is somewhat difficult, biotechnologists often assume to have had specific similar experiences, which can be understood as the process of categorization of the self and the other person in a particular 'Ingroup'. As prototypes represent average similarities between members of the same 'Ingroup', this categorization offers a direction to assume a similar experience. However, since listening was indicated to be very important to change this assumed to less strictly categorized identities, it could be said that a similar shift in 'openness-secrecy' dynamics as observed by De Maeijer et al. (2018) between academics and industry could also change the power relationship between the expert and the layperson during the reconnecting process to improve recognition (De Maeijer et al., 2018).

Re-connecting and acknowledging distinctiveness from different perspectives can re-frame the personal evaluation of inter- and transdisciplinarity

The input session notion that re-connection needs to have its limits as being distinctive is considered important as well (theme 3), can be linked to the continuous movement towards inter- and transdisciplinarity as suggested by scholars (Section 3.2.2). Rafolds and Meyer (2008) illustrate this by suggesting a conceptual framework aimed to 'capture' inter- and transdisciplinarity, in the wider sense of knowledge integration, by assessing the inter- and transdisciplinarity of published articles of bionanoscience by combining two approaches: evaluating 'disciplinary diversity' and 'changes in network coherence'. They state that the knowledge integration process can be seen as "a process in which previously different and disconnected bodies of research become related", which is characterized by both an increase in diversity and a change (increase) in coherence. In their methods, they state that both top-down and bottom-up perspectives need to be used, as both have their constraints in accurately describing the diversity and coherence (on micro-, meso- or macro-level) (Rafols and Meyer, 2010).

Although this thesis acknowledges that the analysis of Rafolds and Meyer (2008) is focused on defining the inter- and transdisciplinarity of research output, a similar method can be proposed to evaluate collaboration practices and mindsets suiting inter- and transdisciplinarity: The system or context participants referred to in their reasoning when explaining their perceived similarity between 'the academic discipline of biotechnology' and 'the group trying to tackle the issue' can be seen as a different perspective, representing the bottom-up approach for perceived similarity, and concurrently as a top-down approach for perceived dissimilarity. These perspectives are instrumental in evaluating the current state of 'ZEB' on the continuum of inter- and transdisciplinarity (as discussed in Section 3.2.2).

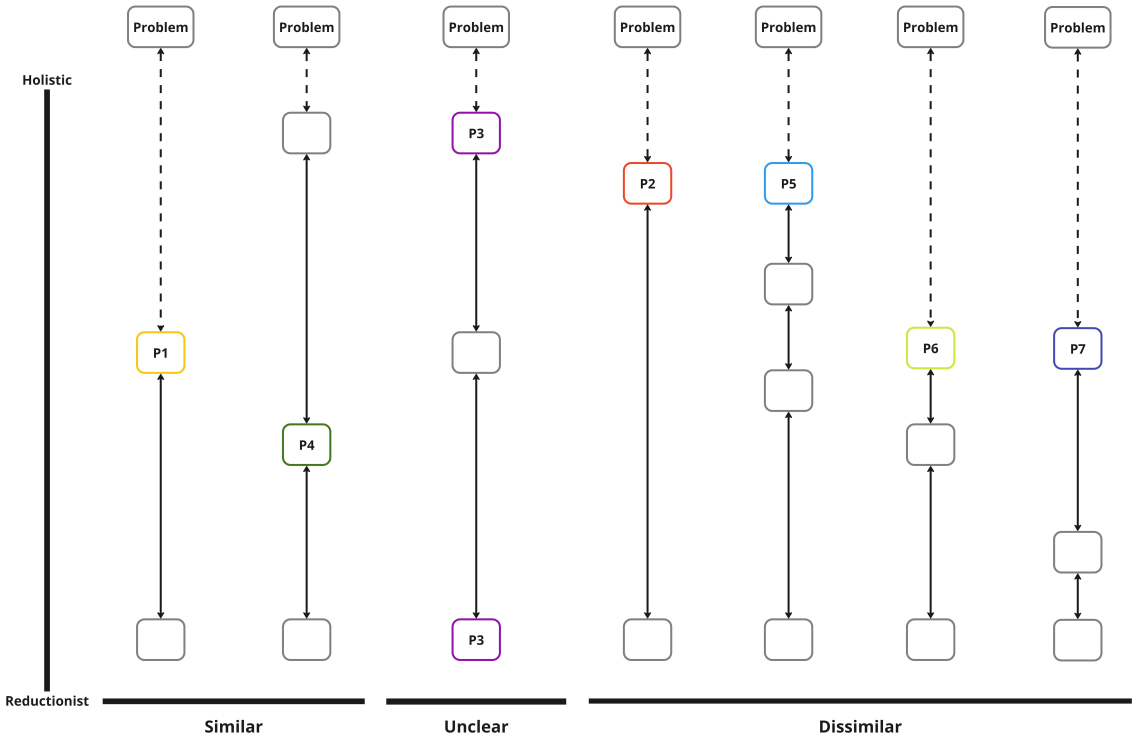


Figure 5.1: **A re-introduction of one of the interview findings: Perceived (Dis)similarity and Contextual Influences.** This figure shows the participants' perceptions of the similarity between 'the academic discipline of biotechnology' and 'the group trying to tackle the issue.' The boxes along the vertical scale represent the reasoning steps initially introduced in Figure 4.16, which span from 'holistic' to 'reductionist.' Color-coded boxes indicate the contextual references invoked by participants in their explanations, and arrows connect reasoning steps to these references. Participants are grouped based on whether their perception of both 'Ingroups' were similar, dissimilar, or whether they were unsure about their perception of (dis)similarity. This visualization provides a summary of how contextual influences impact participants' evaluations of (dis)similarity between the 'Ingroups.'.

Here, it is important to mention that although the interviewed participants of 'ZEB' indicated a certain observation in bottom-up and top-down perspectives linked to similarity and dissimilarity, respectively, these perspectives can result in different perceptions when different groups, at a different stage of moving towards inter- and transdisciplinarity, are evaluated (Figure 5.2). Thus, when groups are not defined (as in the interviews), but assumed based on the categorization of the self and others, discussing the 'diversity' and 'change in coherence' can help re-frame the personal evaluation of inter- and transdisciplinarity. This suggests that when talking about different ways of seeing coherence and diversity in different 'holistic' and 'reductionist' contexts, conversation partners can trigger each other and induce a reflection on the ways contexts influence their perspectives.

Re-connecting with different aspects of yourself, other than rationality, offers a universal language

The input session interpretation of re-connecting yourself as re-connecting with different aspects of yourself and the acknowledged disconnection between scientific reflection and emotions felt (themes 4 & 5) confirmed the need for a revolution in the praxis of learning through reflection: one with room for both cognitive and affective processes (Burga et al., 2017; Lozano, 2014; Shrivastava, 2010).

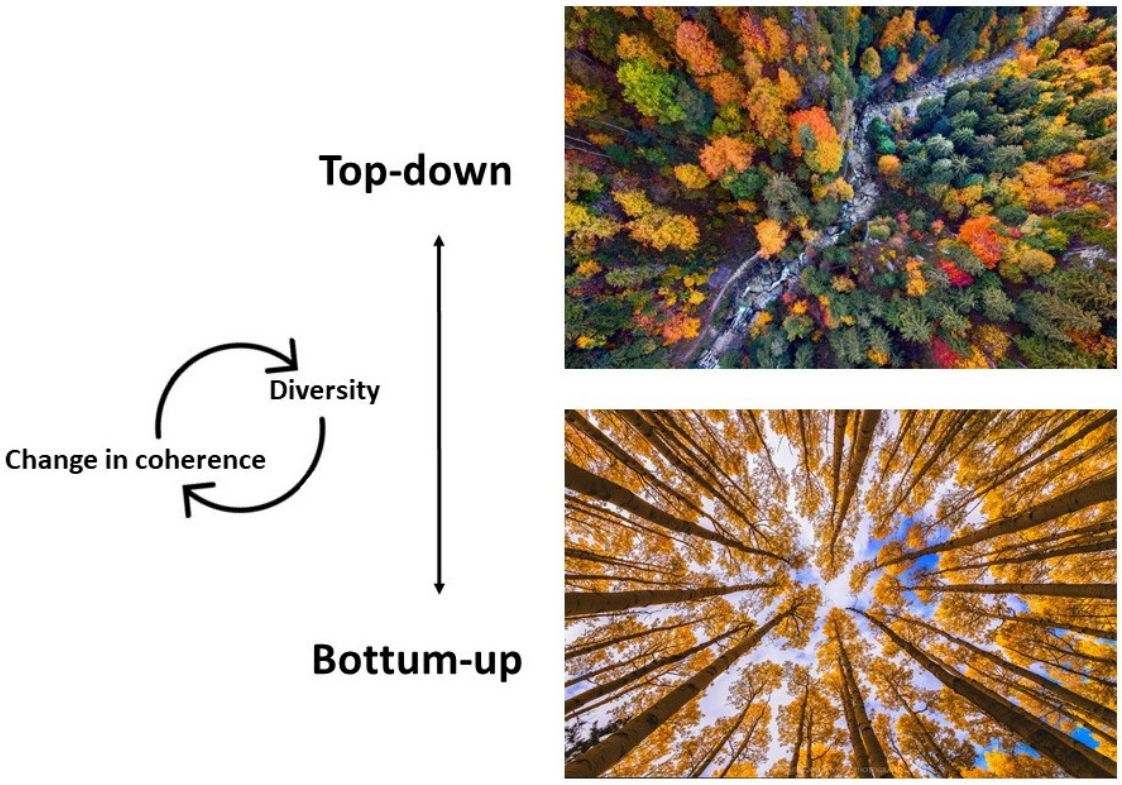


Figure 5.2: **Different bottom-up or top-down perspectives result in different evaluations of 'diversity' and the '(change) in coherence', two concepts that are both needed to 'capture' inter- and transdisciplinarity.**

As explained by Strathern (2007), the language used to discuss how to move in the continuum of inter- and transdisciplinarity is often limited by the language used, as practitioners need to use 'specialized vocabularies' that originate from personal disciplinary backgrounds. To transgress boundaries in communication, 'boundary objects' are suggested as useful: "Something that holds different meanings in different social worlds, yet is imbued with enough shared meaning to facilitate its translation across those worlds" (Strathern, 2007).

To define the purpose of the tool, the idea of using boundary objects to communicate different ways of seeing coherence and diversity in different 'holistic' and 'reductionist' contexts was connected to the importance of involving emotions in reflective practice. Fajans (2006) proposes that the emotion groups 'autonomy' and 'relatedness' are both critical for individual and (scientific) cultural practices, as they can be seen as both parts of the mental model and the individual identity (the basis of the theoretical framework used in this thesis to elucidate contextual influences, Fajans, 2006). Inspired by this, the respective emotion groups can be selected as the communicating language for the conversation partners to trigger each other and induce reflection on the ways contexts influence their perspectives (Figure 5.3).

Figure 5.3: **The dialectical relationship between the emotion groups 'autonomy' and 'relatedness' serves as an emotion language to discuss different ways of seeing 'diversity' and 'coherence'.**

5.4. Insights for tool development

In conclusion, Phase 2 has yielded the following valuable insights that will guide the subsequent stage of tool development, aimed at supporting the continuous cultivation of a 'holistic' mindset within 'the academic discipline of biotechnology':

- The themed findings obtained from the input session underscored various aspects of 're-connecting' within the academic discipline of biotechnology. One notable takeaway from the discussion was the recognition of the importance of distinctiveness within boundaries, emphasizing the need to preserve individuality while fostering connections. This insight carried direct implications for the development of a tool that promotes re-connection without compromising personal identity.
- The concept of boundary objects was introduced to facilitate communication across disciplinary boundaries. This can inform the design of the tool, ensuring its capacity to bridge the gap between different perspectives within the academic discipline of biotechnology.
- The role of emotions, particularly 'autonomy' and 'relatedness,' was considered as a universal language to trigger reflective conversations. On the basis of this, the tool should incorporate elements that engage these emotions, promoting meaningful interactions and discussions among biotechnology professionals.

Summary Chapter 5: Defining what can induce continuous cultivation of a 'holistic' mindset

Main take-away:

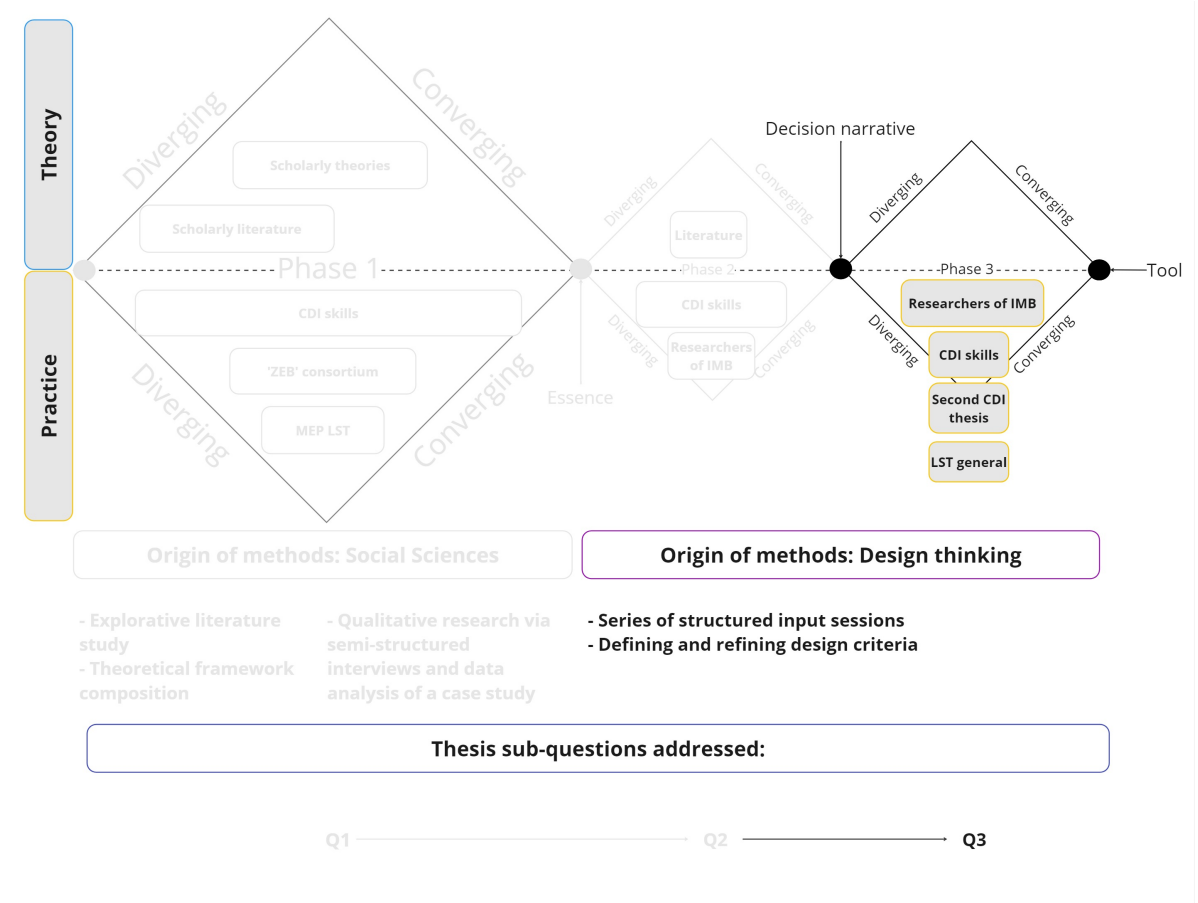
- The Phase described in this chapter involves divergent and convergent thinking to gain new insights via an input session, combining previous findings with additional literature, and defining the purpose of the tool.
- This phase has yielded the following final insights that will guide the subsequent stage of tool development:
  - The findings obtained from the input session underscored various aspects of 're-connecting' within the academic discipline of biotechnology. One notable takeaway from the discussion was the recognition of the importance of distinctiveness within boundaries, emphasizing the need to preserve individuality while fostering connections. This insight carried direct implications for the development of a tool that promotes re-connection without compromising personal identity.
  - The concept of boundary objects was introduced to facilitate communication across disciplinary boundaries. This can inform the design of the tool, ensuring its capacity to bridge the gap between different perspectives within the academic discipline of biotechnology.
  - The role of emotions, particularly 'autonomy' and 'relatedness,' was considered as a universal language to trigger reflective conversations. On the basis of this, the tool should incorporate elements that engage these emotions, promoting meaningful interactions and discussions among biotechnology professionals.

