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Leveraging capacity for transformative sustainability science: a theory of change from the Future Earth Pathways Initiative

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Abstract

Non-technical summary. To address increasingly pressing social–environmental challenges, the transformative strand of sustainability science seeks to move beyond a descriptive-analytical stance in order to explore and contribute to the implementation of radical alternatives to dominant and unsustainable paradigms, norms, and values. However, in many cases, academia is not currently structured to support and reward inter-/trans-disciplinary and transformative endeavors. This paper introduces a theory of change for the Future Earth Pathways Initiative, and similar initiatives, to help leverage the capacity of sustainability scientists to engage in transformative research.

Technical summary. The increasing body of descriptive-analytical knowledge produced by sustainability science over the last two decades has largely failed to trigger the transformation of policies, norms, and behaviors it was aiming to inform. The emergent transformative strand of sustainability science is a proactive alternative approach seeking to play an active role in processes of societal change by developing knowledge about options, solutions, and pathways, and by participating in their implementation. In principle, scientists can enhance their contribution to more sustainable futures by engaging in transformative research. However, a lack of skills and competencies, relatively unmaturing transformative methods and concepts, and an institutional landscape still geared toward disciplinary and descriptive-analytical research, still hinders the sustainability science community from engaging more widely in transformative research. In this paper, the Future Earth Pathways Initiative introduces a theory of change (ToC) for increasing the capacity of sustainability scientists to engage in this type of research. This ToC ultimately aims to build a growing community of practitioners engaged in transformative research, to advance concepts, methods, and paradigms to foster ‘fit-for-purpose transformative research’, and to shape institutions to nurture transformative research-friendly contexts.

Social media summary. What would a theory of change for leveraging the transformative capacity of sustainability science look like?

1. Introduction

Humanity is facing multiple interlinked environmental, social, and political crises, including anthropogenic climate change, biodiversity loss, continued structural injustices, geopolitical threats, armed conflicts, and the rise of populism (Balvanera *et al.*, 2019; IPCC, 2022; Lockwood, 2018; Purvis *et al.*, 2019). These crises are rooted in highly unsustainable societal relations with nature, dominant economic and political logics based on a narrow set of values that both support and arise from power asymmetry and rising inequality (Balvanera *et al.*, 2019; Brand *et al.*, 2021; IPBES, 2022; Pascual *et al.*, 2023). Attempting to resolve these complex and deeply rooted sustainability challenges require transformative changes (Brand *et al.*, 2021; Chan *et al.*, 2019), that is, ‘a fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values’ (Razzaque *et al.*,

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Box 1. Definition for transformative research

What is transformative research?

In this paper, we use Stirling's (2015, p. 1) definition for transformations as 'emergent and unruly political re-alignments, involving social and technological innovations driven by diversely incommensurable knowledges, challenging incumbent structures and pursuing contending (even unknown) ends'. Acknowledging that these transformations are not inherently virtuous, transformative sustainability science refers to the normative responsibility of academia to inform and accompany transformations supporting just and fair futures for people and nature. Transformative research is defined as the ensemble of methods and concepts enabling academics to take an active role in processes of societal change by developing knowledge about options, solutions, and pathways, and by participating in their implementation.

2019, p. 889). To inform and contribute to such fundamental societal transformations, sustainability science must embark on its own transformative journey, wherein scientists reflect and deliberate on the role of science in sustainable development, re-examining and transforming their own role, while taking action to augment the capabilities of the research community to engage in transformative research (see Box 1). In this paper, we propose a theory of change (ToC) for overcoming challenges that currently hinder the sustainability science community from engaging in transformative research, with the aim to support a growing community of practitioners.

2. Transformative sustainability science

2.1 The transformative gap in sustainability science

Nearly 25 years ago, Kates *et al.* (2001, p. 641) stated in their seminal paper that sustainability science seeks 'to focus research attention on both the fundamental character of interactions between nature and society and on society's capacity to guide those interactions along more sustainable trajectories'. Since then, most research efforts have focused on the 'descriptive-analytical' stream of sustainability science. Yet, considerable advances of knowledge in this stream over the last few decades have not triggered the necessary transformation of policies, norms, and behaviors to achieve and sustain acceptable living conditions for humans and nature. This raises fundamental questions about the role and responsibility of sustainability science in society, the type of knowledge it produces, and how this knowledge is developed and shared with others. As a response, the 'transformational' stream of sustainability science is now a growing focus of attention (Salomaa & Juhola, 2020; Wiek & Lang, 2016).

