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Can science on transformation transform science? Lessons from co-design

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Increasingly, 'co-design' is a key concept and approach in global change and sustainability research, in the scholarship on science–policy interactions, and an expressed expectation in research programs and initiatives. This paper situates co-design and then synthesizes insights from real-life experiences of co-developing research projects in this Special Issue. It highlights common co-design elements (parameters and considerations of co-design and purpose-driven engagement activities); discusses challenges experienced in co-design and then emphasizes a range of rarely articulated benefits of co-design for both researchers, societal partners and the work they aim to do together. The paper summarizes some of the knowledge gains on social transformation to sustainability from the co-design phase and concludes that co-design as a process is an agent of transformation itself.

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Introduction

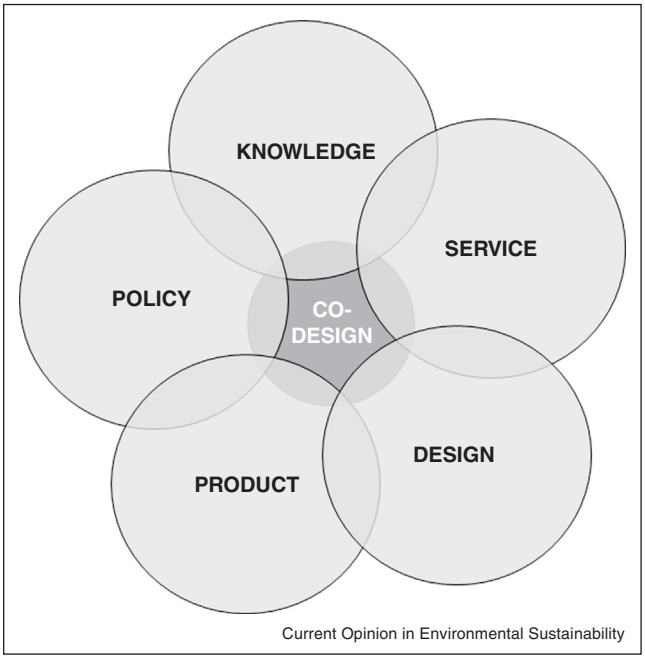
'Co-design' is rapidly becoming a key concept and approach in research on global change and sustainability and in the scholarship on science–policy interactions, but also an expressed expectation in various research programs like the Transformations to Sustainability Programme of the International Social Science Council and global research initiatives like Future Earth [1•,2–5,6•]. Going only slightly beneath this observation, it becomes apparent that contributors to these arenas do not necessarily mean the same thing by 'co-design,' with interpretations ranging from any form of engagement between scientists and non-scientists, to loose equations of co-design with 'co-production of knowledge' or 'transdisciplinarity', to the more specific set of activities used to jointly develop projects and products, and define research questions [1•,7•,8–11]. This range of interpretations is also reflected in the contributions to this Special Issue (SI).

A simple Web of Science search reveals that 'co-design' enjoys popularity in at least five rather separate spheres (Figure 1), even though there are some overlaps between these bodies of literature, and the fundamental motivation to engage beneficiaries in the process of developing that which is meant to benefit them runs across them all. The five arenas include:

- the above mentioned usage of co-design in the context of *knowledge production* to foster knowledge exchange, sharing, and greater salience and legitimacy of research [12–15];
- a body of work that is concerned with the co-design of *services*, which variably aims at greater quality, efficiency, compliance, and sometimes greater trust between service providers and users (e.g. social or human health services) [16–18];
- an arena for collaborative work in the context of *design* to increase fit with human needs and behavioral patterns (e.g. the design of urban development plans, houses or parks) [19];
- a quite substantial literature on the co-design of *products* to foster user-friendliness and fit (e.g. computer programs, household items, or tools) [20], and, finally,
- an area in which *policies and processes* are co-designed to ensure greater public acceptability and responsiveness to actual needs (e.g. energy efficiency programs or planning procedures) [21–23].

Given these widely varying contexts and interpretations, and to some extent separately evolving bodies of work, an even deeper look into the literature reveals a vast and diverse set of activities put under the label of 'co-design.' To the extent such diversity of approaches is actually reviewed and drawn upon as a sort of menu for more creative forms of interaction between those involved in the co-design process, such breadth can only be welcomed. Reality, however, is far from this ideal of reading across disciplinary and sectoral boundaries, across actors

Figure 1



Overlapping bodies of literature on co-design. Source: The author.

and institutions with very different capacities, training and skills.

To facilitate access and uptake of these wide-ranging practices, a number of guidebooks [24–26], syntheses [27,28,29••,30••,31–34] and foundational compendiums [35–38] have appeared to assist individuals interested in co-design and engagement across sectoral and disciplinary boundaries. They can assist in gathering ideas and gaining relevant skills for co-design.

While grounded in experience, such guidebooks rarely give insight into the actual, hands-on work of implementing co-design, and what can be learned from it. The papers in this SI aimed to fill this gap. They present 16 examples of research teams actively co-designing research projects together with a wide variety of societal partners [39–50]. As such, they offer a rare intimate look into, and reflection on, the work of researchers as they do co-design. It gives a glimpse of how it is actually initiated and carried out, what its hopes and opportunities are, but also what challenges emerge in the process and what anticipated as well as surprising outputs and outcomes result from it. This paper then aims to synthesize these empirical observations and insights. In doing so, it does not aim to replicate available knowledge on co-design from the handbooks and anthologies mentioned above. Rather, it aims to capture the actual co-design approaches and experiences as they unfolded, integrate and contextualize what the 16 research teams accomplished and learned, and as such create an empirical, educated entry point for other researchers interested in co-designing projects.

Situating co-design in transdisciplinary research on transformations to sustainability

The case has been made, convincingly, why engagement of scientists and users of scientific knowledge is superior to research conducted in isolation from its practice context, particularly in multi-disciplinary and inter-disciplinary research that aims to be problem-oriented and solutions-focused [9,51,52•,53–57]. Recognizing the validity and importance of non-scientific knowledge, the joint or co-production of knowledge of researchers together with practitioners (broadly conceived) is seen as essential [6•,30••,58–61].

