



# Transdisciplinary transformative change: an analysis of some best practices and barriers, and the potential of critical social science in getting us there

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## Abstract

Biodiversity experts now widely acknowledge that transformative change is best supported through transdisciplinary collaborations. Yet, such collaborations rarely successfully occur in major biodiversity research institutions and those that do rarely achieve the paradigmatic effects they aim to deliver. To gain some insight into this global phenomenon, we surveyed Swiss-based researchers and non-academic stakeholders addressing global change and biodiversity. In this article, we connect our findings to global patterns in transdisciplinary transformative change initiatives (TTCIs) and heuristically divide collaboration barriers into two categories: lack of resources and lack of vital functional elements. Two of the major themes that emerged from this research were the continued difficulties with (1) establishing a common ‘language’, understanding, and goals, and (2) meaningful pluralization of knowledge in transdisciplinary collaborations aimed at addressing global change and biodiversity loss. The former is widely cited in the literature as contributing to the failure of TTCIs in the form of incoherent problem-framing, while the latter is often identified as contributing to the lack of *structural* transformative change (e.g., paradigmatic shifts) in completed initiatives. Another major theme reflected in TTCI literature was limited time. Moreover, based on our own extensive inter- and transdisciplinary experience, we agree with other experts that there is a persistent lack of understanding of the potential contributions of critical social science (CSS) to TTCIs. We thus argue that enhancing resource availability for TTCIs, especially tools for improving CSS literacy, could save time *and* support both problem-framing alignment and delivery of the structural/paradigmatic changes we aspire to.

**Keywords** Transformations · Transdisciplinary collaborations · Critical social science · Science-policy-practice interface

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## Introduction

Acknowledging that biodiversity loss continues to accelerate despite best efforts to slow and reverse this trend, experts across the globe have been calling for radical changes in biodiversity conservation (Büscher and Fletcher, 2020; Locke, 2014; Marris, 2013; Wilson, 2016). Moreover, with the increasing recognition that the global biodiversity and climate crises are interlinked (Kadykalo et al. 2022), it has become clear that they must be addressed in unison (IPBES, 2019b; IPCC, 2022). Thus, international expert panels now advocate for a “fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values” (IPBES, 2019a: XVIII). While such ‘transformative change’ offers new hope for the trajectory of human-driven planetary modifications, it necessarily requires a level of complexity equal to that of the crises it aims to address (Fougères et al. 2022). For many biodiversity and climate change experts, transdisciplinary collaborations (TCs) on transformative change initiatives are the best, if not the only, way to fulfil this need (Caniglia et al. 2021; Fisher et al. 2022; Visseren-Hamakers and Kok 2022).

While interdisciplinary research emphasizes partnerships across academic disciplines, transdisciplinary research seeks to additionally involve non-academic actors in these partnerships in an effort to include and engage multiple forms of theoretical, experiential, embodied, and practical knowledge and creativity (Brandt et al. 2013). Beyond offering more holistic and creative solutions to the biodiversity and climate crises, this inclusive nature of TCs has the potential to address the breakdown of trust in expert knowledge that has accompanied present-day politics (Bouma 2018; Rose 2018). Through the meaningful inclusion of affected stakeholders and their knowledge, TCs innately improve their own visibility and credibility (Lang et al. 2012), bridging the gaps in the science-policy-society nexus (Buizer et al. 2011).

Despite the promise of transdisciplinary transformative change initiatives (TTCIs - i.e., transdisciplinary collaborations that specifically work towards transformative change as defined above), very little information exists on how often and under which circumstances TCs are engaged in projects seeking to address the biodiversity crisis. Some scholars, noting a lack of such TCs, have outlined barriers and strategies for overcoming these from their own perspectives (Papp et al. 2022; Rocha et al. 2020) and from the perspectives of early career researchers (Filyushkina et al. 2022). However, we are unaware of any studies that have sought to understand multiple perspectives and experiences (e.g. by surveying multiple experts, including policy-makers and practitioners) as they relate specifically to the initiation of TCs to address biodiversity loss and global change. Moreover, once developed, TTCIs seldom achieve the paradigmatic effects necessary to meaningfully address the biodiversity crisis (Chambers et al. 2022; Scoones et al. 2020; Turnhout and Lahsen, 2022). In this paper, we combine insights from literature on the global patterns of TTCIs with those from Swiss-based researchers and non-academic stakeholders addressing biodiversity and global change. By situating the perceptions and experiences of our participants within identified global patterns, we explore how to best facilitate more TCs on issues related to biodiversity and global change, as well as how to improve TTCIs, and therefore enhance outcomes. Our exploration is guided by the following research questions:

- What are examples of good practices already in place for both initiating transdisciplinary collaborations and ensuring meaningful collaborations and outcomes?

- What gaps and challenges exist for the initiation of transdisciplinary collaborations and for ensuring meaningful collaborations and outcomes?
- Is there potential for improvement of these interfaces and networks? If so, where is that potential and how do we harness it?

With these questions in mind, we use our empirical data to outline drivers for ensuring access to resources for TTCIs and where and how these need to be enhanced, as well as vital functioning elements for successful TTCIs and current struggles in achieving these. We then draw on the relationship of these needs and struggles to global patterns in TTCIs to make recommendations for addressing them at all scales. Focusing especially on the continued struggles with establishing a common ‘language’, understanding, and goals, and with meaningful pluralization of knowledge, we add our unique contribution of calling for the development of critical social science literacy strategies and tools to be used in the development and operationalization of TTCIs. Critical social sciences (CSS) are those that employ critical theoretical lenses to identify structural knowledge/power dynamics and their causal links with socioecological problems. We therefore argue that improving CSS literacy would assist in problem-framing alignment and paradigm-shifting outcomes, as well as address the related issue of limited time to achieve these.

## Global patterns in transdisciplinary transformative change initiatives

Transdisciplinary collaborations to address sustainability challenges have been tried and tested for decades. Indeed, the field of sustainability science was founded near the turn of this century with the specific goal of using such collaborations to iteratively develop adaptable methods and approaches to sustainability problems (Abson et al. 2017; Kates et al. 2001). Moreover, in recognition of the scale and complexity of the kind of transformative change needed to address the interlinked contemporary global crises of biodiversity loss, climate change, and social inequality, literature on transdisciplinarity in transformative change initiatives has recently been gaining traction (Ely et al. 2020; Fougères et al. 2022; Lawrence et al. 2022). Yet, it is unclear why and how often researchers and non-academic stakeholders who work on issues of biodiversity and global change seek to work in transdisciplinary collaborations. Rocha et al. (2020) note that the discipline-oriented policies and practices of academia act as a barrier for transdisciplinary transformative change initiatives (TTCIs). Papp et al. (2022) quantitatively demonstrate a ‘transdisciplinary deficit’ as it relates to wildlife conservation, particularly with respect to large carnivores. Other studies have examined individual motivations for participation in inter- and transdisciplinary collaborations more generally (see e.g., Augsburg, 2014; Guimarães et al., 2019). Finally, Filyushkina et al. (2022) examine motivations, barriers, opportunities, and benefits of engaging at the science-policy interface from the perspectives and experiences of early career researchers of biodiversity and ecosystem services. However, we were unable to locate a study that seeks to understand the drivers of initiating TCs in biodiversity research in the context of the rising calls for TTCIs, from multiple academic and non-academic perspectives.

