# What role(s) can science and research play in a transformation to sustainability?

## Introduction

In light of the interconnected, complex and persistent nature of the ecological and social problems of the beginning of the 21st century, there is an increasing consensus in political and academic debates that profound societal change is necessary to adequately tackle the current multiple crises and move towards sustainable societal-nature relations (IPCC 2023, Steffen et al. 2015, WBGU 2011). Such a “great transformation” (WBGU 2011), “social-ecological transformation” (Brand and Wissen 2017), “sustainability transformation” (Schäpke et al. 2015) or “transformation to sustainability” (Scoones et al. 2018) would imply structural and paradigmatic changes in all dimensions of society, from the economy and politics over culture and technology to values and imaginaries. In this context, also the traditional role of science in society has been subject to debate, with increasingly more voices calling for the scientific community to contribute more proactively to tackling pressing social and ecological issues. An example of this is the climate change, where science has become a central player in fostering public awareness, shaping policies and guiding mitigation strategies.

However, such a changing role of science in society raises a number of important questions. One example is linked the potential conflict between scientific imperatives and democratic principles. The term "expertocracy" encapsulates this tension, reflecting a governance model where decisions are predominantly guided by scientific experts, which might be perceived as undemocratic as it sidelines broader public participation and input (Bogner 2021). It has been argued that to address this conflict, it is essential to foster a balanced approach that integrates scientific expertise with principles of democratic deliberation (Callon 2009). This involves promoting transparency in the communication of scientific findings, engaging the public in meaningful, active and participatory ways, and ensuring that decision-making processes really consider a diverse range of perspectives (Callon 1999; Callon/Rabeharisoa 2003).

Yet, such research approaches increasingly blur the line between science and society, a separation that has been uphold for centuries, resulting in substantive epistemological, methodological, methodical and normative issues. The objective of this chapter is to shed light on some of these questions and the proposals that have been made to address them. Section 2 starts by describing what sets apart scientific knowledge from other types of knowledge, focussing in particular on the (contested) distinction between facts and values. Section 3 then outlines the transformation of science that has occurred in recent decades, driven by the trend away from traditional discipline-based research towards inter- and transdisciplinary approaches. Finally, Section 4 introduces the emerging perspective of transformation research as a concrete example of how science and research can contribute to studying and shaping profound societal change.

## On science, facts and values

Scientific knowledge is distinct from other forms of knowledge in its systematic, empirical, and objective approach to understanding the world. Rooted in the scientific method, it relies on empirical evidence obtained through observation and experimentation, emphasizing the importance of testable explanations and a consistent and logical formulation of scientific theories and hypothesis. Unlike some other knowledge systems that may incorporate subjective interpretations or rely on tradition and revelation, science prioritizes objectivity and is open to revision based on new evidence and consistent argumentation. Whether in the natural sciences (e.g., physics, chemistry, biology), social sciences (e.g., sociology, economics, psychology), or humanities (e.g., history, philosophy), scientific knowledge is characterized by its commitment to systematic inquiry, reliance on empirical evidence and/or dialectic reasoning, and a continuous process of refinement and adaptation in response to new information, distinguishing it as a dynamic and evidence-driven pursuit of understanding.

Modern science has been founded on the distinction between facts and values, i.e. between descriptive statements about the world (facts) and normative or evaluative statements (values). This distinction is often associated with the works of philosophers like David Hume and later developed in the context of the science and values debate (Is-Ought-Problem). Facts are typically understood as objective and observable statements about the world. They are empirical claims that can be verified or falsified through observation and experimentation. Facts are considered to be value-neutral and independent of individual perspectives or interpretations (Weber 2017). Values, on the other hand, refer to subjective judgments, habits, or moral considerations (doxa). These are normative elements that involve subjective opinions, cultural beliefs, and personal biases.

The traditional view, often associated with logical positivism, posited a strict separation between facts and values, suggesting that scientific inquiry could be entirely objective and value-free. This perspective argued that scientific theories could be derived solely from empirical observations without the influence of personal or cultural values. However, this positivist view has been challenged by various perspectives.