2.2 Addressing complex problems requires integrative and holistic approaches

Sustainability challenges are commonly recognized as 'wicked problems' (Davies *et al.*, 2015; DeFries & Nagendra, 2017; Rittel & Webber, 1973) or more broadly as 'complex problems' (Sharpe *et al.*, 2016). The interdependence and inherent unpredictability of the dynamics of socio-environmental systems at various scales mean that individual scientific disciplines cannot address alone such high levels of uncertainty and complexity. Interdisciplinary research is necessary to understand systemic interactions within coupled social-ecological systems (Liu *et al.*, 2007) and between sometimes conflicting sustainability objectives

(Nilsson *et al.*, 2016; Singh *et al.*, 2018). 'Wide' interdisciplinarity – which refers to collaborations between fields that are conceptually diverse – is crucial in this regard (Kelly, 1996). Social sciences and the humanities play a key role in shaping the goals of societal transformation processes and formulating narratives and strategies to meet them (*ibid.*). In addition, social sciences contribute to a better understanding of how societies and governance bodies mobilize knowledge and shape policymaking (Urai & Kelly, 2023).

Beyond academic knowledge, tackling real-world challenges also requires contextualized and experiential knowledge. Co-development of knowledge with societal actors through transdisciplinary modes of research allows for mutual learning processes between science and society to co-create, re-integrate, and apply solution-oriented knowledge (Lang *et al.*, 2012). Moreover, the diversity of sustainability objectives implies that different groups of actors have different visions of what a more desirable future should look like, depending on their socio-ecological context, culture, and values. Researchers must engage with relevant actors to allow for a plurality of perspectives and iteratively elicit the diversity of values and interests that frame the problem and possible solutions (Leach *et al.*, 2010; Schneider *et al.*, 2019c), while communicating openly on uncertainties and unknowns (Fjelland, 2016).

Finally, working across knowledge systems is required to enact change. Engaging with art, for example, can not only provide powerful ways to convey novel and complex issues to a broad audience, but also invite different ways of apprehending and interpreting complex problems. Through embodied cognition (mobilizing senses, emotions, and intuition), art-based research opens up 'constellations of possible meanings, allowing a large freedom of "lateral", associative thinking' contributing to richer forms of knowledge production (Heinrichs & Kagan, 2019, p. 435). Furthermore, collaborative efforts with societal actors to address concrete problems allow for increasing accountability, legitimacy, and ownership of solutions, enhancing agency by improving actors' capacities to cope with high uncertainty and complexity (Scoones *et al.*, 2020; Turnheim *et al.*, 2015).

3. Where to increase capacity

Scientists can enhance their contribution to more sustainable futures by engaging in transformative research, advancing knowledge on processes and practices of change, and implementing approaches that better link knowledge and action (O'Brien, 2012, 2013).

However, three fundamental challenges remain: (1) researchers often lack the necessary skills and competencies; (2) transformative research is highly context-dependent, which limits the transferability of approaches and ability to anticipate their transformative effects; and (3) across multiple levels, institutional support for conducting such research is insufficient.

3.1 Researchers' skills and competencies

Transformative research methods and concepts are still not adequately recognized as such in academic curricula (Barth *et al.*, 2020; Schneider *et al.*, 2019a). Accordingly, many academic actors do not yet feel at ease employing a scientific approach that deviates from traditional approaches to conducting research and producing knowledge. Even for researchers who consider transformative research critical for addressing sustainability challenges,

designing transformative projects and engaging in processes of co-design with societal actors often falls outside their skillset. Without adequate training and capacity-building opportunities, many researchers, even with years of experience, can be challenged to handle the complex dynamics inherent to processes of co-design, co-production, and co-implementation with actors holding multiple, different or divergent opinions.