Other scholars have noted that, once initiated, TTCIs often fail to achieve the paradigmatic outcomes they aspire to, and there is much debate in the literature on why this is the

case (Bennett et al. 2019; Fazey et al. 2018; Klenk and Meehan 2015; Visseren-Hamakers and Kok 2022). One dominant argument points to a lack of coherent problem-framing, which inevitably leads to disorganized and incoherent application of solutions (Brandt et al. 2013; Fisher et al. 2022; Fougères et al. 2022). To further illuminate this issue, Scoones et al. (2020) typecast approaches to transformation into three general non-mutually-exclusive categories and show how the ways in which the problem is framed govern which of these approaches is prioritized. ‘Structural approaches’ follow the logic of social theorists such as Marx, Lenin, and Gramsci in aiming for a “complete overhaul of the ideological underpinnings of social systems writ large” (ibid., p. 66). ‘Systems approaches’ concentrate efforts on particular parts of a system, for example by shifting to renewable energy, developing innovations aimed at resilience, and revising regulations and policies. Finally, ‘enabling approaches’ are designed to give agency to stakeholders, in both individual and collective form, to direct transformational pathways. While Scoones and colleagues acknowledge that these approaches are often used in various combinations, they call for more strategies that encompass all three, noting that such strategies will require that diverse knowledge forms, plural pathways, and acknowledgement of politics’ role in pathway possibilities be taken seriously.

According to other experts, structural approaches are rarely incorporated in TTCIs because critical theoretical perspectives on the politics of power and knowledge, and their roles in the interlinked crises, tend to be marginalized in the collaborative process (Abson et al. 2017; Chambers et al. 2022; Fazey et al. 2018; Weiland et al. 2017). Any formulated solutions that ignore these structural causes are therefore inevitably doomed to reproduce the status quo and exacerbate the crises (Büscher et al. 2022; Massarella et al. 2021). Moreover, while many different connotations of transformative change have been operationalized in various contexts, certain voices and perspectives are often muted or completely absent (Martin et al. 2020; Visseren-Hamakers and Kok 2022). As a result, the debate on possible paradigm-shifting alternatives is foreclosed before such solutions can even be considered (Klenk and Meehan 2015; Theriault et al. 2020), despite research pointing to unconventional approaches being more successful (Etzion et al. 2017). For example, successful outcomes have been noted in approaches that center art (Fernández-Giménez 2015; Harrower et al., 2018; Rivera Lopez et al., 2018), Indigenous teachings (Fabre et al., 2021; von der Porten et al., 2019), and alternative economies (Klein and Morreo, 2019), to highlight just a few.

To draw attention to these unaddressed and related issues of incoherent problem-framing and epistemological exclusion, Turnhout and Lahsen (2022) escalate the argument that it is necessary to transform research itself to (better) contribute to and support sustainability transformations. In response to a recent article in *Climate and Development* calling for a moratorium on climate science until the science-society contract is mended, they question whether more of the same environmental research is indeed what is needed to move from scientific results and consensus to action. Instead, they call for a profound shift in research priorities, moving away from the prioritization of natural sciences to allow for meaningful integration of critical social sciences (CSS). We elaborate on this CSS integration dilemma in the global examples of IPBES and Future Earth below before turning toward our empirical findings to explore TC drivers and to contextualize the struggles with problem-framing and knowledge pluralization at multiple scales.

## TTCI struggles in IPBES and future earth

Future Earth and IPBES, both established in 2012 (the year of Rio+20), are intended to improve the societal relevance of global environmental change/biodiversity research (Lahsen and Turnhout, 2021), but with different roles at the science-policy interface. IPBES is an intergovernmental body which collates “the best expertise from across all scientific disciplines and knowledge communities – to provide policy-relevant knowledge and to catalyze the implementation of knowledge-based policies at all levels in government, the private sector and civil society” as they relate to biodiversity conservation (IPBES, 2023). It thus arguably represents *the* authority on which governing bodies, research institutions, and funding implements, *at all levels*, rely for recommendations pertaining to biodiversity conservation. Future Earth has been a strategic partner of IPBES since 2017. As “a global network of scientists, researchers, and innovators collaborating for a more sustainable planet” (Future Earth, 2023), they represent an authority on collaborations seeking to initiate transformative change. While both have made huge strides towards inclusivity, they nonetheless reflect the struggles with frame-alignment and knowledge pluralization documented in similar bodies and collaborations across multiple scales (Lahsen and Turnhout, 2021; Lidskog et al., 2022; Wiegleb and Bruns, 2022).

Recognizing the interconnections between nature and humans, as well as the need for inclusivity, transparency, and broad participation, the IPBES conceptual framework was built in a multi-year consultative process (Díaz et al. 2015a) and reflects different (scientific) disciplines, and a large variety of societal actors and their diverse knowledge systems (Díaz et al. 2015b). Although the conceptual framework, methodologies, and tools are intended to be inclusive, Lahsen and Turnhout (2021) explain how IPBES is still stuck in a natural sciences approach that is driven by the norms and values embedded in (Western) science, leaving very little space for other ideas and understandings of what ‘living nature’ represents (Pascual et al., 2021). The complex relationships between humans and the rest of nature are captured in six interconnected components of the conceptual framework. Here, we focus on the component “*Nature’s Contributions to People (NCP)*” to demonstrate IPBES’ struggles with CSS integration. Broadly defined as “actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (Cohen-Shacham et al., 2016: 2), the NCP component has evolved considerably over time to embrace pluralism. On the one hand, it offers a generalization of context-specific perspectives and, on the other, analytical tools to represent interactions between people and the rest of nature. A combination of these approaches, or ‘lenses’ then allows for the observation of patterns and processes in nature from a variety of different viewpoints, increasing common understandings across different scales and contexts (Hill et al. 2021). Yet, such approaches have been criticized for their lack of attention to broader issues of social and environmental justice (Cousins 2021) and ecological justice (Pineda-Pinto et al., 2021). CSS could help to highlight the ‘roots’ (i.e. structural causes) of these issues and is thus arguably invaluable for assessing the potential of proposed solutions. For example, noting that attempts to address power in conservation research are often insufficient or superficial, Shackleton et al. (2022) summarize six approaches to CSS power analyses, including “actor-centered, institutional, structural ... discursive/governmental (and) non-human and Indigenous perspectives” (pp. 1). They then use these approaches to offer guiding principles for accounting for power in

conservation research. As a more specific example, Mabele et al. (2023) recently used a bibliometric analysis to show how knowledge on biodiversity conservation in Tanzania is produced and disseminated along unequal power structures that perpetuate a narrow and disconnected approach to conservation policy and practice.

