

Transformative research for sustainability: characteristics, tensions, and moving forward

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Abstract

Technical summary. The question of how science can become a lever in achieving the Sustainable Development Goals permeates most recent sustainability research. Wide-ranging literature calling for a transformative approach has emerged in recent years. This ‘transformative turn’ is fueled by publications from fields such as sustainability science, social-ecological research, conservation science, sustainability transitions, or sustainability governance studies. However, there is a lack of a shared understanding specifically of what is meant for research to be transformative in this developing discourse around doing science differently to tackle sustainability problems. We aim to advance transformative research for sustainability. We define transformative research and outline six of its characteristics: (1) interventional nature and a theory of change focus; (2) collaborative modes of knowledge production, experimentation and learning; (3) systems thinking literacy and contextualization; (4) reflexivity, normative and inner dimensions; (5) local agency, decolonization, and reshaping power; (6) new quality criteria and rethinking impact. We highlight three tensions between transformative research and traditional paradigms of academic research: (1) process- and output-orientation; (2) accountability toward society and toward science; (3) methodologies rooted in scientific traditions and post-normal methodologies. We conclude with future directions on how academia could reconcile these tensions to support and promote transformative research.

Non-technical summary. Dominant ways of doing research are not enough to achieve the UN Sustainable Development Goals. The typical response of science to dealing with the current local and global sustainability crises is to produce and accumulate more knowledge. Transformative research seeks to couple knowledge production with co-creating change. This paper defines the transformative way of doing research to pro-actively support society’s fight against pressing societal and environmental problems. We present six characteristics of transformative research. We reflect on the challenges related to implementing these characteristics in scientific practice and on how academia can play its part.

Social media summary. Sustainability transformation needs to be reflected in science, but what makes sustainability research transformative?

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1. The need for transformative sustainability research

The way science can support society in dealing with today’s global crises is changing from fundamentally understanding sustainability problems toward finding solution-options to the challenges presented by climate change and biodiversity loss (O’Brien, 2021). Research about and for transformative change emerged in response to the need for all societal actors including

science to contribute toward meeting global sustainability goals such as those of the 2030 Agenda for Sustainable Development (Hölscher et al., 2021; UN, 2015). It has roots in understandings of societal change and biophysical, environmental change, and indeed on the intersections therein. Bringing together different knowledge types for sustainability research has long-acknowledged tensions of bridging between different epistemic communities (e.g. Cairns et al., 2020; Freeth and Caniglia 2020). Not least, there is a continued domination of physical science research, and a squeezing of social science and humanities perspectives into physical science paradigms (Lahsen & Turnhout, 2021; Overland & Sovacool, 2020; Shove, 2010). However, the imperative of transformations to sustainability is that we go beyond interdisciplinarity. It requires knowledge that is overwhelmingly normative, political, and contested, and that reshapes power in knowledge (Lahsen & Turnhout, 2021). Indeed, today's global crises delineate a shift in the role of research and researchers in exploring, creating and contributing to moving society closer to a sustainable trajectory.

In meeting these requirements, there is a growing agreement that in order to reach for societal transformations, science needs to be conducted in a transformative way (e.g. Kläy et al., 2015). Since the beginning of the last decade, sustainability science distinguished between its transformative branch focused on how to intervene in sustainability problems, and a descriptive-analytical branch focused on describing and analyzing sustainability problems (Wiek et al., 2012, Table 1). The 'transformative turn' (Blythe et al., 2018) goes beyond the field of sustainability science and is driven by publications from social-ecological research (Pereira et al., 2018), socio-technical transitions research (Loorbach et al., 2017), conservation science (Fougères et al., 2022; Wyborn et al., 2021), and natural resource management (Hakkarainen et al., 2022). Developments that followed were backed by the policy agenda (UN 2030 Agenda for Sustainable Development), by research programs (Future Earth, 2013; van der Hel, 2016), research institutes (Schneidewind et al., 2016), and funding agencies (e.g. Belmont Forum, Volkswagen Foundation). As a UN body, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) also recognizes 'science' as a key actor for achieving pathways toward sustainability, without specifying how science and scientific institutions should act to find 'innovative solutions for

transformative change towards a more sustainable world' (IPBES, 2019, 2021). In recent years, publications that argue for or apply a transformative approach have gained unprecedented momentum (e.g. Colloff et al., 2017; Hölscher et al., 2021; Lam et al., 2021).

However, both sustainability research and practice currently lack a coherent understanding of what transformative sustainability research is. Although other authors have described antecedents to transformative research (Wiek & Lang, 2016, Table 1), a persistent knowledge gap remains for systematized guidance about the characteristics of transformative research, and about how such research can be operationalized and promoted between and across actors in academia. In addition, there is a need to uncover the tensions that arise with the traditional paradigms of academic research when planning and carrying out transformative research for sustainability.

Here, we aim to define, characterize, and advance the understanding of transformative research for sustainability. We are interested in specifying the nature of transformative research to both increase its chances of actively advancing sustainability transformation and to improve its visibility in the academic world. Our practical intention is to consolidate an introduction targeted at those outside the transformative research community, but who, in the context of their work, need or seek to connect with it. In so doing, we are driven by advocating what transformative sustainability research *should aspire to* in order to unlock the potential of science as active contributor to meeting today's global challenges. We are also motivated to prevent the use of 'transformative' as token language, but rather as an approach that does carry a certain meaning, responsibility, and objective. Indeed, there is a distinction between *transformation research* which builds knowledge by inquiring about transformations, and *transformative research* which seeks to bring about these changes by organizing the inquiry process differently (Table 1; Linnér & Wibeck, 2019; Meisch, 2020; WBGU, 2011). This distinction between building knowledge *about* and knowledge *for* transformation (Liniger et al., 2017) shifts the focus from 'the what?', i.e. more or better knowledge, to 'the how?', i.e. better processes of knowledge. This means that research can still count as sustainability transformation research without being transformative (see also Kok et al., 2019; Liniger et al., 2017), making it all

Table 1. Antecedents to transformative research introduced as transformative branches in sustainability research

Key references identifying a transformative-other dichotomy in sustainability research	Transformative branch in sustainability research	Other branches in sustainability research
Spangenberg (2011)	Science of sustainability	Science for sustainability
German Advisory Council on Global Change (WBGU, 2011)	Transformative research	Transformation research
Wiek et al. (2012)	Transformational mode	Descriptive-analytical
Miller (2013)	Process-oriented approach	Knowledge-first approach
Feola (2015)	Solution-oriented research	Analytic descriptive research
Wiek and Lang (2016)	Transformational stream	Descriptive analytical stream
Fazey et al. (2018)	2 nd order transformation research	1 st order transformation research
Linnér and Wibeck (2019)	Research for transformations	Research on transformations
Institute for Advanced Sustainability Studies (IASS, Meisch 2020)	Transformative research	Transformation research
Lang and Wiek (2022)	Solution-oriented trajectory	Problem-oriented trajectory

Key references are selected based on their identifying similar dichotomies between a more transformative way of doing sustainability and transformation related research, and the other, more traditional ways.

the more important to delineate what makes research transformative.

