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Co-designing transformation research

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Co-designing transformation research: lessons learned from research on deliberate practices for transformation

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Abstract

Co-production of new knowledge can enhance open and integrative research processes across the social and natural sciences and across research/science, practice and policy interrelationships. Thus, co-production is important in the conduct of research about and for transformations to sustainability. While co-design is an integral part of co-production, it often receives limited attention in the conduct of co-produced research. This paper reports on lessons learned from an early stage of the co-design process to develop research on deliberate practices for transformative change. Key lessons learned are the need to: (1) ensure co-design processes are themselves carefully designed; (2) encourage emergence of new ways of thinking about problem formulation through co-design; (3) carefully balance risks for the participants involved in co-design while also enhancing opportunities for intellectual risk taking; (4) facilitate personal transformations in co-design as a way to stimulate and encourage further creativity; and (5) for funders to carefully and constructively align criteria or incentives through which a project or future proposal will be judged to goals of the co-design, including both instrumental objectives and for creativity and imagination to emerge. Further, since co-design necessarily involves a reflective practice that can iteratively guide emergence of new thinking about the practices of change, co-design can itself be considered an important deliberate practice used to help transform how research is done and how research can be part of the process of facilitating social transformations.

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Introduction

Overcoming unprecedented and persistent global environmental challenges, such as climate change, risks and vulnerabilities to ecosystem functioning and associated impacts on human well-being requires fundamental societal changes well beyond technological advances [1,2]. Such transformation requires deep re-evaluation of many aspects of society, including the values, beliefs, structure and function of institutional, economic and social systems [2,3]. It also includes re-examining how knowledge is produced and used, such as through greater emphasis on the co-production and democratization of knowledge [1,3–5] and through holistic approaches that more directly focus on learning about and facilitating change [6–8].

One of the ways to improve knowledge for transformation is the co-production of research. The co-production of research refers to a collaborative process between multiple stakeholders, including academics, that aspires to generate useful knowledge connected to decision-making [9]. It includes three interrelated and sometimes overlapping phases: co-design (joint framing, research design); co-development (scientific integration, development of knowledge, operationalising research methods); and co-dissemination of findings for generating impact from research [8]. Co-production of research is important to help ensure knowledge is credible, salient, and legitimate [7]. Viewing co-production as a collaborative approach to research is different from, but complementary to, other uses of the term which refer to co-production as the co-evolution between science and society [6]. This latter perspective evokes questions about the role of politics and power in shaping the way knowledge is produced and used [10]. Power dimensions are also important in co-produced research but is often poorly considered [11,12] and raises an important question of the extent to which research can be genuinely credible, salient and legitimate given that all forms of research are influenced by society in some way [13].

While there has been considerable effort to understand knowledge production during the co-development and co-dissemination phases of research [14,15], there has been much less attention given to co-design. Co-design is important because initial stages have such a major influence on research outcomes [8]. It is especially important for transformation research, which requires creativity to see existing patterns and paradigms, and find innovative solutions to more effectively address issues that are ambiguous, complex and normative [9,10]. For example, the need to learn from attempts to do early stage co-design has been highlighted at prominent conferences (e.g. http://transformations2015.org/) with such learning needing to be applied to the development of larger scale networks and processes like Future Earth [16].

This paper reports on the lessons learned from an early stage of a co-design process that focused on the development of a research agenda regarding the practice of transformation and potential formation of a knowledge network. This included a series of interactions with researchers and practitioners through regional ‘hubs’ across the globe and over time. In the paper we first explain what the co-design process was meant to achieve and some of the concepts that emerged from the process. We then outline the approach taken and discuss key lessons learned from the process. The paper will be of relevance to a wide range of academics and other stakeholders engaged in co-design of research and wider knowledge co-production processes.