Kuhn (1970), for instance, introduced the concept of paradigm shifts, highlighting that scientific theories are often deeply influenced by social, cultural, and historical factors. Feyerabend (1976), in his critique of a monolithic scientific method, emphasized the diversity of scientific practices and argued that there are no fixed rules that universally define science. Against a rather positive view of scientific facts, Ludwig Fleck (1980) argued that scientific facts are not discovered in an objective, value-free manner but are socially constructed within a thought collective (“Denkkollektiv”). The thought collective refers to a community of scientists who share a common set of beliefs, assumptions, and thought patterns. Within this framework, values may come into play at various stages, such as when scientists make decisions about research priorities, select methodologies, or interpret results (Stack 1969; Putnam 1981; Putnam 1998). Following Ludwig Fleck, Bruno Latour (1991, 1999; Latour/Woolgar 1986) contends that scientific facts are not discovered but rather "assembled" through the collaboration of various actors, including scientists, instruments, and institutions but also non-scientists such as politicians, citizens, or entrepreneurs. This perspective challenges the notion of a *secluded* science by highlighting the vast network of interactions within which facts and scientific knowledge are assembled or “constructed” throughout society.

While contributions of scholars like Bruno Latour or other sociologists of science such as Karin Knorr-Cetina have challenged the *strict* separation between facts and values, their perspectives have not been without critique. Critics contend that blurring the lines between facts and values may lead to a relativistic view where all knowledge is perceived as equally valid, undermining the notion of objective truth. While acknowledging the social and contextual influences on scientific inquiry, critics argue that objective truth is possible only on the condition of a clear cut between science and society. For example, Gaston Bachelard, a French philosopher of science, introduced the concept of an "epistemological break" to describe a radical shift in the way knowledge is acquired and *constructed* in the scientific process. According to Bachelard (1987), this break involves a rupture with common sense and everyday opinions which are viewed as obstacles to true understanding (by claiming that the break is *constructed*, Bachelard distinguishes himself from traditional positivism). Bachelard argues that scientific inquiry requires a departure from preconceived notions and subjective beliefs, emphasizing the need for a rigorous, objective approach that transcends personal biases and cultural assumptions. The autonomy of science is a prerequisite for this (Bourdieu 1975).

In summary, there are *two principal ways* of thinking about the relationship between science and society or facts and values. Either one considers that science has a social context, but nevertheless insists on an epistemological break between scientific and non-scientific knowledge as a prerequisite for objective truth; or one assumes that scientific facts are “made” in contingent and historic processes in which the connection between scientific and non-scientific factors is to be seen as a prerequisite for objective truth.

## Science under transformation: from discipline-based to inter- and transdisciplinary research

Science and technology play a key role in modern societies. Many of the problems and crises faced by these societies cannot be overcome without the contribution of scientific and technical expertise. One reason for this is that modern societies are increasingly designed and built on the basis of scientific knowledge and technical artifacts. Scientific knowledge becomes a foundation for political decisions and technological innovations that shape people's lives. Against this background, scientific disciplines no longer see their task solely in solving purely scientific problems, but increasingly also in dealing with the real-world problems of modern societies. In this sense, the disciplinary boundaries of scientific research are being *transcended* in order to deal with issues that lie beyond them: Research is becoming increasingly *transdisciplinary*.

Transdisciplinary research has gained prominence in addressing complex global challenges since the 1990s, particularly concerning issues like climate change and sustainability (Brandt et al 2013; Groß & Stauffacher 2014). This approach is crucial for tackling "wicked problems", which resist simple solutions and demand holistic, collaborative approaches. The multiple and heterogeneous nature of current crises underscores the necessity of methods, that transcend disciplinary boundaries as these challenges span scientific, social, economic, and policy dimensions and cannot be adequately addressed within the confines of individual disciplines.

Jürgen Mittelstraß (1992, 2005) presented an early concept of transdisciplinarity. Transdisciplinarity presents itself as a form of scientific research, where the aim is to solve *non-scientific problems* (e.g., environmental problems). In this sense, transdisciplinarity is a *principle* of research that enters the scene *where it is not possible to define problems and solutions solely in disciplinary or specialist terms* or where it goes beyond such definitions. For Mittelstraß, research is transdisciplinary when scientific disciplines no longer deal with objects and problems that belong to the canon of their discipline, but with objects and problems that point beyond it and require the cooperation with other disciplines. For Mittelstraß, transdisciplinary research is therefore nothing other than genuine interdisciplinary research: i.e. interdisciplinary cooperation in relation to transdisciplinary problems. In the absence of this fundamental reference to transdisciplinary problems, Mittelstraß speaks of multidisciplinarity, i.e., the situation in which different disciplines research the same topic separately from each other without transcending their disciplinary problems to a common, transdisciplinary problem. While multidisciplinary efforts can contribute valuable insights from individual disciplines, they may lack the integration and synthesis required to fully understand and address the multifaceted nature of contemporary challenges.