We structure the paper as follows: In section 2, we briefly introduce our research backgrounds, and explain how we draw on such experience in shaping the presented understandings of transformative research. In section 3, we define transformative research for sustainability. We then summarize six characteristics of transformative science (section 4), and surface three tensions between transformative and traditional paradigms of academic research that become apparent when trying to conduct transformative research in practice (section 5). Finally, we envision ways forward for three critical actors in academia: researchers, universities, and funding agencies (section 6).

2. Positioning ourselves and limitations

We are a group of scientists at different stages of their career having worked on research projects, such as Leverage Points for Sustainability Transformation (Abson et al., 2017), SUSPLACE – Sustainable Place Shaping (Quinn & de Vrieze, 2019), ENVISION – inclusive conservation (Raymond et al., 2022), WildlifeNL (2023) and Lüneburg 2030 (2020), that sought to understand and support interventions for systems change toward desirable futures. We have interdisciplinary backgrounds such as transdisciplinary sustainability science, social-ecological research, practical philosophy, environmental social sciences and psychology, environmental governance, political science, and human geography, and we draw on these bodies of knowledge.

Our paper is written iteratively, in part informed by existing literature, but also by reflections within the authors team on what transformative research should consider based on our collective research and praxis experience working within diverse transformative processes. The literature on how to reconsider knowledge generation to support sustainability transformations is still fragmented, with little convergence toward a common theoretical language and even less consensus on how to do transformative science (Jacobi et al., 2022). Consequently, we cannot rely on a systematic protocol, and instead use our expert knowledge to identify relevant literature and recurrent transformative research characteristics. Their existence may be relatively established within communities sitting at the science-society interface, including the transformative community, but less so for those engaging on the margins. We also acknowledge notable examples of studies seeking to conceptualize and organize academic experiences and reflections with research that is intentionally transformative drawing on the sustainability transitions research community (Hölscher et al., 2021; Kump et al., 2023; Wittmayer et al., 2021). Similar discourses on the outlined characteristics of transformative research together with the challenges they bring are also happening within other communities of engaged research such as knowledge co-production (Norström et al., 2020), action research (Caniglia et al., 2021; Fazey et al., 2018), or the transdisciplinary sustainability science community (Lam et al., 2021; Spiering & Barrera, 2021). Notably, there is a large overlap between transformative research, as described in this paper, and other forms of interventional engaged research (e.g. transdisciplinary or participatory action research, Wyborn et al., 2019) that will be further addressed below.

For the purpose of this paper, we conceive of transformation as a ‘fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values, needed for the conservation and sustainable use of biodiversity,

long-term human wellbeing and sustainable development’ (IPBES, 2019). Because the focus of the paper is on the meaning of the how of ‘transformative’, and not on the what of ‘transformation’, a review of what is understood by ‘transformation’ falls outside the scope of this paper, but see Feola (2015), Patterson et al. (2017), or Scoones et al. (2020) for an analysis of transformation conceptualizations.

3. Defining transformative research for sustainability

We define transformative sustainability research as the reflexive collaborative production of transformation knowledge (processes, pathways, levers and leverage points) organized as an intervention that facilitates intentional change toward a desirable future in a contextually defined system. It aims to (co-)produce, test and implement transformation knowledge.

For the above definition of transformative (sometimes termed ‘transformational’) research, we start from the established distinction between the transformative (solution-oriented) branch and other branches (problem-oriented) in sustainability research (Table 1). In addition, we build on three types of knowledge, needed for sustainability transformations, namely system knowledge, target knowledge, and transformation knowledge (adapted from Brandt et al., 2013; Jerneck et al., 2011; ProClim, 1997; Stepanova et al., 2020). System knowledge builds an understanding of a system’s current dynamics, function and components, as per the majority of the social-ecological studies. Target knowledge refers to an understanding of a system’s desirable future state, often associated with a sustainability-aligned vision, for example the 17 UN Sustainable Development Goals. Transformation knowledge refers to *how to* reach that desirable state, as per, for example, the summary of possible actions and pathways to achieve transformative change (IPBES, 2019). We further conceptualize transformation knowledge as knowledge about *how to* intervene (interventions, processes, pathways, and levers), and *where to* intervene (leverage points), with the assumption that transformative science plays a reflexive role in *who* intervenes. Although transformative research may also engage with system and target knowledge, it does so not as an end goal in and of itself, but as a prerequisite to the co-production of transformation knowledge.

Epistemologically, transformative research is grounded in mode-2 science, including the closely related idea of post-normal science (Funtowicz & Ravetz, 1993), as well as participatory action research (Janes, 2016). Mode-2 describes a dynamic science-society relationship, moving from a one-way transfer of knowledge from science to society as per mode-1, toward transdisciplinary co-production of knowledge with a variety of societal actors (Horcea-Milcu, 2022). In mode-2 science knowledge is produced in ‘the context of application’ in a dialog, following the rethinking of the role of science in society (Gibbons et al., 1994, pp. 3–7). Mode-2 questions the assumption that action automatically follows from knowledge (Bai et al., 2016), while mode-1 contains assumptions among others about what and how to research or learn. Transformative research is also linked to the transformative worldview of Creswell (2014), one of the epistemic worldviews which researchers bring in their scientific inquiry, alongside post-positivism, constructivism, and pragmatism. Mertens (2009) also amply articulates ontological, epistemological, and axiological assumptions of a transformative approach addressed at social issues, however without any direct connection to the topic of sustainability, or sustainability transformations.

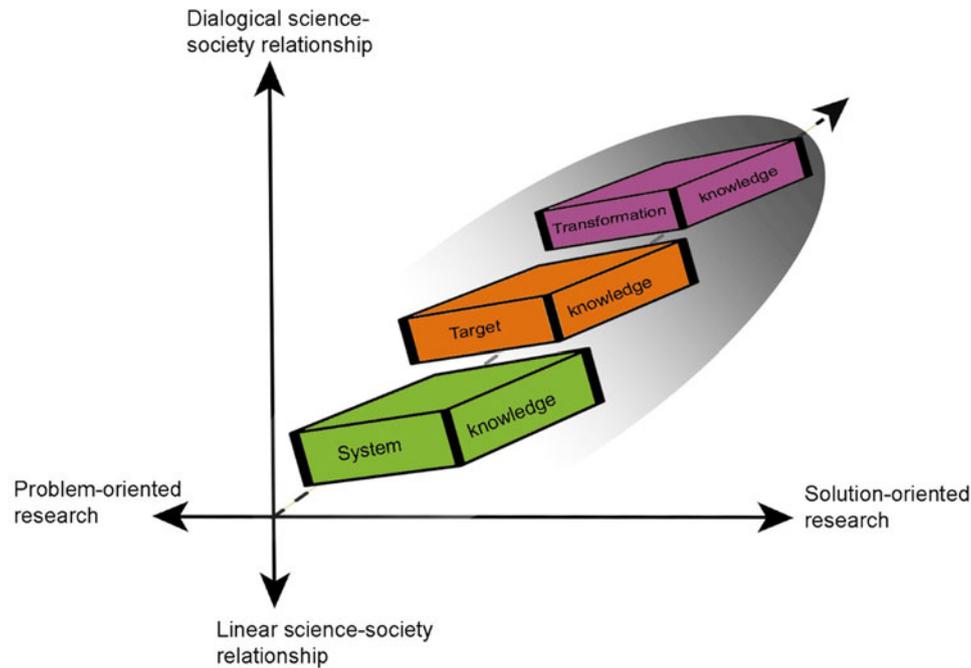


Figure 1. Transformative research at the intersection of solution-oriented research and a reflexive dialogical science-society relationship.