Link with Chapter 6:

- These insights will guide the development of the tool to support the cultivation of a 'holistic' mindset in the academic discipline of biotechnology, which is described in Chapter 6.

6

Tool design



This chapter describes Phase 3, in which research continues to employ divergent and subsequent convergent thinking, this time focusing on fine-tuning the purpose of the tool and designing the tool.

The primary objective is to assess how the tool, designed to support the continuous cultivation of a 'holistic' mindset within the academic discipline of biotechnology, aligns with the specific needs and requirements of the participants belonging to 'the academic discipline of biotechnology'. It aims to bridge both these insights and the insights gained during Phase 2 together with the practical development of a tool prototype. The overarching goal is to translate the theoretical foundations and ideas established thus far into a tangible instrument that can effectively catalyze the cultivation of a 'holistic' mindset within the biotechnology academic community.

Doing so, this phase addresses the final research sub-question:

Q3: *What tool can be used to support the cultivation of a more 'holistic' mindset of members of the academic discipline of biotechnology?*

Phase 3 attempts to bring together the theoretical foundations, insights from previous phases, and the practical implementation of a prototype tool. Through the tool design, it contributes to the overarching research question (Q):

Q: *How can members of the academic discipline of biotechnology be incited to continuously and consciously cultivate a more 'holistic' mindset suiting inter- and transdisciplinarity?*

6.1. Methods: Input session and prototyping

To evaluate whether the purpose of the tool resonated with the needs of participants in 'the academic discipline of biotechnology,' several key design criteria were established. These design criteria were formulated by the researcher based on the insights obtained at the end of Phase 2. They served as the basis for the subsequent input session, helping to guide the development of the tool prototype. Then, to gauge how well these design criteria and the purpose of the tool resonated with the specific needs of participants from the 'the academic discipline of biotechnology' and to gain new (**diverging**) insights, an input session was conducted. To **converge**, design criteria were refined and a prototype tool was made.

6.1.1. Design criteria and a 'decision narrative'

To evaluate whether the purpose of the tool resonated with the needs of participants in 'the academic discipline of biotechnology,' several key design criteria were established by the researcher:

1. **Contextual Relevance:** Building on the themed findings of Phase 2, which emphasized the importance of 're-connecting' within 'the academic discipline of biotechnology', the tool must be contextually relevant. It should address the specific needs and challenges faced by academics in the field while preserving individuality and fostering (inter- and transdisciplinary) connections.
2. **Facilitation of Creative and Comfortable Discussion:** The concept of 'boundary objects,' introduced in Phase 2, should inform the tool's design. The tool should facilitate creative and comfortable discussions, allowing participants to bridge the gap between different perspectives within the academic discipline of biotechnology.
3. **Integration of Personal Beliefs:** Given the role of emotions, particularly 'autonomy' and 'relatedness', in the findings of Phase 2, the tool should allow participants to integrate their personal beliefs and experiences into discussions. It should create a platform where personal experiences and emotions can be openly discussed. When doing so, the tool design should acknowledge the impact of contextual factors on shaping these individual beliefs, consistent with the insights obtained in Phase 2.

These design criteria, directly drawn from the insights of Phase 2, were encapsulated in a comprehensive 'decision narrative' (Appendix F) that depicts a specific scenario for tool usage.

To evaluate whether these design criteria resonated with the needs of participants in 'the academic discipline of biotechnology,' they were captured in a 'decision narrative' (Appendix F). The narrative describes one possible situation to use the tool: when you are intrinsically motivated to start a conversation about ongoing inter- and transdisciplinary attempts during a group meeting. The narrative emphasizes that, at the end of the meeting, the tool facilitated a process where both you and other participants engaged in discussions, aiming to reach a shared 'consensus mindset' suitable for transcending current boundaries and initiating change, as outlined in the model presented in Chapter 3 (Section 3.4.2):

"The tool made both you and other people 'recalibrate' a consensus mindset suitable to transgress current boundaries, combined with the underlying beliefs shaping it."

Thus, in this narrative, the tool serves as a catalyst for achieving this collective change in mindset.

6.1.2. Input session: Probing the decision narrative

To evaluate how the purpose of the tool (captured in a 'decision narrative') resonated with the needs of participants of 'the academic discipline of biotechnology', the 'decision narrative' (Appendix F) was probed through a second input session organized with three members (PhD'ers, postdocs and experienced technicians) of the group 'Industrial Microbiology' (IMB). The selection of three participants for this session was based on their availability and interest, consistent with the approach taken in the previous chapter.

The session lasted one hour and took place in a real-life setting, in a neutral meeting room at the TU Delft. Participants were invited by email and informed that their participation constituted consent for handwritten notes to be taken from their input, but no direct quotes were recorded.

The researcher's role during the session was that of an active facilitator, characterized by the use of nondirective probing questions to encourage thoughtful reflection and discourse and taking intensive notes. The questions asked were facilitated by a PowerPoint slide.

During the probing session, members were briefly introduced to the starting point of this thesis: the normative claim that scientists tackling complex issues need to adapt their perspective on science towards a more 'holistic' one, accompanied by moving towards inter- and transdisciplinarity via continuous reflection (Section 1.4). After this, they were asked to take some time to read the decision narrative and evaluate what it meant to them.

The following questions were then asked:

1. What did you think of the story?
2. Can you recognize yourself in the story?
3. Do you feel like you can initiate such an intervention about the mindset and beliefs described?
4. Do you think the described tool is useful in the context of research in the discipline of biotechnology?
5. Would you like to use the tool in a meeting as described, in smaller interactions, or maybe even on your own?
6. Do you think you can go 'meta' with this tool?
7. How would you envision this tool for yourself?

Per question, a discussion was held to discuss the various opinions and responses of the members in relation to the decision narrative they had just read.

Notes were analyzed based on whether they were in agreement with the first three design criteria. When they were not in agreement or when they indicated additional design criteria, summarized findings are presented in the next section of this thesis. This data analysis approach allowed for a comprehensive understanding of how the decision narrative and the tool's purpose resonated with the participants' needs, as well as any potential insights that emerged during the session.

6.1.3. Tool design

To develop a tool that is not only intuitive for participants in the consortium 'ZEB' (the case study) and members of the 'Industrial Microbiology' (IMB) group, but also for other academics of the discipline of biotechnology, the tool prototyping steps were carried out using a co-design approach: a researcher (student) developing a different tool as part of the Double Degree thesis for a similar context ('the academic sub-discipline of nanobiology') co-designed the tool for this thesis, and vice versa. Tool prototyping was performed according to the three steps described in this section.

Step 1: Explicating the purpose of the tool

In the first step of tool prototyping, a collaborative effort was made to clearly articulate the purpose of the tool. The process involved sharing a comprehensive summary of the research, including the main findings up to that point. Together, convergent thinking was applied to define a precise and meaningful purpose for the tool, aligning it with the research's overarching goal of promoting a 'holistic' mindset within 'the academic discipline of biotechnology'.

Step 2: Exploring shapes, textures, and colors
This step was crucial in ensuring that the tool's design was not only visually appealing, but also intuitively meaningful for participants in 'the academic discipline of biotechnology.' Various combinations of shapes, textures, and colors were explored. The goal was to create a design that resonated with the comfortable design criteria established earlier in the research. Shapes, textures, and colors were evaluated in terms of their potential to facilitate creative and comfortable discussions and integrate personal beliefs and emotions into the tool's usage. This step aimed to ensure that the tool's design would encourage open engagement and discussions among biotechnology professionals.

Step 3: Prototyping
The final step focused on prototyping. This involved brainstorming and experimenting with different ideas and design elements. It was an opportunity to play around with concepts and configurations, refining the tool's design based on the insights gained in the earlier phases. The focus was on creating a tangible tool prototype that effectively embodied the tool's purpose and design criteria. This iterative process allowed the development of a tool that not only addressed the specific needs of the case study consortium 'ZEB' and the group 'Industrial Microbiology' (IMB) but also addressed a broader audience within the academic discipline of biotechnology.

6.2. Design process

6.2.1. Input session: Probing the decision narrative

The probing session yielded two key design criteria based on the insights of the participants:

Design Criterion 4: Support for Minor Interactions and Individual Use

After reading the narrative and discussing questions 1-5, various members indicated that although they recognized themselves as intrinsically motivated to start a conversation about ongoing inter- and transdisciplinary attempts, they would often only do this in relatively small meetings. Instead, they preferred smaller meetings or informal interactions to start a discussion.

Further discussion of this preference elucidated that members felt strongly they needed to know exactly what they wanted to address about the mindset and inter- and transdisciplinary practice before using the tool in interactions. They expressed that they were uncomfortable using a tool that made previous experiences and emotions explicit before evaluating whether they wanted to share this in the different contexts of their academic life. If the tool would do this, they would prefer to use it independently.

Design Criterion 5: Establishing a Common Ground

When discussing questions 6 and 7, various members indicated that they felt that they themselves and their interacting partner would easily get lost when reflecting on the environment that influenced their mindset in an interactive manner (meta-reflection), and that the tool would therefore require many instructions. They agreed that meta-reflection was something they preferred to do on their own.

The members agreed that if the tool was going to be used in more minor interactions, the tool should help you define and visualize a common ground when 'recalibrating' the mindset of the interacting partners. This way, it would not be too uncomfortable for them to initiate a conversation about mindset.

6.2.2. Tool design

Step 1: Explicating the tool's purpose

Firstly, the main steps and insights of phase 1, phase 2 and the tool probing session were discussed. As a result, the following purpose was explained:

The tool facilitates mutual learning about how the people using it associate aspects of each of their mindsets in relation to inter- and transdisciplinarity, and why they do so, with an emphasis on their contextual influences.

As explained in Phase 2 (Chapter 5), this mutual learning is facilitated by evaluating both the 'diversity' and the 'coherence' associated with these aspects, communicated via the emotion groups 'autonomy' and 'relatedness' as a boundary object. Communication through emotion translates the associations to contextual influences. The principle of using these emotion groups instead of describing specific emotions felt leaves room for the users to determine for themselves how much they want to share, without losing the strength of the users re-connecting themselves with each other by recognizing themselves in the mindset-specific aspects introduced, or the feelings associated with it (a common ground).

As listening was indicated to be very important to prevent direct assumptions of strictly categorized identities, and allow a shift in 'openness-secrecy' dynamics, the tool's purpose of facilitation is also based on listening to each other (through an abstract emotion language) before an actual conversation about mindset is held through words (a context-specific language).

As suggested, conversation partners can trigger each other in a cognitive-affective manner and induce reflection on the ways contexts influence their perspectives. However, this reflective practice is not directly part of the tool's purpose. When participants are open to reflection when using the tool, it can have this direct effect. However, it can also indirectly inspire people who use it to reflect more comfortably outside of the interaction in which the tool is used.

Step 2: Exploring shapes, textures and colors
The process of exploring shapes, textures and colors resulted in the following realizations:

- Circles or cylinders intuitively represented a system capturing emotions, i.e. cells of microorganisms.
- The pink color intuitively represented emotions of 'relatedness'.
- The blue color intuitively represented emotions of 'autonomy'.
- When circles or cylinders can be positioned on top of each other, the order of doing so intuitively represented the relevance of feelings associated, i.e. the core of cells (DNA) is more important than the cell membrane.

Step 3: Prototyping
Using the insights of Steps 1 and 2, a prototype was designed for **'Out of Context'** (Figure 6.1, Figure H.1).

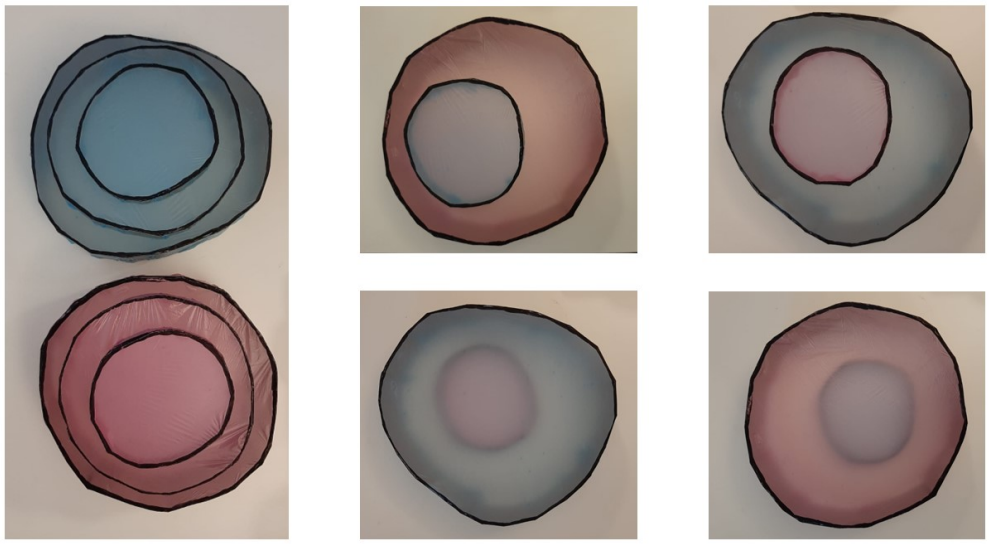


Figure 6.1: **The tool prototype: 'Out of Context'.** Various possibilities for step 2 of the instructions are photographed.

This tool, 'Out of Context,' is used according to the following instructions:

1. Person 1 writes down at least three aspects of the mindset linked to inter- and transdisciplinary practice, on separate pieces of paper, without saying a word.
2. Person 2 responds by doing the following:
    - Evaluating the emotions felt when reading the pieces of paper.
    - Reorganizing the pieces of paper according to the emotions felt.
    - Positioning one of the red circles (emotions of 'relatedness') and one of the blue circles (emotions of 'autonomy') on the pieces of paper according to the emotions felt. The order of positioning red and blue is up to person 2.
3. The conversation starts.

After this, the roles of both persons can be switched.