Future Earth was created to move away from siloed global environmental change research toward integrated research on sustainability (for the history and evolution of Future Earth, see e.g., Lahsen, 2016; Leemans, 2016; van der Hel, 2016, 2018). In recognition that ‘science for transformation to sustainability’<sup>1</sup> remains elusive, and plagued by funding limitations, insufficient collaborative and integrative activities, and the need for better connections between different entities of Future Earth, the program underwent a transition in 2020/21, broadening its governance to include representatives from its global research networks (GRNs), early career researchers, and researchers from the global south. As I (third author) observed during the discussions at the Future Earth 2022 Assembly, there is clear acknowledgement that greater integration and collaboration between different ‘types’ of projects to leverage existing expertise in CSS, and to build the CSS base within Future Earth, is needed to truly produce research for transformation to sustainability. Nevertheless, there is also the fear being voiced that basic/fundamental research, in particular on Earth systems processes, will be lost as the focus of research is perceived to shift to ‘applied’ research and implementation.

It’s furthermore hard to grasp what the ‘value-added’ of belonging to Future Earth for the different GRNs means – what it is that belonging to the Future Earth network of networks brings to the table in addition to their own networks and activities. GRNs within Future Earth are very diverse, owing to their history. Some GRNs were already part of the Global Environmental Change Programs that merged into Future Earth, while others were only established more recently with the aim to integrate around specific initiatives and themes. Each of these networks have different approaches to co-design and co-production and interact with societal actors and decision-makers at different levels and scales. To enable the diversity of networks under the Future Earth umbrella to foster co-production in their activities and approaches, Schneider et al. (2021) propose a strategic tool that allows the GRNs not only to develop co-production approaches, but also fosters self-reflection and learning. Lahsen and Turnhout point out that this reflection is needed for the transformation of science, and devise strategies to contribute to transformations to sustainability (Lahsen and Turnhout, 2021; Turnhout and Lahsen, 2022). However, despite this tool being available, a coherent approach of using and meaningfully integrating CSS is lacking from my (third author) observations, as well as from those of colleagues in Future Earth who share this view. Although CSS is perceived as being useful in facilitating co-production and co-design of research and implementation, many GRNs still struggle with how to put this into practice, and do not recognize the full potential CSS can offer.

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<sup>1</sup> The term ‘Transformations to Sustainability’ was coined by the International Social Science Council (ISSC, now ISC) in 2014 in order to promote research on the fundamental and innovative processes of social transformations necessary to secure effective, equitable and durable solutions to today’s global challenges.

## Study design and methods

We use a case study approach to investigate transdisciplinary collaborations in the thematic area of biodiversity and global change. We chose the Swiss science-policy-practice interface as both a representative and a unique case study (see Yin 2003); representative in the way that processes at the science-policy-practice interface and establishing TTCIs follow similar patterns in many countries – but still uniquely set in a direct-democratic, multi-lingual system. Many biodiversity researchers in Switzerland have an international background and both case studies (see below) use English as their working language, even though English is not a Swiss national language. Additionally, many of our participants do research on a global scale and are involved in global platforms like IPBES and Future Earth (see Sect. 2.1). Thus, we are convinced that our results are applicable to a broad context on different scales.

Corresponding to our thematic focus, we surveyed and interviewed researchers and non-academic stakeholders from two different, ongoing research initiatives: The *University Research Priority Program on Global Change and Biodiversity* at the University of Zurich (URPP GCB), and the project *ValPar.CH – Values of the Ecological Infrastructure in Switzerland*, which involves five Swiss universities. The URPP GCB was launched in 2013 and is currently in its final phase, ending in December 2024. The program brings together complementary knowledge of scientists from five different institutes, ranging from biology to mathematics, geography, and ethics. Research in the program examines the interactions and feedbacks of biodiversity change and drivers of this change across scales, using a variety of methods and approaches. The aim of the program is to advance integrative biodiversity and global change research that is of societal and policy relevance (Zuppingier et al., 2017). ValPar.CH, is commissioned by the Swiss Federal Office for the Environment (FOEN) and includes approx. 30 researchers – including biologists and environmental scientists, economists, and social scientists. This project thus differs from the URPP GCB as it was co-developed with policy actors and more strongly involves transdisciplinary approaches, working closely together with stakeholders, such as regional nature parks (Reynard et al. 2021).

The two initiatives facilitated our access to a very diverse set of researchers and non-academic stakeholders, all working to a different extent in interdisciplinary settings, some of them also with a strong transdisciplinary focus. Hence, we were able to receive insights from researchers with varying science-policy-practice exchange experiences. Furthermore, focusing on two research initiatives allowed a strategic selection of relevant non-academic stakeholders and institutions.

We follow a mixed-methods survey approach bringing together data from an online questionnaire and qualitative, semi-structured interviews. The online questionnaire (see Supplementary Material) – provided in English, German, and French – included closed- and open-ended questions and was sent out to 27 different institutions: Researchers from the two initiatives and additional relevant researchers based in Switzerland, NGOs, national and international science-policy-practice platforms, as well as federal and cantonal (i.e., state) offices. The selection of these institutions was based on criteria sampling, i.e., actors involved in either science, policy, practice, or any combination, and thematically linked to our focus. A total of 131 people responded, with 58 (44%) completely filling in the main part of the questionnaire. Out of 45 participants sharing their details, 22 are scientists, 9 are government employees, 7 are practitioners, 5 are working for a science-policy-practice

interface, and 2 are politicians. We conducted descriptive statistics using frequency distribution charts to examine the results of the closed-ended, multiple choice questions. In a second step, open-ended questions were translated to English (if written in German or French) and analyzed by applying qualitative content analysis to identify prominent themes.

Based on the online questionnaire, we developed an interview guideline for the semi-structured interviews, aiming for a more in-depth understanding of current contexts, processes, and challenges to collaborations within national and international science-policy-practice interfaces. We followed a three-tier sampling strategy: First, we asked survey participants to leave their email address when they were interested in participating in an interview. Second, we selected interviewees based on theoretical and maximum variation sampling strategies aiming for representatives of different institutions and hierarchy levels (see Patton 1990). And third, we based part of the selection process on an opportunistic sampling, since some participants mentioned further prospective interviewees. This strategy resulted in seven interviewees (Table 1). The interviews were audio-recorded, transcribed using automatic transcription software (Otter.ai), and manually corrected for accuracy. One interview was translated and transcribed manually since it was not in English. Interview data was analyzed along the lines of Mayring's (2014) content analysis, including inductive and deductive coding steps in order to identify common themes. All questionnaire participants and interviewees were assigned a Respondent or Interview ID to link their answers, while remaining anonymous. We refer to RIDs when quoting a questionnaire respondent, and to IIDs when presenting interview quotes.