The focus of the research

The co-design process was part of a project to develop a Knowledge Network for Enabling Transformation (KNET), and was funded by the International Social Science Council’s

Transformation Programme. KNET is a proposed international network spanning six continents (including academics and practitioners from Australia, Bangladesh, France, Germany, Ghana, Norway, Mexico, Papua New Guinea, U.K. and USA) with the aims of facilitating the capture, synthesis and transfer of new thinking and practices for systemic societal change (i.e., transformation). KNET was envisioned as a response to calls for a new 'thought and action collective' for helping contribute to societal transformation [7] through more effective and efficient global innovation (knowledge co-production) systems [17].

The main goal of the co-design process was to creatively examine how research might better contribute to accelerating desirable societal change in relation to the kinds of challenges highlighted above. In this sense, the project aimed to take a step back from specific contexts or issues (e.g. water and food security, governance, agriculture etc.) and instead to allow a new and meaningful research focus to emerge that was more aligned to the need for improving and accelerating understanding and learning about change itself.

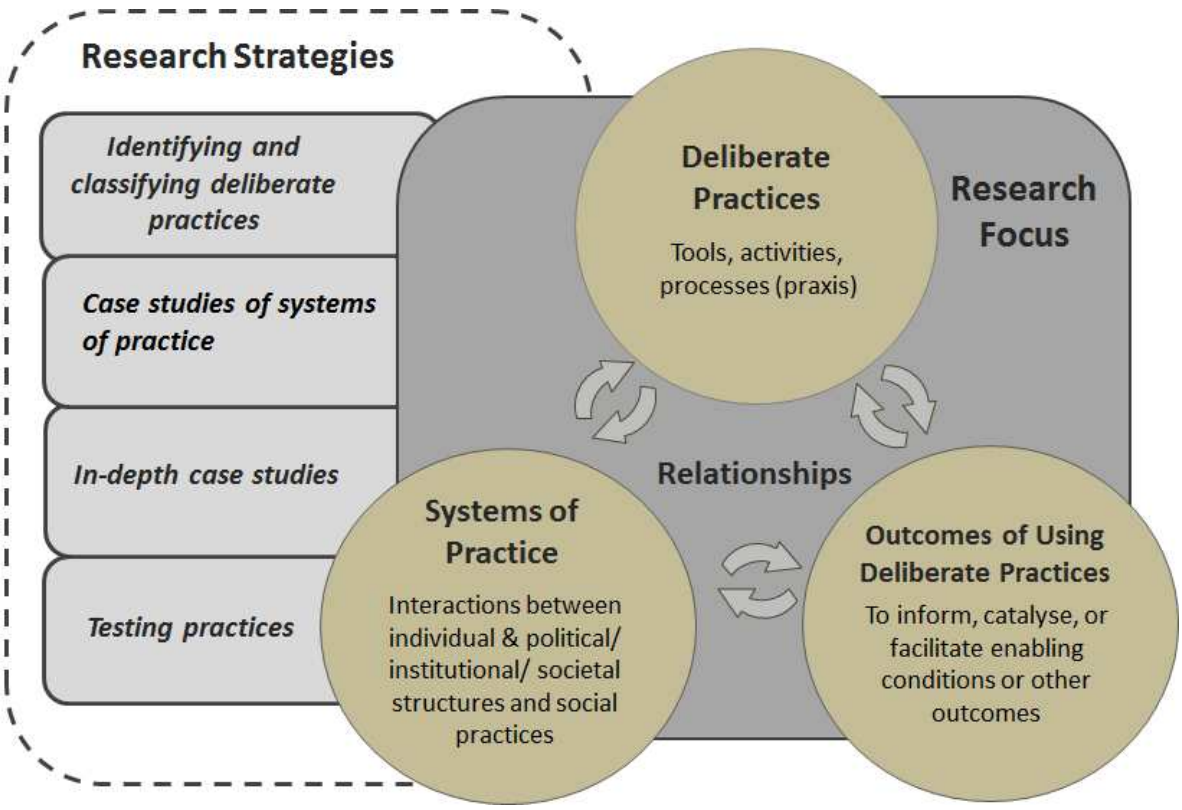
A concrete focus that emerged early in the co-design was to enhance understanding of the '*deliberate practices*' used for facilitating systemic and transformative change. We defined deliberate practices as the tools, activities and processes used by change makers that stand out from many other well-intentioned approaches as being particularly useful for facilitating significant change. Actors of different identities and roles in knowledge co-production use tools and methods (practices) applied through some kind of process (praxis) [18], which we refer to collectively as 'practices'. These intentional practices are not applied in isolation and are embedded in and influenced by everyday, less conscious, social practices and contexts of application [19], and can be part of longer term strategies and negotiations for change [18].