To demarcate transformative research, we locate it at the intersection of solution-oriented research and a reflexive dialogical science-society relationship (Figure 1). We recognize that most of the engaged forms of research that seek to link knowledge and action (e.g. transition or participatory action research) can also be located in the area delineated by solution-orientation and a dialogical science-society relationship. However, transformative research aspires toward the far ends of the spectra and has a clearer focus on transformation knowledge in pursuit of sustainability. In its interventional aspiration to connect knowledge and action to address social-ecological challenges, transformative research is distinguished by a simultaneity of characteristics (section 4) which reframe the relationship between knowledge and action for sustainability to ‘knowledge becomes action’ or ‘knowledge is action’.

4. Characteristics of transformative research

Hereinafter, we mainly build on recent sustainability research developments (sections 2 and 3), and on our backgrounds and expertise (section 2). We also draw on the theory of Gibbons et al. (1994) on new modes of knowledge production, on the text of Mertens (2009) on transformative research and evaluation, and on the transformative worldview developed by Creswell (2014) (section 3). We extract and distill six aspirational characteristics which are likely to unleash or at least increase the transformative potential of sustainability research. With time, the practice of transformative sustainability research, now at its dawn, may consolidate other characteristics. We recognize some may be common to other forms of engaged research, although they are found in combination with other characteristics. We outline the six literature-reoccurring and interconnected characteristics below (Figure 2), acknowledging their normative nature and the limitations of science and academia in contributing to societal change. We trace each characteristic to representative literature, which although sometimes not labeled as ‘transformative’, fits an explanatory purpose.

4.1 Interventional nature and a theory of change (ToC) focus

At the heart of transformative research is the desideratum to go beyond observing and analyzing current states of the world, to enacting change toward desirable states of the world (Fazey et al., 2020; Schneidewind et al., 2016). A transformative sustainability research project implies the existence of a knowledge co-production interventional stage (Lam et al., 2019; Wiek & Lang, 2016). This can take the form of sustainability pathways building (Chambers et al., 2022), guided deliberative nature valuation (Stålhammar, 2021), or the formulation of new narratives of sustainable societies (Linnér & Wibeck, 2020). Sustainability-oriented labs in all their forms (see McCrory et al., 2020) are one of the main formats or settings for the contextualization of transformative research, as they are often composed by an sequence of knowledge co-production interventions (Charli-Joseph et al., 2022, see also the transformative transdisciplinary interventions and living labs subtype in Busse et al., 2023) or experiments (Caniglia et al., 2017, see also 4.2).

In comparison with transdisciplinary sustainability research, the knowledge co-production process in itself (see 4.2) is the main intervention, in addition to expecting that the co-produced knowledge will generate societal and scientific impact by feeding other external policy, governance, or technological interventions. These knowledge co-production interventions hold transformative potential for all participants involved, from researchers to community members who become themselves changed in the process (Leventon et al., 2021, see also 4.4). Looking at knowledge co-production as an intervention affects the research design, especially when planning for monitoring and evaluation (see 4.6), and when formulating the research question. Answering hypothesis testing or ‘what is’ questions, diagnosing problems and their causes may not necessarily translate into actionable knowledge or provide solution-options to solving a problem. Maintaining humility regarding the capacity of transformative research to offer solution-options is necessary, seeing the entanglements between science, politics and the economy (Spiering & Barrera, 2021; van der Hel, 2018).

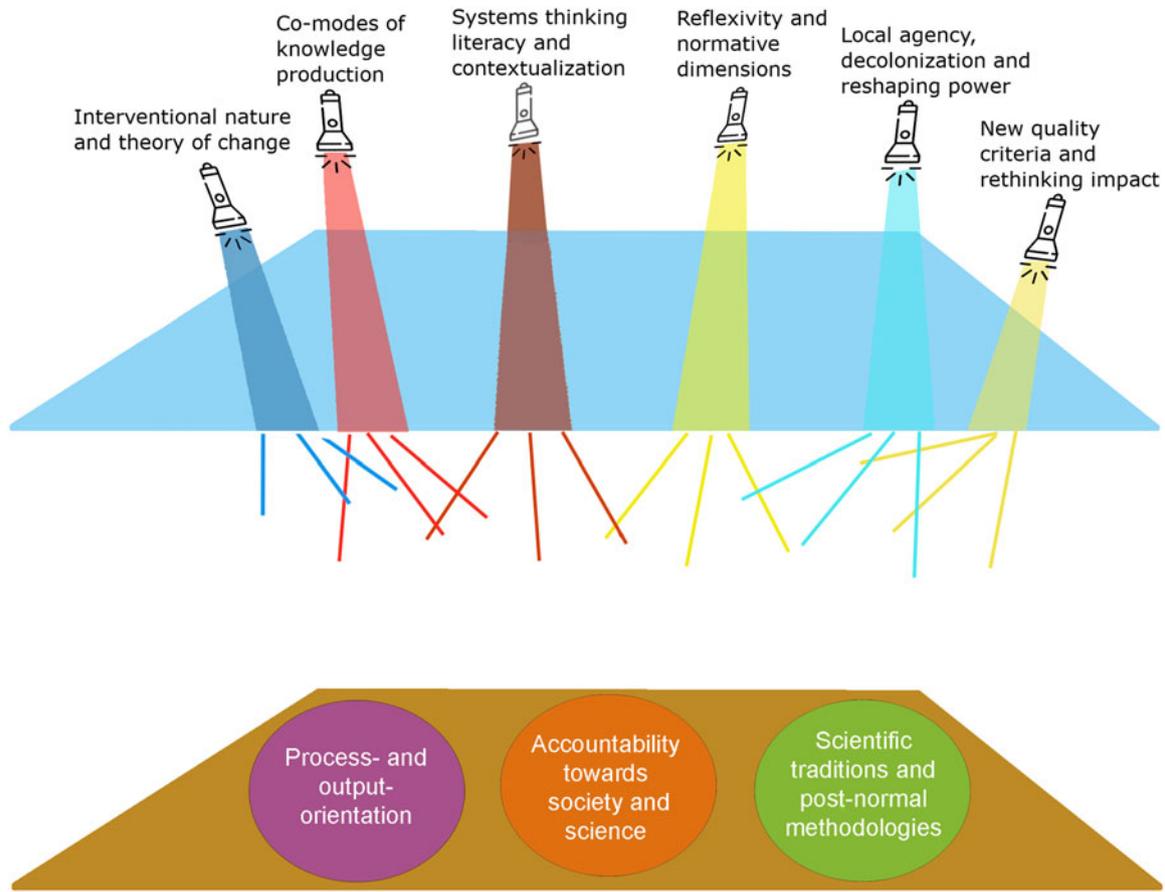


Figure 2. Characteristics of transformative research for sustainability. When passing through the filter of practical implementation, they illuminate three tensions with the traditional academic paradigm.