Throughout data collection and analysis processes we followed a triangulation design – both regarding methodology and researchers (see Flick 2004). This allowed us to extend knowledge production by incorporating diverse perspectives and approaches. Moreover, by conducting interviews and coding steps in pairs, we were able to balance subjective influences by individuals. We therefore believe that our interdisciplinary team with diverse backgrounds substantially enhances the synthesis of the gathered data.

## Results and discussion

Our initial aim was to discover participant experiences with knowledge transfer across the science-policy-practice interface broadly, including conferences and one-time-events. However, we found that many participants framed this knowledge transfer in terms of longer-term collaborations, or emphasized that successful knowledge transfer required long-term engagement. For example, one participant commented that it “takes time to get to know

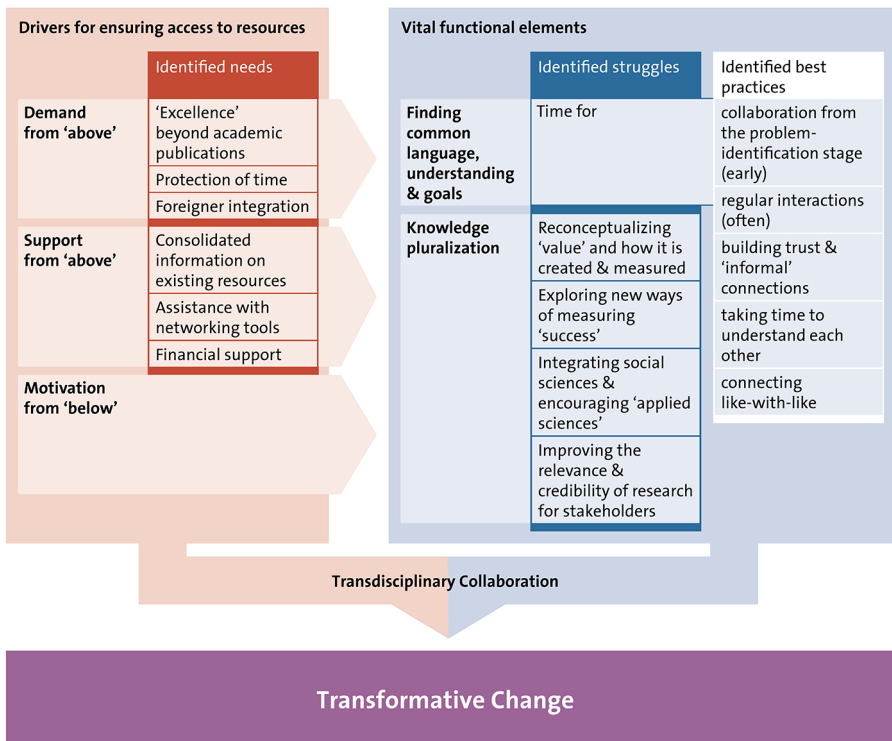
**Table 1** Functions of interviewees

Interview ID	Function
IID1	Professor
IID2	Research program manager, science foundation
IID3	Ph.D. candidate
IID4	Politician, federal government employee
IID5	Postdoctoral researcher
IID6	Member of management team, platform for science-practice transfer
IID7	Professor



each other’s needs and interests. But when this time is taken, it usually results in a lively and fruitful exchange” (RID 3). Following this unanticipated yet natural shift in focus, we discuss our results in terms of longer-term transdisciplinary collaborations (TCs), rather than distinct knowledge transfer events.

Best practices described by participants aligned with those suggested in the literature, and they similarly noted that the time these practices require is the main barrier to instituting them. In this section, we thus discuss this ‘time deficit’ in the context of ongoing issues and struggles, but integrate the identified best practices into the recommendations (Sect. 5) to avoid redundancy. Based on our data and analyses, we further identified barriers for both initiating TCs at the science-policy-practice interface and for ensuring the success of TCs aimed at biodiversity and global change issues, and their outcomes (Fig. 1). Below, we summarize these by heuristically dividing them into two main requirements for initiating and maintaining successful collaborations: ensuring access to resources and accounting for vital functional elements. We note that many of the issues and struggles we highlight are well-documented in the literature. Nonetheless, we felt that it was important to contextualize them to show how, why, and to what extent they persist. This method of analysis allows us to pinpoint specific recommendations for addressing ongoing issues in TTCIs, both in the Swiss context and at larger scales.



**Fig. 1** Drivers and elements of successful collaborations and identified needs and struggles, respectively, based on questionnaire and interview analyses

## Ensuring access to resources

Based on our data, ensuring access to necessary resources for successful transdisciplinary collaborations can be broadly structured into three crucial drivers. Below we describe each of these drivers, as well as missing components (identified needs in Fig. 1) in these drivers.

### Demand from ‘above’

Although key Swiss governmental and funding bodies, such as the State Secretariat for Education, Research, and Innovation (SERI) and the Swiss National Science Foundation (SNSF) are beginning to emphasize TTCIs for addressing sustainability problems, many participants felt that current demand is insufficient. Others have highlighted similar patterns in international funding schemes, noting that the recognition of the need for transdisciplinarity has not translated into more transdisciplinarity and is thus not enough on its own (Papp et al. 2022; Rocha et al. 2020). Here, we build on these findings by using our empirical data to argue that demand from ‘above’ (i.e., those with the power to make decisions that affect research and funding priorities at all scales) must include ‘demanding’ a different type of excellence, protection of time for building collaborations, and the better integration of foreign experts.

At least part of the sentiment that demand from ‘above’ is lacking is related to the way ‘excellence’ in academia continues to be defined by peer-reviewed academic publications (Atolani et al. 2019; Génova and de la Vara 2019; Jarvis et al. 2020). Overall, there was a sense that this definition overlooks the wealth of knowledge and experience needed for TTCIs, and that it is mismatched with the kind of unorthodox thinking that leads to transformational solutions. One interviewee described this as follows: “[research funding] is driven by this excellence thing. And [it’s] the basic researchers [that] define what excellence is” (IID2). Many experts have similarly called for a reformation of academia to make space for other achievements that contribute to transformations (Steele and Rickards 2021; Turnhout and Lahsen, 2022), including long-term collaborations, care work, and practical experience (Care et al. 2021), and community-engagement (Bell and Lewis 2022). The widely accepted Declaration on Research Assessment (DORA) has offered alternative assessment criteria since 2012. However, uptake by major funding bodies has been slow, with the EU only signing in November 2022 and the US National Science Foundation yet to do so. Although the SNSF signed in 2014, it has taken eight years for their assessment criteria to reflect DORA principles, in the form of a new CV format. However, these changes are promising, and it will take some time before they can be evaluated in the context of transdisciplinary projects and experts.