In the context of research on social transformation, such an approach seems particularly important. While scholars differ in their specific definitions, transformation is a change process that aims at fundamental change of a system's form, structure, function and purpose [62–64]. Drawing on a wide range of theories and fields, each of the papers in this SI points to systems that require such fundamental change because perpetuating current management trends would be fundamentally unsustainable in an ecological, social and economic sense. But the specific transformative changes needed — whether it is in the context of securing food for all, sustaining small-scale fisheries, building and housing people in cities, or managing drylands from Tibet to sub-Saharan Africa — differ. Thus, the papers in this SI are united by the fundamental premise that transformation is needed, but each takes on different questions to advance understanding — for example, what is the specific transformation required or desired?; what transformation pathways are available?; what is the role of different actors in affecting transformational change?; what opportunities or levers of change are most effective in advancing the transition to sustainability?; what is the role of conflict in transformation?; how do fundamental values change? and so on.

Co-designing solutions-oriented research projects on such a diverse set of circumstances and questions about transformation is not just about advancing scientific understanding or theory, but launches from the assumption that scientific knowledge combined with others' knowledge is itself a powerful agent of change. It places science in the midst of transformative changes underway, and thus often requires grappling with different interpretations of the core concept of 'transformation,' across disciplines, spheres of actors, sectors, regions and cultures, as well as with the very understanding of science and its role in society itself.

For the purposes of this paper then, co-design is understood not in the broad sense of generalized science-practice engagement, transdisciplinarity or co-production

of knowledge, but in the narrower sense of that *first phase of the knowledge co-production process, in which researchers and non-academic partners jointly develop a research project and define research questions that meet their collective interests and needs*. This definition is broadly consistent with that offered by [1•], and how co-design is understood in Durham *et al*. [25] and the initial design of Future Earth [65]. The literature differs, however, on how this phase is bounded and thus what types of activities are included [7•,66]. Some conceive of it as an instrumental element on the way to producing relevant research during which knowledge is integrated, values and preferences reconciled, and ownership of a project developed [11,67]; for others it is boundary work [68]; others essentially conceive of co-design as an initial learning process [69,70]; and for yet others it is social capital building [71]. An emerging literature is critically reviewing this early stage of the co-production process [14,57,72••,73].

As a matter of operationalizing the concept in pragmatic terms for the purposes of this paper, co-design refers to the full range of activities used to jointly develop a research proposal during a 6-month seed grant period for which research teams received up to €30 000. During this time, they developed major research grant proposals on some topic related to social transformation to sustainability.[3] Below, I synthesize some cross-cutting insights from this phase emerging from the papers in this SI. In particular, the review points to the surprising breadth and diversity of activities and approaches involved in co-design and the different purposes they serve as critical elements of building effective collaborative research teams. It further focuses on the choices made in developing co-design processes (such as the selection of academic and non-academic partners), which — in the case of research on social transformation — opens the door to an intense confrontation of researchers with their own theories and perspectives on the world. The discussion of challenges encountered in and benefits from doing co-design highlights a theme that runs across the entire SI: how doing co-design changes the people involved and the research projects envisioned, while inviting critical reflection of the role of science in society.

Cross-cutting insights on co-design

Co-designing social-science led research on social transformations involving partners from multiple countries in each project is a diverse endeavor. It is as rich and varied as the teams involved. Contrary to best-practice guides or normative assumptions, the empirical evidence shows that there is no uniform approach to co-designing research projects in part because of differential capacities among those facilitating the process as well as among those participating in it, in part because of the different topics, actors and purposes involved.

Elements of co-design

It is helpful to ask what factors were considered in these real-life situations in deciding on a particular approach to co-design. Figure 2 lists these co-design parameters and considerations.

The choices made across the 16 examples reporting in this SI underline the great variety of approaches co-design can involve. On the basis of the reflections offered in these papers, it is safe to say that the more direct, frequent and interactive the processes were, the more co-ownership did the invited partners take of the process, and the more empowered they became in the co-design of the research proposal. Importantly, these outer parameters do not yet fully tell the story of what actually happened in the co-design process. Figure 3 summarizes the purpose-driven engagement activities that the teams used over the course of their co-design processes.

Again, a wide range of activities were used, reflecting the creativity of the teams, the skill in facilitating different activities, and the range of needs that had to be met during co-design: from making initial connections and building a trustful team, to exchanging knowledge and learning from each other, to developing and evolving the project together, to delivering on a number of outputs.

What is maybe surprising is the range of outputs and outcomes achieved. Besides the immediate goal of the co-design process, namely, to develop a research proposal and a well-organized team to implement it, if funded, the co-design itself involved active research [47,48,50,74], produced peer-reviewed publications [46,75] along with a number of non-academic outputs [43,50]. For the limited amount of seed funding available, these intense co-design periods appear to be highly productive.