To operationalize the solution-orientation and interventional nature of a transformative project, a growing scholarship employs a 'theory of how and why a certain intervention will be successful' (Deutsch et al., 2021; Schneider et al., 2019a; Wanner et al., 2018). To explain how change might happen within respective research projects, generic elements of theories of change (ToC) such as interventions (knowledge co-production activities), pathways, impacts, and the roles of scientists need to be articulated (Oberlack et al., 2019). Specifying from the onset a ToC with an appropriate level of detail can reveal flaws in the underlying assumptions or management of change, and facilitate planning for additional activities needed for the intended impact (Belcher & Claus, 2020). In addition, a ToC can serve as a living monitoring, evaluation and learning tool (Belcher & Claus, 2020). However, an over-specified theory of change may hinder responsiveness to emergent challenges. Adopting a systems approach that allows for the modularity and adaptability of the ToC may be more suitable (Fritz et al., 2019, see also 4.3). Without the involvement of non-academics and the willingness to learn, ToC runs the danger of becoming a non-reflected top-down box ticking exercise. Transformative researchers have experimented with combining a ToC with other design tools (e.g. Theory U) to counteract its mechanistic side (Moriggi, 2021).

4.2 Collaborative modes of knowledge production, experimentation and learning

A commitment to collaboration between science, civil society, governments, and industries is necessary when weaving

knowledge production to processes of social change (Cvitanovic & Hobday, 2018; UN Environment, 2019). To minimize the barriers between science, society, policy, and action, new collaborative forms of knowledge production and use are employed (Irwin et al., 2018; Jacobi et al., 2022). The co-modes of co-design of research, co-production and co-implementation of knowledge have been highlighted as suitable to address complex, wicked problems of planetary boundaries, human institutions and behavior (Chambers et al., 2021; Hakkarainen et al., 2022; Moser, 2016; Norström et al., 2020; UNESCO, 2017). Other authors point to the ambition of co-production to build capacities, strengthen social networks and relationships, and transform norms and institutional structures within science and society (Jagannathan et al., 2020, see also 4.6). In this vein, an essential requirement is for the co-design of the research process to start from problem framing that is from the creation of a joint understanding of the sustainability problem to be addressed (Lang et al., 2012). Researchers and stakeholders as problem co-definers have been also emphasized by other interventional research communities including action research (Bradbury, 2015). In fact, prior to problem framing, to maximize the transformative potential of knowledge collaborations, researchers deploy substantial resources to, for example, initiate a transdisciplinary process. Neglecting this initiation phase risks glossing over the tangible challenges that arise in real-world problem constellations, and prevents them from being fully addressed (Horcea-Milcu et al., 2022).

Beyond co-production, another collaborative knowledge creation process is experimenting with co-produced knowledge

(Fazey *et al.*, 2018, see also 4.1). Epistemological attention has recently focused on observing experiments in real-world settings, often conceptualized as real-world laboratories (McCrorry *et al.*, 2020; Schöpke *et al.*, 2018b; Stojanovic, 2021). Transformative experiments produce empirical evidence through iterative prototyping, evaluating and learning from outcomes (Caniglia *et al.*, 2017). Unlike classical experiments in the natural and social sciences, transformative experiments offer the opportunity to link co-produced knowledge to real-world contexts, enhance interactive learning, and generate outcomes for innovative solutions (Weiland *et al.*, 2017). Experimental settings with potential for upscaling may also accelerate social innovation. To build the capacity to link knowledge with action for sustainability, scientists encourage the creation of organizational safe spaces fit for experimentation (Clark & Harley, 2020; Pereira *et al.*, 2020).

The collaborative modes of knowledge production and experimentation collectively emphasize the importance of learning together along the whole of knowledge co-design, co-production or co-implementation processes (Hakkarainen *et al.*, 2022). Co-learning is seen as a necessary premise for reflexive collaboration to occur or to produce evidence within transformative experiments. A transformative research design actively creates and fosters opportunities for learning not as a by-product of research, but as an intentional outcome, while action research plans for learning as an integral part of the research process (Bradbury, 2015). More so since some practitioners of change frame transformations in terms of learning at the level of values and paradigms (Waddell, 2016), while in natural resource management they regard co-learning as supporting positive change (Hakkarainen *et al.*, 2022).

4.3 Systems thinking literacy and contextualization

There is an increasing demand for a systems perspective on sustainability transformations from both policy and academia (Voulvoulis *et al.*, 2022). Systems thinking is well placed to comprehend the non-linearity of wicked sustainability problems, and allows for the generation of transformation knowledge, such as the identification of points of intervention or leverage points, supporting the interventional nature of transformative research (Leventon, 2021, see also 4.1). As a holistic cognitive framework, 'thinking in systems' (Meadows, 2008) shifts the focus of analysis from elements to interrelationships and stimulates the ability to identify and deal with uncertainty. Especially the notion of social-ecological systems has highlighted the constantly evolving relationships between human societies and their environment (Partelow, 2018). Despite sometimes being criticized for a mechanistic approach, systems thinking notions, such as leverage points, have been largely taken up as a metaphor, while knowledge about system properties such as emergence and hierarchical organization has been integrated as everyday heuristics, practical wisdom (Caniglia *et al.*, 2023; Fazey *et al.*, 2020), or cognitive skill (Chowdhury, 2023). The UN Educational, Scientific and Cultural Organization (UNESCO) cites systems thinking among the eight key sustainability competencies needed to think and act for sustainable development (Leicht *et al.*, 2018).