Summary Chapter 6: Tool design

Main take-away:

- Phase 3 focuses on designing a tool to promote the continuous cultivation of a 'holistic' mindset within the academic discipline of biotechnology.
- The methods for this study consisted of the following:
  - **Step 1: Explicating the purpose of the tool:** This step involves clarifying the precise purpose of the tool, focusing on mutual learning about the associations of mindset related to inter- and transdisciplinarity, contextual influences, and emotions. The purpose of the tool is built on the findings of Phase 2 and the insights obtained from the input session. The design criteria 'Contextual relevance', 'Facilitation of Creative and Comfortable Discussion' and 'Integration of Personal Beliefs' were established by the researcher. To evaluate whether these criteria resonated with the needs of participants in the academic discipline of biotechnology, they were captured in a 'decision narrative'.
  - **Step 2: Exploring shapes, textures, and colors:** During this phase, various visual elements, such as circles, colors, and textures, are explored to design a tool that intuitively represents emotions, autonomy, and relatedness.
  - **Step 3: Prototyping:** The final step focuses on the actual design and prototyping of the tool, translating the purpose and design criteria into a tangible instrument.
- The input session led to two additional design criteria:
  - **Design Criterion 4: Support for Minor Interactions and Individual Use:** Participants expressed a preference for using the tool in smaller meetings or informal interactions, emphasizing the need to know exactly what they wanted to address about their mindset and inter- and transdisciplinary practice.
  - **Design Criterion 5: Establishing a Common Ground:** Participants suggested that the tool should help define and visualize a common ground when 'recalibrating' mindsets during minor interactions to make conversations about mindset more comfortable.
- From this, the following was designed:
  - 'Out of Context' is the prototype tool designed to facilitate mutual learning about mindset associations with inter- and transdisciplinarity and contextual influences. It involves a simple process in which people write down aspects of their mindset, evaluate emotions related to these aspects, and engage in a conversation about them, using circles and colors to represent the emotions and 'autonomy' and 'relatedness'.

Link with Chapter 7:

- Chapter 7 is dedicated to the validation of the 'Out of Context' prototype tool.

7

Tool validation

This chapter is dedicated to the validation of 'Out of Context,' the developed tool, where the effectiveness and user-friendliness among members of 'the academic discipline of biotechnology' are assessed. Building on the findings and design process outlined in the previous chapter, the focus now shifts to the practical evaluation and validation of the tool. The primary objective is to ascertain whether 'Out of Context' effectively serves its intended purpose - i.e. facilitating mutual learning about how individuals associate aspects of their mindsets in relation to inter- and transdisciplinarity -, emphasizing their contextual influences, and whether it resonates with members of 'the academic discipline of biotechnology.'

This validation process aims to bridge the gap between theoretical design and real-world usability, focusing on the readiness of the tool for practical implementation. Through this process, research subquestion 3 (Q3) is addressed and, in turn, the overarching research question (Q) is responded to:

Q3: *What tool can be used to support the cultivation of a more 'holistic' mindset of members of the academic discipline of biotechnology?*

Q: *How can members of the academic discipline of biotechnology be incited to continuously and consciously cultivate a more 'holistic' mindset suiting inter- and transdisciplinarity?*

7.1. Validation approach

To validate whether the tool served the purpose stated and whether it was intuitive to use for members of 'the academic discipline of biotechnology', two tool validation sessions, each lasting 1 hour, were organized with members (PhD'ers, postdocs, and experienced technicians) of the 'Industrial Microbiology' (IMB) group. The selection of members participating in these sessions was based on their availability and interest in using a tool for the cultivation of a 'holistic' mindset. Three members participated in the first session, while two members participated in the second session.

The tool's instructions and questions asked were facilitated by PowerPoint slides, and the sessions took place in a real-life setting, in a neutral meeting room at the TU Delft. Participants were invited by email and informed that their participation constituted consent for handwritten notes to be taken from their input, but no direct quotes were recorded. The notes were analyzed based on direct responses of the participants to the questions asked. In addition, all points of improvement given are described in this chapter of the thesis.

During both validation sessions, members were briefly introduced to the starting point of this thesis: the normative claim that scientists tackling complex issues need to adapt their perspective on science towards a more 'holistic' one, accompanied by moving towards inter- and transdisciplinarity via continuous reflection. Following this introduction, the members were presented with the tool prototype and provided with detailed instructions on its use. Subsequently, they were tasked with engaging in discussions about mindsets that are conducive to inter- and transdisciplinarity using the tool.

Throughout this phase of the tool validation sessions, the researcher played a purely observational role after the initial introduction. Notes were taken to capture the reactions, thoughts, and behaviors of the participants at specific points during the use of the tool.

To systematically assess the effectiveness and adherence of the tool to the design criteria, a set of questions were initially posed to the participants. These questions aimed to verify whether the tool fulfilled the five design criteria established for it:

1. Did the tool exhibit contextual relevance within the academic discipline of biotechnology?
2. Was the tool successful in facilitating creative and comfortable discussions among participants?
3. Did the tool effectively integrate personal beliefs and experiences into the discussions?
4. Is the tool applicable to facilitate discussion in minor interactions in the academic discipline of biotechnology?
5. Did the tool assist in establishing a common ground when recalibrating mindsets during the discussion?

Furthermore, members were encouraged to provide direct feedback at the conclusion of each validation session, allowing them to express their impressions, opinions, and suggestions about the tool openly. Additionally, based on the detailed notes taken during the sessions, the researchers asked follow-up questions to gain deeper insights into the participants' experiences and perspectives. This comprehensive approach ensured a thorough examination of the tool's performance and its alignment with the research objectives. Finally, with permission to present their own words in this thesis, they were asked to send an email explaining their impression of using the tool.

7.2. Insights of the tool validation

All participants consistently and positively responded to the questions designed to test the alignment of the tool with the established design criteria. These responses affirmed the tool's effectiveness in meeting the criteria and its potential to support the cultivation of a 'holistic' mindset within the academic discipline of biotechnology.

As explained, members were also asked to give direct feedback after the initial questions were asked. In general, their feedback was positive. Here, some points are worth mentioning:

- Members noted that, after getting used to using the tool, they quickly started to relate to the red and blue circles or cylinders as something that represented their emotions;
- Increasing the circles' or cylinders' transparency would improve the tool, as it would enable the users to read still the mindset aspects written on the pieces of paper after the circles or cylinders are positioned on top of it;
- Members were very positive about the roles of person 1 and person 2 of the tool, as extroverted people who generally dominate conversations (the role of person 1) are forced only to write and first listen to the response of the other (person 2);
- Members suggested improving the tool's instructions by adding a note that the topic of discussion, i.e. the mindset, should be connected to the past, present or future.

In addition, members were asked to reflect on their experience with the tool and, voluntarily, send an email with their feedback after reflection to use anonymously in this report. This feedback (after reflection) was generally positive and indicated that the tool served its purpose (Appendix G). To illustrate:

"I think the game is very useful, as it made me contemplate about my approach to research and that, although I work closely with my colleague, we actually do not fully agree on certain aspects. The game made us realize this and sparked a conversation about how we could improve this. I can recommend the tool, it's simple but well thought out."

As these feedback points were considered valuable, they are all processed in the final manual (Appendix H), or recommended to be processed in the final tool design.

8

Discussion

This thesis started with the normative claim that scientists who tackle complex issues need to adapt their perspective on science to a more 'holistic' one, accompanied by moving toward inter- and transdisciplinarity through continuous reflection. It evaluated current attempts to do so, connected to the cultivation of a more 'holistic' mindset that suits this, from a social constructivism point of view, focused on the contextual influences of 'the academic discipline of biotechnology'.

In the first phase, a social science methodology was developed to explore the concept of mindset as a collection of individual and collective beliefs expressed by interviewed participants in the context of inter- and transdisciplinary practice. This exploration utilized a theoretical framework that encompassed a mental model perspective, theories related to social identity (complexity), cognitive dissonance, and the theory of learning through reflection. The research delved into the contextual influences on participants' current mindsets and their reflective practices for cultivating a more 'holistic' mindset.

Phase 1 findings highlight the profound influence of 'the academic discipline of biotechnology' on participants' mindsets. Diverse perspectives emerged regarding their research's connection to the 'technical implementation group.' These perspectives emphasized the varying impact of 'holistic' contexts on mindset-specific beliefs, particularly social inclusion. The participants predominantly leaned towards rational approaches in problem solving. Reflective practices revealed the multifaceted nature of fostering a 'holistic' mindset, marked by cognitive and affective processes, alongside a recognition of 'embeddedness' in the academic landscape. Consequently, the core concept of cultivating a more 'holistic' mindset in academics within the consortium studied was defined as "Re-connecting yourself".

8.1. Findings related to research sub-question 2

Based on the essence defined in phase 1, the divergent and convergent thinking of phase 2 employed a combination of methodologies to gather insights on the factors that can stimulate the continuous and conscious cultivation of a 'holistic' mindset among members of the academic discipline of biotechnology. This phase aimed to answer the following research sub-question:

Q2: *"According to members of the academic discipline of biotechnology, what can induce the continuous and conscious cultivation of a more 'holistic' mindset?"*

During the input session, several themes emerged that shed light on the multifaceted nature of 're-connecting' within the broader context of the academic discipline of biotechnology. These themes encompassed diverse aspects of re-connecting, including reconnecting with different research contexts, with fellow professionals, with one's own distinctiveness, with diverse aspects of oneself beyond rationality, and on a meta-level by considering how the academic environment influences reflective practices.

From the reiteration process with additional literature and previous insights from phase 1, insights for tool development were derived. These insights focused on the importance of preserving individuality within defined boundaries and facilitating communication through 'boundary objects.' Additionally, they highlighted the role of emotions, specifically 'autonomy' and 'relatedness,' as a universal language for stimulating reflective conversations. These insights served as initial design criteria for designing a tool that fosters the continuous cultivation of a 'holistic' mindset within the academic discipline of biotechnology, promoting individuality, effective communication, and emotional engagement among professionals.

8.1.1. Reflecting on methodology

A quantitative approach to broaden the context of research

As explained, the methodology employed in phase 2 - i.e. input session followed by an explorative literature search informed by the findings of the input session - aimed to extend the research scope beyond the confines of the consortium context explored in phase 1. In retrospect, considering the broader academic discipline of biotechnology, alternative approaches are worth considering. One potential avenue is a quantitative research design, which could offer a more generalized perspective. However, it is important to acknowledge that the input session conducted during this phase allowed participants to interact and respond to one another's viewpoints. This interactive element was a valuable aspect of the methodology, suggesting that focus groups or additional input sessions may also be valuable in future research endeavors. An alternative strategy might involve beginning with a quantitative approach to gather initial insights and then conducting focus groups to further explore and refine the findings, thus ensuring a comprehensive understanding of the research context.

Steering Literature Search and Potential Bias

In addition, the input session, which involved only four participants, played a pivotal role in steering the explorative literature search approach conducted in this phase. This raises considerations about the methodology's potential limitations. For instance, it can be argued that a quantitative research approach, as mentioned earlier, could have been better suited to guide the literature search for reiteration. Alternatively, an indirect quantitative approach could have been used, wherein the findings of a quantitative study were used as a foundation for input session discussions that subsequently informed the literature review.

Minimizing Researcher Bias in Literature Selection

Finally, reflecting on the methodology used in this phase, it is important to address the potential for researcher bias when selecting relevant literature, as the process of deciding which literature to include in the study could be susceptible to subjective judgment. To mitigate this bias, an alternative approach might involve involving a third researcher or collaborator, such as the other (student) researcher developing a different tool as parts of the Double Degree thesis for a similar (nanobiology) context, in the literature selection process. This approach would have reduced the impact of individual biases, ensuring a more objective selection of the literature that aligns with the research objectives.

8.2. Findings related to research sub-question 3

In phase 3, design-based research progressed toward the development and implementation of a tool aimed at cultivating a 'holistic' mindset within the academic discipline of biotechnology. This phase sought to address the following research sub-question:

Q3: *"What tool can be used to support the cultivation of a more 'holistic' mindset of members of the academic discipline of biotechnology?"*

In response to this sub-question, a prototype tool was made. This prototype drew upon the insights gathered from phases 1 and 2, capturing the essence of 're-connecting' within the academic discipline of biotechnology. The tool was designed as a facilitator and was designed to respect individuality, improve communication, and engage the emotional dimensions of academic professionals. It was envisaged as a catalyst for change, fostering a 'holistic' mindset by promoting reflection, adaptability, and a sense of interconnectedness within and outside of the academic context.

8.2.1. Reflecting on methodology

Confirmation of appropriateness of first three design criteria

The methodology for this phase was grounded in a collaborative approach, with a key input session conducted to gather feedback and refine the tool's design criteria. During this input session, the participants provided valuable insights that mainly contributed to the formulation of additional design criteria, numbered 4 and 5. The first three design criteria were found to resonate with participants, emphasizing the importance of preserving individuality and facilitating effective communication. However, in retrospect, it could have been beneficial to explicitly seek participants' agreement on these design criteria, ensuring alignment with their perspectives.

Selection of fellow researchers for the tool design process

Moreover, it is noteworthy that the tool design process was carried out collaboratively with a fellow researcher. This collaborative approach was intentional and aimed at minimizing the potential contextual biases of subgroups within the academic discipline of biotechnology. However, it should be acknowledged that both researchers were acquainted and shared a common academic background within the relatively small CDI group. In hindsight, involving an external expert with a design background, unaffiliated with the CDI context, could have enriched the tool development process by introducing fresh perspectives and mitigating potential contextual biases.

8.3. Reflecting on the theoretical framework of Phase 1

8.3.1. Social identity complexity

With the information gathered from the subsequent phases of this investigation, it is valuable to re-examine the theoretical framework that underpinned phase 1. As this theoretical framework, influenced by the perspective of social identity complexity, served as inspiration for this thesis' model for initiating change, it was woven throughout the entirety of the research. Therefore, it is important to critically reflect on whether various 'Ingroups' indeed hold the capacity to influence the "overall" social identity of academics in the discipline of biotechnology, or whether the disciplinary environment primarily shapes their social identity. Notably, the current academic literature generally lacks a strong focus on academics' professional identity and its role in the realm of inter- and transdisciplinarity. However, Bentley et al. (2019), in their exploration of "academic identity construction among doctoral students," found that:

"participants who were able to access multiple identity resources were more likely to perceive a navigable pathway to a future professional self (e.g., as an academic), unless they perceived these identities to be incompatible with those held by leading members of the profession (e.g., their supervisors)." (Bentley et al., 2019)

This finding suggests that the social identity complexity perspective, which this thesis has used, could indeed offer relevance in the evaluation of inter- and transdisciplinary approaches.

However, it is important to acknowledge that, with the limited existing literature utilizing this specific theoretical lens based on social identity complexity rather than traditional social identity theory, its true applicability remains to be confirmed through future research endeavors. As this research stands as an innovative exploration of the link between social identity complexity and inter- and transdisciplinary mindsets, it can serve as a source of inspiration for further investigations in this evolving field.