There are diverse kinds of change makers that use different practices to try to create change. Examples include facilitators, researchers or practitioners in non-government organisations and public service, who work in international development, planning, sustainability, health, education, biodiversity conservation, business, water, transport, and energy sectors. In all of these, while not always made explicit, some aspect of change is a core focus [18]. Deliberate practices include, for example, those used for developing strategies, changing mind-sets, working with conflict, incorporating ethics and aesthetics in decisions; creating new ways of thinking, enhancing environmental consciousness, generating creativity, imagination and innovation; or those used to disrupt the status quo or empower groups for action [18,20,21]. While many different kinds of deliberate practices exist, there has been no attempt to bring together and make sense of these practices, and how they relate to wider social practices and longer term processes of change. The co-design process in the KNET project was important in helping this focus of the research emerge. Consequently, it involved spending considerable time helping to define and explore what kinds of practices exist, how such deliberate interventions can affect larger scale outcomes, and the ways in which research and academia more generally can contribute better to facilitating change.

The process then led to the development of a research proposal that included a research framework to understand the relationships between deliberate practices, wider systems of practice, and outcomes from applying the practices (Figure 1). A significant challenge was how to learn from and enhance practical kinds of knowledge such as 'know how' and 'wisdom' as defined by Aristotle, in addition to abstract and academic forms of epistemic knowledge [22]. It was recognized, for example, that action, iterative, participatory and reflexive approaches would be needed to enable KNET research to engage more directly with, and assist the development of,

practical forms of knowledge [23,24]. Examples of how this kind of research can assist the acceleration of learning about practice include those used to develop deliberate practices in relation to futures, change and wider tools for facilitating more sustainable trajectories [20,21,25–28].

Figure 1: The research focus, framework and strategies emerging from the co-design process.