3.2 Transformative methods and concepts

Transformative research aims to bridge the gap between informed analyses of complex social–environmental issues and the development and implementation of alternative narratives and trajectories toward just and more desirable futures. Because of its focus on social dynamics and power relations, transformative research is highly context-dependent and approaches must therefore be adapted to specific cases through iterative and reflexive processes (Lam et al., 2021; Wittmayer et al., 2021). The exploratory and experimental qualities of these processes mean that several concepts, tools, and methods are often combined (Midgley, 2011). In turn, the hybridization and adaptation of existing concepts and methods, paired with the specificities of each project, make transformative approaches difficult to generalize or transfer (Bennett et al., 2021; Nagy et al., 2020). Additionally, there is a lack of understanding on the extent and the mechanisms through which different approaches contribute to social transformations (Lam et al., 2021; Schneider et al., 2019b).

3.3 Institutional support

The ‘academic productivist regime’, epitomized by the relentless pressure to publish and the increasing importance of metrics ‘through which research is assessed and academics can establish their reputation, advance their career, and obtain funding’ has entrenched the predominance of disciplinary approaches and reduced opportunities to explore more collaborative, holistic, and innovative ways of doing research (Lorenz-Meyer, 2018, p. 152; Paasche & Österblom, 2019). Transformative research still remains a niche field in the broader scientific landscape. Science efforts in support of sustainable development (e.g. to contribute to addressing the sustainable development goals in an integrated fashion) are insufficient, owing in part to constraints in research funding as well as fragmentation, misalignment, misplaced priorities (e.g. national research over international collaboration to achieve global societal and environmental benefits for the common good), and large disparities, between the Global North and Global South, in the capacity to produce knowledge (Chankseliani, 2023; Irwin et al., 2018; Reidpath & Allotey, 2019; Sabzalieva et al., 2020).

4. The Future Earth Pathways Initiative’s ToC

The Future Earth Pathways Initiative aims to increase the capacity of research to contribute to societal transformation by strengthening capabilities for transformative sustainability science. Anchored in the Future Earth network, an international and interdisciplinary community of scientists and societal actors, the Pathways Initiative is ideally positioned to support researchers wanting to engage in transdisciplinary processes of adaptive learning.

4.1 ToC of the Pathways Initiative

To achieve the aims of the Initiative, the steering committee of the Pathways Initiative created a ToC, outlining our working hypotheses about how and why the Initiative’s activities might contribute to desired changes in research and education. The hypotheses link activities, which directly stem from the Initiative, to desired changes, through plausible pathways of outcomes and impacts. Acknowledging that societal transformations rarely unfold in linear ways, these initial hypotheses will be continuously refined in future through cycles of action and reflection (Dhillon & Vaca, 2018; Schneider et al., 2019b).

To construct the ToC of the Future Earth Pathways Initiative, in a series of workshops, we jointly reflected about plausible pathways for the Initiative; iteratively reflecting on the initiative’s capabilities, required changes, possible outcomes of various actions as well as pathways to impact. We considered what could be defined in a transformative context as meaningful goals, and assessed external developments and actual and possible power relations. The frameworks and insights of Belcher and Hughes (2021), O’Brien (2018), Schneider et al. (2021), and Schneider et al. (2019b) served as prompts for the reflection process. Table 1 summarizes how each of these informed the development of our ToC.

In line with the challenges identified in the previous section and the initiative’s goal of strengthening capabilities for transformative sustainability science, we identified three foci of action where the Pathways Initiative can provide relevant and effective support: scientists, scientific methods, and concepts, as well as in the functioning of institutions in charge of formulating scientific agendas and of providing funding vehicles. In our ToC, these three focus points correspond to three pathways along which efforts are required. Because science, scientists, and scientific institutions are intrinsically linked, these three pathways are closely intertwined and specific outputs and outcomes achieved along each of them individually are assumed to be essential for progressing along the other ones (Figure 1). We outline and describe the individual pathways, and discuss linkages, feedback, and interactions between these.

Supporting newcomers to build a growing community of practitioners engaged in transformative research (Figure 1, middle row): Sustainability science needs committed and competent scientists, who can legitimately claim expertise in transdisciplinarity and pursue a career as transformative researchers (Hoffmann et al., 2022). This legitimacy, along with a strong sense of belonging to a community of like-minded individuals, empowers them as credible change agents (Barth et al., 2020). The Initiative aims to enable and support such a *growing community of practitioners engaged in transformative research*. We therefore adopt a path that starts with the education and training of newcomers (i.e. researchers who seek to adopt transformative approaches in their work), and are looking for opportunities to engage in knowledge exchange with other researchers.