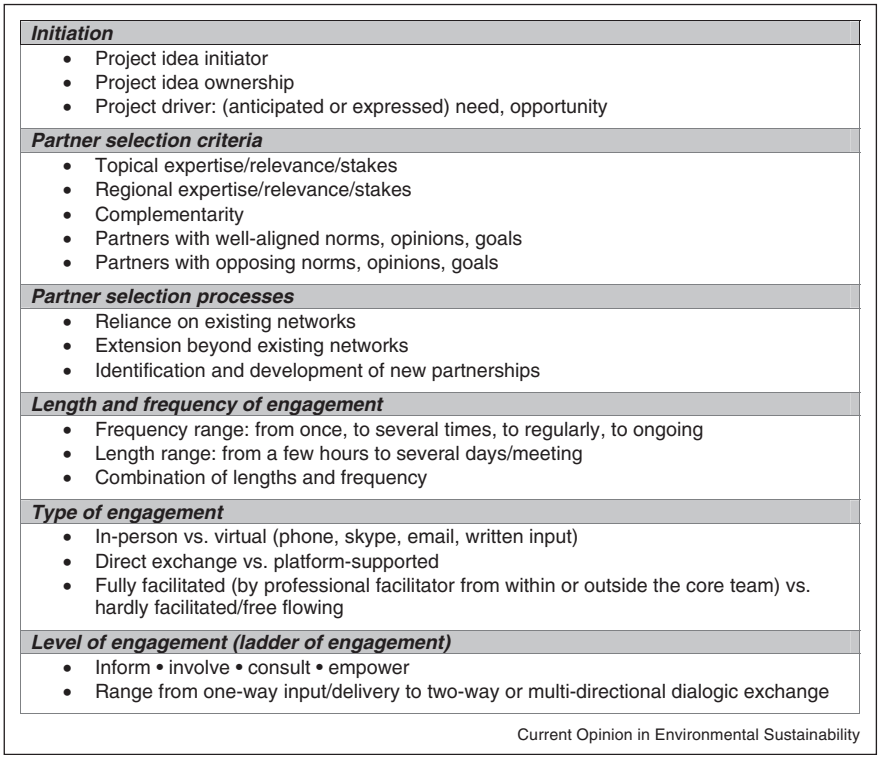
Partners in co-design

The above-mentioned handbooks on participatory research, engaged science or 'stakeholder involvement' in research offer long lists of practically any type of stakeholder imaginable to bring to the table for co-design. A superficial summary of who all was involved in the 16 projects synthesized here would result in the same long and diverse list, maybe made only more diverse by the fact that the projects — by funder requirement — had to involve participants from at least three countries from at least two world regions, including low-income and middle-income countries.

What is maybe more interesting, however, is to consider who was invited to the co-design table in projects focused on some aspect of *social transformations* to sustainability, and how that substantive focus affected the range of

[3] For the detailed seed grant and full grant application criteria, see: http://www.worldsocialscience.org/activities/transformations/.

Figure 2



Co-design parameters and considerations. Source: The author.

partners, and the resulting challenges and benefits of co-design. In the instances described in this SI, partners included:

- Agents of change with frequently radicalized perspectives and agendas (e.g. social movement participants and leaders [44,45]).
- Representatives of groups often marginalized and underprivileged in contemporary society (e.g. indigenous, or poor, or not formally educated people [46]).
- Actors located in places that faced logistical challenges of participation (e.g. people located in low-income, remote places, places of conflict [74]).
- Actors whose cultural socialization and personal lives resulted in priorities, values, and meanings from activities, outputs and outcomes that were sometimes quite different than those important to researchers (e.g. knowledge as an instrumental means to other ends versus knowledge as a value in itself; time as unconstrained spaciousness for human connection versus time as a limited commodity in which to deliver products [75,76]).
- Decision-makers from contexts that were very different from those of the scientists organizing the co-design process (e.g. urban planners from low-income versus high-income countries [40,77]).

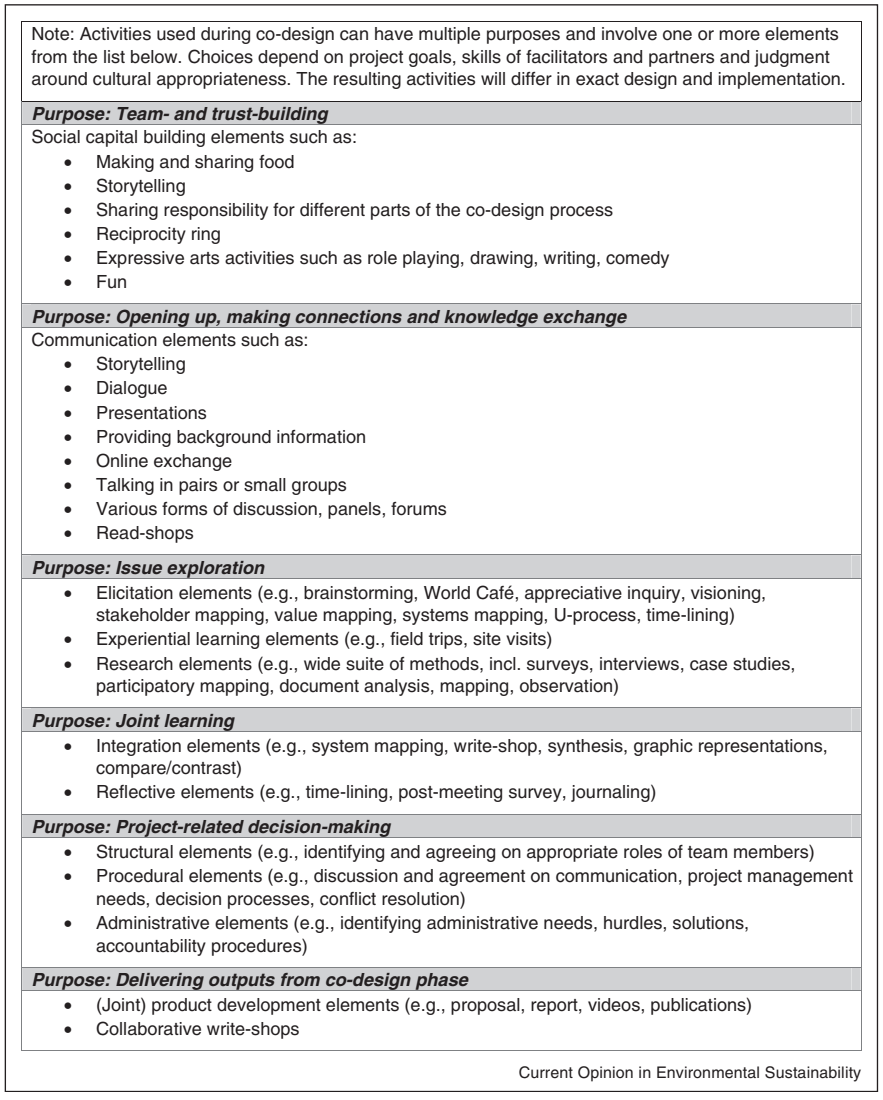
While many social scientists have deep expertise (from training and experience) in researching communities that are very different from the researchers themselves, in a co-design process the ambition is to develop projects co-equally. The authors were frank about the ambiguities, difficulties, and transformative opportunities these encounters involved. And even a 6-month collaboration period was often not long enough to establish solid, trustful working relationships to bridge the vast differences in orientation, background, goals and skills. This is why many teams chose to rely on existing partnerships, and those who launched new partnerships faced a steep learning curve [42].