Alongside this theoretical literacy, sustainability problems and solution options are context-dependent, situating the practice of transformative research in 'real-life' circumstances, which demand attention to bounded political, institutional, socio-economic, and ecological contexts. Context dependencies, their implications for method selection, and corresponding societal and scientific

effects, are still insufficiently understood in co-modes of research (4.2). Neglecting contextualization, through generalization and aggregation, can obscure system inequalities and perpetuate power asymmetries and colonial structures in science: who transforms what for whom? (Lahsen & Turnhout, 2021, see also 4.5; Lam *et al.*, 2020). Translating transformation pathways or sustainable development goals to specific contexts can be done relative to a place or system at a certain scale (e.g. national energy system or regional mobility system) (Luederitz *et al.*, 2017; Schneider *et al.*, 2019b). Place-based interdisciplinary research has made valuable theoretical and methodological contributions to addressing cross-scale social-ecological dynamics and global drivers of change while maintaining a focus on locally relevant issues (Martín-López *et al.*, 2020). However, place-based contextualization should not be done at the expense of overlooking non-linearities and scale interdependencies (e.g. telecoupling). Hence, transformative research aspires to alternate between zooming in on the small-scale system for contextualization and zooming out on the level of the embedding system for coherence, permanently managing the tension between place-based and wider systems transformations.

4.4 Reflexivity, normative and inner dimensions

Reflexivity is a way to bring transparency to the normative dimensions of transformative research. Reflexivity expands and challenges the conventional role of researchers to interrogating the assumptions they bring to the transformative research inquiry (Evans, 2021; Horlings *et al.*, 2020). In the case of science seeking to steer transformative change, it is essential that researchers become more reflexive about their non-epistemic values underpinning methodological choices (Horcea-Milcu *et al.*, 2019; Minna *et al.*, 2024). Added to this, the interrogation of epistemic values embedded in scientific practices is useful for bridging gaps between fields within collaborative contexts (MacLeod & Nagatsu, 2018; Nagatsu *et al.*, 2020; Sojininen *et al.*, 2022). Allocating resources for critical self and group reflection in inter- and transdisciplinary teams could support the development of reflexivity as a common practice in academia (Borie *et al.*, 2020; Freeth & Vilsmaier, 2020). This calls for redefining notions of success and rethinking productivity within academic reward systems (see section 6).

The normative core of transformative research is perhaps what differentiates it the most from other forms of engaged research. Transformative research has the normative mission of orientating societal development toward human values (Lang *et al.*, 2021) such as empathy (Brown *et al.*, 2019). Normativity and values-thinking in transformative research includes making values in research explicit, but also building upon and promoting certain values (Redman *et al.*, 2021). Recent work by IPBES focuses on 'sustainability-aligned values', such as justice and stewardship (IPBES 2022), and advocates for their 'unleashing' (IPBES, 2019) by multiple actors across sectors including academia. The IPBES Values Assessment refers to 'values-centered, system-wide transformations' and recognizes the values underpinning different sustainability pathways (e.g. green economy or degrowth). For example, green economy is underpinned by instrumental values, emphasizing the role of nature as an asset, while degrowth is underpinned by values of sufficiency and egalitarianism for shaping people's balance with nature (IPBES, 2022). These underlying values should be scrutinized and iteratively re-evaluated against other criteria such as justice and equity, and against the

community values where the co-production intervention takes place (see 4.2). Theories of change and associated interventions need not only be articulated (as described in 4.1), but also unpacked to reveal their normative assumptions and value orientations, for example with the help of ethicists.

The transformative way of doing science may also change interiorities (Wamsler et al., 2021) including those of researchers. It invites deep reflection regarding the relationship between the researched and the researcher (Wittmayer & Schöpke, 2014), and between knowledge and underlying values (Hansson & Polk, 2018), constantly challenging gained perspectives. Future knowledge systems need to be capable of actively working with values and emotions (Fazey et al., 2020) so that proposed solution-options can be acknowledged as both personal and political (Pereira et al., 2020; Spiering & Barrera, 2021; Vogel & O'Brien, 2022; Wamsler & Osberg, 2022). Tackling the complexity and unpredictability of steering transformative change requires not only new ways of producing knowledge (4.2), but also the capacity to make collaborative knowledge processes, sustainability-aligned values (Daedlow et al., 2016), and inner dimensions to resonate (Wamsler & Osberg, 2022).

4.5 Local agency, decolonization, and reshaping power

Transformative research recognizes the limitations of the traditional linear science-society relationship in addressing sustainability challenges (Figure 1). It dismantles existing hegemonies such as the neoliberalisation of academia, or the Trust in Numbers imperative of quantitative research (Porter, 1995), and problematizes dominant framings of science (Hölscher et al., 2021; Temper et al., 2019). It recognizes the ideal to fundamentally change existing knowledge systems toward epistemically diverse ones, equipped to work with complex systemic issues (see 4.3) and with values (see 4.4) (Fazey et al., 2020). Existing ways of creating and applying knowledge are often a product of the same system and power dynamics driving the sustainability problems that transformative research is seeking to address in the first place (e.g. climate change, biodiversity loss). Critically inquiring knowledge (co-)production for whom and with whom (Fritz & Binder, 2020; Manuel-Navarrete et al., 2021; Turnhout et al., 2020) becomes central to the organization of the transformative scientific process. In order to build socially inclusive spaces and prevent marginalization of voices, breaking ingrained power relations is needed (Temper et al., 2018; Vogel & O'Brien, 2022). As are decolonizing social relations in the practice of knowledge creation (Gram-Hanssen et al., 2022) and celebrating plural ways of knowing that challenge narrow scientific framings (Latulippe & Klenk, 2020; Nightingale et al., 2022). Within the conservation field, the 'transformative turn' prompted conservation researchers to promote inclusivity (of underrepresented voices) and plurality (of ways of knowing) when revisiting biodiversity research and action (Colloff et al., 2017; Raymond et al., 2022; Wyborn et al., 2021).

Transformative research moves from considering those taking part in the research process as design participants (see 4.2) to considering them agents of change. The agenda of transformation needs to be shared with local people (Nightingale, 2017), recognizing the centrality of human agency in responses to global crises (Mehta et al., 2021). Applications in local decision-making, as opposed to the global level, present conditions necessary for a higher proportion of human-nature relationships to be represented instead of aggregated. Transformative research acknowledges existing efforts, experiences and agency in a given place (Lam et al., 2019). Its goal is to support and enable sustainability

transformation processes according to the local target knowledge. Initiatives driven by local actors and communities can lead the pathway to sustainability according to an explicit or implicit context-specific vision of social-ecological well-being (Fischer et al., 2019). Failing to explore, understand, and capitalize on such ongoing efforts is a missed opportunity and risks disempowering individual and group agency. For example, to favor ownership and empowerment, the notion of sustainability and its associated target vision needs to be locally elicited or collectively co-created (McPhearson et al., 2016). Weaving together place-based conceptualizations of sustainability and of transformative change can mitigate the risk of continued colonial imaginaries and dependencies (Lam et al., 2020; Tengö et al., 2017).