Methods: The collaborative design process

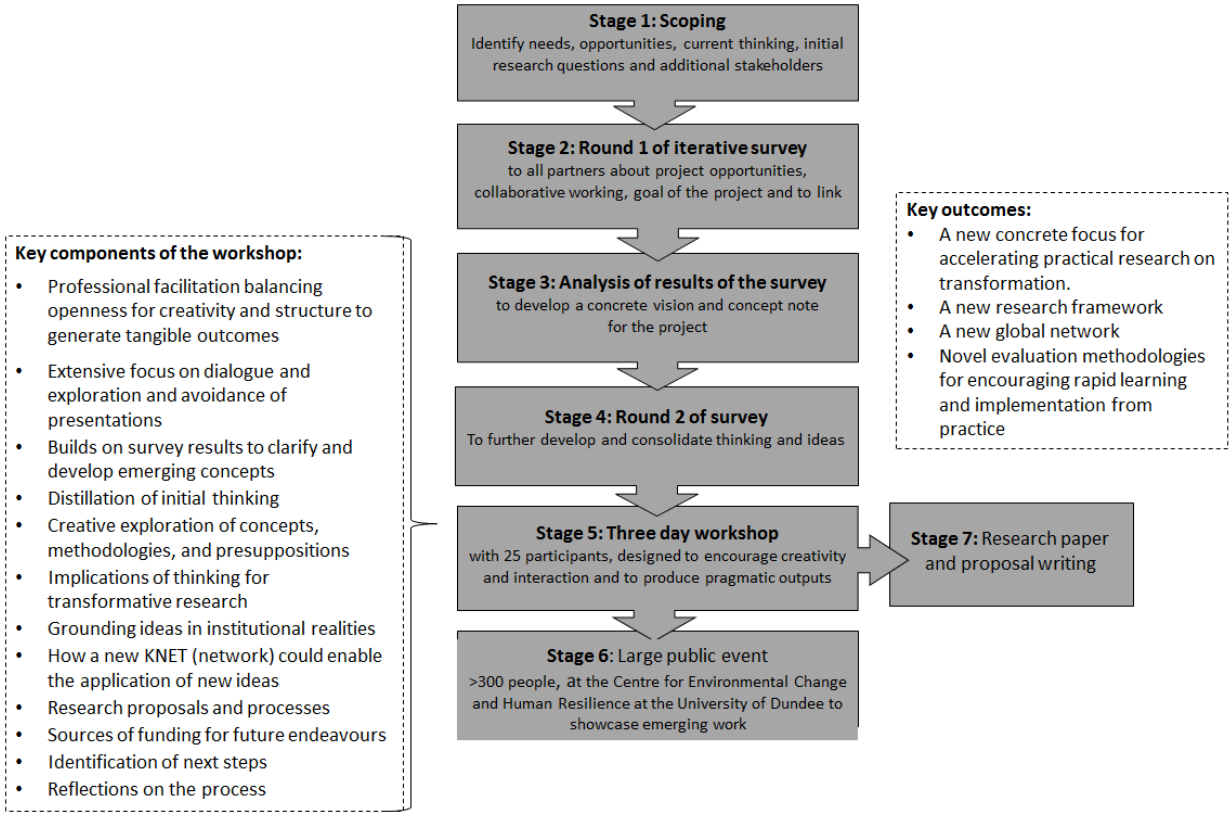
The design of the KNET project included a series of interactions with researchers and practitioners through regional 'hubs' across the globe and over time through seven key steps (Figure 2). This included careful selection of partners, two iterations of pre-workshop surveys, a three-day workshop with 25 researchers and practitioners from 11 countries, and a large public event for wider dissemination. Participants included experts in the practice of transformation, those who study practice, and those who design, implement and evaluate transformative practice. Professional facilitation of the workshop was an essential aspect for encouraging co-learning among practitioners and researchers and the development of new insights about transformative change. In the workshop key practice-oriented concepts, logistics of networks, knowledge exchange strategies, and methods were explored, clarified and developed.

The approach drew on three aspects. First, it included people experienced in the practice of transformation from different perspectives (e.g. academics, consultants, government and private sector stakeholders), different geographies (11 countries and 6 continents), and who also had common interest in developing a research network to generate new knowledge of transformative practice. Second, the process focused on engaging the diverse group before, during and after the workshop to advance a research agenda. The intensive pre-and post-effort by all participants and the highly collaborative design of the workshop activities (i.e. breakout groups, un-structured dialogue sessions) was designed to create a common experience and foster an early stage of network formation. Networks emerging from a workshop-type experience can easily dissolve unless there is a 'mediating structure' to facilitate communication and create the link to move the effort forward [29]. We therefore also conducted a survey after the key event to better understand the value of the process to participants and interest in further development of a network.

Finally, multi-tiered learning approach and participation methods [12,30] were used to help facilitate learning and encourage collaborative potential and creativity. This approach explicitly recognized that learning often depends on the extent to which project participants engage in the project (e.g. core team members have greater opportunities to learn and shape processes than other participants) [31]. It enabled more direct targeting of activities that could encourage sharing of thinking, drawing out different cultural perspectives (e.g. across research and practice domains, and across continents), ideas, and underlying assumptions.

Overall, since co-design of the research strategy was the main objective, the potential of network development was a secondary target because we knew it would be tied to the success of further grant funding to support the research agenda. Thus, co-design in this case was based upon first defining shared purpose and a common research agenda, identifying how the collaborative process could move through clear stages of development as a network, informal mapping of how the network could expand and further grow, and gathering information about the desired level of integration into the network by early-stage participants. These aspects are all considered essential in building and measuring high quality collaboration [32].

Figure 2: Iterative cycles of engagement between academic and non-academic stakeholders for the co-design of KNET.