8.3.2. An alternative theoretical framework with motivational theories

In the second phase of this research, the significance of discussing 'diversity' and 'change in coherence' emerged as key factors for re-framing personal evaluations of inter- and transdisciplinarity. When considering the use of an emotion-based language as boundary objects in these discussions, two specific emotion groups, 'autonomy' and 'relatedness,' were selected to facilitate conversations among participants. In doing so, participants could be encouraged to (unconsciously) reflect on how contextual influences shape their perspectives on inter- and transdisciplinarity.

However, it's important to note that the concepts of 'autonomy' and 'relatedness' are not unique to this study; they are well-established components of motivational theories found in existing literature. Given this, it is worth reflecting on whether adopting motivational theories as the foundation for our theoretical framework could have provided similar insights more efficiently. While predicting the precise outcomes of an alternative theoretical lens is speculative, it is essential to consider the implications of this choice.

For instance, motivational theories such as Self-Determination Theory (SDT) are built around concepts such as 'autonomy', 'relatedness', and 'competence'. These theories offer a comprehensive framework for understanding human motivation, suggesting that individuals are driven by innate psychological needs for autonomy (the need to make choices and be in control), relatedness (the need to connect with others), and competence (the need to feel capable and effective) (Ryan and Deci, 2000). In contrast to the social identity (complexity) perspective, which assumes that contextual influences are not consciously experienced, SDT proposes that individuals actively seek environments that support their basic psychological needs, implying a conscious awareness of these influences.

This leads to the following question that is central to this thesis: Are contextual influences of motivational factors like autonomy and relatedness consciously experienced by members of academic participants in biotechnology, or would a theoretical framework based on motivational theories lead to a comparable interview setup and data analysis to indirectly deduce contextual influences? This critical reflection highlights the choices made in shaping the research perspective and the unique contributions that the social identity (complexity) perspective brings to understanding inter- and transdisciplinary mindsets.

8.4. Reflecting on the research and tool's relevance

8.4.1. About the tool

In the third diamond (Phase 3, Chapter 6), a tool ('Out of Context!') was developed with the following purpose:

"The tool facilitates mutual learning about how the people using it associate aspects of each of their mindsets in relation to inter- and transdisciplinarity, and why they do so."

Using the tool, conversation partners can trigger each other in a cognitive-affective manner, and induce a reflection on the ways contexts influence their perspectives. However, since the input of the 'decision narrative' probing session indicated that academics were uncomfortable using a tool that made previous experiences and emotions explicit before they had evaluated whether they wanted to share this in the different contexts of their academic life, this reflective practice is not a direct part of the purpose of the tool. When users are open to reflection when using the tool, it can have this direct effect. However, it can also indirectly inspire people who use it to reflect more comfortably outside of the interaction in which the tool is used.

Here, it is essential to recognize that the purpose of the tool does not inherently impose or spark reflection in an extrinsic manner. Instead, users must have the motivation and willingness to reflect. Therefore, to fully utilize the tool's potential for reflection, users must be encouraged to approach it while embracing the opportunity for self-reflection. By fostering an intrinsic motivation for reflection, the 'Out of Context!' tool can effectively contribute to cultivating a more 'holistic' mindset and promote meaningful discussions on inter- and transdisciplinarity. Here, it is important to note that this thesis did not specifically focus on assessing whether biotechnology professionals are intrinsically motivated to reflect on how contextual influences impact their perspectives. Future research endeavors may delve into this aspect, examining the level of motivation among biotechnology professionals to engage in such reflective practices and how tools like 'Out of Context!' can be tailored to suit their needs.

8.4.2. About the tool's validated relevance

As elaborately explained in this thesis report, specifying the process of tool development was done by diverging and converging with experiences from the researcher herself (technical thesis) and other academics of 'the discipline of biotechnology (participants of the 'ZEB', members of IMB, and a (student) researcher developing a different tool as part of the Double Degree thesis). As the tool validation was done with tool users that originated from the same academic groups, it must be noted that the validation did not fully test whether the tool was useful and intuitive to use for other general members of the academic discipline of biotechnology.' Although the validation provided valuable information within the specific academic context, future research efforts could expand the validation process to include a more diverse set of participants representing the broader academic discipline. This would allow for a more comprehensive assessment of the tool's usability and relevance beyond the confines of the specific groups involved in this study.

9

Conclusion

This thesis started with the normative claim that scientists who tackle complex issues need to adapt their perspective on science to a more 'holistic' one, accompanied by moving toward inter- and transdisciplinarity through continuous reflection. It evaluated current attempts to do so, connected to the cultivation of a more 'holistic' mindset that suits this, from a social constructivism point of view, focused on the contextual influences of 'the academic discipline of biotechnology'.

By using a mixed method design-based research approach (triple diamond model), three subsequent phases of divergence and convergence were executed: by translating the normative starting point to the essence of what is required to 'move towards inter- and transdisciplinarity' (first diamond); by translating the essence into insights for tool development (second diamond); and translating these insights to a tool prototype design (third diamond).

In the first phase, insights into the underlying mindsets of academics in the discipline of biotechnology and their engagement with inter- and transdisciplinary approaches were gained through qualitative interviews and in-dept analysis. The core concept of "Re-connecting yourself" emerged as a means to cultivate a more 'holistic' mindset within this academic discipline.

These insights were reiterated in the second phase, focusing on defining the factors that can continuously cultivate a 'holistic' mindset within the academic discipline of biotechnology. This resulted in three key findings: Firstly, the importance of preserving individuality while fostering connections within the academic discipline became apparent, emphasizing the need to create a tool that promotes 're-connection' without compromising personal identity. Second, the concept of boundary objects, which facilitate communication across disciplinary boundaries, emerged as a valuable guiding principle for tool design, ensuring that it bridges gaps between various perspectives within biotechnology. Third, emotions, particularly 'autonomy' and'relatedness', were identified as universal triggers for reflective conversations. These insights indicated that the tool design should incorporate elements that engage these emotions, promoting meaningful interactions among biotechnology professionals.

In the third phase, these findings in addition to more input were processed into five design criteria for a tool designed to facilitate cognitive-affective reflection: Contextual Relevance, Facilitation of Creative and Comfortable Discussion, Integration of Personal Beliefs, Support for Minor Interactions and Individual Use, and Establishing a Common Ground. Using these criteria, the 'Out of Context!' tool prototype was designed, whose objective was to facilitate the continuous development of a 'holistic' mindset and support interdisciplinary practices among biotechnology professionals. However, it was evident that intrinsic motivation for reflection is crucial for the tool's efficacy. The willingness to engage in self-reflection remains with the individuals themselves.

In conclusion, the findings of this thesis have illuminated the intricate relationship between mindsets, contextual influences, and inter- and transdisciplinary practices within the academic discipline of biotechnology. The initial normative claim, advocating for a 'holistic' perspective and continuous reflection, remains not only relevant but also more precisely defined. Alltogether, this research serves as a foundation, inviting further exploration into the conscious experiences of contextual influences and the motivational aspects driving academic professionals to reflect on their inter- and transdisciplinary practices.

10 Outlook

The research performed for this thesis indicates two recommendations as outlooks to discuss.

Reporting constructive (re-)defining of inter- and transdisciplinarity
This research provides a relatively unique approach to studying the current academic transition towards inter- and transdisciplinarity: it evaluates this transition, connected to the cultivation of a more 'holistic' mindset, from a social constructivism point of view. It has shown that studying participants' experiences attempting to practice inter- and transdisciplinarity can provide valuable insights concerning what it means to bridge theory and practice. Therefore, it is recommended for practitioners to report more about their experiences and respond to the reports of others.

Tool recommendation
The tool developed via this thesis offers a new, sustainable way for its users to learn how and why they and their discussion partners associate aspects of their mindsets in relation to inter- and transdisciplinarity. However, to use it, academics in the discipline of biotechnology need to be aware of the existence of the tool and be convinced about its contribution. To achieve this, the tool must initially be recommended to academics who have a leadership role (PIs, professors, etc.) in biotechnological research with an (applied) societal purpose. Of course, before recommendations can happen, the tool's contribution to discussions about the 'holistic' mindset must be evaluated more extensively.

11

Reflection

Interest in 'Holistic' Thinking:
The topic of this thesis aligns closely with my personal interests. I have always wondered why research in biotechnology tends to be relatively compartmentalized, with a focus on well-defined boundaries. My education in biotechnology rarely explored the idea of zooming out or addressing the complexities of a broader context. Conducting this research has revealed that the motivation to zoom out and embrace 'holistic' thinking is not widespread in the context of biotechnology. However, it has also shown that there are people who share my curiosity and interest in navigating this uncharted territory. They are still exploring how to integrate these perspectives into their careers, just as I am.

Challenges of Combining Research Projects:
Combining this research with a technical thesis was challenging. One of the difficulties I encountered was articulating the insights gained from the experiences of the technical thesis within the context of this research, as the technical work was subject to confidentiality constraints. Additionally, balancing time and effort between both projects and switching between relatively reductionist thinking and 'holistic' thinking presented its own set of challenges. Yet, this experience has underscored the importance of bridging the gap between reductionism and holism, ultimately, at least for me, emphasizing the need for more 'holistic' perspectives in biotechnology and beyond.

Conceptualization and Operationalization:
This research was based on a specific conceptualization and operationalization of the abstract and nontangible concept of mindset in relation to various interpretations of inter- and transdisciplinarity and 'holistic' science. As a result, it was challenging to achieve a suitable conceptualization and operationalization to study mindset. Looking back at the results, it becomes evident that conceptualization and operationalization were appropriate and yielded valuable insights. However, it also required much interpretation by the researcher performing the data analysis. Upon reflection, the experience of doing this thesis sparks curiosity about alternative approaches to conceptualization and operationalization utilized in different fields.

Embracing 'Holistic' Thinking:
As indicated, the foundation of this thesis was built upon the normative claim that scientists attempting to tackle complex societal issues ought to adapt their perspective on science towards a more 'holistic' approach, accompanied by a transition towards inter- and transdisciplinarity through continuous reflection. Through the experiences gained during this research, it became evident that individuals often resist this notion, mistakenly believing that they must constantly possess a 'holistic' perspective. However, their enthusiasm for embracing this transition grew when they realized that they could constructively shape their approach. This insight led to reflection on the role of science communicators in this transition and emphasized the value of highlighting the constructive aspect when persuading academics to embark on this journey.

Developing a Tool for 'Holistic' Thinking:
This research resulted in a notable observation regarding the divergent perspectives on inter- and trans-disciplinarity among professionals. Surprisingly, for academics other than the interviewed participants of the case study, there was a lack of inclination to engage in discussions about these disparities: they seemed intimidated by the complications of discussing vaguely determined concepts. Therefore, it was satisfying to develop a tool that encourages individuals to think more 'holistically', even without requiring them to explicitly delve into the intricacies of inter- and transdisciplinarity. This realization has been a gratifying outcome of the technical thesis, as it indicates that people are more willing to embrace 'holistic' thinking when it is not presented as an abstract and daunting concept. Instead, the tool fosters 'holistic' insights through a more accessible pathway, focusing on the broader scope of science, tackling complex problems, and fostering collaboration with fellow researchers.

12

Acknowledgements

I express my sincere gratitude to the following individuals and groups for their invaluable contributions to the completion of my thesis:

First and foremost, I extend my heartfelt thanks to Éva Kalmár, my first supervisor. I am deeply grateful for the unwavering support and insightful guidance provided during our regular meetings.

I would also like to extend my gratitude to Caroline Wehrmann and Marieke Klijn for their crucial roles as members of my thesis committee. Their feedback during the official Green Light moment was instrumental in shaping this research.

I am grateful to all the members of 'The Towards Zero-Emission Biotechnology Consortium' for their willingness to participate in interviews, which significantly enriched the quality of my work.

Last but not least, I wish to thank the research group of 'Industrial Microbiology' for their flexibility and the inspiration they provided throughout my Double Degree Thesis journey. Their participation in the input sessions was invaluable to my research.

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A

Appendix 1: Hits of explorative literature search

A.1. Explorative literature search performed to outline the perspective on 'inter- and transdisciplinarity' and 'holistic' mindsets

Search terms	Hits Scopus	Hits Web of Science
Mindset & Transdisciplinary	66	55
Mindset & Transdisciplinary & Paradigm	6	8
Mindset & Interdisciplinary & Paradigm	20	23
Mindset & Consciousness	207	172
Mindset & Biotechnology	50	51
Mindset & Transdisciplinary & Sustainability	23	25
Mindset & Interdisciplinary & Sustainability	33	38
Mindset & Transdisciplinary & Complexity	10	8
Mindset & Interdisciplinary & Complexity	38	29
Mindset & Academics & Transdisciplinary	10	6
Mindset & Academics & Interdisciplinary	48	44
Mindset & Academics & Complexity	70	38
Mindset & Discipline & Transdisciplinary	13	10
Mindset & Discipline & Interdisciplinary	83	61
Mindset & Discipline & Complexity	41	28

A.2. Explorative literature search performed to outline the concept and theory of 'continuous reflection'

Search terms	Hits Scopus	Hits Web of Science
Transdisciplinary & Transformative & Reflection	56	54
Interdisciplinary & Transformative & Reflection	100	104
Transdisciplinary & Reflexivity & Transformative	24	22
Interdisciplinary & Reflexivity & Transformative	15	16

A.3. Explorative literature search performed to select theories to consider to compose a theoretical framework and place it within a model for initiating transformative change through reflection

Search terms	Hits Scopus	Hits Web of Science
Transdisciplinary & Constructivism	30	28
Interdisciplinary & Constructivism & Theory	91	105
Transdisciplinary & Contextual & Perception	11	20
Transdisciplinary & Contextual & Theory	43	47

B

Appendix 2: Interview protocol

Main part for all participants

Introduction about thesis (4 min)

This interview is part a research study that tries to identify how insights about the mindset of academic participants of the biotechnology discipline can improve the discipline's transdisciplinary practices to solve complex sustainability problems. The purpose of this interview is to evaluate how you as a participant of the Towards Zero Emission Biotechnology consortium program see your mindset in relation to different research collaboration possibilities and practices. From now on I will refer to this group with you as participant by 'ZEB'.

Part 1 of this interview will first focus on how you see yourself, your research collaboration practices, and your mindset in the context of being an academic in 'ZEB'. Here, the focus is on your own representation, which cannot be right or wrong. In **Part 2** of the interview, unusual visuals are given, and the questions asked will focus on reflecting on your initial answers. In **Part 3** of the interview, questions will focus on whether you feel like you have reflected and on how aspects or characteristics of the biotechnology discipline influence these reflection possibilities generally.

Helping aids

In front of you, you'll find a pen and paper. If you want to, you can use this to draw or write down elements that, for instance, help you think. However, as the interview will be analyzed on what you express in words, you are asked to still answer questions verbally.

Consent points

- **Q1:** Are you okay with me recording both video and audio, used to make anonymized transcripts? (Yes/No)
  - If not: Are you okay with me recording only the audio of this interview, which is used to make anonymized transcripts? (Yes/No)

As stated in the informed consent form, no questions directed to sensitive or confidential information will be asked. In addition, you are free to demand specific (parts of) answers to be removed when sensitive or confidential information is shared by accidence.

You are free to do this any time during the interview. However, to ensure that you can keep focusing on the questions asked without reflecting on possible sensitivity or confidentiality, you will be given time to reflect on your answers at the end of the interview. After this, you will be explicitly asked if you want specific parts to be removed from the transcript.