Challenges in co-design

Given the inevitable stretch asked of participants in a co-design process that is supposed to be multi-disciplinary, inter-disciplinary and transdisciplinary, involve partners from multiple linguistic and cultural backgrounds, and from low-income, middle-income and high-income countries, the challenges in co-design are maybe brought to the surface more starkly than in projects with more homogenous participation.

Not surprisingly, one of the most frequently mentioned challenges are those related to communication and, as many put it, the time-consuming process of 'finding a

Figure 3



Note: Activities used during co-design can have multiple purposes and involve one or more elements from the list below. Choices depend on project goals, skills of facilitators and partners and judgment around cultural appropriateness. The resulting activities will differ in exact design and implementation.

Purpose: Team- and trust-building

Social capital building elements such as:

- Making and sharing food
- Storytelling
- Sharing responsibility for different parts of the co-design process
- Reciprocity ring
- Expressive arts activities such as role playing, drawing, writing, comedy
- Fun

Purpose: Opening up, making connections and knowledge exchange

Communication elements such as:

- Storytelling
- Dialogue
- Presentations
- Providing background information
- Online exchange
- Talking in pairs or small groups
- Various forms of discussion, panels, forums
- Read-shops

Purpose: Issue exploration

- Elicitation elements (e.g., brainstorming, World Café, appreciative inquiry, visioning, stakeholder mapping, value mapping, systems mapping, U-process, time-lining)
- Experiential learning elements (e.g., field trips, site visits)
- Research elements (e.g., wide suite of methods, incl. surveys, interviews, case studies, participatory mapping, document analysis, mapping, observation)

Purpose: Joint learning

- Integration elements (e.g., system mapping, write-shop, synthesis, graphic representations, compare/contrast)
- Reflective elements (e.g., time-lining, post-meeting survey, journaling)

Purpose: Project-related decision-making

- Structural elements (e.g., identifying and agreeing on appropriate roles of team members)
- Procedural elements (e.g., discussion and agreement on communication, project management needs, decision processes, conflict resolution)
- Administrative elements (e.g., identifying administrative needs, hurdles, solutions, accountability procedures)

Purpose: Delivering outputs from co-design phase

- (Joint) product development elements (e.g., proposal, report, videos, publications)
- Collaborative write-shops

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Purpose-driven engagement activities in the context of co-design. Source: The author.

common language' [45,48,50]. The contributions to this SI make clear, however, that the challenges go beyond becoming familiar with each other's disciplinary or practice-specific jargon. In a number of instances, this issue was aggravated by English being the dominant language, but not an easy one for all participants to converse in [74]. Lack of familiarity with cultural differences, and the particular challenge of coming to a common understanding across value differences were singled out repeatedly [76]. To the extent such dialogues became more controversial, there is the added challenge of facilitating and managing such exchanges, when the ultimate goal is to build an effectively collaborating team [75,77]. Finally, among the specific communication challenges mentioned was the extended communication beyond those who were involved directly in the co-design process [39,47,48]. All participants are connected to wider networks who did not have the co-design experience of working toward common goals directly [47]. While difficult, the fact that this was even mentioned points to the ripple effect that co-design processes can have in real-world processes.

Related to communication were challenges regarding pre-co-design and post-co-design engagement. Some teams mentioned how much more preparation would have been needed to make the co-design even more effective. Others emphasized that co-design is not an end point, but requires maintenance of and ongoing communication with network partners during the wait for funding decisions [39,48,49]. Maintaining partner connections necessarily rests on the assumption that funding will come through, at the same time that project leads must manage

partners' assumptions that the project will only go forward *if* the funding materializes — a difficult tension indeed [41]. A further challenge that could be turned into an opportunity in this regard was that for some the full benefits of co-design were fully understood only post-engagement [77]. Thus, the waiting period could be effectively used for post-co-design reflection to surface further insights, many of which will be useful even if funding does not manifest from the initial proposal.

Many teams singled out the challenge of working across differences in background, training, experiences, needs, ideologies and interests. The issue here went beyond finding a common language, to finding agreement on a consensual framework for the research, on methods, standards of work and priorities, being confronted with different ontologies and epistemologies [41,44–46,48,50]. In some instances, groups had to work through the skepticism among partners of working with each other, for example NGO or movement leaders or small-scale fishermen working with big business [40]. And in several instances, teams mentioned the importance of confronting power dynamics consciously [45,46,50]. Dismantling initially unspoken hierarchies, including knowledge hierarchies (whose knowledge counts (or counts more)?), is maybe some of the most difficult — and transformational — work reported in this SI, given that professional positions, organizational expectations, responsibilities for funding and delivery of a project are deeply engrained legacies and matters of identity. Such power dynamics emerged among academics from different disciplines and among academics and non-academics. Some also mentioned the specific challenge of letting go of intellectual legacies or ownership of an idea for the benefit of effective collaboration [77]. Crucial lessons can be learned from overcoming these challenges consciously for the topic of transformation.

The research teams further mentioned challenges around building, deepening and maintaining engagement [39,42]. Trust building cannot be rushed but proved essential, particularly across the various differences mentioned above. The time-consuming nature of co-design is well established [30••] but the authors in this SI added the time commitment for ongoing consultation, the particular challenge of building new relationships, and dealing with the fact that co-design creates the expectation of not only loose affiliations, but partnering around substantive work and contents [49]. This implies that co-design processes had to be built for inclusivity and creativity, not just for efficiency and effectiveness in the sense of producing a joint proposal.

Another set of concerns surfaced around political sensitivities and practical instabilities in the projects. Discomforts on both sides — among researchers and societal partners — arose around the involvement of academics in hot politics [50], the potential of participation endangering partners [45], as well as around the engagement of certain partners (see discussion of partners above) [75], which made communication of transformation strategies highly sensitive. At the same time, the legitimacy of the project required just that kind of dialogue. In other instances, the co-design required travel to or from politically or militarily unstable countries or regions [74].