Lessons learned from doing co-design

Responses from the survey (60% response rate) highlighted a number of lessons about co-design. First, the project itself needed to be carefully designed. In this case, an explicit theory of change was developed based on a conceptual design and learning pedagogy. It also included provision of key process oriented activities and practices, such as space for thinking differently about problem formulation. For example, one senior male researcher noted the value of the '*many opportunities from an early stage to influence the focus and design of the project'*, while another senior male practitioner highlighted the importance of '*the high levels of participation and dialogue, plenty of visual mapping to help hold the complexity in mind*.' One senior female researcher identified the '*willingness to take risks (within reason) e.g. being as open as possible from the outset about KNET's research agenda, its nature, its way of operating*' as a central factor of success of the co-design process. Another senior female researcher noted that the experience '*created a sense of purpose, direction, and enthusiasm amongst the very great diversity of interests*.' Expert facilitation was essential as identified by one male researcher '*to keep on track…gently to allow things to happen.*' In this case the approach to facilitation involved carefully 'holding the space' as the male facilitator reiterated, to allow different emotions to wax and wane, for different motivations to come to the fore, and for deeper ideas to surface, all of which are considered important for innovation [33].

There were also tensions relating to the costs and risks associated with co-design. Costs included obvious aspects such as financial costs of participation, including accommodation, travel, and in-kind contributions of labor. Yet respondents also highlighted the costs and risks of letting go of

their intellectual legacy/perspective to enable a more collaborative process to occur. Collaborations require the right emotional conditions and appropriate incentives for intellectual risk taking, including appropriate support mechanisms that help groups and individuals explore new fields [33]. Further, for creativity in transformation research, a critical mass of certain kinds of individuals will be needed who offer diverse perspectives and who have developed dispositions towards being intellectual risk takers. In this case, care was not only needed to select participants that provided different perspectives (e.g. from having come from different backgrounds and cultures) but also to include individuals who were likely to enable risk-taking to occur.

A key lesson was also the importance and need for co-design to consider how to influence participants in ways that would significantly enhance their awareness of, and capabilities for, enabling transformation. For example, many participants recognized after the process that they had created important new network connections, identified research opportunities, and enhanced their awareness of how to characterize, study and prioritize various practices as potentially influential. For example, one female researcher noted the following: '*Be the change you seek is a key message I got out of the workshop and I am continually trying to live this*.' Another male practitioner noted how the process led to them to '*trying to connect French national adaptation policies to transformative research and to connect KNET with other initiatives and fieldwork on transformations*.' Recognizing the importance of '*effective futuring/visioning that catalyzes deeper awareness and understanding of the need and urgency for systemic change*' was central to one male practitioner's modification of their current practices. Another male researcher noted, '*(the workshop) has resulted in new concepts and applications and has forced me, in very significant ways, to develop conceptual thinking about deliberate practices and, more importantly, the failure of many current research processes to contribute to wider and significant change*.' Overall, this highlights the need to create the environment for people to reflect and think more deeply about the core purpose of the co-design, to engage with their deeper emotions, values and implications for their work. In this case, this inner transformation then helped the emergence of new transformative thinking about externally oriented research considered important by others who focus on transformation and collaboration [34,35]. This echoes calls for greater attention to potential shifts, or at least activation, in consciousness and values internally [21,36,37] as a key part of achieving societal transformations. Designing for the less tangible outcomes of personal change, as a way to draw out novelty and creativity, is therefore likely to be key in the process of co-design for transformation research.