4.6 New quality criteria and rethinking impact

Traditionally, the scientific production of knowledge is evaluated through criteria such as reliability, replicability, and validity. As sustainability challenges have become more pressing, sustainability scholars feel increasingly obligated toward society, exploring options such as scholar-activism (Sandover, 2020), where researchers take an explicit political standpoint in their work, and have a social change agenda to influence policy or public opinion. Thus, to adequately capture and assess the impact and quality of transformative research, classic quality criteria must be revisited and complemented. In turn, implementing new or other standards of how we define quality of research may shift the focus of knowledge production to incentivize research that catalyzes sustainability transformation (see 4.1, 6.3). Similarly, transformative research demands rethinking impact in terms of more diverse and expanded metrics of success encompassing social outcomes such as improved community relationships, social learning or trust building (Bergmann et al., 2021; Davies et al., 2021; Fischer et al., 2019; Karcher et al., 2021; Schneider et al., 2019a; Spiering & Barrera, 2021) and personal outcomes such as consciousness expansion (Woiwode et al., 2021) and mindfulness (Wamsler et al., 2021).

To expand the notion of quality of scientific knowledge production, we are drawing on the following previous suggestions on the issue: In 2003, Cash et al. (2003) offered a first starting point for evaluating the effectiveness of scientific information in mobilizing action through three knowledge usability parameters: credibility (scientific adequacy), salience (relevance compared to needs) and legitimacy (fair treatment of divergent values and interests). Credibility and legitimacy were also brought forward by Hansson and Polk (2018). Daedlow et al., 2016 emphasized the role of social robustness or socially responsible research, while Shaw 2022 adds practical feasibility and moral justifiability. In the work of Mertens (2009), quality criteria in transformative research include among others: authenticity (a fair presentation of all perspectives), deep understanding of the community, and critical reflexivity (high level of awareness concerning self and others, see also 4.4). Taken together, it becomes evident that transformative research is characterized by an understanding of quality that (a) focuses on whether and how research results are usable to contribute to sustainability transformation, and (b) puts special emphasis on the process of knowledge production (such as inclusivity and researchers' accountability [Hölscher et al., 2021]).

5. Tensions when doing transformative research

Implementing a transformative research design that respects the six characteristics outlined in the previous section

illuminates three prominent tensions (Figure 2), in both theory and practice, partly shared with those conducting and documenting transdisciplinary and action research (Bulten et al., 2021; Sellberg et al., 2021; Thapa et al., 2022; Witjes et al., 2022). However, due to its methodological character systematically tailored for enacting sustainability transformations, these tensions culminate in transformative sustainability research, creating paradoxical situations both for researchers and institutions.

5.1 Process- and output-orientation

The process-oriented nature of transformative research, with its place-based focus at the science-society interface often conflicts with the output-oriented and productivity-based reward system in academia typically seeking global relevance, high citation indices and number of publications (Fam et al., 2019; König, 2015). For example, the laborious stage of initiating knowledge processes in co-modes (see 4.2) is seldom acknowledged and documented, perpetuating an academic system that does not allow it space and time. Similarly, trying to fit evaluation and monitoring costs within the strict bounds of a research project proves to be challenging, despite opportunities for mutual learning. Tensions arise due to the process-oriented research strategy primarily aiming at (co-)modeling and inciting societal change, with the academic output being treated as secondary. In contrast, the output-oriented strategy primarily aims at publishable results, with societal change as a side effect. Although the two orientations can be complementary (Schacter & Toonen, 2010), researchers often encounter the paradoxical situation where process-orientation hinders academic outputs because of administrative or bureaucratic constraints (Reid et al., 2021), while output-orientation drives low quality engagement (Kirchherr, 2023). Transformative researchers are torn between needing to prove adequate contributions to science according to the expectations of their academic institutions and system, and wanting to engage in processes of creating change (Mitchell et al., 2015). Interestingly, funding context was found to affect achieving both academic and societal outcomes (Newig et al., 2019).

This is a well-documented tension for many forms of collaborative knowledge production such as those employed by transformative research (Chambers et al., 2022; see 4.2, Reid et al., 2021). The specific form this tension takes does not solely derive from the co-modes of knowledge production (4.2), but from their interactions with other characteristics such as normativity (4.4) and reshaping power (4.5), which push researchers to tailor their methodology to the situated on the ground knowledge and values assumptions. While creating additional strain on the researchers, such science-society collaborations do not enable proper academic compensation and recognition, often forcing them to choose between creating either academic or societal impact. Collaborating with non-academic actors has a positive influence on societal outcomes and a negative one on academic outputs and citations (Newig et al., 2019). Conversely, Chambers et al. (2021) demonstrated that within science-society collaborations solely pursuing knowledge production negatively correlates with obtaining outcomes that inspire action, such as empowerment, building networks, or process learning. However, carefully designing collaborative process phases and sequenced methods of knowledge integration has the potential to weaken the trade-off between academic and societal impacts (Newig et al., 2019).

5.2 Accountability toward society and accountability toward science and the scientific method

Transformative sustainability research problematizes the question of researchers being accountable to society or to the institution of science, invigorating the debate about the aim of science in society (Gibbons et al., 1994; Kitcher, 2011). Some argue for strict accountability toward the scientific method, against adapting the presented data and models to socio-political realities (Geden, 2015). Others point to the novel roles opening for researchers when embedding knowledge production in processes of social change, such as ‘honest brokers’ of knowledge (Goodrich et al., 2020; Karcher et al., 2021; Pielke, 2007), process and dialogue facilitators (Bulten et al., 2021; Horlings et al., 2020), or even change agents (Wittmayer & Schöpke, 2014) and co-conspirers (Temper et al., 2019). Similarly, researchers now have the option to publish their results with open access, following the proliferation of ‘transformative’ journals. Although salutary, such efforts toward open science pose equity problems when considering how diverse funding availability and institutional requirements are for the various researchers across the globe. These intricate responsibilities, limited options, yet diversified roles may lead to identity conflicts (Kump et al., 2023), and leave researchers in uncharted territory where mainstream academic training is not always helpful (Nature Editorial, 2023).

The accountability issue is also tightly connected with perspectives on the roles of values in research (see 4.4). Transformative modes of research explicitly recognize that values play a role in the ethical assumptions underlying research and researchers’ epistemic choices (Douglas, 2000; Kincaid et al., 2007), and in the normative scenarios guiding a system’s trajectory (Stojanovic, 2021, see also 4.4; Weiland et al., 2017). This stands in radical opposition to the traditional academic adherence to the ideal of scientific objectivity (i.e. splitting facts from values) and commitment to normatively neutral academia (Schneider et al., 2019b). The new roles proposed for sustainability and especially for transformative researchers, ultimately based on a normative orientation of their work and an arguable diminishing of the empirical part of their research, exemplify this tension starkly. The accountability tension leads to a paradoxical situation where the engagement of transformative researchers in brokering social processes reduces the role of empirical methods in the scientific practice and increases the importance of other competences and skills (Leicht et al., 2018; Redman et al., 2021). Yet, their focus on accountability toward science risks producing socially irrelevant knowledge (Wuelser, 2014). The two-fold accountability toward science and society is a challenge also known to other forms of engaged research, especially in the transdisciplinary community (Sellberg et al., 2021). Transformative or transdisciplinary researchers often need to ‘walk a tightrope’ between these two extremes in order to survive and prosper in university institutions.