Through activities such as summer schools or workshops developed with different academic and institutional partners, our aim is to contribute to equipping scientists with strong transformative skills and competencies. We further aim to spark enthusiasm to take on the challenges of co-producing transformative and sometimes contested knowledge with a diversity of actors, implementing novel transformative research approaches, and catalyzing sustainable change on the ground. Ultimately, these trained researchers will form a community of practitioners engaged in transformative research that earns visibility and

Table 1. Influential frameworks

Framework/insights	Key takeaways from framework/insights	Influence on Pathways ToC
Understanding and evaluating the impact of integrated problem-oriented research programs (Belcher & Hughes, 2021)	‘Appropriate evaluation approaches are needed to evidence research impact and generate learning for continual improvement’. ‘Nested project- and program-scale theories of change; research quality assessment; theory-based outcome evaluations to empirically test ToCs and assess policy, institutional, and practice influence’ are part of a holistic, multi-method, and integrated approach to evaluate transdisciplinary programs.	The need to evaluate the effectiveness of transformative approaches influenced the evaluation feedback loops featured in our <i>evolving science</i> (top) pathway.
The three spheres of transformation (O’Brien, 2018)	The three spheres is a heuristic highlighting the interdependent dynamics between behaviors, systems, culture in transformation processes: • ‘<i>Practical sphere</i> is at the core of the figure, and it represents specific actions, interventions, strategies, and behaviors that directly contribute to a desired outcome. • <i>Political sphere</i> represents the systems and structures that facilitate or constrain practical responses to climate change. • <i>Personal sphere</i> of transformation represents the subjective beliefs, values, worldviews, and paradigms that influence how people perceive, define, or constitute systems and structures, as well as their behaviors and practices’.	The interplay between subjective values, practical capabilities, and supporting/constraining structures was a key influence in the design of the Pathways ToC, and is evident through the way our three pathways are interconnected.
The network compass (Schneider et al., 2021)	Four generic fields of action through which networks seek to foster co-production: (1) ‘Connecting actors and scales to enable co-production. (2) Supporting the network community in co-production. (3) Fostering co-production to leverage the network community’s transformative power. (4) Innovating the network to strengthen co-production’.	This framework was useful to reflect on the capacity of the Pathways Initiative’s activities to support the four different fields of action, and how these fields of action relate to the end-goals of our ToC pathways.
Three generic mechanisms of impact generation (Schneider et al., 2019c)	Three generic mechanisms through which transdisciplinary co-production of knowledge is expected to lead to sustainability transformations: • ‘<i>Knowledge promotion</i>: promoting systems, target, and transformation knowledge for more informed and equitable decision-making. • <i>Social learning</i>: fostering social learning for collective action. • <i>Competence building</i>: enhancing competences for reflective leadership’.	Acknowledging that these mechanisms are not mutually exclusive, and are most effective when combined, our ToC tried to adopt a mixed approach (through three pathways) using elements of all three mechanisms to reach our overall objective of increasing capacity for transformative research.

recognition, thereby deconstructing existing stereotypes and shifting scientific norms. Such a shift, in turn, implies that transformative approaches to research are fully integrated across scientific disciplines and promoted equally to others through training and education, academic positions, as well as funding schemes.

Evolving the science by advancing concepts, methods, and paradigms to foster ‘fit-for-purpose transformative research’ (Figure 1, top row): Increasing researchers’ skills and competencies to overcome the barriers of classical, disciplinary science inevitably needs to be paired with advancing the specific scientific concepts, methods, and paradigms that underpin transformative research. While individual scientists of certain scientific fields have started to develop novel approaches, these must be further developed and adapted according to the needs of different disciplines, scientific communities, impact goals, and contexts. The Pathways Initiative aims to enable and support reflexivity and learning processes among scientists of different disciplines and scientific communities, within Future Earth and beyond, to catalyze the development of *fit-for-purpose transformative-science*. To achieve