*Time constraints* were mentioned frequently both in the questionnaire (Fig. 2) and in the interviews, and has long been an identified challenge in literature on TCs addressing sustainability and biodiversity issues (e.g., see Brandt et al., 2013; Lang et al., 2012; Mitchell et al., 2017). Because of the continued pressure to publish, researchers still feel urged to prioritize activities that support their ‘publishing pipeline.’ Although the ECRs in Filyushkina, et al.’s survey (2022) largely felt that the trade-offs between investing time in academic publications and science-policy interfaces were roughly even, our participants indicated that engaging in science-policy-practice interfaces is often considered ‘nice to do’ and not a ‘must do.’ As one interviewee put it: “Because ... early career researcher(s) like me, we



**Fig. 2** Survey results of researchers and stakeholders when asked why they don't participate in knowledge transfer

are on the hunt for jobs and we are already juggling ... our work, hunting for jobs. We are also regular humans with 'other responsibilities, and if there is something else that we would really like to do, but that is not recognized or doesn't help us or where the benefits are perhaps not obvious ... it is an additional thing that's being added to our list of responsibilities.' (IID5). Thus, the motivation to collaborate is there, but time becomes an important constraint. As another participant describes: "Unfortunately, I do not have the time. If the situation in our section/department has changed, I would like to get involved. I find this an important task" (RID 11).

Some participants also felt that it can be *challenging for foreigners* to acquaint themselves with a new political system and relevant stakeholders. Moreover, information in Switzerland is often scattered in multiple formats and languages, making it difficult to orient oneself. And, although English is the working language in most biodiversity and sustainability fora in Switzerland, exchanges with policymakers and practitioners are mostly in German or French (two of the four official languages in Switzerland). While this can make it challenging for many foreigners to participate, we have found that there is an ongoing conversation about how to resolve this issue and that organizers are often open to multi-language formats (e.g., slides in English with talks in German or French). Meeting the challenge of foreigner inclusion is relevant across scales as foreigners can provide new perspectives on old problems that challenge dominant conceptual understandings. Such 'disorienting dilemmas' are thought to catalyze transformative thinking in transdisciplinary environments (Pennington et al., 2014).

### Support from 'above'

Aside from demand, it's necessary to support the initiation of TCs with financial and methodological resources. It seems that not many funding bodies in Switzerland provide this

support yet, but one interview partner said that “one trend that you see is that also in the National Science Foundation there are more and more programs or funding schemes where you can get additional funding if you ... build networks” (IID2). Such funding schemes are also beginning to develop in other countries, such as Canada’s Partnership Development Grants and the UK’s Global Challenges Research Fund Networking Grants. And while international support for networking is improving, funding still mainly focuses on pre-formed collaborations. Moreover, many participants noted a dearth of knowledge on existing resources, mainly due to the *lack of a consolidated resource overview for TTCIs*. Even without language barriers it can be *challenging to discover what TTI networking tools exist, how they work, and for whom they are relevant*. As one interview partner elaborates: “You can ask 20 people from different organizations, and you receive 20 different answers on how they find the partner and what they think are valuable ways of doing that. So, it’s very, very diverse” (IID6). Similarly, Filyushkina, et al. (2022) found that this lack of knowledge on resources was a common barrier for early career researchers (ECRs) working at the science-policy interface on biodiversity and ecosystem services. In Switzerland there is a growing number of initiatives that work at the science-policy-practice interface, but their visibility is still limited. And even within institutions, researchers sometimes aren’t aware of such initiatives or their participation requirements. For example, one interviewee was “part of ... [a research] community because of [a] previous job but ... was not aware that [those] meetings are open [for everyone]” (IID5). This lack of knowledge on existing exchange platforms is also an issue for practitioners and policymakers: “Many cities and municipalities don’t have the resources to inform [themselves]; an overview is lacking” (IID4). The challenge is how to organize this best, as different stakeholders might have different needs. Or as an interviewee put it: “Do we need one actor that represents the whole community, or do we need different actors in different places?” (IID4). This challenge might be particularly relevant for a country like Switzerland with four official languages and different cultures, but other countries might have similar constraints too.

It’s also *crucial to have financial support for collaborations and work at the science-policy-practice interface*: “You can only make (knowledge) transfer(s) if you have money. You cannot make this without money” (IID2). Finances are needed to support development of collaborations and to involve experts in knowledge transfer. Even if researchers are motivated to engage in the science-policy-practice interface, they may also need support for ‘translating’ the scientific findings into policy-practice-relevant information. It’s difficult to estimate an appropriate amount that needs to be invested but, according to an interviewee, Swiss National Research Programmes (NRPs) usually invest about 10% of the overall budget in transfer activities. Those activities involve different communication activities and the exchange with relevant stakeholders but, as another participant notes, “(t)he process that accompanies knowledge transfer usually requires more resources than have been budgeted for” (RID 126). These findings echo those of Filyushkina, et al. (2022) who noted a lack of funding as a major barrier for early career researchers wanting to work at the science-policy interface on biodiversity and ecosystem services. Moreover, in the final chapter of a recent edited volume on *Transforming Biodiversity Governance*, Kok et al. (2022: 349) consolidate and echo calls to those working on biodiversity governance at all scales to go beyond dedicated funding for transformative change to include “creating *new spaces for transformative action* and new institutions” (emphasis in original).

## Motivation from ‘below’

In addition to demand and support from above, motivation from researchers and practitioners is foundational for successful collaborations. This currently appears to be the strongest driver for TTCIs in Switzerland, yet this motivation must be connected to demand and support from above in order for TTCIs to succeed. Overall, our data indicate a *frustration that transdisciplinary research has yet to become mainstream*, despite being around for decades. As one researcher describes: “I think that I’m not the only one who is motivated by making an impact. (...) I think that [this] is really a core motivation for many researchers...” (IID5). And the same person laments: “I would love to speak more with people [practitioners and policy-makers] ... and understand their needs” (ibid.). And there seems to be an increasing motivation from practitioners too. While describing a networking event to pair researchers and practitioners, one interviewee remarked: “The need ... has been growing all the time. Now we have 500–600 companies per year that take advantage of this” (IID6). While we know of no other studies that gauge motivation to participate in TTCIs specifically, the numerous calls for TTCIs in the literature indicate that this motivation is shared across scales.

## Vital functional elements

An important part of both the questionnaire and the interviews focused on opportunities and best practices for science-policy-practice interfaces to properly function. Based on our findings, we broadly divide the vital functional elements of successful collaborations into two main challenges, which align with those highlighted by TTCI literature as described in Sect. 2: *finding a common language, understanding, and goals* and *knowledge pluralization*. Moreover, participants repeatedly noted that these two challenges are compounded by the time it takes to address them. In some cases, participants articulated some of the best practices necessary for addressing these challenges and we describe these below.