The crucial point here is that Mittelstraß – following the classic understanding of science, founded on the strict distinction between (scientific) facts and (societal) values – argues for science to address social problems, but that it should remain within the boundaries of scientific research when doing so. In other words, science should deal with social problems, but non-scientific knowledge should not be involved. Rather, science should work in interdisciplinary cooperation to define problems and develop solutions, which will then serve as a basis for political decision-making.

Mittelstraß thus argues for a relationship between science and politics that can be conceived as a “deficit model”. The deficit model, in the context of the relationship between science and the public, is a conceptual framework that assumes a lack of scientific knowledge or understanding among the public. According to this model, it is believed that public skepticism or resistance to scientific findings is primarily due to a deficit in knowledge or understanding on the part of the public. The deficit model suggests that if people were adequately informed about scientific facts, they would accept and support the scientific consensus.

In the context of science and politics, the deficit model is to be interpreted as a “linear model of expertise”. In this model, there is an assumed linear relationship between science and policy, where scientific experts provide objective and unbiased information, and policymakers use this information to make informed decisions. This model implies a one-way flow of information from scientists to policymakers, with the assumption that scientific facts can and should determine policy outcomes. Furthermore, the linear relationship between science and politics is accompanied by a tendency to transform political questions into epistemic questions. This in turn can lead to a simultaneous depoliticization (Bogner 2007) of democratic-deliberative procedures, as decision-making authority tends to be transferred to a supposed scientific authority (expertocracy); and a (false) politicization of scientific procedures, as political actors and lobby groups tend to occupy the field of science in order to push through political agendas (Bogner 2021).

However, this model has been widely criticized for oversimplifying the complex relationship between science and politics (Bijker et al 2017). Sheila Jasanoff (2003, 2007), following Latour, Knorr-Cetina and others, challenges this linear model by highlighting the complex and dynamic interactions between science and politics. She argues that scientific expertise is not value-neutral and is often shaped by societal values, cultural contexts, and political considerations. In the real world, the relationship between science and policy is more iterative and involves negotiation, contestation, and the *co-production* of knowledge. In particular, Jasanoff's concept of co-production in science underscores the mutual shaping of scientific knowledge and societal values. Rather than seeing science as an objective, value-neutral enterprise, co-production acknowledges that scientific facts are actively constructed through interactions with social, cultural, and political contexts. It involves a collaborative process where scientists, policymakers, the public, and other stakeholders contribute to shaping scientific knowledge, and in turn, this knowledge influences societal values and decision-making. Co-production challenges the traditional view of a linear relationship between science and policy, emphasizing the bidirectional and complex interactions between scientific expertise and the broader sociopolitical landscape as well as an emphasis on the role of *intermediate* structures and actors (Meyers & Kearnes 2013) such as boundary organizations (Guston 2001; Miller 2001).

“Mode 2 knowledge production”, as conceptualized by Gibbons et al (1994), marks a departure from traditional disciplinary approaches (Mode 1) by adopting a context-driven and problem-solving orientation. Thus, socially robust knowledge (Nowotny 2003) within Mode 2 distinguishes itself by prioritizing societal relevance, active engagement with various perspectives, and a commitment to addressing practical challenges, in contrast to the more insular and academic focus of Mode 1 knowledge production (Gibbons 1999). This shift reflects a broader transformation in the dynamics and priorities of knowledge creation, emphasizing responsiveness to the complexities of the world and the diverse needs of society. Unlike the more rigid and academic nature of Mode 1 as envisioned by Mittelstraß, Mode 2 knowledge is generated collaboratively in real-world settings, involving not only academic researchers but also a diverse array of stakeholders in processes of co-production.

This also involves the concept of "post-normal science". Post-normal science, coined by Silvio Funtowicz and Jerome R. Ravetz (1993), describes an approach to scientific inquiry in situations marked by high uncertainty, complexity, and the involvement of diverse societal values. In post-normal science, traditional scientific methods face challenges due to a lack of clear facts and agreed-upon methodologies. Issues addressed in this framework often involve significant ambiguity and a multiplicity of perspectives, requiring decisions that go beyond scientific evidence to consider ethical, social, and political dimensions. The extended peer community, including scientists, policymakers, and the public, collaboratively contributes to the co-production of knowledge and decision-making. Quality assurance in post-normal science involves a reflexive and transparent process that acknowledges uncertainties and contextual factors, challenging the conventional notion of linear and value-neutral scientific inquiry. The framework emphasizes inclusivity and participation to address complex issues that fall outside the scope of "normal" scientific practice.