this aim, our pathway to impact starts with the creation of reflective spaces in which sustainability science practitioners (scientists, stakeholders, etc.) come together in mutual learning environments. Such environments serve to share experiences, exchange ideas, question and refine existing practices and methodologies, experiment, and co-create new methods and approaches best suited to address current challenges at local to regional scales. Our Initiative fosters these spaces in different ways: via the exchange of experience, insights, and reflections that happen as part of our webinars, summer schools, and workshops. Spaces for discussion, knowledge exchange, and experimentation enable the emergence of critical reflections on the norms and values of transformative research as a way to reappraise conventional narratives and develop new ones (Kläy et al., 2015; Singer-Brodowski et al., 2018; Vogt & Weber, 2020). The advanced concepts and methods co-produced (*sensu* Norström et al., 2020) within these incubators are intended to overcome the limitations of disciplinary science and of sectoral governance. These advances are also meant to acknowledge that different ways



Figure 1. The Pathways Initiative theory of change to increase capacity for transformative research.

of producing and applying knowledge can magnify the transformative impact of science. They are designed to accommodate the requirements of place-based research as well as address the tension between local and broader scales by allowing for transposition of results to other contexts, upscaling, extrapolation, and generalization. Through a process of evaluation, experimentation, and validation by experienced scientists, these concepts and methods gradually become *fit-for-purpose* transformative research.

Shaping institutions to nurture transformative research-friendly contexts (Figure 1, bottom row): Transformative sustainability science needs institutional endorsement and support, for example, through funding initiatives or (career) incentive schemes. The Initiative aims to catalyze progress toward a *transformative research-friendly environment through collaboration with institutional actors*. Our pathway to impact therefore starts with an engagement with institutional actors such as universities and science funding bodies to clarify the options that transdisciplinary science offers and the opportunities it both creates and unlocks in a context of evolving social and scientific norms and paradigms. Dialogues, proofs of concept, and knowledge-based negotiations serve to sensitize institutions to the pivotal roles and responsibilities they play in creating an enabling environment for transformative research (Gordon et al., 2019). Such work with institutional actors toward normalizing and legitimizing inter- and trans-disciplinary and transformative research at the institutional level is essential to make sure that researchers who decide to seriously engage in such types of sciences do not do so at the expense of their own career (Bammer et al., 2020; Haider et al., 2018; Hoffmann et al., 2022; Lyall, 2019). Furthermore, by sharing knowledge-based insights and experiences, institutional actors are supported in enhancing their competencies for creating favorable conditions, including evaluation criteria, funding mechanisms, and career incentives (Schneider et al., 2021). We aim to encourage institutions to engage in a process of reframing their policies and reformulating their priorities such as to enable the gradual evolution of higher education

institutions (Loorbach & Wittmayer, 2024; Lotz-Sisitka et al., 2015) and funding mechanisms. Moreover, as an initiative of Future Earth, the Pathways Initiative acts as a ‘test bed’ for demonstrating how international scientific networks have a key role to play in convening and connecting the wide diversity of actors and catalyzing the innovative collaborations across disciplinary, cultural, and social knowledge divides that are required to support sustainability transitions.

4.2 Final words: placing the ToC within a wider context

The Pathways Initiative is an addition to an evolving dynamic where researchers and the science systems they are a part of – such as Future Earth – are becoming increasingly engaged with the societal role of science. They are concerned with creating the science *for* sustainability transformations, reflecting on their capacity and responsibility to participate in catalyzing such transformations, and collaborating with societal actors to develop pathways toward radical socio-ecological transformations at various scales. Restoring and strengthening the link between science and society through transformative research is critical as we head toward increasingly uncertain futures. The shifts in norms, in scientific stereotypes and paradigms, as well as in values and power that the Pathways Initiative aims to elicit are admittedly ambitious. However, the growing number of initiatives, organizations, and scientists sharing similar objectives not only makes the task less daunting, but also magnifies the complementary and cumulative impact of this transformative dynamic in sustainability science through partnerships and collaborations. To this end, the Pathways Initiative already collaborates with the Belmont Forum and the UNESCO-MOST BRIDGES Coalition (the UNESCO-MOST BRIDGES Coalition is an international network for humanities-centered transdisciplinary research in sustainability), and is looking to expand partnerships.

This moment in time represents a delicate yet necessary turning point for redefining the contributions science and scientists

can make to society as we collectively work to tread a path toward more desirable futures. We look forward to the journey ahead together with all of the motivated and daring scholars who constitute the fundamental drivers of change for a transformative sustainability science.

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