Finally, there were also subtle influences that affected the nature of the new thinking that emerged. A key realization in this project was that to engage with transformation, it was necessary to genuinely rethink how research on transformative change is approached. In this case, rather than start with an issue like water, food, or energy challenges, the openness of the co-design process allowed emergence of a more generic research question that focuses on understanding the nature and role of deliberate practices for facilitating significant personal, community and systems change. This led to greater emphasis on finding the right kinds of methods that could help accelerate learning about how to promote and enable change, which were deemed most likely to come through action research and reflexive approaches. This focus on practices that could be applied broadly across a range of problem areas was different to the notions of a concrete focus required in the calls for research funding for which the seed funding was expected to help networks prepare. This highlights that perspectives of what makes meaningful research useful (in this case a particular perspective of what constituted a concrete

focus) can also constrain emergence of different ways of formulating problems. This is less of a problem in the arts, for example, where creativity is the desired outcome of research. Future funding initiatives may therefore benefit from greater consideration of mechanisms for arts funding, as well as encouraging iterative and developmental forms of evaluation that build on new thinking and creativity as it emerges [30,38]. Overall, the key lesson from this project is the need for greater constructive alignment between the criteria by which the research will be judged and the intended outcomes, with those outcomes including imagination and creativity as well as more instrumental ones.

Discussion and Conclusions

The five lessons learned from a co-design process to develop a knowledge network for enabling transformation and associated research agenda can be summarised as the need for co-design processes to: (1) ensure they are themselves carefully designed; (2) seek to encourage emergence of new ways of thinking and about problem formulation; (3) carefully balance risks for the participants involved while also enhancing opportunities for intellectual risk taking; (4) facilitate personal transformations as a way to stimulate and encourage further creativity; and (5) carefully and constructively align criteria or incentives through which a project or future proposal will be judged to goals of the co-design, including both instrumental objectives and those associated with creativity and imagination. Clearly, other aspects will be important, the insights may not equally apply in all contexts, and further studies will be needed to qualify the findings from the experience gained in this project.

The lessons from the project also raise critical questions about the role of early-stage co-design for transformation research and societal transformation. For example, how can those involved in early stage of co-design become clearer about whether they are observing patterns of change or being involved in shaping that change? Many of these same questions are raised in other related literature [6] such as at what stage should a broader constituency of stakeholders be involved to increase the collaborative nature of the research design? [39] This in turn requires researchers in the early stages of co-design to more carefully consider who transformation is meant to be for, and who decides what that transformation should be, as well as wider ethical issues that emerge when researchers attempt to shape change [27,40]. This then raises many further questions about how co-design fits with broader conceptualizations of transformation research. Does engagement with co-design naturally lead to new ways of engagement between science and society? In what ways (or not) does science and policymaking need to change for co-design to be taken seriously? What is required to make transformation research engender the much-needed creativity to step out of existing paradigms within and beyond science? How can early stage co-design balance the need for pragmatic and time driven outcomes on a ‘concrete focus’ versus openness for exploration and new thinking to emerge, which itself is essential for societal transformation? What mechanisms, incentives, and kinds of support (e.g. expertise in participation and facilitation) are needed to encourage co-design?

Overall, there seems to be much to be gained from encouraging the adoption of reflective and developmental forms of practice [18,25] as part of the process of doing co-design. If the right spaces for creativity are provided, the conceptual and practical shifts that can be achieved can be significant [41,42]. Co-design may also contribute to the kinds of shifts that are synonymous with more recent discussions about the kinds of systems of knowledge co-production and use that are needed for a transforming world [43]. Thus co-design itself could be viewed as an

important deliberate practice that can play a part in helping to transform how research is done to assist the facilitation of social transformations more widely. Advancing research on this topic will need to examine both transformative practice as well as team science including process and effectiveness, institutional and organizational support, as well as funding and developmental evaluation of team science [44].

Declaration of no conflict of interest

The authors have no conflict of interest in the preparation of this manuscript.

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1. Future Earth: *Future Earth Strategic Research Agenda 2014*. 2014.

2. O'Brien K: **Global environmental change II: From adaptation to deliberate transformation**. *Prog. Hum. Geogr.* 2012, **36**:667–676.

3. Hackmann, H., St. Clair AL: **Transformative Cornerstones of Social Science Research for Global Change**. In *International Social Science Council, Paris*. 2011:117–152.

4. O'Brien K, Sygna L: **Responding to climate change: The three spheres of transformation [Internet]**. *Transformation in a Changing Climate*. Edited by O'Brien K, Sygna L. University of Oslo; 2013:16–23.