In summary, the challenges of co-design point to the ongoing need to balance trade-offs and reconcile tensions: between scientific rigor and an open, bottom-up design; codified data and the non-reductive work with parallel narratives; an emphasis on the advancement of science (and theory) for its own sake and the instrumental character of research with practical benefits in specific grounded realities; the immediate needs and wishes of actors and the long-term focus on a more transformative agenda; work at multiple scales with diverse geographies and site-specificity; and, finally, between funder requirements involving multiple innovations creating challenges around feasibility and cost (the opportunity, monetary and environmental costs of global collaboration) and the familiarity and ease of collaboration following more familiar standard procedures.

Benefits of co-design

Given these very real and practical challenges of co-design, why should researchers take on such added burden? Figure 4 summarizes the benefits the teams reaped from deliberately, consciously, and reflectively undertaking the hard work of engaging academic and societal partners in the development of joint projects.

Maybe the most salient feature of this summary is that it highlights benefits that go far beyond the typically foregrounded advantages of transdisciplinary work, such as greater relevance, enhanced legitimacy, buy-in and so on [51,78–82]. Simply put, co-design changes projects and the breadth, depth and quality of research; it changes researchers, societal partners and the relationships between them; and it is not just 'preliminary' or preparatory work, but highly productive work, resulting in outputs and outcomes that benefit various audiences and actors.

Summary

Co-design already produces knowledge about transformation

Nearly each paper in this SI reports on substantive knowledge gained in the co-design phase about social transformation. Teams clarified the range and roles of actors critical to a transformative process; they mapped and refined existing understandings of the systems in need of transformation; they began charting pathways of transformation, identified conflicts likely to emerge in the transformation process, and learned to see conflict as a site of transformation [40]. They also allowed engaged partners to articulate, and in some instances negotiate and agree upon, transformative 'outcomes' that could serve as

Figure 4

Enhanced topical understanding, knowledge advances
• On topic (clarified project vision, research priorities, new research sites and opportunities) • On transformation (inner/outer dimensions, pathways, actors/change agents, role of conflict) • On co-design (as transformative process itself, role of academia, production of demand-driven knowledge, confrontation with difference)
Research collaboration
• More creative, more exciting research proposal with improved conceptual/theoretical approach • Cross-fertilization of ideas • Improved (articulation of) ethics of research • Equity in research team • Established a research project implementation strategy more solid than before • Accountability mechanisms
Communication
• Common language • Better understanding of different languages • Increased empathy for others
Interpersonal relations
• Got to know each other (better) • Improved personal chemistry • (Greater) Trust • Enhanced networking, new relationships
Grounding in local realities
• Accuracy improved • Relevancy increased • Ethics clarified and improved
Increased reflectivity of researcher
• Confronted with other ways of conceptualizing or looking at the world, a particular topic • Power dynamics foregrounded • Improved understanding across different epistemologies • Clarified differences in cultural norms and values • "Slower", more inclusive and just scholarship • Increased skills for collaborative work (facilitation, conflict negotiation, engagement design)
Increased motivation
• More energized to the work • Encouraged to move forward • Stimulated by challenges, novelty, discoveries, relevance
Production of outputs from co-design for various audiences
• Peer-reviewed papers • Non-academic outputs • Reports • Joint proposal
Practical outcomes
• Social learning transformed participating actors • Better system understanding opened up new pathways, intervention possibilities • Networking aided coalition-building • Greater access to policy spaces

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Benefits of engaging in co-design. Source: The author.

critical beacons throughout the transformation process [48,49].

This repeated finding from a number of papers in this SI is encouraging and somewhat surprising, given common connotations with co-design as 'merely' the *preparatory work prior to knowledge production*. Instead, co-design emerges as *a critical time of knowledge generation* in its own right.

Co-design serves as an instrument of transformation

Maybe as or even more importantly, co-design itself is an agent of transformative change [49]. As multiple papers acknowledged, through the co-design process, pre-existing knowledge systems were not just amended, but challenged, integrated and thus altered to generate surprising new insights and perspectives [40,45,46]. The ethics of, and equity in, research, particularly transformative research, became a central concern [42,43,45]. The highly engaged, iterative process, involving multiple rounds of reflection, enabled triple-loop learning at least among some of the academics (leads) involved, but possibly also among some of their partners [44]. Moreover, the respectful and meaningful involvement required, and in some instances resulted in, capacity building among the engaged partners, thus leaving a lasting impact [74].

Finally, because of the intense interactions and trusted relationships that emerged during co-design, dialogues surfaced — intentionally or serendipitously — a number of transformative opportunities and spaces that researchers were previously not aware of [75,76].

Conclusions

The reflection encouraged in each project through a contribution to this SI is maybe one of the most important aspects of effective co-design. It extended from the first draft through the engagement of each team with reviewers' comments and the editor, in each case making the papers even more valuable to the teams themselves. This learning orientation is maybe the hallmark of effective transdisciplinary work, but certainly of work that aims to contribute to social transformations. Ideally, such intense reflection and learning would occur between an initial seed grant period and the time of developing a full research proposal, allowing the learning to become a substantive element of subsequent research.

Clearly, not all transdisciplinary projects have the luxury of a six-month development phase, nor the luxury of seed funds to support such meaningful in-depth engagement. The experiences in co-design synthesized here, however, offer significant insights for and encouragement to other researchers, and might be invaluable to research program designers and funders. Given how much flows from the initial design of a project, the importance of effective co-design cannot be overstated. And as the papers in this SI make clear, there is an art and emerging scholarship in co-design that could itself be transformative — for the knowledge production process and for the value of science to society.

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References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. • Mauser W, Klepper G, Rice M, Schmalzbauer BS, Hackmann H, Leemans R, Moore H: **Transdisciplinary global change research: the co-creation of knowledge for sustainability**. *Curr Opin Environ Sustain* 2013, **5**:420-431.

A foundational overview paper of the importance, conduct and different phases of knowledge co-production in the context of global change and sustainability research.

2. Turner BL II, Esler KJ, Bridgewater P, Tewksbury J, Sitas N, Abrahams B, Chapin FS III, Chowdhury RR, Christie P, Diaz S *et al.*: **Socio-environmental systems (SES) research: what have we learned and how can we use this information in future research programs**. *Curr Opin Environ Sustain* 2016, **19**:160-168.