5.3 Methodologies rooted in scientific traditions and post-normal methodologies

Both previous tensions are tightly correlated with the methodological tension between traditional scientific methodologies, based on a Cartesian specialization and compartmentalization of knowledge, and post-normal systemic approaches characterized by contested facts, urgent decisions, and high stakes (Funtowicz & Ravetz, 1993). Indeed, in most pressing sustainability problems emergent properties and non-linear system dynamics cannot be

reduced to (nor deduced from) its subunits (Mitchell, 2009). This challenges a reductionist view and the idea that science seeks to explain phenomena by accounting for its micro-structure, where explanations ‘flow from below’. In transformative research, methodological tensions thereby arise from the necessity of a paradigm shift, leaving the scientific methodology built according to disciplinary rules and inherited model templates validated across generations of scholars, to test methods appropriate for contemporary societal problems. The problem with not making this paradigm shift is twofold: (i) often researchers want to accomplish the aspirations and aims of transformative research with the traditional tools and methods of mode-1 science or by overlooking some of the transformative characteristics (4.1–4.6); and (ii) transformative research is assessed and evaluated using the quality criteria suited for mode-1 science (see 4.6). However, researchers engaging in transformative research also have to strike a balance between being interdisciplinary by blurring disciplinary boundaries, and epistemic trespassing into methodologies or topics they are not equipped to deliver (Ballantyne, 2019).

This multilayered methodological tension contributes to another paradox intensified in the case of transformative sustainability research by the systemic integration of post-normal features into a methodological framework which, unlike other socially engaged approaches, challenges the traditional science in all six key features (section 4) ideally at the same time. Although there is a growing need for and proliferation of transformative research approaches, many of them are difficult to evaluate according to traditional quality criteria or fall short when scrutinized against established scientific standards (see 4.6). Consequently, researchers grapple with aligning the implementation of transformative research designs with the existing institutionalized science and its proven reliability, sometimes at the expense of purposeful innovation. Conversely, attempts to stay within the validated institutionalized science are proving increasingly unreliable and inappropriate to tackle sustainability problems (Mitchell, 2009), and to meet expectations of ‘solving them’ which society increasingly puts forward as a new main aim of the institution of science (Saltelli et al., 2016). In sum, transformative research seeks to transform knowledge systems (Fazey et al., 2020), and therefore may not be rewarded by an academic and funding system designed around the knowledge systems that need to be transformed.

6. Moving forward together: researchers, universities, funding bodies

To navigate and to help reconcile the three tensions, we respectively formulate ways forward that address the main actors in academia: researchers, universities, and funding agencies.

6.1 Moving forward together: researchers

First, in line with the collaborative ethos of transformative research, the formation of communities of practice of transformative researchers (e.g. the Transformative Learning Hub at the Wageningen University, the Working Group Transdisciplinarity for Transformation of the Programme on Ecosystem Change and Society) can help them share their own experience regarding the allocation of scarce resources between output and process as per tension 5.1. Setting such communities of practice encourages peer learning by comparing transformative work across case studies, approaches and teams (Balvanera et al., 2015; Cundill et al., 2015).

Coming together around transformative research facilitates access to insights on practical tools and steps used by peers in this still emerging research mode. Expanding these communities to welcome disciplinary academics and non-academic participants interested in transformative research builds bridges between transformative research and other research modes. Examples of spaces and communities that are already developing a transformation science norm are the Sustainability Transitions Research Network, Action Research Plus (AR+), and the Transformations Community (2023), with some of them also providing resources for conferences to bring people together. These communities can become change agents of the current academic institutions and funding schemes by creating spaces that co-exist parallel to more traditional forms of knowledge creation. Further, communities such as the TransformERS (COST, 2023) network specifically seek to bring together the ‘old’ (traditional) and the ‘new’ (transformative) toward a common aim of sustainability transformation.

Second, making transformative research more reliable and accountable toward science and society also lies within the hands of researchers and project managers (tension 5.2). The recent eroding of quality control mechanisms across sciences, specifically of replicability, are strong arguments against methodologically loose disciplines and research modes (Peterson, 2021). What rigor and quality mean in doing transformative research is not yet established (see 4.6). However, researchers can look into, carefully select, and adapt those suitable criteria available from various research designs, disciplines, or modes. Emerging efforts, such as the Coalition for Advancing Research Assessment (COARA, 2023) working group on transdisciplinarity, can contribute to creating evaluation criteria for transformative research. For rigor in transformative research, Mertens (2009, p. 195) suggests starting from the notions of internal validity and borrows criteria used to evaluate qualitative research, such as ‘prolonged and substantial engagement and persistent observations’, third party debriefing, or self-reflection on own subjectivity. Maintaining a design and protocol for planning, tracking and documenting phases in the transformative process (see also Newig et al., 2019) refers to external validity (Mertens, 2009). A transformative project used a formative accompanying researcher as a way to study the quality of the collaborative modes of knowing and learning (Freeth & Caniglia, 2020). Such protocols could be published using platforms with transparent peer review processes (e.g. Open Research Europe).

Third, becoming aware that to do transformative research, a methodological paradigm shift toward mode-2 and post-normal methodologies, away from mode-1 science is critical. Being able to distinguish and depending on the task at hand chose between, for example mode-1 and mode-2 science, is another step forward in addressing tensions between methodologies rooted in scientific traditions and post-normal methodologies (Horcea-Milcu, 2022, see also tension 5.3).

6.2 Moving forward together: universities

Seeing universities as actors and places of and for transformative change illustrates their potential manifold role: As the place where research is undertaken and new knowledge is being produced and critically discussed, as the place where future change agents are educated, and also as a place with its own impact and sustainability performance. Tackling the three tensions mentioned above touches upon universities’ multiple roles: Tension 5.1 between process- and output-orientation can be addressed by universities

through a recognition system adapted to transformative research. While the need to improve how researchers and their work are evaluated beyond the productivity-based reward system was already recognized in 2012 by the San Francisco Declaration on Research Assessment (DORA), more and more bright spots of innovation are emerging (Chambers *et al.*, 2020). Notably, Utrecht University has recently abandoned easy-to-measure citation metrics such as impact factors and h-indexes to evaluate its researchers. Researchers are now assessed based on other standards, including societal impact and efforts to promote open science (Woolston, 2021). While some researchers hail this change in the culture of the evaluation system, others feel more uncomfortable and are, for example, concerned that researchers at Dutch Universities may not be competitive internationally (Open letter ScienceGuide, 2021). Importantly, such a change in the reward system provides room for transformative researchers to be recognized based on the process of transformative research rather than on output only.