### Finding a common language, understanding, and goals

*“The thing is that practitioners and researchers use different languages and therefore a kind of ‘translation’ is needed in a good format” (IID4).*

A common struggle emphasized by participants was the difficulty with communication in a transdisciplinary environment. Scientists, disciplines, policy-makers, and practitioners often work through and speak about problems in very different ways that are specific to their peer group. This makes it difficult to communicate with and understand each other, and presents a significant challenge when attempting to identify common goals. Moreover, the ongoing issue of frame alignment discussed in Sect. 2 first requires common understandings of the problem. Although most participants continued to struggle with this challenge, they highlighted several vital practices necessary for overcoming it.

First, interactions between researchers and other stakeholders need to *start as early as possible*. According to one participant, “(m)any project managers do not plan knowledge transfer until shortly before the end of the project. It seems central to me to point out that

knowledge transfer must already be considered during project planning and that the interests and needs of the intended target group should also be included at an early stage” (IID2). The interviewee illustrated the effects of connecting too late with an example of a multi-year research project that ends soon: “They did not talk to the stakeholders in the beginning (...). And now this [research project] comes slowly to its end and the ... administration asked us ‘so, what are the results now? (...) And now we ... try hard to get the actors ... in. And it’s too late” (ibid.). The ideal process looks different: “In the beginning of the program we make stakeholder assessment. So, we check who the relevant actors ... in these fields are” (ibid.). Additionally, participants emphasized that once interactions have been initiated, they must happen *regularly*, but can be flexibly determined by participants’ schedules. Some team members may be more involved and/or have more responsibilities, while others may not feel a need to be involved in every decision or step of the initiative. Differential levels of commitment are to be expected and should be accounted for.

When interacting with collaborators, participants also stressed that team members need to *take the time to understand each other* and *build trust*, especially through ‘*informal*’ *connections* (e.g., brief personal ‘check-ins’ with team members at the beginning of a meeting). As one interviewee stated “(a) lot of interactions are built upon trust” (IID5) and trust often builds from knowing each other over time and with regular interactions. Adhering only to well-established formats like presentations at conferences are not sufficient because they don’t offer these types of connection. One interviewee asked different Swiss practitioners in biodiversity management what they needed regarding knowledge transfer, “and many of them told us that they like the direct exchange outside, in the field, with experts who explain things there” (IID4). If presentations must be used, another participant recommended “different presentations than the ones used in the academic world (not easy to understand the graphs, put in context, use pictures, explain simply, use talking pictures)” (RID 39).

Finally, one interviewee suggested organizing *events for people at similar career stages or in similar positions* within their organizations. “We are PhD students. In politics, there are probably also (similar) roles. And it seems if there could be some events where we could mingle together and understand each other better, that would be also very helpful” (IID3). They noted that this could be a good place to start building knowledge and connections that can then be expanded on in (more) mixed collaborations.

## Knowledge pluralization

A related struggle to that of finding a common language, understanding, and goals is the superficial recognition and acknowledgement of multiple epistemologies and their potential for catalyzing innovative solutions. Reflecting the patterns noted across TCI contexts as described in Sect. 2, many participants recognized that there is a lack of deep engagement with different forms of knowledge, but were unsure of how to address the struggles related to this issue. Such struggles included how to conceptualize and quantify diverse forms of ‘value’, measure and define ‘success’ in the context of multiple value outputs, meaningfully integrate social sciences and encourage (more) applied sciences, and engage stakeholder interest.

In domains like technology or natural sciences, collaborations between research and industry are well established, and it’s more or less ‘easy’ to agree on a definition of value (usually in economic terms) and a common means for measuring that value. But *assessing*

*non-economic values in TTCIs is much more difficult and needs to be further discussed.* The way that value is defined and measured also has *important implications for how the ‘success’ of a project is determined.* These issues are also noted in the TTCI literature and CSS experts caution that ‘success’ is often driven by dominant narratives (Klenk and Meehan 2015; Turnhout et al. 2020) that fail to acknowledge what is being transformed and for whom (Bennett et al. 2019; Massarella et al. 2021). As one interviewee indicated, “for the social impact in the end we still tend to think in social economic terms. You know, if you do that, how much in health insurance can we save? Or how much will ... the general cost of the public go down? I’m not sure that this is the way to go. But we’re developing these kinds of tools and metrics as we go. And I think there’s a lot of challenges and work ahead to really value the impact in a non-monetary way” (IID6).

The struggle to capture ‘value’ beyond economic terms often means that only those types of knowledge that contribute to this ‘value’ are seriously engaged in TTCIs (Büscher et al. 2022; Lahsen and Turnhout, 2021). The combination of defining societal value in economic terms and scientific value in terms of academic publications has led to a persistent lack of recognition of the (potential) contributions of social and applied sciences. In Switzerland, support for applied sciences is improving and funding agencies like Innosuisse “promote science-based innovation in the interest of the economy and society in Switzerland” (Innosuisse 2022). This would also include social sciences and social innovations such as those proposed by TTCIs. But as one interviewee explained, innovation-driven project funding in Switzerland has tried for “two years to go into the social sciences fields. But it’s not very well known in the social science community. And it’s not very well developed yet” (IID2). Still, they acknowledge that progress has been made: “Two years ago they didn’t know what social innovation could be. But now they are starting to come up with instruments.” (ibid.).

The role of science and scientific findings was controversially discussed during the Covid19-pandemic in Switzerland, but also in other countries. The learnings from this crisis still need to be further developed and discussed, but one interviewee mentioned that “we need to re-install credibility to scientific findings” (IID4). The relevance of some research is also often unclear to other stakeholders. “Certain topics are more interesting for policymakers and others less”, one interviewee stated, “and I’m not the one who can decide what’s relevant for policymakers” (IID1). Deep engagement with multiple forms of knowledge necessitates meaningful inclusion of all stakeholders, which in turn improves both the relevance and the credibility of research for stakeholders, as their perspectives are transparently included (Lang et al. 2012; Rose 2018). This means working together on mutual benefits where it makes sense, or as the same interviewee mentioned, “you have to bring people in and to make them all actors somehow” (IID2).

## Recommendations

Many recommendations have been offered by those working on co-productive processes (e.g. see Verschuere et al., 2012; Voorberg et al., 2015; Turnhout et al., 2020; Chambers et al., 2022), on inter- and transdisciplinary collaborations more generally (e.g. see Hirsch Hadorn et al., 2008; Hoffmann et al. 2017; Jaeger-Erben et al. 2018) and TTCIs more specifically (see e.g., Fougères et al., 2022; Strand et al., 2022). Our goal here is three-fold. First, we summarize recommendations for improving transdisciplinary opportunities and

interactions, based on the data collected, available literature/theory, and our participant observation as academics in transdisciplinary collaborations. Second, in making these recommendations, we emphasize the struggles of frame-alignment and knowledge pluralization that continue without resolution, despite prolific literature offering solutions. Finally, we add a novel recommendation to assist with these struggles.