3. Alvargonzalez D: **Multidisciplinarity, interdisciplinarity, transdisciplinarity, and the sciences**. *Int Stud Philos Sci* 2011, **25**:387-403.

4. Scholz RW, Steiner G: **Transdisciplinarity at the crossroads**. *Sustain Sci* 2016, **10**:521-526.

5. Leemans R: **The lessons learned from shifting from global-change research programmes to transdisciplinary sustainability science**. *Curr Opin Environ Sustain* 2016, **19**:103-110.

6. • van der Hel S: **New science for global sustainability? The institutionalisation of knowledge co-production in Future Earth**. *Environ Sci Policy* 2016, **61**:165-175.

One of the first studies empirically studying the work of the new global research platform, Future Earth. It highlights the various motivations that drive participating researchers and leaders in that initiative to co-design and co-produce research with societal partners.

7. • Lawrence RJ: **Advances in transdisciplinarity: epistemologies, methodologies and processes**. *Futures* 2015, **65**:1-9.

An important recent overview and orientation of common understandings of transdisciplinarity, methods and processes used in transdisciplinary work.

8. Brandt P, Ernst A, Gralla F, Luederitz C, Lang DJ, Newig J, Reinert F, Abson DJ, von Wehrden H: **A review of transdisciplinary research in sustainability science**. *Ecol Econ* 2013, **92**:1-15.

9. Pohl C: **From science to policy through transdisciplinary research**. *Environ Sci Policy* 2008, **11**:46-53.

10. Frescoln LM, Arbuckle JG: **Changes in perceptions of transdisciplinary science over time**. *Futures* 2015, **73**:136-150.

11. Lang DJ, Wiek A, Bergmann M, Stauffacher M, Martens P, Moll P, Swilling M, Thomas CJ: **Transdisciplinary research in sustainability science: practice, principles, and challenges**. *Sustain Sci* 2013, **7**:25-43.

12. van Kerkhoff L: **Developing integrative research for sustainability science through a complexity principles-based approach**. *Sustain Sci* 2014, **9**:143-155.

13. Guimares MH, McKee A, Lima ML, Vasconcelos L, Boski T, Dentinho T: **Putting transdisciplinarity into practice: a mixed mode procedure for stakeholder participation in natural resource management**. *J Environ Plan Manag* 2016, **59**:1827-1852.

14. Gaziulusoy AI, Ryan C, McGrail S, Chandler P, Twomey P: **Identifying and addressing challenges faced by transdisciplinary research teams in climate change research**. *J Clean Prod* 2016, **123**:55-64.

15. Felt U, Igelsböck J, Schikowitz A, Völker T: **Transdisciplinary sustainability research in practice: between imaginaries of collective experimentation and entrenched academic value orders**. *Sci Technol Hum Values* 2016, **41**:732-761.

16. Peigne J, Lefevre V, Craheix D, Angevin F, Capitaine M: **Participatory assessment of innovative cropping systems combining conservation agriculture and organic farming**. *Cah Agric* 2015, **24**:134-141.

17. Robinson S, Notara D: **Building belonging and connection for children with disability and their families: a co-designed research and community development project in a regional community**. *Commun Dev J* 2015, **50**:724-741.

18. Gutberlet J, Kain J-H, Nyakinya B, Ochieng DH, Odhiambo N, Oloko M, Omolo J, Omondi E, Otieno S, Zapata P *et al.*: **Socio-environmental entrepreneurship and the provision of**

critical services in informal settlements. *Environ Urban* 2016, **28**:205-222.

19. Chanal V, Raynauld J: **Describing and assessing co-design competences: some preliminary results**. In In *Proceedings of the 2nd International Conference on Innovation and Entrepreneurship. Proceedings of the International Conference on e-Learning.* Edited by Ribiere V, Worasinchai L. *Proceedings of the 2nd International Conference on Innovation and Entrepreneurship. Proceedings of the International Conference on e-Learning* 2014:24-28.

20. Hazard L, Gauffreteau A, Borg J, Charron MH, Deo M, Enjalbert J, Goutiers V, Gressier E: **Using innovative approaches to meet the challenges of a rapidly changing climate and world: the utility of co-design in plant breeding programmes**. *Fourrages* 2016, **225**:39-47.

21. Trencher G, Bai X, Evans J, McCormick K, Yarime M: **University partnerships for co-designing and co-producing urban sustainability**. *Glob Environ Change* 2014, **28**:153-165.

22. Christie P, Pietri DM, Stevenson TC, Pollnac R, Knight M, White AT: **Improving human and environmental conditions through the Coral Triangle Initiative: progress and challenges**. *Curr Opin Environ Sustain* 2016, **19**:169-181.

23. Isaacs M: **Multi-stakeholder process of co-designing small-scale fisheries policy in South Africa**. *Reg Environ Change* 2016, **16**:277-288.

24. Moulaert F, MacCallum D, Mehmood A, Hamdouch A: *International Handbook on Social Innovation: Collective Action, Social Learning and Transdisciplinary Research*. Cheltenham: Edward Elgar Publishing Ltd; 2013.

25. Durham E, Baker H, Smith M, Moore E, Morgan V: *BiodivERsA Stakeholder Engagement Handbook Best Practice Guidelines for Stakeholder Engagement in Research Projects*. Paris: BiodivERsA, Fondation pour la Recherche sur la Biodiversité; 2014.

26. Young JC, Watt AD, Van den hove S, SPIRAL project team: *Effective Interfaces Between Science, Policy and Society: The SPIRAL Project Handbook*. 2013.

27. Alexandrescu F, Bleicher A, Weiss V: **Transdisciplinarity in practice: the emergence and resolution of dissonances in collaborative research on brownfield regeneration**. *Interdiscip Sci Rev* 2014, **39**:307-322.

28. Bieluch KH, Bell KP, Teisl MF, Lindenfeld LA, Leahy J, Silka L: **Transdisciplinary research partnerships in sustainability science: an examination of stakeholder participation preferences**. *Sustain Sci* 2016:1-18. [online first].