This calls for a new understanding of transdisciplinary. As with Mittelstraß, transdisciplinary research in Mode 2 knowledge production is defined by transcending disciplinary problems to non-scientific and thus real-world problems; in contrast to Mittelstraß , however, it is emphasized that – especially in situations of high uncertainty and complexity – both the identification and formulation of the problems and the way in which they are solved need to be co-produced by the participation of non-scientific actors such as political decision-makers, economic entrepreneurs, affected citizens, patients, users or consumers, rather than by excluding them on dubious epistemological reasons.

Assuming that non-scientific actors should participate in research on social problems and solutions, the question ultimately arises as to the extent to which this participation should occur. Against this background, Michel Callon (1999) has distinguished three models in which laypeople can relate to science.

1. The first model is the already mentioned “deficit model”. Trust between laypeople and scientists is crucial in this model, since science claims exclusive right to valid knowledge, but can only do so if this privilege is also granted to it by society. Thus, any mistrust threatens the relationships and the balance between science and society. The solution to mistrust is considered to be intensified educational and informative actions. The legitimacy of political decisions, according to this model, depends on the representativeness of those speaking for citizens and the resources mobilized, guided by scientific knowledge for foreseeing the effects of actions. Political action involves consultation on goals and explanation of realistic possibilities.
2. In the second model, the relationship becomes more intricate. It replaces an undifferentiated public of the first model (i.e., the public as a homogeneous and uninformed mass) with *differentiated publics* based on diverse conditions such as profession, locality, age, and sex. These publics possess specific, concrete knowledge and competencies, derived from experiences and observations, *enriching* the abstract knowledge of scientists. Thus, scientific knowledge, though universal, is considered incomplete and deficient due to its abstraction and dependence on rare laboratory conditions. The *complementary relationship between universal and local knowledge* is exemplified in various contexts, such as drug testing, and sociological analyses by laypeople. This model suggests opening discussions and deliberations to enrich scientific knowledge, emphasizing negotiation of opinions and knowledge, with agreement reached through compromise. In this model, non-scientific knowledge is considered to counter the deficiency that abstract scientific knowledge has in relation to real-world problems. This means that non-scientific knowledge is considered, however, as a form of knowledge that is to be integrated and translated into scientific procedures and is therefore not equivalent to scientific knowledge. This is the case, for example, when it comes to inviting (or not inviting) stakeholders or collecting opinions on problems via surveys. Just as model 1 this model continues to maintain a strict separation between science and society (Callon & Rabeharisoa 2003).
3. Model 3, the "co-production of knowledge model," departs from the demarcation obsession seen in Models 1 and 2 by actively involving lay people in the creation of knowledge concerning them. Unlike the exclusive approaches of the first two models, this model recognizes the essential role of non-specialists in knowledge production (Wynne 1998). The dynamics involve a constant tension between standardized universal knowledge and knowledge accounting for the complexity of singular local situations, fostering a collaborative process where specialists and non-specialists work closely together. The concept of "concerned" groups replaces differentiated or undifferentiated publics, and collective learning occurs as different forms of knowledge (Rabeharisoa 2017) mutually transform each other. The model emphasizes the active contribution of laypeople or “layexperts” (Epstein 1995), who become an integral part of a hybrid collective or “epistemic community” (Haas 1992), challenging the traditional division of tasks within the learned collective. This participatory dynamic not only allows non-scientists to control *knowledge concerning their conditions* but also contributes to the construction of new identities and fosters a unique relationship between science and the constructed, negotiated identities of the concerned groups (Rabeharisoa et al 2014). The legitimacy of this joint enterprise depends on the ability of concerned groups to gain recognition for their actions, highlighting the crucial role of financial resources and public involvement in sustaining research and constructing new identities (Callon et al 2009).