Tensions regarding the double accountability and methodological choices (tensions 5.2 and 5.3) can be addressed by deliberately incorporating the developments of transformative research into the curriculum of higher education, thus responding to a shift in requirements and expectations of universities as active actors (Evans *et al.*, 2015) within societal transformation. Promising approaches can be found on the level of individual courses and curriculum development as well as at the university-wide level. A whole-institution approach (Kohl *et al.*, 2022), as put forward by the UNESCO (2020) Education for Sustainable Development roadmap, aspires to transform the learning environment as a whole, which opens up a space for experimentation and empowerment on campus that also brings sustainability teaching closer to the science-society interface. Project- and experience based learning settings, as *e.g.*, developed within the Glocal Curriculum (John *et al.*, 2017), support the development of students as informed and responsible citizens in an interconnected world. Finally, international collaboration networks among universities are generally posited to accelerate the spread of transformative characteristics concerning both teaching and research (Withycombe *et al.*, 2016).

6.3 Moving forward together: funding agencies

We envision a science landscape where the transformative and conventional forms of research co-exist, and where the diversity of the funding and institutional mechanisms reflects this co-existence. The various modes of knowledge production and use (*e.g.* Table 1, mode-1, mode-2 science) although different in terms of knowledge processes, are all needed to inform and complement each other to support sustainability transformation. However, in the current academic landscape, system and descriptive-analytical knowledge, as well as producing knowledge for the purpose of accumulating knowledge is disproportionately represented compared to transformation knowledge and producing knowledge for intentional change. Correspondingly, mainstream funding requirements dominate the academic scene, with less arising funding options for transformative research.

National and EU funding schemes now formalize the need to work with actors beyond academia to shape the research focus. For example, research funded through the Dutch Research Agenda (NWA) takes place and is co-designed in consortia consisting of researchers and societal partners from the public and private sector. Similarly, in the current EU funding program

(Horizon Europe), there is an expectation that practice partners have been involved in shaping the research need and designing impact into the project. Such approaches fulfill the purpose of normalizing a multi-actor or participatory approach to research. However, considering tensions in 5.1 and 5.2, they also ingrain the expectation that this level of consultation and co-design occurs outside of the funded project. Moving the initiation of a multi-actor research intervention or collaboration outside of the funded project carries three risks: (1) that it is turned into a box-ticking formality that is rushed and therefore not meaningful; or the opposite (2) that it becomes exploitative of the time and energy of researchers and stakeholders who are not compensated or recognized for their efforts; (3) taking into account success rates, a very likely failure to secure funding after a laborious unfunded initiation phase may discourage researchers and stakeholders from engaging in future transformative endeavors. To counteract these risks and tensions step-change approaches are available. To address tension 5.1, seed funding may be suitable to cover the transaction costs of initiating knowledge processes in co-modes that can be fully deployed in future applications. The seed funding time period would also allow to link to established theories and methodologies and thus to tailor proposals to existing funding panels. This would perhaps increase the perceived legitimacy of submitted transformative projects, but could also dilute or co-opt the transformative elements as they are taken over by the dominant scientific paradigms or discipline-related industries. To tackle tension 5.2, there is an opportunity to organize in addition to scientific panels, supplementary mixed panels consisting of citizens, practitioners, private stakeholders, and early-career researchers, which could evaluate proposals for relevance to their lived experiences.

The methodological tension 5.3 highlights the lack of (pre-identifiable) fit of transformative researchers to evaluation panels. Transformative research usually transcends disciplinary boundaries and responds to emerging knowledge, rather than testing theories or hypotheses within existing disciplines. The standard of most funding agencies (*e.g.* German Research Foundation, European Research Council) is to evaluate proposals within disciplinary panels. Thus, a transformative research proposal addressing biodiversity loss would be evaluated by either an ecology panel or a sociology panel, both of which will often deem it as being outside of the scope of the discipline and/or not tied to the cutting edge of their field. Changes are being made in this direction, such as the establishment in 2021 of the ERC evaluation panel SH7 ('Human Mobility, Environment, and Space') which includes sustainability science. Sustainability science was included under one of the ERC evaluation panels as of 2014. A drawback to this approach is that it 'others' transformative research into a single panel, rather than creating space and allowing transformative research to be a central component in various research communities. Further, this 'othering' disconnects transformative research from the other disciplines rather than positioning its contribution with other theoretical, methodological, and empirical disciplinary knowledge contributions. Such holistic bringing together of knowledge represents what is truly transformative and meets the calls for knowledge plurality (Caniglia *et al.*, 2021; Turnhout *et al.*, 2020). Ways forward to tackle tension 5.3 may be represented by separate funding streams for transformative spaces (Pereira *et al.*, 2020) or for living labs (Schäpke *et al.*, 2018a). These spaces would enable long-term collaborations between transformative researchers and other actors and act as a potential remedy against project short-termism, research biases,

and academic output focus. Moreover, based on their research design, proposals submitted to disciplinary panels could fulfill the expectation of being relevant to these transformative spaces.

7. Conclusion and future research

In this paper, we tried to consolidate the beginning of a ‘transformative paradigm’, where science is a potential lever for reaching the Sustainable Development Goals (or indeed, for challenging their role in sustainability transformations) and where knowledge processes in co-modes are supporting interventions. Our vision is that this transformative paradigm is nurtured and supported by researchers, their institutes/universities, and funders. To support this vision, we have provided an introduction into conceptualizing and doing transformative research for various types of audiences. Transformative research is a reflexive collaborative inquiry about how to intervene, conducted as a purposeful intervention, while engaging with and negotiating new framings of power, agency, impact and contextualization. Future empirical research should test the recurrence of the six outlined characteristics. When translated into research practice, three tensions between transformative research and traditional academic paradigms become apparent: (1) process-orientation and output-orientation, (2) accountability toward society and science, (3) methodologies rooted in scientific traditions and post-normal methodologies. There is a growing need to provide conditions that enable actors (i.e. researchers, universities, funders) to overcome highlighted tensions (and others which we did not develop here – [e.g. scale tensions]). Such conditions include the creation of transformative knowledge communities, the provision of applicable evaluation and funding criteria, and the reframing of our understandings of what knowledge counts. Future research should develop a more ample reflection on the barriers and possibilities encountered by each actor when doing or facilitating transformative research, as well as when weaving it to conventional modes of creating knowledge.

Developing our understandings of the transformative research paradigm in this way is essential and urgent. Doing so will ensure researchers are enabled in working within this knowledge paradigm in contributing to, understanding, and supporting sustainability transformations. This enabling can be achieved alongside, and in collaboration with, more traditional forms of knowledge generation. But it cannot be overlooked or crowded out by these traditional knowledge approaches. We therefore appeal to all researchers (transformative and traditional), their university colleagues and those in research-supporting roles (e.g. funders) to use this paper to understand what transformative research is, and consider their role in supporting it.

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