5. 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 [Internet]**. *Environ. Sci. Policy* 2013, **28**:60–70.

6. Jasanoff S: **Science and citizenship: A new synergy**. *Sci. Public Policy* 2004, **31**:90–94.

7. *Kläy A, Zimmermann AB, Schneider F: **Rethinking science for sustainable development: Reflexive interaction for a paradigm transformation**. *Futures* 2015, **65**:72–85.

   Assuming the need for societal transformation, the authors propose that science as an institution needs a corresponding paradigm transformation aligning it to the idea of sustainable development and enhancing public accountability. A transdisciplinary

'thought collective' is proposed as a way towards this transformation.

8. 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.

9. Lemos MC, Morehouse BJ: **The co-production of science and policy in integrated climate assessments**. *Glob. Environ. Chang.* 2005, **15**:57–68.

10. Jasanoff S: **Ordering knowledge, ordering society**. In *States of Knowledge: The Co-production of Science and Social Order*. Edited by Jasanoff S. Routledge; 2004.

11. Wyborn C (2015): **Connectivity conservation: Boundary objects, science narratives and the co-production of science and practice**. *Environ. Sci. Policy* August 2015, **51**:292–303.

12. Turnhout E, Stuiver M, Judith J, Harms B, Leeuwis C: **New roles of science in society: Different repertoires of knowledge brokering**. *Sci. Public Policy* 2013, **40**:354–365.

13. Aufenvenne P, Egner H, Von Elverfeldt K: **On climate change research, the crisis of science and second-order science**. *Constr. Found.* 2014, **10**:120–129.

14. Fazey I, Evely AC, Reed MS, Stringer LC, Kruijsen J, White PCL, Newsham A, Jin L, Cortazzi M, Phillipson J, et al.: **Knowledge exchange: A review and research agenda for environmental management [Internet]**. *Environ. Conserv.* 2013, **40**:1–18.

15. Reed MS, Stringer LC, Fazey I, Evely AC, Kruijsen JHJ: **Five principles for the practice of knowledge exchange in environmental management**. *J. Environ. Manage.* 2014, **146**:337–345.

16. Future Earth: *Future Earth Initial Design: Report of the Transition Team [Internet]*. 2013.

17. Leach M, Rockström J, Raskin P, Scoones I, Stirling AC, Smith A, Thompson J, Millstone E, Ely A, Arond E, et al.: **Transforming innovation for sustainability**. *Ecol. Soc.* 2012, **17**.

18. Vaara E, Whittington R: **Strategy-as-practice: Taking social practices seriously**. *Acad. Manag. Ann.* 2012, doi:10.1080/19416520.2012.672039.

19. Reckwitz A: **Basic elements of a theory of social practices: A perspective in social theory**. *Z. Soziol.* 2003, **32**:282–301.

20. Frame B, Brown J: **Developing post-normal technologies for sustainability**. *Ecol. Econ.* 2008, **65**:225–241.

21. Sharpe B, Fazey I, G, Leicester G, Hodgson, Lyon C: **Three horizons: A powerful practice for transformation**. *Ecol. Soc.* [date unknown], [no volume].

22. Aristotle: *The Nicomachean ethics*. Penguin Books; 2004.

23. Reason P, Bradbury H (Eds): *The Sage Handbook of Action Research: Participative Inquiry and Practice*. Sage; [date unknown].

24. Fazey I, Fazey JA, Fazey DMA: **Learning more effectively from experience**. *Ecol. Soc.* 2005, **10**.

25. Fazey I, Kesby M, Evely A, Latham I, Wagatora D, Hagasua JE, Reed MS, Christie M: **A**

three-tiered approach to participatory vulnerability assessment in the Solomon Islands. *Glob. Environ. Chang.* 2010, **20**:713–728.

26. Clark WC, van Kerkhoff L, Lebel L, Gallopin GC: **Crafting useable knowledge for sustainable development'**. *Proc. Natl. Acad. Sci. U. S. A.* 2016, **113**:4570–4578.