However, there are several problems and difficulties associated with transdisciplinary and, in particular, participatory approaches. One criticism is that although problem-oriented and context-sensitive research has several advantages, it also means that it is difficult to generalize results beyond their singular context (Pohl 2011; Rosendahl et al 2015). This poses a problem. Not only is it difficult to transfer what has been learned from individual cases to other cases, it also calls into question one of the prerequisites of scientific knowledge: the reproducibility of findings. It has been pointed out time and again that citizen participation often remains superficial and usually only serves to legitimize existing problems and decisions a priori. The question also arises as to who should/must be involved in participatory processes. On the one hand, such processes must be understood as open processes in which new concerned groups can emerge again and again. On the other hand, the distinction between invited and uninvited participation must be considered, as the latter represent perspectives (e.g., protest movements) that are often ignored in planning and public discussion. In addition, in participatory processes, the question of power usually emerges (Wehling 2012). There can always be power imbalances, clashing interests and conflicts in these processes, and these are often difficult to reconcile with the knowledge interests of the researchers. This point also refers to the problem of reflexivity, which arises in these procedures due to the direct involvement of the researchers. The relationships that researchers develop with participants and their role as neutral observers (Model 2) or engaged facilitators (Model 3) must therefore be questioned (Herberg 2018). Finally, it should be emphasized that to date there is no elaborated theory of transdisciplinary research in which the relevant epistemological, methodological and methodical questions have been uniformly clarified (Pohl 2014; Ukowitz 2014, Renn 2021). Even the question of whether such a theory is needed at all is still unresolved (Mittelstraß 2018).

## Transformation research: towards a new research field

As the urgency of addressing social and ecological crises such as climate change and biodiversity loss has intensified, the call for researchers to partake more actively in crafting concrete solutions to these and other societal problems has increased. Against this backdrop, transformation research has emerged as a new research perspective aiming to “study complex and pervasive societal problems and to search and support long-term and fundamental societal change processes and dynamics towards sustainability” (Wittmayer et al., 2018: 9). Various empirical and theoretical approaches have been developed in recent years, accompanied by a lively debate on adequate research methods to study and support a sustainability transformation. However, transformation research does not (yet) constitute an established or closed research field. Rather, it can be characterised as a new perspective in which various existing research directions and approaches converge, bringing together a variety of different thematic foci, concepts, methods and frameworks. As of today, the most important contributions stem from transition research, specific subsets of social-ecological or sustainability research, social innovation research, resilience research, political or social ecology and ecological economics as well as individual contributions from disciplines like sociology, political science, psychology and future studies (Haum and Pilardeaux 2014, Patterson et al. 2015).

Most of the research in question revolves around three overarching topics shedding light on different aspects of transformation: the objects of transformation (i.e., what is/ought to be changing), the dynamics of transformation processes and emergent pathways (i.e., how do processes of change unfold) and the drivers of transformative change (i.e., how and by whom/what are transformation processes initiated and supported) (Wittmayer et al. 2018). In addition, four cornerstones of transformation research have been identified which help to map out some of its central requirements and thereby allow to better demarcate this emerging perspective (Ibid.).

Firstly, transformation research involves an explicit normative orientation, as it aims to study and address concrete and pressing societal issues which are connected to radical change (e.g., the de-carbonisation of the energy sector). However, while it is generally agreed on that, for the current multiple crises to be adequately tackled, fundamental and radical change is required, what exactly this radicality implies is contested. Similarly, the normative orientation towards sustainability as an overarching guiding principle is a common denominator within transformation research, even though there is no unanimous interpretation of what sustainability actually means[[1]](#footnote-2). While normativity plays a central role, it is not necessarily the case that transformation research is more normative than other types of research (Grunwald 2015). Instead, what sets it apart from traditional research approaches, e.g., in economics or engineering, is that it makes its own normativity more explicit.

The engagement with complex real-world problems, which are interdisciplinary by nature, implies, secondly, a prominent role for inter- and transdisciplinary research approaches. Indeed, the importance of involving more than one scientific discipline as well as social actors to better understand the problem at hand and explore possible solutions has been championed in the transformation literature (WBGU 2011, Haum & Pilardeaux 2014, Wiek & Lang 2016, Brandt et al. 2019) – though not without controversy (Strohschneider 2014). The emphasis on creating transdisciplinary spaces to bring together diverse actors, problem perceptions, values and types of knowledge to work on pressing societal issues is in line with the conception of transformation as a societal search, learning and experimentation process (Reißig, 2009, Grin et al. 2010).