- **Q2:** Do you have any questions at this point you would like to ask? (Yes/No)

Part 1: Mental model elucidation

Complex issue (4 min)

The first questions are focused on one of the goals of 'ZEB', which is 'trying to convert resources to products, while minimizing emission or maximizing utilization of CO_2'.

- **Q3:** Can you describe how you see the issue for which reaching this goal serves as a solution? (Elaborate answer)
- **Q4:** To what extent do you think this issue is complex, or in other words, that it is interconnected with many things? (Elaborate answer)
- **Q5:** Do you think that other people trying to come up with a solution define the problem the same way as you do? (Yes/No/Elaborate answer)
  - If no: Where do you expect their definition to differ from yours?

Response to uncertainty and ambiguity (1 min)

- **Q6:** How do you generally respond to uncertainties or ambiguity related to an issue?

From this moment, when questions refer to the (complex) issue, your personal description of the issue or 'problem' is meant. This is different from the goal of ZEB, which is a solution.

Collaboration types (8 min)

The following questions will focus on how you think collaborations set up for 'ZEB' are happening at this moment, and what results they have or will have. Each time, a statement will be introduced. Then, you will be expected to say to what extent you agree with this statement.

- **Q7/statement 1:** Collaborations set up for 'ZEB' only happen within disciplines or sub-disciplines. (Agree/Disagree/Something in between)
- **Q8/statement 2:** Collaborations set up for 'ZEB' happen between members stemming from different disciplines, each analysing the issue from the perspective of their individual discipline. (Agree/Disagree/Something in between)
- **Q9/statement 3:** Collaborations set up for 'ZEB' result in integrating different perspectives or theoretical frameworks from members stemming from different disciplines. (Agree/Disagree/Something in between)
- **Q10/statement 4:** Disciplines and sub-disciplines that are connected to 'ZEB' are coordinated via hierarchical levels, in which higher levels gives a sense of purpose to lower levels. (Agree/Disagree/Something in between)
- **Q11/statement 5:** Collaborations set up for 'ZEB' result in co-creation or co-design together with non-academic actors. (Agree/Disagree/Something in between)
- **Q12/statement 6:** Interactions within collaborations set up for 'ZEB' are mutually affective for collaboration participants, uncovering underlying assumptions, values and uncertainties related to the (complex) issue. (Agree/Disagree/Something in between)
- **Q13/statement 7:** Collaborations set up for 'ZEB' result in participants acknowledging multiple levels of reality, accompanied by different modes of reasoning and spirituality aspects such as feeling and intuition. (Agree/Disagree/Something in between)

Social identity complexity (8 min)

The following questions will focus on how you see the relationship between two social groups. One of them is 'the discipline of biotechnology', which we will call 'Group A'. The other social group is 'the group of which its members are trying to tackle your description of the (complex) issue'. So, this group exists of all members trying to solve the problem as you see it. We call this group, 'Group B'.

- **Q14:** Do you feel like you are a member of 'Group A'? (Yes/No)

- **Q15:** Do you feel like you are a member of 'Group B'? (Yes/No)
- **Q16:** Of persons within 'Group A', how many do you think are also in the 'Group B'? (Estimation)
- **Q17:** To what extent do you think a typical person of 'Group A' is similar to a person of 'Group B'? (Estimation)

There exist different ways in which people see or picture the relationship between their membership of two social groups. For the next question, cards with both a visual representation and a verbal description of each way to see this relationship will be handed to you. After you've looked at each, you can lay them on the table.

- **Q18:** From the options given, how do you think the relation between both your memberships can be best represented? (Participant picks one)
  - Can you elaborate on why you choose this representation? (Elaborate answer)

Mindset and interconnections (10 min)
The following questions will focus on how you see your mindset.

- **Q19:** Can you describe what the concept 'mindset' means to you? (Elaborate answer)
- **Q20:** How do you think your current mindset relates to your description of the (complex) issue? (Elaborate answer)
- **Q21:** How do you think your current mindset relates to the type of collaborations set up for 'ZEB' that are currently happening? (Elaborate answer)
- **Q22:** How do you think your current mindset relates to how you see the relationship between your membership in 'Group A' and 'Group B'? (Elaborate answer)

Part 2: Reflection triggers
Now, we're at Part 2 of the interview. In this part, two unusual visuals are given. For each, questions asked will focus on reflecting on your answers of Part 1.

Trigger 1: "Research for a shared future ideal" (8 min)
- **Q23:** What do you think these words in combination with the artwork represent? (Elaborate answer)
- **Q24:** Do these words in combination with the art work raise a specific emotion or feeling for you? (Yes/No)
  - What is this emotion or feeling? (Answer)
- **Q25:** If you think about how you see this artwork (and the emotion/feeling you have), do you want to add something to how you earlier described the (complex) issue? (Answer)
- **Q26:** If you think about how you see this artwork (and the emotion/feeling you have), do you want to change something in the collaborations set up for 'ZEB'? (Answer)
- **Q27:** If you think about how you see this artwork (and the emotion/feeling you have), do you want to pick a different representation of the relation between your memberships in 'Group A' and 'Group B'? (Answer)
- **Q28:** If you think about how you see this artwork (and the emotion/feeling you have), do you want to change an aspect of your mindset in relation to 'ZEB'? (Answer)

Trigger 2: "Responsibility and expertise for the ecosystem" (8 min)

- **Q29:** What do you think these words in combination with the artwork represent? (Elaborate answer)
- **Q30:** Do these words in combination with the art work raise a specific emotion or feeling for you? (Yes/No)
  - What is this emotion or feeling? (Answer)
- **Q31:** If you think about how you see this artwork (and the emotion/feeling you have), do you want to add something to how you earlier described the (complex) issue? (Answer)
- **Q32:** If you think about how you see this artwork (and the emotion/feeling you have), do you want to change something in the collaborations set up for 'ZEB'? (Answer)
- **Q33:** If you think about how you see this artwork (and the emotion/feeling you have), do you want to pick a different representation of the relation between your memberships in 'Group A' and 'Group B'? (Answer)
- **Q34:** If you think about how you see this artwork (and the emotion/feeling you have), do you want to change an aspect of your mindset in relation to 'ZEB'? (Answer)

Part 3: Meta-reflection (9 min)

Now, we're at part 3 of the interview. The questions of this part will focus on whether you feel like you've reflected and on how aspects or characteristics of the biotechnology discipline influence such reflection possibilities generally.

- **Q35:** Did part 1 and part 2 of the interview cause you to reflect on what type of mindset is required to responsibly or ethically collaborate in research to solve complex issues? (Yes/No)
  - If yes: Was this reflection caused by artworks and words linked to it presented, or by one of the artworks and words linked to it presented? (Yes by both/Yes by one of the two/no)
    - If only one: Which of the artworks and words linked to it caused you to reflect? (Answer)

Questions for participants indicating reflection did not happen

- **Q36:** Why do you think reflection did not happen? (Elaborate answer)
- **Q37:** Were you able to relate artwork 1 and the words linked to it to your role or responsibility linked to the issue addressed by 'ZEB'? (Yes/No)
- **Q38:** Were you able to relate artwork 2 and the words linked to it to your role or responsibility linked to the issue addressed by 'ZEB'? (Yes/No)
- **Q39:** Why do you think the artworks and the words linked to it did not cause you to reflect? (Elaborate answer)

Now, we're almost at the end of the interview.

- **Q40:** When you evaluate your answers given, do you want specific parts to be removed from the transcript? (Answer)
- **Q41:** Do you have any remaining remarks you would like to give? (Answer)

Thank you again for participating. I will stop the recording.

Questions for participants indicating reflection happened, but none of the triggers caused reflection

- **Q36:** What did cause you to reflect? (Elaborate answer)
- **Q37:** Were you able to relate artwork 1 and the words linked to it to your role or responsibility linked to your description of the (complex) issue? (Yes/No)
- **Q38:** Were you able to relate artwork 2 and the words linked to it to your role or responsibility linked to your description of the (complex) issue? (Yes/No)
- **Q39:** Do you think such a reflection is valuable for academics who are a member of the 'discipline of biotechnology'? (Yes/No)
  - Why/why not? (Elaborate answer)
- **Q40:** Do you generally reflect on what type of mindset is required to responsibly or ethically collaborate in research to solve complex problems? (Yes/No)
  - Why/why not? (Elaborate answer)
- **Q41:** Are there aspects or characteristics of the 'discipline of biotechnology' that can limit these type of reflections? (Elaborate answer)
- **Q42:** Are there aspects or characteristics of the 'discipline of biotechnology' that can support these type of reflections? (Elaborate answer)

Now, we're almost at the end of the interview.

- **Q43:** When you evaluate your answers given, do you want specific parts to be removed from the transcript? (Answer)
- **Q44:** Do you have any remaining remarks you would like to give? (Answer)

Thank you again for participating. I will stop the recording.

Questions for participants indicating 1 of the two triggers caused reflection

- **Q36:** Were you able to relate artwork (1/2) and the words linked to it to your role or responsibility linked to your description of the (complex) issue? (Yes/No)
- **Q37:** Why did artwork (1/2) and the words linked to it cause you to reflect? (Elaborate answer)
- **Q38:** Do you think such a reflection is valuable for academics who are a member of the 'discipline of biotechnology'? (Yes/No)
  - Why/why not? (Elaborate answer)
- **Q39:** Do you generally reflect on what type of mindset is required to responsibly or ethically collaborate in research to solve complex problems? (Yes/No)
  - Why/why not? (Elaborate answer)
- **Q40:** Are there aspects or characteristics of the 'discipline of biotechnology' that can limit these type of reflections? (Elaborate answer)
- **Q41:** Are there aspects or characteristics of the 'discipline of biotechnology' that can support these type of reflections? (Elaborate answer)

Now, we're almost at the end of the interview.

- **Q42:** When you evaluate your answers given, do you want specific parts to be removed from the transcript? (Answer)
- **Q43:** Do you have any remaining remarks you would like to give? (Answer)

Thank you again for participating. I will stop the recording.

Questions for participants indicating both triggers caused reflection

- **Q36:** Why did artwork 1 and the words linked to it cause you to reflect? (Elaborate answer)
- **Q37:** Why did artwork 2 and the words linked to it cause you to reflect? (Elaborate answer)
- **Q38:** Do you think such a reflection is valuable for academics who are a member of the 'discipline of biotechnology'? (Yes/No)
  - Why/why not? (Elaborate answer)
- **Q39:** Do you generally reflect on what type of mindset is required to responsibly or ethically collaborate in research to solve complex problems? (Yes/No)
  - Why/why not? (Elaborate answer)
- **Q40:** Are there aspects or characteristics of the 'discipline of biotechnology' that can limit these type of reflections? (Elaborate answer)
- **Q41:** Are there aspects or characteristics of the 'discipline of biotechnology' that can support these type of reflections? (Elaborate answer)

Now, we're almost at the end of the interview.

- **Q42:** When you evaluate your answers given, do you want specific parts to be removed from the transcript? (Answer)
- **Q43:** Do you have any remaining remarks you would like to give? (Answer)

Thank you again for participating. I will stop the recording.

C

Appendix 3: Attribute and magnitude coding

Question(s)	Attribute codes
Part 1, Q14: Do you feel like you are a member of group A	Yes, no (based on answer as expressed)
Part 1, Q15: Do you feel like you are a member of group B?	Yes, no (based on answer as expressed)
Part 1, Q17: To what extent do you think a typical person of group A is similar to a person of group B?	Similar (S), unclear (U), dissimilar (D) (S & D based on answer as expressed, otherwise U)
Part 1, Q18: From the options given, how do you think the relation between both your memberships can be best represented?	Intersection (I), dominant A (DA), dominant B (DB), compartmentalization (C), merger (M) (based on answer as expressed)
Part 2, Q24 & Q30: Do these words in combination with the artwork raise a specific emotion or feeling for you?	Cognitive reflection (CR), cognitive-affective reflection (C-AR) (CR when answered with 'no', C-AR when answered with 'yes')
Part 2, Q25 – Q28 & Q31 – Q34 (questions focused on whether participants wanted to change each of the topics discussed in part 1)	Change (C), not change (NC) (based on answer as expressed)
Part 3, Q35: Did part 1 and part 2 of the interview cause you to reflect on what type of mindset is required to responsibly or ethically collaborate in research to solve complex issues?	No reflection (NR), reflection not induced by visuals (R), reflection induced by visual 1 (RV1), reflection induced by visual 2 (RV2), reflection not induced by both visuals (RV) (based on answer as expressed)

Question(s)	Magnitude codes
Part 1, Q4: To what extent do you think this issue is complex, or in other words, that it is interconnected with many things?	High, low, medium (based on adjectives expressed in answer indicating magnitude, such as: 'very' & 'extremely' for high, 'a little', 'a bit' for low and 'quite' or no adjective for medium)
Part 1, Q5: Do you think that other people trying to come up with a solution define the problem the same way as you do?	High, low, medium (based on adjectives expressed in answer indicating magnitude, such as: 'very' & 'extremely' for high, 'a little', 'a bit' for low and 'quite' or no adjective for medium)
Part 1, Q7 – Q13 (statements of inter- and transdisciplinary attributes as suggested by scholars)	Completely agree (CA), leaning towards agree (LTA), neutral (N), leaning towards disagree (LTD), completely disagree (CD) (based on one of the following expressed: completely agree or agree for CA, partly agree while emphasizing more agreement compared to disagreement for LTA, U when arguments for both agreeing and disagreeing are expressed, partly agree while emphasizing more disagreement compared to agreement for LTD, completely disagree or disagree for CD)
Part 1, Q16: Of the persons within group A, how many do you think are also in group B?	Very high (80-100%), high (60-79%), medium (40-59%), low (20-39%), very low (0-19%) (based on answer as expressed)

D

Appendix 4: Data analysis showcases

D.1. Mental model elucidation

The data analysis of this thesis used for mental model elucidation was based on a (fuzzy cognitive) mapping process: Using the online software of Miro, in vivo, concept and values codes of Part 1 of each interview were mapped based on the causal reasoning of each participant.

D.1.1. Theming code groups and causal relations in reasoning

In this step, the interviews transcript codes from various sections, including A) the complex issue, B) response to uncertainty/ambiguity, C) collaboration types, D) social identity complexity, and E) mindset and interconnections, were thematically organized.

Transcript sections A & B and codes:
I: Interviewer
P5: Participant 5

0:06:0.150 - 0:06:17.820
I: So, the first questions are focused on the goals of 'ZEB', or [on] one of the goals of 'ZEB', which is 'trying to convert resources to products while minimizing emission or maximizing utilization of CO2'.

P5: Yeah.

I: Can you describe how you see the issue for which reaching this goal serves as a solution?

0:06:18.680 - 0:07:10.150
P5: It probably the **single most important problem today that we're facing as humanity**. So, you know… **I think that all humanity needs to address this issue from many different disciplines**… You know… Starting from policy change, to the economic model and the economic system… To technological solutions to [the] actual problems that, you know, the actual problem is generating: **Waste and harmful gases that are destroying the climate and planet**. So, **one of the vectors to solve that is technology**, [but] not the only one.

I: Yeah, Okay. Thanks.