In the previous section, we situated our empirical data from two Swiss research initiatives within existing literature across scales. On a global scale, our findings reflect those identified *within* IPBES and Future Earth as ongoing problems. Our recommendations are thus not only relevant for regional and national governing and decision-making bodies, but also for IPBES and Future Earth, as they continue to struggle with the same issues found at multiple scales *and* represent the authorities on the decisions made to address them at all scales (see also Sect. 2.1).

### **Recommendations for governing bodies and decision-makers across all scales: Strengthen demand and support for TTCIs**

It was clear from our data, as well as from our participant observations and the notable proliferation of calls for TTCIs in the literature, that researchers, practitioners, and policy-makers are highly motivated to participate in TTCIs. However, this motivation is often frustratingly deterred by the perceived lack of demand and support from governing bodies and decision makers. Therefore, we call on those with the power to make decisions that affect research and funding priorities for biodiversity on all scales to (continue to):

- *Redefine excellence* to include, for example, long-term collaborations, care work, practical experience, and community-engagement.
- *Protect time for those wanting to get involved in TTCIs*, for example, by actively promoting long term funding, providing more permanent positions early in academic careers, and rewarding time spent in collaborations.
- *Improve integration of foreign experts* working at the science-policy-practice interface.
- *Consolidate information on existing resources*, including initiatives at different scales, funding opportunities, networking tools, collaboration tools, etc.
- *Provide dedicated assistance with networking tools*.
- *Explicitly provide more funding and funding schemes for TTCIs* (e.g., earmark funding specifically for TTCIs).

These (continued) changes must happen at all levels of government and funding agencies. However, as the internationally recognized authority, it is incumbent upon IPBES, as well as others aiming for transformative change (e.g., IPCC), to provide an example for others to follow at multiple scales.

### **Recommendations for transdisciplinary collaborators at all scales: Account for vital functional elements**

Many of the struggles with finding a common language, understanding, and goals can be addressed by following best practices identified in the literature and as suggested by our participants with more experience in TCs. These practices include:



- *Collaborate as early as possible* (e.g., as soon as you begin to frame the problem).
- Meet with your team *as often as possible*, while still respecting differential levels of commitment within the team.
- *Take time to understand each other*; Learn to listen reflectively.
- *Actively build trust and make space for informal connections*.
- Consider arranging *separate meetings or events for people at similar career stages or in similar positions* within their organizations.

Incorporating more and multiple forms of knowledge can complicate the process of finding a common language, understanding, and goals. However, recall from Sect. 2 that Scoones et al. (2020) emphasize that diverse knowledge forms, plural pathways, and acknowledgement of politics' role in pathway possibilities must be taken seriously to achieve paradigm shifts. It is important to note here that pluralizing *voices* is different than pluralizing *knowledges*. In the former, each stakeholder has an equal chance of speaking, while in the latter, each knowledge system has an equal chance of representation in the validation process of problems and, therefore, solutions. Such an approach, often referred to as the 'Multiple Evidence Base' approach, allows for "an enriched picture of understanding, for triangulation and joint assessment of knowledge, and a starting point for further knowledge generation" (Tengö et al. 2014, p. 579) and moves beyond material justice to (also) include epistemic justice (Massarella et al. 2022). We therefore urge governing and funding bodies, as well as TTCI initiators and teams to:

- *Reconceptualize 'value'* beyond economic output and, therefore, how it is created and measured.
- Explore *new ways of measuring 'success'* that reflect multiple forms of value.
- *Integrate (critical) social sciences and encourage applied sciences*.
- *Include affected stakeholders* to improve both the relevance and credibility of future research.

As mentioned at the beginning of this section, many of our recommendations are not necessarily new and already exist in the literature. The literature on pluralization and politicization in co-production is particularly prolific here (e.g. see above references; also Colloff et al., 2021; Gorddard et al., 2016; Turnhout et al. 2020; West et al., 2020; and West and Schill, 2022). However, what is most notable is that *there is an ongoing struggle* to translate this knowledge into the transformative change that is needed to halt and reverse biodiversity loss. We thus contribute to this literature by adding our own recommendation in the next section.

### **Recommendation to address struggles with vital functional elements: Develop critical social science (CSS) literacy tools**

Despite following their own best practices, our participants' experiences still reflected the ongoing struggles noted in the literature with respect to securing the vital functional elements for TTCIs to thrive. Here, we suggest a novel intervention to assist with these struggles.

Social sciences are often conceptualized as a single homogenous group and attempts to incorporate social sciences in TTCIs tend to favor those that support traditional (i.e. non-paradigm-shifting) conservation goals, such as those that focus on changing individual behaviors without addressing the structural barriers to this, or calculating cost-benefit ratios (Ejderyan et al., 2019; Turnhout and Lahsen, 2022). To reiterate, critical social scientists are those who approach socio-ecological issues from critical theoretical perspectives (e.g. see Shackleton et al., 2022). They focus on structural knowledge/power and agency dynamics and their causal links to systems decisions and resultant socio-ecological problems. They are thus arguably particularly qualified to provide TTCI participants with an understanding on how to merge structural, systemic, and enabling approaches to transformation and how to take diverse knowledges, plural pathways, and pathway politics seriously. In other words, they are essential for ensuring the functioning of vital TTCI elements and for securing paradigm-shifting structural outcomes, as many have now argued (Cousins 2021; Fisher et al. 2022; Massarella et al. 2021; Wyborn et al. 2021). Moreover, by ensuring meaningful knowledge pluralization (Lahsen and Turnhout, 2021; Pascual et al., 2021), CSS could open the floor for new alternatives and guide governing bodies and funding agencies in reconceptualizing ‘value’ beyond its economic connotation, and in exploring new ways of measuring ‘success’ that reflect plural values. Guidance in knowledge pluralization would also include better integration of social and applied sciences, and meaningful inclusion of stakeholders. By meaningful inclusion of stakeholders, we refer to many of our participants’ suggested best practices (e.g. inviting stakeholders to participate in every part of the process from problem identification onward), but also to the consideration of multiple needs and perspectives, and of power asymmetries in the design of collaborative spaces and projects (e.g. see Chambers et al., 2022 and Tengö et al., 2017), and active decentering of Western scientific knowledge systems to create the space for plural knowledge enrichment (Latulippe and Klenk 2020).

Many scholars have contributed to the growing recognition of these potential unique contributions of CSS (Abson et al. 2017; Lahsen and Turnhout, 2021; Weiland et al., 2017). Yet, despite enduring demand for their inclusion (Emmenegger et al., 2017; Wiegleb and Bruns, 2022), even in fields that haven’t traditionally been associated with social sciences (e.g. physical geography; see Tadaki et al., 2015; Tadaki, 2016), CSS remain marginalized in TTCIs (Shackleton et al. 2022; Turnhout and Lahsen, 2022). Moreover, it was clear from our data, the literature, and our own participant observations that most TCs *want* to include CSS but are unsure what that means or how to go about doing so. This fits with an observation our team have made as participants in inter- and transdisciplinary environments, where we have witnessed, and spoken with others who have witnessed, the repeated disconnect between what CSS has to offer and what non-CSS experts *think* they have to offer.