27. Williamson GR, Prosser S: **Action research: Politics, ethics and participation**. *J. Adv. Nurs.* 2002, **40**:587–593.

28. Gulari MN, Fremantle C: **Are design-led innovation approaches applicable to SMEs? [Internet]**. In *Proceedings of the 17th International Conference on Engineering and Product Design Education: Great Expectations: Design Teaching, Research and Enterprise, E and PDE 2015*. . 2015:556–561.

29. Prager K: **Local and regional partnerships in natural resource management: The challenge of bridging institutional levels**. *Environ. Manage.* 2010, **46**:711–724.

30. **Patton MQ: **What is essential in developmental evaluation? On integrity, fidelity, adultery, abstinence, impotence, long-term commitment, integrity, and sensitivity in implementing evaluation models**. *Am. J. Eval.* 2016, **37**.

    The author presents eight essential principles of Developmental Evaluation which serve as guides to be interpreted and applied contextually acting as navigational aids in complex, dynamic contexts. Fidelity to all eight principles is essential to support development of new approaches to intractable problems and thus a much better fit in sustainability science versus more traditional forms of formative-summative types of evaluation that fit best with stable contexts.

31. Fazey I: **Resilience and higher order thinking**. *Ecol. Soc.* 2010, **15**.

32. Woodland RH, Hutton MS: **Evaluating organizational collaborations: Suggested entry points and strategies**. *Am. J. Eval.* 2012, **33**:366–383.

33. Parker JN, Hackett EJ: **Hot spots and hot moments in scientific collaborations and social movements**. *Am. Sociol. Rev.* 2012, **77**:21–44.

34. Rhoten D, O'Connor E, Hackett EJ: **The act of collaborative creation and the art of integrative creativity: Originality, disciplinarity and interdisciplinarity**. *Thesis Elev.* 2009, **96**:83–108.

35. Augsburg T: **Becoming transdisciplinary: The emergence of the transdisciplinary individual [Internet]**. *World Futures* 2014, **70**:233–247.

36. O'Brien K: **The courage to change: Adaptation from the inside out**. In *Successful Adaptation: Linking Science and Policy in a Rapidly Changing World*. . 2013.

37. **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.

    Creative and co-produced learning environments are important aspects of co-design. Those involved in co-design should be willing participants, open to a co-evolving and flexible process. Co-design processes should acknowledge and value the multifarious types of knowledge, the variety of forms of expression, the importance of listening and

debating, and the flexibility and patience on the part of participants.

38. Fazey I, Bunse L, Msika J, Pinke M, Preedy K, Evely AC, Lambert E, Hastings E, Morris S, Reed MS: **Evaluating knowledge exchange in interdisciplinary and multi-stakeholder research [Internet]**. *Glob. Environ. Chang.* 2014, **25**:204–220.

39. 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.

40. Lacey J, Howden SM, Cvitanovic C, Dowd AM: **Informed adaptation: Ethical considerations for adaptation researchers and decision-makers**. *Glob. Environ. Chang.* 2015, **32**:200–210.

41. *Sanders L, Stappers PJ: **From designing to co-designing to collective dreaming: Three slices in time**. *Interactions* 2014, **21**:24–33.

    The authors survey the last 30 years of design: co-design is an emerging, evolving concept and practice. The authors also speculate about the future development of co-design highlighting its potency in harnessing peoples' collective creativity.

42. Follett G, Rogers J: *Articulating co-creation for economic and cultural value [Internet]*. 2016.

43. 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.

44. **National Research Council: **Enhancing the Effectiveness of Team Science.** Washington, DC: The National Academies Press, 2015. doi:10.17226/19007.

    The authors examine both individual factors and team dynamics that influence the effectiveness and productivity of team science. They examine management approaches and leadership styles, incentives and other factors that influence the productivity and effectiveness of collaborative science. Organizational factors such as human resource policies and practices and cyber infrastructure are examined with specific recommendations for organizational structures, policies, practices, and resources that are needed to promote effective team science.