29. •• Scholz RW, Steiner G: **The real type and ideal type of transdisciplinary processes: part I — theoretical foundations**. *Sustain Sci* 2016, **10**:527-544.

The introductory paper to a special issue on transdisciplinarity, an excellent and comprehensive overview of the origins and evolution of the concept of transdisciplinarity.

30. •• Scholz RW, Steiner G: **The real type and ideal type of transdisciplinary processes: part II — what constraints and obstacles do we meet in practice?** *Sustain Sci* 2015, **10**:653-671.

The concluding paper of a special issue on transdisciplinarity, the paper details the phases, and critically examines the challenges and benefits of transdisciplinary work.

31. Wiek A: **Challenges of transdisciplinary research as interactive knowledge generation: experiences from transdisciplinary case study research**. *GAIA Ecol Perspect Sci Soc* 2007, **16**:52-57.

32. Wickson F, Carew AL, Russell AW: **Transdisciplinary research: characteristics, quandaries and quality**. *Futures* 2006, **38**:1046-1059.

33. Grunwald A: **Transformative science — a new order in academia?** *GAIA Ecol Perspect Sci Soc* 2015, **24**:17-20.

34. Fernández RJ: **How to be a more effective environmental scientist in management and policy contexts**. *Environ Sci Policy* 2016, **64**:171-176.

35. Brown VA, Lambert JA: *Collective Learning for Transformational Change: A Guide to Collaborative Action*. Oxford: Routledge; 2012.

36. Bergmann M, Jahn T, Knobloch T, Krohn W, Pohl C, Schramm E: *Methods for Transdisciplinary Research. A Primer for Practice*. Frankfurt am Main: Campus Verlag; 2012.

37. Klein JT, Grossenbacher-Mansuy W *et al.*: *Transdisciplinarity: Joint Problem Solving Among Science, Technology, and Society. An Effective Way for Managing Complexity*. Basel: Birkhauser; 2001.

38. Pohl C, Hirsch-Hadorn G: *Principles for Designing Transdisciplinary Research*. München: oekom verlag; 2007.

39. Galvin KA, Reid RS, Fernández-Giménez ME, Kaelo Do, Baival B, Krebs M: **Co-design of transformative research for rangeland sustainability**. *Curr Opin Environ Sustain* 2016, **20**:8-14.

40. Huchzermeyer M, Misselwitz P: **Coproducing inclusive cities? Addressing knowledge gaps and conflicting rationalities between self-provisioned housing and state-led housing programmes**. *Curr Opin Environ Sustain* 2016, **20**:73-79.

41. Iwaniec DM, Metson GS, Cordell D: **P-FUTURES: towards urban food — water security through collaborative design and impact**. *Curr Opin Environ Sustain* 2016, **20**:1-7.

42. Richard-Ferroudji A, Faysse N, Bouzidi Z, Menon TPR, Rinaudo J-D: **The DIALAQ project on sustainable groundwater management: a transdisciplinary and transcultural approach to participatory foresight**. *Curr Opin Environ Sustain* 2016, **20**:56-60.

43. Saunders FP, Gallardo-Fernández GL, Van Tuyen T, Raemaekers S, Marciniak B, Plá RD: **Transformation of small-scale fisheries — critical transdisciplinary challenges and possibilities**. *Curr Opin Environ Sustain* 2016, **20**:26-31.

44. Tschakert P, Tuana N, Westskog H, Koelle B, Afrika A: **TCHANGE: the role of values and visioning in transformation science**. *Curr Opin Environ Sustain* 2016, **20**:21-25.

45. Temper L, Del Bene D: **Transforming knowledge creation for environmental and epistemic justice**. *Curr Opin Environ Sustain* 2016, **20**:41-49.

46. Lotz-Sisitka H, Ali MB, Mphepo G, Chaves M, Macintyre T, Pesanayi T, Wals A, Mukute M, Kronlid D, Tran DT *et al.*: **Co-designing research on transgressive learning in times of climate change**. *Curr Opin Environ Sustain* 2016, **20**:50-55.

47. Van Holt T, Weisman W: **Global production network mapping for transforming socio-ecological systems**. *Curr Opin Environ Sustain* 2016, **20**:61-66.

48. Chigbu UE, Masum F, de Vries WT, Siegert F, Mekuria ZA, Sakaria P, Agboeze AI, Assoua KL, Ntiador AM, Mulenga C *et al.*: **Participatory rapid co-design for transformative resource governance research in the Gulf of Guinea**. *Curr Opin Environ Sustain* 2016, **20**:15-20.

49. Friend RM, Anwar NH, Dixit A, Hutanuwatr K, Jayaraman T, McGregor JA, Menon MR, Moench M, Pelling M, Roberts D: **Re-imagining inclusive urban futures for transformation**. *Curr Opin Environ Sustain* 2016, **20**:67-72.

50. Horlings LG: **Connecting people to place: sustainable place-shaping practices as transformative power**. *Curr Opin Environ Sustain* 2016, **20**:32-40.

51. Cash DW, Clark WC, Alcock F, Dickson NM, Eckley N, Guston DH, Jäger J, Mitchell RB: **Knowledge systems for sustainable development**. *Proc Natl Acad Sci U S A* 2003, **100**:8086-8091.

52. • Clark WC, van Kerkhoff L, Lebel L, Gallopin GC: **Crafting usable knowledge for sustainable development**. *Proc Natl Acad Sci U S A* 2016, **113**:4570-4578.

An important recent paper focused on what is known from scholarship and practice about what enables the creation of 'usable' knowledge. The authors lay out critical skills and training needs for researchers to be effective collaborators at the science–society interface.

53. Whitmer A, Ogden L, Lawton J, Sturner P, Groffman PM, Schneider L, Hart D, Halpern B, Schlesinger W, Raciti S *et al.*: **The**

engaged university: providing a platform for research that transforms society. *Front Ecol Environ* 2010, **8**:314-321.