In vivo codes:

- single most important problem today that we're facing as humanity
- I think that all humanity needs to address this issue from many different disciplines
- Waste and harmful gases that are destroying the climate and planet

- one of the vectors to solve that is technology

Concept codes:

- Big problem
- Different perspectives
- Value of different perspectives
- Waste and consequences

Values codes:
B: Belief; V: Value; A: Attitude

- B: Collaboration between disciplines increases changes of success (Implicit)
- V: Cross-(sub)disciplinary collaboration (Explicit)
- V: Talking about perspectives (Implicit)
- B: Technology is one of the vectors required to solve the solution (Explicit)

0:07:11.290 - 0:07:17.670
I: And to what extent do you think this issue or problem is complex, meaning that it's interconnected with many things?

0:07:18.610 - 0:07:51.130
P5: Well, **it's connected with everything… With every human activity, right?** Right now, most of the activities… You know… **Everything that humans do requires energy. And right now… Most of our energy… We generate by burning fossil fuels.** So, it's connected to everything, basically.

I: So, you would say it is complex?

0:07:54.110 - 0:08:34.410
P5: It's extremely complex. Yeah. Also, part of the complexity is that… It is some… It is a problem that is common to everybody. So, [it] is a comments problem, right? We need to **collectively solve it** and **everybody has to participate**. That's also part of the complexity and **the social issue of having to agree**, right? Well, there's some stakeholders that could say… Well, you know, "I'm just going to follow my own interest". [This is a] short term interest, which is… You know, making more money or whatever… Uh, and you know…?

0:08:35.930 - 0:08:38.200
I: Yeah, sure. Yeah, that's clear. Thanks.

In vivo codes:

- it's connected with everything… With every human activity, right?
- Everything that humans do requires energy. And right now… Most of our energy… We generate by burning fossil fuels
- collectively solve it
- everybody has to participate
- social issue of having to agree

Concept codes:

- Complex problem itself

Values codes:
B: Belief; V: Value; A: Attitude

- B: Complexity is reflected in a connection with every human activity (Implicit)
- B: We need to collectively solve it (Implicit)
- B: We have to agree (Implicit)

0:08:39.620 - 0:08:46.140
I: And do you think that other people trying to come up with a solution define the problem the same way as you do?

0:08:50.420 - 0:09:33.100
P5: … Umm, yeah. Probably not. I mean… In the same way... What? What does that mean? So… You know… [It] depends. There's many problems, and there's many underlying problems. So, **people are looking at different aspects of this problem**, right? And there's people looking at **policy changes**, at how… You know… **How to organize the economic system to benefit [the] climate**… How to… In our case: How to **develop new technologies**, so that there's different people [that] are **looking at different underlying problems that require different types of solutions**.

0:09:34.760 - 0:09:36.640
I: Yeah, okay. That's really clear. Thanks.

In vivo codes:

- people are looking at different aspects of this problem
- policy changes
- How to organize the economic system to benefit [the] climate
- develop new technologies
- looking at different underlying problems that require different types of solutions

Concept codes:

- Different general issue description
- Technical/scientific approach

Values codes:
B: Belief; V: Value; A: Attitude

- B: The problem has many underlying problems that require different solutions (Explicit)

0:09:36.830 - 0:09:44.360
I: And how do you generally respond to uncertainties or ambiguity related to a problem?

0:09:52.870 - 0:10:19.400
P5: … You know… **Doing science is, basically, facing uncertainty all the time**. **If you're not facing uncertainty, that means you're not doing good science**. So… Well, you try to come up with a strategy to solve the ends… To remove the uncertainty, basically… To find some certainty. That's from the scientific point of view, right?

0:10:21.30 - 0:12:0.640
I: And is there another point of view or is this the answer you would like to give?

P5: Well, this is the answer from my point of view. You know, professionally… As a scientist. I guess that in other issues… You know… In other parts of this problem of sustainability, there is… It's not that clear to come up… You know… Here, **in science, we use scientific method and it's a very precise way to remove uncertainty, right? But, there's issues where it… Where you… It's hard, basically. For instance, in in policy, right? There's different policies that you can implement, and it boils down to ideology, right? It boils down to ideas… And different people can see [that] differently. So, that's another type of uncertainty, right? And that requires political discussion** and… You know… That's…. I have also my own ideas regarding that, but… You know… I don't know if that's also part of the…?

I: If you want to, you can answer that, but you can also stick to what you already said.

P5: Yeah. Honestly, I do believe that **developing clean technologies is essential, but not sufficient**. I do think that **we need a bigger political and economic change** if we need… If we want to solve this problem.

In vivo codes:

- Doing science is, basically, facing uncertainty all the time
- If you're not facing uncertainty, that means you're not doing good science
- in science, we use scientific method and it's a very precise way to remove uncertainty, right?
- scientific method
- But, there's issues where it… Where you… It's hard, basically. For instance, in in policy, right? There's different policies that you can implement, and it boils down to ideology, right? It boils down to ideas… And different people can see [that] differently. So, that's another type of uncertainty, right? And that requires political discussion
- boils down to ideology, right? It boils down to ideas
- requires political discussion
- developing clean technologies is essential, but not sufficient
- we need a bigger political and economic change

Concept codes:

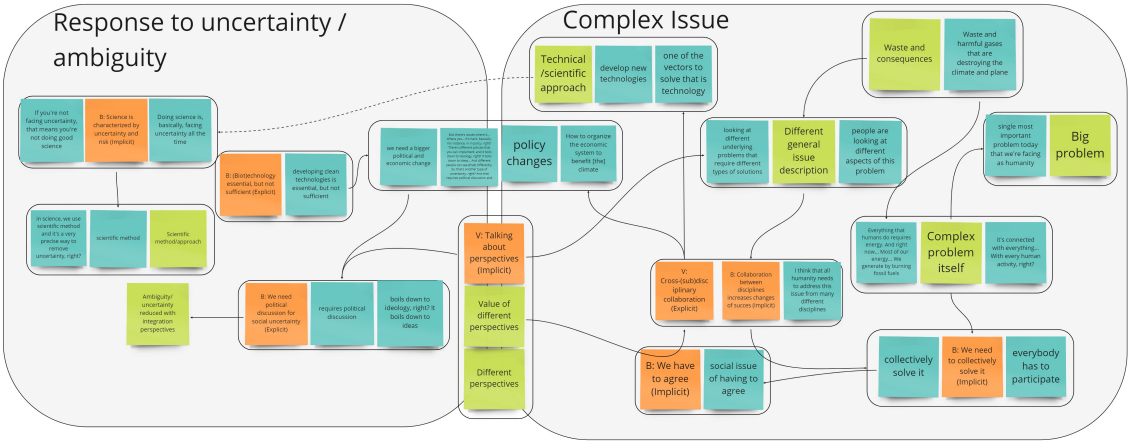
- Ambiguity/uncertainty reduced with integration perspectives
- Different perspectives
- Scientific method/approach
- Value of different perspectives

Values codes:
B: Belief; V: Value; A: Attitude

- B: Science is characterized by uncertainty and risk (Implicit)
- V: Talking about perspectives (Implicit)
- B: In science, the scientific method very precisely removes uncertainty (Explicit)
- B: Uncertainty and ambiguity in implementing policies are reflected in different ideas (Implicit)
- B: We need political discussion for social uncertainty (Explicit)
- B: (Biot)echnology essential, but not sufficient (Explicit)
- B: We need a bigger political and economic change to solve this problem (Explicit)

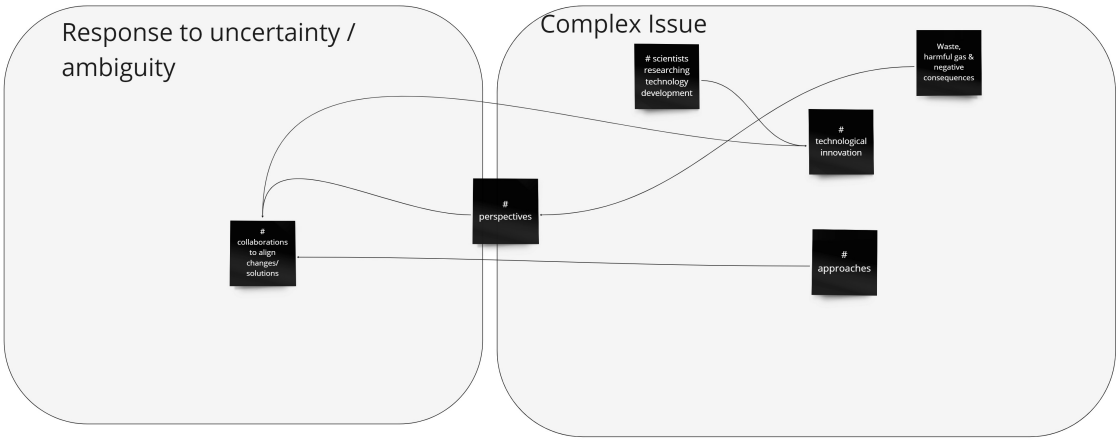
Thematically grouped and mapped codes for the transcript sections included:
Blue cards: in vivo codes
Red cards: values codes
Green cards: concept codes

Note that the themes can have more causal relations than depicted, as only section A & B are given as an example.



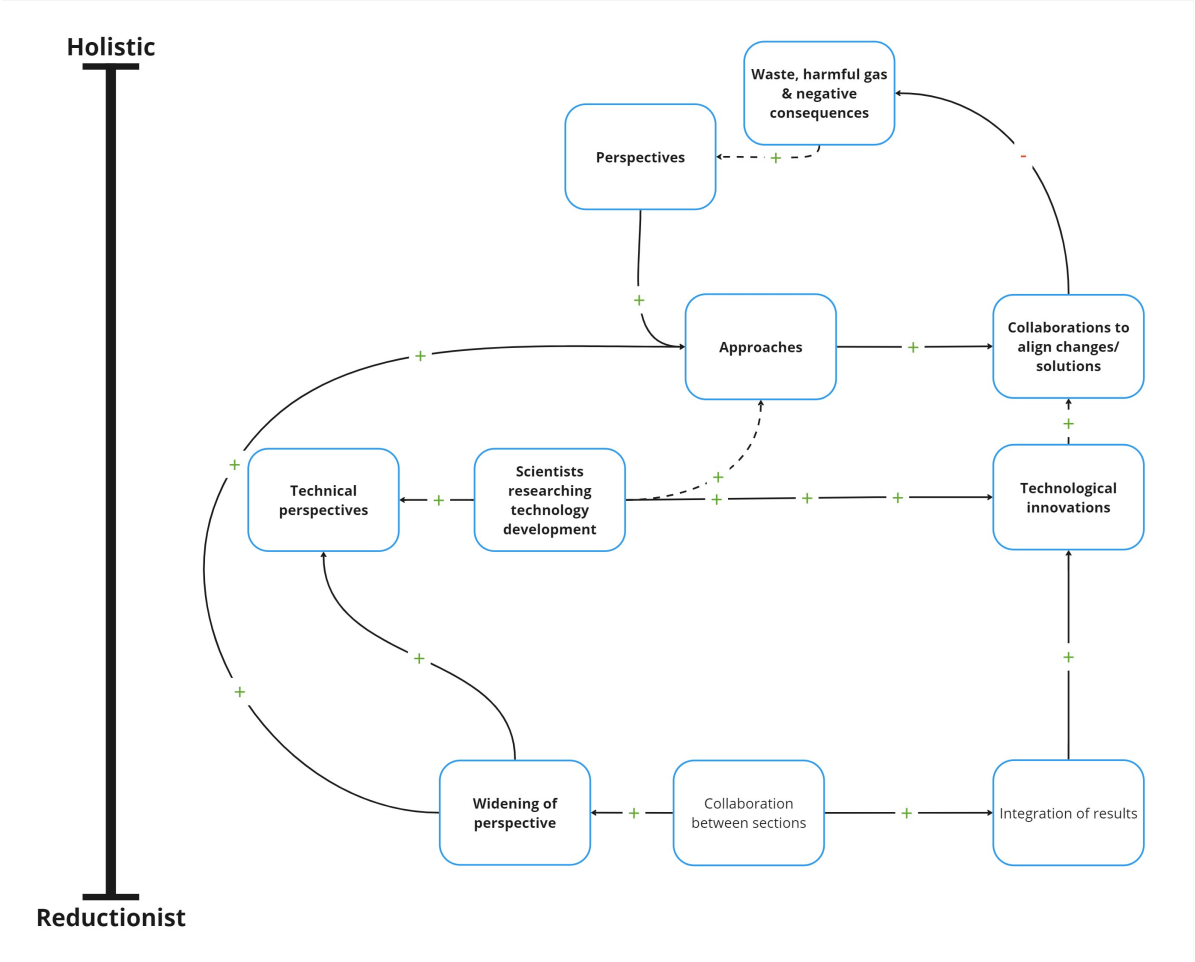
D.1.2. Simplifying

In this step, themes that had fewer than three causal connections to other themes and isolated feedback loops with only a few reasoning steps were removed. After doing so, themes with high similarities were merged.



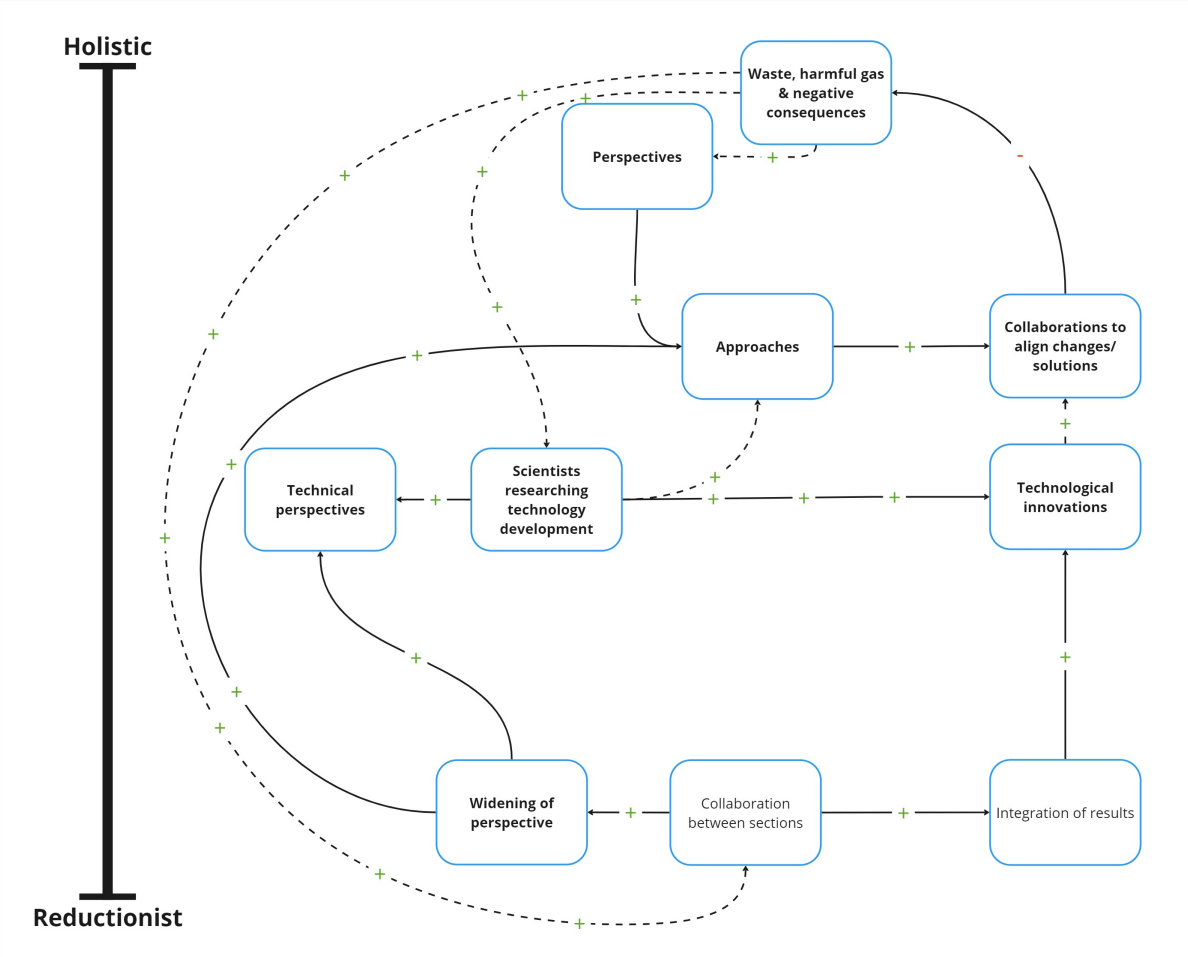
D.1.3. Mapping themes on a reductionist to holistic scale based on reasoning given in A & B

In this step, themes were placed on a spectrum ranging from reductionist to holistic based on their alignment with the reasoning of the participants about A) complex issues and B) responses to uncertainty/ambiguity. The positioning of themes was made by the researcher based on the interpretation of participants' explanations, with the following reasoning: the themes were positioned based on the explicit reasoning of participants regarding the bigger problem and ways to tackle it versus the smaller, more concretely described subproblems and ways to address them, as well as any related aspects. In this context, the bigger problem was considered the most holistic, whereas the smaller, more concretely defined problems were considered more reductionist.