First recorded as an observation by David Foster Wallace at a commencement speech, it is often remarked that the influence of power and culture on social norms and behaviors are like water is to a fish (Rahmawati and Taylor 2018; Risseuw 1988). It is not intuitive for a fish to be aware of the water in which it swims because it is a taken-for-granted ubiquitous presence. The fish must be taught to ‘see’ the water and then it cannot help *but* to see the water. It can never *un-see* it and so its new perspective on water becomes the new ‘intuitive.’ If this is the case, critical social scientists may be operating under the assumption that power structures are equally visible to other participants in TTCIs. Thus, the occasional simple explanation should suffice. However, it is clear from both our literature review and our own

observations that there is a mismatch in what critical social scientists believe is visible to others and what is actually visible. We therefore propose the development of CSS literacy tools to build the capacity both of critical social scientists in communicating CSS concepts and of non-CSS experts in understanding them, and thus improve and accelerate integration of CSS in TTCIs.

These tools could build on already existing tools designed to help engage different perspectives in inter- and transdisciplinary (ITD) collaborations. The ESTER project<sup>2</sup> (Ethische und soziale Aspekte Integrierter Forschung) encourages reflexivity on ethical considerations in technology development projects (combining an enabling approach with systems). COL-LAB<sup>3</sup> offers board games that enhance interdisciplinary research collaborations by encouraging discussions on diverse disciplinary principles. Dressel (2022) developed a tool for mapping actor assumptions for use in ITD settings. SHAPE-ID<sup>4</sup> (Shaping interdisciplinary practices in Europe) and Michigan State University's Toolbox Dialogue Initiative<sup>5</sup> provide tools to create collaborative spaces and environments. Such projects aim to foster common understandings of different disciplines and worldviews.

CSS tools would add the structural dimension to these tools and assist with developing generalizations across scales. For example, IPBES' 2022 Values Assessment introduces a framework to integrate diverse values of nature into policy and decision-making processes. Here, CSS literacy tools could play a key role in facilitating the integration of CSS in order to address power dynamics among different knowledge systems, scales, and dimensions. Addressing such complexities of power would then assist with the adequate inclusion of diverse values in the IPBES framework, as well as with the development of value indicators for policy and decision-making. Moreover, we believe that CSS tools could cut down on the time needed for reaching a common language, understandings, and goals by teaching participants how systems of knowledge and power work from the outset, both in the problem being defined and in the TC itself.

## Conclusion

In this paper we have situated empirical data from a Swiss-based survey within a global context to show how demand and support for TTCIs from 'above' could be improved, and how struggles with finding a common language, understanding, and goals, and knowledge pluralization could be addressed on multiple scales. We outline best practices for problem frame-alignment identified by our participants and offer recommendations based on these, the literature, and our collective experiences in inter- and transdisciplinary environments. To these, we have added our distinct contribution of calling for CSS literacy tools.

The recent IPBES Value Assessment (IPBES 2022) offers a framework that allows the interweaving of diverse values of nature, providing a tool to bring multiple values into future IPBES assessments. This is of particular importance for two currently ongoing assessments,

<sup>2</sup> See <https://integrierte-forschung.net/teilprojekt-ester>.

<sup>3</sup> See <https://www.interdisciplinarygames.net/>.

<sup>4</sup> See <https://www.shapeidtoolkit.eu/>.

<sup>5</sup> See <https://tdi.msu.edu/research-overview/#pubs>.

the Transformative Change Assessment<sup>6</sup> and the Nexus Assessment<sup>7</sup>. Work on biodiversity and ecosystem services scenarios has also considerably evolved since the Scenarios Assessment (IPBES, 2016). In a broad, iterative consultative process with a wide range of stakeholders and the aim to build positive visions for nature, the pluralistic Nature Future Framework was developed (Lundquist et al. 2021; Pereira et al. 2020). The framework enables the development of scenarios at a range of different scales and (geographical) contexts, while recognizing diverse worldviews. Both assessments provide a great opportunity to actively incorporate CSS. The Transformative Change Assessment aims “at identifying and providing understanding of factors at various scales in human society. ... These factors span ... social [and] ... institutional ... dimensions” (IPBES 2021a). And the Nexus Assessments aims at evaluating “the role of the most important indirect (i.e., societal values, ... culture, and governance) and direct drivers of change ... [and] the role of both formal and informal institutions ...” (IPBES, 2021b). To both highlighted aims, CSS can provide fundamental inputs on structural power dynamics to be targeted for change, but *only* if CSS literacy is present.

Time is of the essence. As the new co-chairs of the IPBES Transformative Change Assessment noted in a recent media release, the assessment “will offer practical options for concrete action to foster, accelerate and maintain the transformative change necessary for a more sustainable future” (IPBES Secretariat, 2022). Our recommendations are both practical and concrete and we add to the growing assertion that meaningful integration of CSS in TTCIs at every scale is one of the best ways to foster, accelerate, and maintain paradigmatic structural change. Moreover, as Dr. Anne Larigauderie, Executive Secretary of IPBES proclaimed: “These new IPBES assessments will be among the most complex and interdisciplinary ever undertaken” (ibid.). We contend that this cannot be done without taking critical social sciences and scientists seriously and that this begins with better understandings of what they have to offer. We believe that CSS literacy tools could help us get there.

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**Author Contribution** RK, CK, and AM chose the case studies and secured funding for this project. All authors co-designed the research questions, questionnaire, and interview guide. AM launched and compiled descriptive statistics for the questionnaire. RK provided translations of German and French responses to English, as well as the transcription and translation of one French interview. SD and RK conducted all interviews except one, which was conducted by RK and CK. SD and RK conducted all content analyses and iteratively discussed findings with CK and AM to triangulate and adapt identified themes. SD provided the initial conceptualization of the paper, but all authors contributed to the expansion of the conceptualization and the development of the text. AM designed Table 1, SD and RK designed Fig. 1, and AM designed Fig. 2. CK assisted with triangulation of the data based on her experiences with IPBES, Future Earth, and as the science liaison for the URPP GCB. All authors contributed their participant observations from working in inter- and transdisciplinary environments, including in URPP GCB and Valpar.CH. SD drafted the main text and RK, CK, and AM contributed sections. Responsibilities for revisions were assigned based on original

<sup>6</sup> Thematic assessment of the underlying causes of biodiversity loss, determinants of transformative change and options for achieving the 2050 vision for biodiversity.

<sup>7</sup> Thematic assessment of the interlinkages among biodiversity, water, food and health.

section authorship, while SD was additionally responsible for aligning sections and revisions with the overall framing of the manuscript. All authors reviewed the original and revised manuscript.

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