54. DeFries R, Ellis EC, Chapin FS III, Matson PA, Turner BL II, Agrawal A, Crutzen PJ, Field C, Gleick P, Kareiva PM *et al.*: **Planetary opportunities: a social contract for global change science to contribute to a sustainable future**. *BioScience* 2012, **62**:603-606.

55. Jasanoff S (Ed): *States of Knowledge: The Co-Production of Science and Social Order*. New York: Routledge; 2004.

56. Armitage D, Berkes F, Dale A, Kocho-Schellenberg E, Patton E: **Co-management and the co-production of knowledge: learning to adapt in Canada's Arctic**. *Glob Environ Change* 2011, **21**:995-1004.

57. Polk M: **Transdisciplinary co-production: designing and testing a transdisciplinary research framework for societal problem solving**. *Futures* 2015, **65**:110-122.

58. Cornell S, Berkhout F, Tuinstra W, Tàbara JD, Jäger J, Chabay I, de Wit B, Langlais R, Mills D, Moll P *et al.*: **Opening up knowledge systems for better responses to global environmental change**. *Environ Sci Policy* 2013, **28**:60-70.

59. Puente-Rodríguez D, van Slobbe E, Al IAC, Lindenbergh DE: **Knowledge co-production in practice: enabling environmental management systems for ports through participatory research in the Dutch Wadden Sea**. *Environ Sci Policy* 2015, **55**:456-466 [Part 3].

60. Vilsmaier U, Engbers M, Luthardt P, Maas-Deipenbrock RM, Wunderlich S, Scholz RW: **Case-based mutual learning sessions: knowledge integration and transfer in transdisciplinary processes**. *Sustain Sci* 2015, **10**:563-580.

61. Wals AEJ, Rodela R: **Social learning towards sustainability: problematic, perspectives and promise**. *NJAS Wagening J Life Sci* 2014, **69**:1-3.

62. Brown K, O'Neill S, Fabricius C: **Transformation and social science perspectives**. *World Social Science Report 2013: Changing Global Environments. Edited by International Social Science Council (ISSC)*. United Nations Educational Scientific and Cultural Organization (UNESCO): UNESCO, ISSC, OECD; 2013:: 98-104.

63. Feola G: **Societal transformation in response to global environmental change: a review of emerging concepts**. *AMBIO* 2014, **44**:376-390.

64. O'Brien K: **Global environmental change II: from adaptation to deliberate transformation**. *Prog Hum Geogr* 2012, **36**:667-676.

65. Future Earth: *Future Earth Initial Design: Report of the Transition Team Paris*. France: ICSU, Future Earth; 2013.

66. Jahn T, Bergmann M, Keil F: **Transdisciplinarity: between mainstreaming and marginalization**. *Ecol Econ* 2012, **79**:1-10.

67. Mobjörk M: **Consulting versus participatory transdisciplinarity: a refined classification of transdisciplinary research**. *Futures* 2010, **42**:866-873.

68. Gieryn TF: **Boundaries of science**. In *Handbook of Science and Technology Studies*. Edited by Jasanoff S, Pinch T, Petersen JC, Markle GE. Sage Publications; 1995:393-443.

69. Ison R: **Methodological challenges of trans-disciplinary research: some systemic reflections**. *Nat Sci Soc* 2008, **16**:241-251.

70. Cundill G, Roux DJ, Parker JN: **Nurturing communities of practice for transdisciplinary research**. *Ecol Soc* 2015:20.

71. McKee A, Guimaraes MH, Pinto-Correia T: **Social capital accumulation and the role of the researcher: an example of a transdisciplinary visioning process for the future of agriculture in Europe**. *Environ Sci Policy* 2015, **50**:88-99.

72. •• Wülser G, Pohl C: **How researchers frame scientific contributions to sustainable development: a typology based on grounded theory**. *Sustain Sci* 2016:1-12. [online first].
An empirical study critically examining what actually happens in the early stage of research formulation (co-design) between researchers and societal partners.

73. Enengel B, Muhar A, Penker M, Freyer B, Drlik S, Ritter F: **Co-production of knowledge in transdisciplinary doctoral theses on landscape development — an analysis of actor roles and knowledge types in different research phases**. *Landsc Urban Plan* 2012, **105**:106-117.

74. Tanko AI: **Urban energy challenges in sub-Saharan Africa**. *Curr Opin Environ Sustain* 2016, **20**:80-85.

75. Marin A, Ely A, Van Zwanenberg P: **Co-design with aligned and non-aligned knowledge partners: implications for research and coproduction of sustainable food systems**. *Curr Opin Environ Sustain* 2016, **20**:93-98.

76. Parsons M, Fisher K, Nalau J: **Alternative approaches to co-design: insights from indigenous/academic research collaborations**. *Curr Opin Environ Sustain* 2016, **20**:99-105.

77. Page GG, Wise RM, Lindenfeld L, Moug P, Hodgson A, Wyborn C, Fazey I: **Co-designing transformation research: lessons learned from research on deliberate practices for transformation**. *Curr Opin Environ Sustain* 2016, **20**:86-92.

78. Edelenbos J, van Buuren A, van Schie N: **Co-producing knowledge: joint knowledge production between experts, bureaucrats and stakeholders in Dutch water management projects**. *Environ Sci Policy* 2011, **14**:675-684.

79. Musvoto C, Mason N, Jovanovic N, Froebrich J, Tshovhote J, Nemakhavhani M, Khabe T: **Applying a transdisciplinary process to define a research agenda in a smallholder irrigated farming system in South Africa**. *Agric Syst* 2015, **137**:39-50.

80. Leith P, Vanclay F: **Translating science to benefit diverse publics: engagement pathways for linking climate risk, uncertainty, and agricultural identities**. *Sci Technol Hum Values* 2015, **40**:939-964.

81. Kunseler E-M, Tuinstra W, Vasileiadou E, Petersen AC: **The reflective futures practitioner: balancing salience, credibility and legitimacy in generating foresight knowledge with stakeholders**. *Futures* 2015, **66**:1-12.

82. Hegger D, Zeijl-Rozema A, Dieperink C: **Toward design principles for joint knowledge production projects: lessons from the deepest polder of The Netherlands**. *Reg Environ Change* 2014, **14**:1049-1062.