Thirdly, in analogy to the two-fold goal of transformation research of contributing to a better understanding of transformation processes and actively shaping and supporting them, two broad research approaches can be identified: a descriptive-analytical and a transformative approach (Wittmayer et al. 2018)[[2]](#footnote-3). This distinction resembles debates on “post-normal science” (Funtowicz & Ravetz 1993), “Mode 2 knowledge production” (Gibbons et al. 1994) and the more established approach of “action research” (Greenwood & Levin 2007). A descriptive-analytical approach is primarily interested in describing, analysing and explaining existing challenges as well as past processes of social change, while also providing insights on possible solution strategies, mainly through the production of conceptual knowledge. A transformative approach, instead, is more solution- and process-oriented, striving to search for and help implement solutions to concrete societal problems. In doing so, it is open to a variety of scientific and non-scientific actors and types of knowledge, which are typically integrated through a transdisciplinary, participatory research design directed towards the co-development of actionable knowledge[[3]](#footnote-4). The descriptive-analytical and the transformative research approach can be considered as two poles characterising different ways to approach a set of research questions within the broader frame of transformation research. In practice, combinations and overlaps between the two approaches are possible and quite common.

Finally, in light of the increasing transcendence of traditional boundaries between science and society, there is an ongoing debate on quality criteria for transformation research. While some argue that clear, incontestable criteria to assess the quality of transdisciplinary research may no longer be available and instead call for an openness to a plurality of definitions of quality (e.g., Nowotny et al. 2003), others stress the importance of identifying and adhering to generalised quality criteria also within transdisciplinary and transformative research approaches (e.g., Schneidewind and Singer-Brodowski 2013). Some provisional criteria that have been discussed in this context are the scientific and the social impact as well as the credibility or trustworthiness of the research and its results (see, e.g., Bergmann et al. 2005, Schwartz-Shea 2006, Greenwood & Levin 2010). Beyond these outcome-related factors, also the transparency about research goals, approaches, methods and procedures (see, e.g., Cash et al. 2002, Schwartz-Shea 2006) as well as the reflexivity employed in the research process – implying, among other things, critically reflecting on the epistemological and normative assumptions involved, the relationship between the researchers and the researched as well as the situatedness of the researchers and the research itself (see, e.g., Finlay 2002, Schwartz-Shea 2006, Stirling 2006) – have been stressed.

However, as hinted at in the previous section, there remain substantive epistemological, methodological and methodical questions, especially when it comes to participatory approaches in transdisciplinary contexts. Regarding the last point, Wittmayer et al. (2017: 70-82) have offered a useful starting point for reflection by providing an overview of social science methods within transformation research that can be used for data collection (e.g., experiments, participant observation, Delphi method), data analysis (e.g., grounded theory, conflict analysis, social network analysis) and participatory frameworks (e.g., transition management, communities of practice, living labs).

Other future challenges for transformation research include navigating the plurality of research foci, concepts and frameworks – which is considered one of its core strengths – by clearly delineating the epistemological and ontological differences between various research strands while also strengthening a common conceptual ground. This includes sharpening the understanding of key concept like transformation and transformative change in order to reduce the risk of the terms becoming mere buzzwords that are easily co-opted and increase their analytical value. What is more, fostering practices of critical (self-)reflection regarding the research process and its results will be central to increase the legitimacy and accountability of transformative research. Finally, in order to further strengthen and refine transformation research, also the scientific system in which transformative research practices are embedded would need to be transformed, including current funding structures, established quality criteria and academic curricula (Wittmayer et al. 2018).

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1. Furthermore, key concepts of transformation and transition are often used either interchangeably by different scholars and research communities, leading to some conceptual confusion. A few attempts have tried to provide a heuristic distinction between the two, characterising transitions as more intentionally, top-down steered types of change within existing political-institutional orders, while transformations are conceived of as all-encompassing, socio-economic, political and sociocultural kinds of change that involve the contestation of predominant power relations and are impossible to fully control (Brand 2014, Stirling 2015). However, especially transition scholars might object to this distinction (Hölscher et al. 2018). [↑](#footnote-ref-2)
2. Some publications in the German debate have proposed to distinguish between transformation research and transformative research (e.g., WBGU 2011, Grunwald 2015). However, we follow Wittmayer et al. (2018) in considering them as two research approaches within the broader frame of transformation research. [↑](#footnote-ref-3)
3. The distinction between “conceptual” and “actionable” (or “usable”) knowledge (Wittmayer et al. 2018) is similar to that between “scientific” and “social” knowledge developed in action research (Greenwood & Levin 2007). Both distinctions refer to the intended use of a specific kind of knowledge. A different, content-related distinction can be found in transdisciplinary research between system, target and transformation knowledge (Pohl et al. 2008). [↑](#footnote-ref-4)