D.1.4. Closing causal relations in reasoning loops

In this step, dotted lines were used to represent ”obvious” causal relations in reasoning that were not explicitly expressed by participants in the interview transcript.



D.2. 2) Perception of inter- and transdisciplinarity

The purpose of this second analysis step was to gain deeper insight into the mental models of inter- and transdisciplinarity of participants, specifically by assessing their perceptions through the evaluation of attributes as described by scholars. These attributes were previously positioned along a continuum, moving upward toward inter- and transdisciplinarity (Section 3.2.2, Figure 3.1).

Using the software of ATLAS.ti, participants were grouped according to to what extent they agreed with the inter- and transdisciplinary attributes as suggested by scholars (attribute and magnitude coding), and both concept and in vivo coding describing their argument. All participants were grouped according to their level of agreement with the statement itself, as expressed and confirmed in the interview. Concept and in vivo coding were used to map their perception for the current situation and/or for the future or ideal situation in terms of the amount of collaborations happening in the consortium they based their (dis)agreement.

D.2.1. Example 1:

Transcript:
I: Interviewer
P5: Participant 5

0:16:20.950 - 0:16:28.520
I: Okay. ‘Collaborations set up for ‘ZEB’ result in co-creation or co-design together with non-academic actors’.

0:16:31.330 - 0:17:6.30
P5: Well. Yeah. So, **one of the goals, in my case in, in our project…** One of the goals is to make this system efficient enough so that it's economically viable. Umm. And that means that **somebody from outside of academia is going to** be able to implement it and actually put it into practice, right? Integrate in the market, and so on…

I: Okay. So, you would agree with it?

P5: Yes.

Coding and grouping:
Level of agreement for the statement itself:

- MQ11: St5: Completely agree

Perception of the future or ideal situation:

- "one of the goals, in my case in, in our project…" (In vivo)
- "somebody from outside of academia is going to" (In vivo)
- (Trying to) attract industrial partners (Concept)
- Implementation outside of scope of research (Concept)

Perception of attribute evaluated concerning inter- and transdisciplinarity

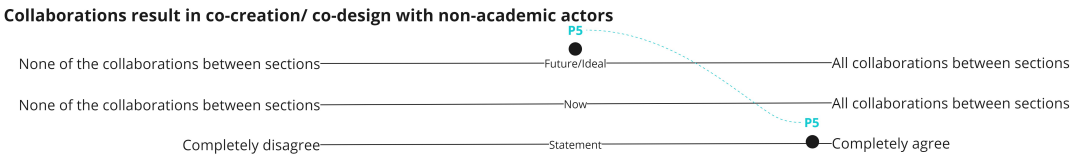


Figure D.1: **Mapping of participant 5 based on the level of agreement for the statement 'Collaborations set up for 'ZEB' result in co-creation or co-design together with non-academic actors', and based on the perception for the future or ideal situation in terms of the amount of the collaborations happening in the consortium.**

D.2.2. Example 2

Transcript:
I: Interviewer
P3: Participant 3

0:18:11.970 - 0:18:17.890
I: Yeah. It's a clear answer. Thanks. 'Collaborations set up for 'ZEB' result in co-creation or co-design together with non-academic actors'.

0:18:19.500 - 0:19:47.880
P3: Uh, that is **difficult to say at the moment**. **The plan is to attract initial partners to co-finance follow up projects, or participate in the ongoing projects**. The way it was set up was a little bit difficult. Like, we got all that money internally, and we were supposed to ask for co-funding. But to directly start the project… Because it didn't work out this way. So, we started the project… And now, we're going to have an **'industry day'** at the end of the year to attract industry partners to collaborate. But, how it's going to be set up set up is not clear yet. There are people like myself who… **R2**… But… Like, **I don't know if they would co-create knowledge, or [if] they would just support us in the development that we are going to do here**. But in other projects,… **R2**… So, that's the end goal, I would assume. **I would hope so, because that would also make it more true.** And will [focus on] that whatever we are developing, it's for the real world. That's always what we are trying to do. We are not doing science to do science. We are doing science[s] that are relevant to nowadays issues.

0:19:49.270 - 0:19:53.580
I: And if you were to answer the question for right now, so the collaborations right now?

0:19:54.430 - 0:20:9.610
P3: Yeah. As I said, right now, I don't think…**R1**… I don't think… **As far as I'm aware, there is no companies on board, right?** So, then then it makes it easy to answer.

Coding and grouping:
Level of agreement for the statement itself:

- MQ11: St5: Neutral

Perception of the current situation:

- "difficult to say at the moment" (In vivo)
- "'industry day'" (In vivo)
- "I don't know if they would co-create knowledge, or [if] they would just support us in the development that we are going to do here" (In vivo)
- "As far as I'm aware, there is no companies on board, right?" (In vivo)
- (Trying to) attract industrial partners (Concept)
- Uncertain about co-creation (Concept)
- (Co-)funding (Concept)

Perception of the future or ideal situation:

- "I would hope so, because that would also make it more true." (In vivo)
- Impactful solutions for society (Concept)

Perception of attribute evaluated concerning inter- and transdisciplinarity

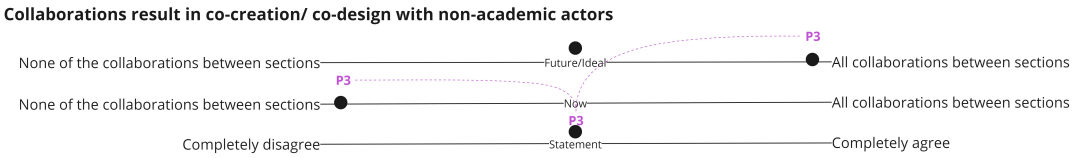


Figure D.2: **Mapping of participant 3 based on the level of agreement for the statement 'Collaborations set up for 'ZEB' result in co-creation or co-design together with non-academic actors', and based on the perception for both the current and the future or ideal situation in terms of the amount of the collaborations happening in the consortium.**

D.3. 3) Deducing contextual influences:

In this step, the 'Ingroup context(s)' affecting specific beliefs expressed and 'contextual reference(s)' expressed that influence the participant's mental model are identified. These contextual references are related to the social identity complexity and mental model components of this thesis' theoretical framework and are deduced through an examination of participants' chosen subjective representations regarding the relationship between two key 'Ingroups' - 'the academic discipline of biotechnology' and 'the group dedicated to addressing the issue'.

The goal here is to understand how these contextual influences impact the mental models of the participants, which were previously placed on a scale from reductionist to holistic in Step 1. This analysis relied on attribute coding for the categorization of chosen subjective representations and on in vivo coding to elucidate the underlying explanations.

To interpret these contextual influences, the reasoning steps articulated by the participants in sections A) and B), which had guided the positioning of themes on the 'reductionist' to 'holistic' scale in Step 1, were referred to.

Relevant in vivo codes of step 1:

- Waste and harmful gases that are destroying the climate and planet
- everybody has to participate
- we need a bigger political and economic change
- I think that all humanity needs to address this issue from many different disciplines
- one of the vectors to solve that is technology

Transcript segments:
I: Interviewer
P5: Participant 5

0:19:41.910 - 0:20:12.120
I: Okay. So, the following questions will focus on how you see the relationship between two social groups. One of them is 'the discipline of biotechnology', which we call 'Group A' in this story. The other social group is 'the group of which its members are trying to tackle your description of the complex problem'. So, this group exists of all members trying to solve the problem as you see it. And, we call this group, 'Group B'. Is that clear?

0:20:13.210 - 0:20:19.870
P5: So that would be all people… Like actors in society that are trying to address climate change and…?

0:20:20.610 - 0:20:31.0
I: Well, it's the way you see it. But, all members trying to tackle the problem, or solve the problem, the way you see it. So, it's not up to me to judge who's in there. It's up to you.

0:20:32.330 - 0:20:43.720
P5: The problem being climate change, right? Or?

I: As you have described it in the first question. Yeah. So, how you see it.

P5: Yeah. Yeah.

I: Yeah? Okay. Do you feel like you are a member of 'Group A'?

0:20:45.320 - 0:20:45.650
P5: Yeah.

0:20:46.430 - 0:20:47.280
I: Okay. Thanks.

P5: …

0:20:48.510 - 0:20:51.520
I: Do you feel like you are a member of 'Group B'?

P5: Yes... ehh...

0:20:52.230 - 0:20:54.700
I: Great. Do you want to say why, or is it just [yes]?

0:20:56.410 - 0:21:9.620
P5: I think... I think… You know… **Any responsible citizen in this time we're living should be in 'Group B', basically**.

0:21:10.820 - 0:21:12.90
I: These are all great answers.

Attritube codes:

- Yes (member of 'Group A')
- Yes (member of 'Group B')

In vivo codes:

- Any responsible citizen in this time we're living should be in 'Group B', basically.

0:21:13.560 - 0:21:19.330
I: So, of the persons within 'Group A', how many do you think are also in 'Group B'?

0:21:23.150 - 0:22:1.960
P5: Probably **everybody**. I want to think…

I: So, 'Group A' is biotechnology and 'Group B' is the other group.

P5: 'Group B' is… In my understanding, 'Group B' is the whole of people that is trying to address the problem of… You know… Environmental breakdown or climate change, whatever you want to call it.

I: Sure. I just wanted to check if you understood [that].

P5: And, **I think that biotechnologists trying to come up with new technologies are definitely part of this broader group trying to address this problem**.

I: Yeah, Okay. No, that's really clear. Thanks.

0:22:3.380 - 0:22:8.380
I: To what extent do you think a typical person of 'Group A' is similar to a person of 'Group B'?

0:22:17.880 - 0:22:49.990
P5: Umm… Well… Since… I see that, because it's a complex problem, '**Group B' has… It's very heterogeneous**… So, People in 'Group A' are part of this heterogeneity, I guess. But, there is probably people that are similar and people that are very different in 'Group B'. Does that…?

0:22:51.440 - 0:22:54.830
I: Yeah, that's an answer.

P5: …

Attritube codes:

- Dissimilar (D)

In vivo codes:

- everybody
- I think that biotechnologists trying to come up with new technologies are definitely part of this broader group trying to address this problem
- Group B' has… It's very heterogeneous

0:22:56.830 - 0:23:18.620
I: So, there exist different ways in which people see or picture the relationship between their memberships in two social groups. For the next question, cards with both a visual representation and a verbal description of each way to see this will be handed to you. And, after you've looked at each, you can, for instance, lay them on the table. And then, the next question will be asked.

A part of the transcript has been omitted.

P5: Okay, okay. These are clear.

I: Okay. Nice. So, from the options given, how do you think the relation between both your memberships can be best represented?

0:24:57.210 - 0:25:1.230
P5: I guess this one [Simultaneously recognized].

I: Okay. And, can you elaborate [on the reason] why?

0:25:3.570 - 0:25:34.40
P5: Well. Because **I'm a professional in biotechnology**, but I'm also a **citizen that is worried about the world** we're living for our kids, right? and. And, I think those are equally important. And, I try to make… I try to melt them in the same vision of… You know…

0:25:39.450 - 0:26:7.410
P5: Yeah. I tried. I try to make them part of this… Of my vision for ‘what do I want to do’, right? Both professionally and [in the] outside world, where I could… You know… Do activities related to ‘[Group] B’, but not necessarily to ‘[Group] A’.

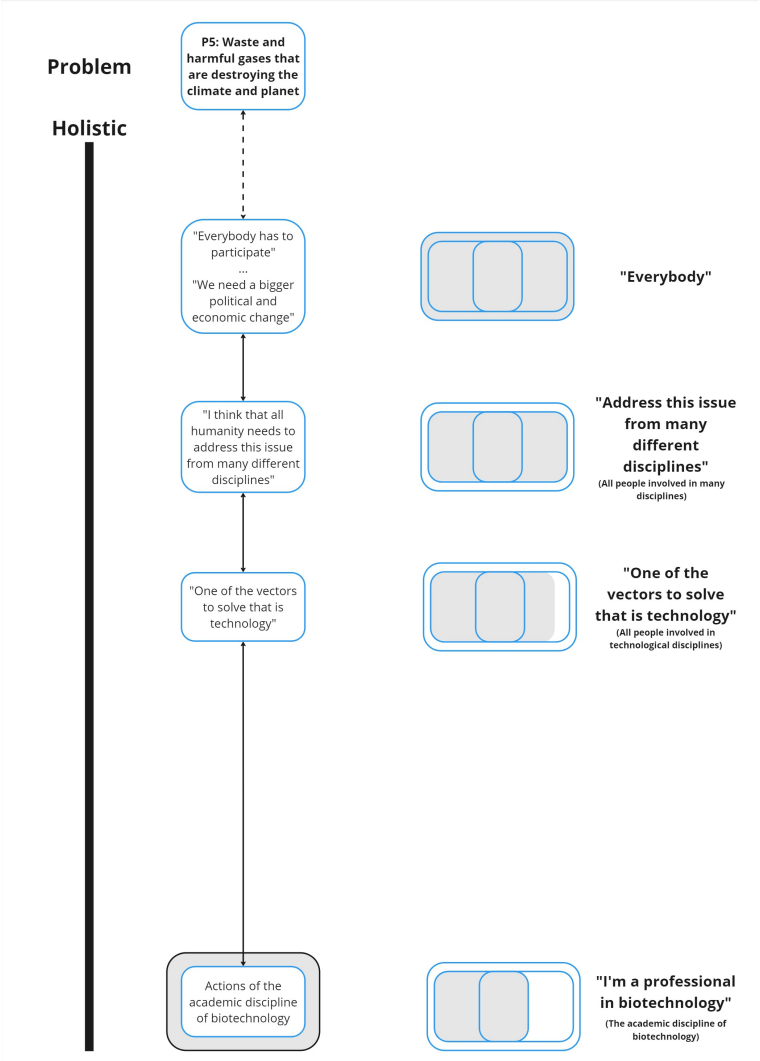
Attritube codes:

- Merger (M)

In vivo codes:

- I’m a professional in biotechnology
- citizen that is worried about the world

Contextual influences deduced and linked to reasoning steps on a ’holistic’ to ’reductionist’ scale:
For transparency, direct quotes (in vivo codes) are included when presenting the final outcome of this data analysis step.



E

Appendix 5: Mindset-specific beliefs versus all beliefs

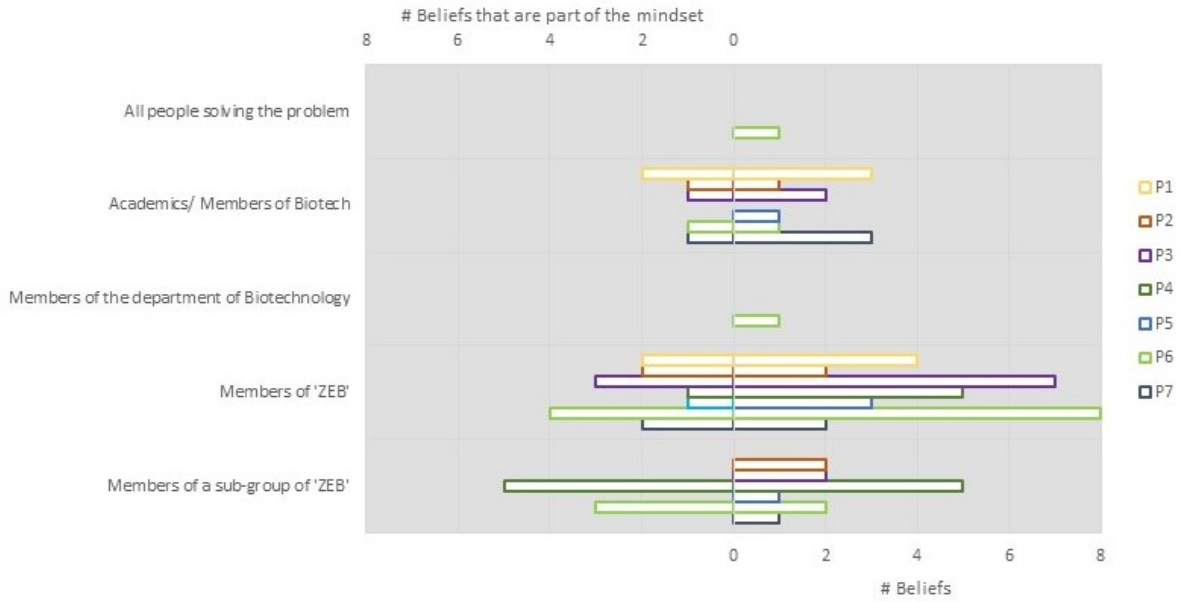


Figure E.1: **Overview of the number of context-specific beliefs indicating positive differentiation per 'Ingroup' for each participant versus the number of mindset-specific beliefs indicating positive differentiation per 'Ingroup' for each participant.** The number of context-specific beliefs is depicted in bars on the right, the number of mindset-specific beliefs is depicted in bars on the left.

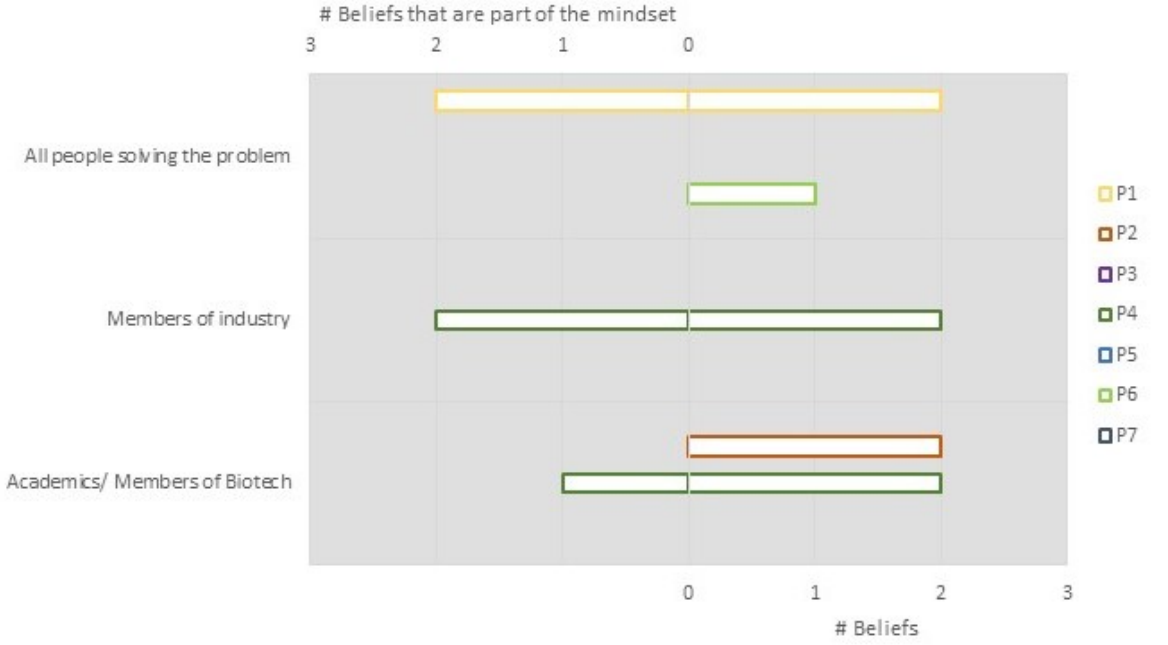


Figure E.2: **Overview of the number of context-specific beliefs indicating a bias per 'Outgroup' for each participant versus the number of mindset-specific beliefs indicating a bias per 'Outgroup' for each participant.** The number of context-specific beliefs is depicted in bars on the right, the number of mindset-specific beliefs is depicted in bars on the left.

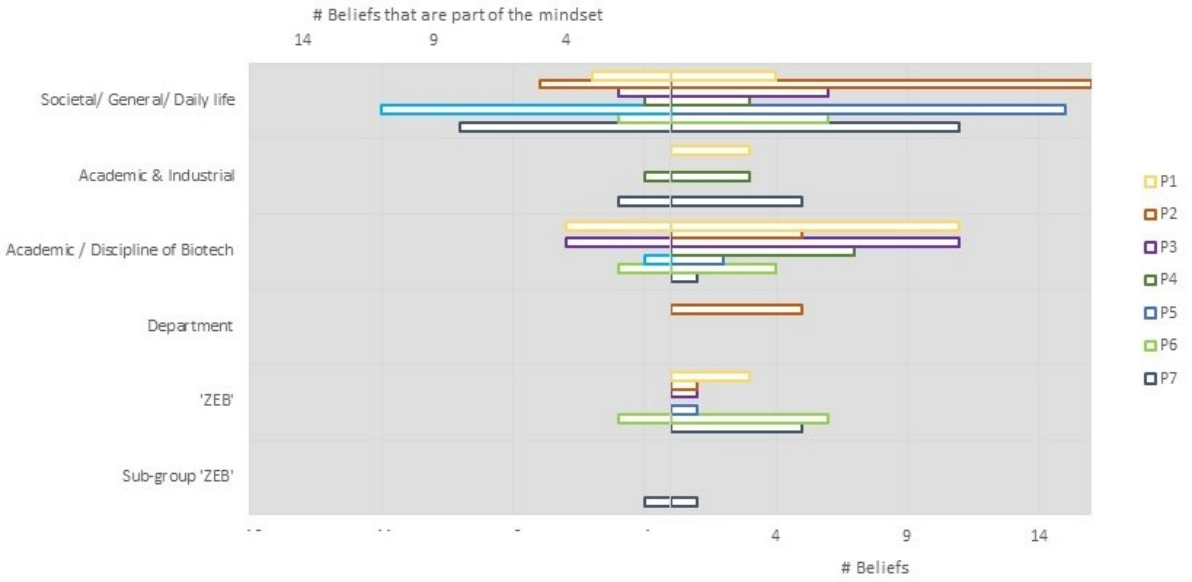


Figure E.3: **Overview of the number of context-specific beliefs indicating normativity per context for each participant versus the number of mindset-specific beliefs indicating normativity per context for each participant.** The number of context-specific beliefs is depicted in bars on the right, the number of mindset-specific beliefs is depicted in bars on the left.

F

Appendix 6: Decision Narrative

Because of your valuable input, you're invited to join meetings of academics of a promising consortium. The consortium focuses on research in the field of biotechnology and aims to tackle a current societal challenge: food shortages that arise with an increasing global population size. A year ago, you already got quite excited when reading the proposal for the first time: the plan aims to transgress 'normal' boundaries of disciplinary research and encourages continuous collaboration to do so. It's definitely something you support and hope to recognize in more proposals in the future.

It's been a while since the last meeting, and everyone has had some time to proceed on their own sub-projects. From earlier updates, you already know the approach everyone has taken so far. Although people are working hard and with integrity, you personally feel like little steps are taken to actually transgress current disciplinary boundaries. It annoys and frustrates you. However, you're struggling with pinpointing what exactly is causing this feeling and how to properly describe it for yourself.

For the past weeks, this feeling has made you feel a bit awkward and insecure. What if you're worrying for nothing and transgressing boundaries is just a matter of time? After all, people probably joined this consortium because they had the same mindset. Therefore, the beliefs that are shaping every person's mindset will probably align as well. However, as all these people are experts who are educated for many years in their own discipline, you wonder: Is there an influence of the social and research norms of these disciplines that also affects every person's mindset in a specific way? If so, can we adapt our mindset depending on how we perceive the consortium's context? Or, perhaps our mindset is unconsciously shaped by the way we perceive and experience our environment? And, can it be that, for some people, the mindset and the connected beliefs are something very personal and deeply rooted? And, if so, is it even appropriate to comment on someone's mindset and ask for a change?

You're excited, yet uncomfortable when walking into the meeting. You know there is time reserved to discuss the mindset in relation to how it's going, and you just really hope it's going to be effective for the group. To surprise you even more, you see some new unfamiliar people joining the meeting as well. Then, it's time to discuss the mindset. While you're searching for the right words to clearly describe what you mean, someone suggests to use a tool. The tool helps you to describe different mindsets by linking each to experiences, emotions and the system for which your description is applicable. When you start describing the appropriate mindset you had in mind for the consortium, you realise that your system is really big: it's the whole world that is struggling with this food problem! Two familiar persons and one unfamiliar person start to join in. They relate to the experiences, emotions or the system level you're addressing, in a surprisingly creative and therefore understandable way. The discussion feels comfortable and open, as the contexts shaping everyone's beliefs are acknowledged as well. All of a sudden, you realize something: although the system you described for the mindset you had in mind was very big, the beliefs that were behind it actually originated strongly from personal experiences in a much smaller system! **It turns out, the tool made both you and other people 'recalibrate' a consensus mindset suitable to transgress current boundaries, combined with the underlying beliefs shaping it.**

G

Appendix 7: Feedback participants of the tool probing session

Anonymous user 1
"I am a 2nd year PhD in the group of industrial microbiology. With another colleague we tried out Effie's game and although it took some time to get outside of the hard-science attitude into the abstract, creative mindset required for the game, it immediately sparked an interesting conversation about what both of us value in science. It is often not easy to initiate conversations like this, and so I am convinced that such a game can potentially help new groups to align what kind of mindset they want to aspire toward. I think the game is very useful, as it made me contemplate about my approach to research and that although I work closely with my colleague we actually do not fully agree on certain aspects. The game made us realize this and sparked a conversation about how we could improve this. I can recommend the tool, it's simple but well thought out."

Anonymous user 2
"The tool is a great conversation starter to discuss mindset differences between people. The person that wants to initiate the change will take the lead in this game which helps the other people to start off more comfortably. I especially like that the game focuses on sharing feelings and experiences rather than polarizing mindsets. I would recommend this tool to start conversations about mindset, whether on the work floor or in your private life."

Anonymous user 3
"I can see how the tool can be helpful for promoting further consideration of the current mindset within a team. Additionally, I also see added value of the tool for conflict resolution within a team, as the tool is focused on promoting further understanding of other's feelings, rather than only explaining your own. Overall, the experience was insightful and led to some new perspectives on how my teammate saw our collaboration."

Anonymous user 4
"The tool added values and interconnection to different statements which gave it an extra element and dept in the discussion beyond simply stating an opinion. The user is forced, in a playful manner, to access the values ascribed to the subject. Secondly, the partly covering of the keywords and combining them invited structure in the discussion as both parties were invited to hear out the arguments behind the choices made by using the tool."

H

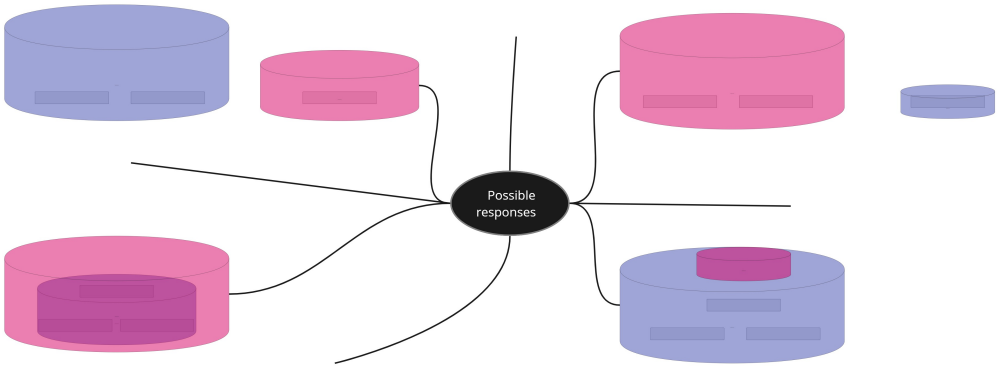
Appendix 8: Tool manual

Out of Context!

Step 1. Person 1 writes down at least 3 aspects of the mindset, linked to inter- and transdisciplinary practice, on separate pieces of paper, without saying a word. Specify beforehand if the topic of discussion (mindset) is related to the past, present or future.

Step 2. Person 2 responds by doing the following:

- Evaluating the emotions felt when reading the pieces of paper.
- Reorganizing the pieces of paper according to emotions felt.
- Positioning one of the red (emotions of 'relatedness') and one of the blue (emotions of 'autonomy') circles over the pieces of paper according to the emotions felt. The order of positioning red and blue is up to person 2.



Step 3. The conversation starts.

Figure H.1: **The final manual of the tool 'Out of Context'.**