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Simon Westsim_patrickwest, Lorrae van Kerkhoff & Hendrik Wagenaar

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Beyond "linking knowledge and action": towards a practice-based approach to transdisciplinary sustainability interventions

Simon West [a,b,c], Lorrae van Kerkhoff [b] and Hendrik Wagenaar [d,e]

[a]Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden; [b]Fenner School of Environment and Society, Australian National University, Canberra, Australia; [c]Northern Institute, Charles Darwin University, Brinkin, Australia; [d]The Policy Institute at King's College London, London, UK; [e]Institute for Governance and Policy Analysis, University of Canberra, Canberra, Australia

ABSTRACT

The imperative to "link knowledge and action" is widely invoked as a defining characteristic of sustainability research. The complexities of sustainability challenges such as climate change and biodiversity loss mean that linear models of knowledge and action, where knowledge is produced first (by researchers) then "applied to" action (by policy actors), are considered insufficient. Researchers have developed more dynamic, open-ended and collaborative forms of policy engagement such as transdisciplinary and co-production research. Although promising these approaches often remain captive to linear assumptions that hinder their transformative potential. We contribute by providing a relational model of knowledge and action rooted in contemporary practice theory. A practice-based approach suggests the primary task of participants in transdisciplinary interventions is to find workable solutions to situations of dynamic complexity that are fundamentally indeterminate and unpredictable. Knowledge is not "applied to" action, but drawn upon, produced and used from within the situation at hand, allowing researchers and policy actors alike to better harness the emergent character of situational developments and outcomes. A practice-based approach provides a conceptual language that captures the experienced complexities of intervening for sustainability, reconfigures the nature of "actionable knowledge," and identifies appropriate modes of evaluation for transdisciplinary and co-produced research.

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1. Introduction

The imperative to "link knowledge and action" is widely invoked as a defining characteristic of sustainability research, and as essential to address urgent challenges such as climate change, biodiversity loss and pollution (Kates et al. 2001; Clark and Dickson 2003; Fang et al. 2018).

CONTACT Simon West simon.west@su.se Stockholm Resilience Centre, Stockholm University, Kräftriket 2B, Stockholm 10691, Sweden; Fenner School of Environment and Society, Australian National University, Linnaeus Way, Canberra, ACT 2601, Australia; Northern Institute, Charles Darwin University, Ellengowan Drive, Brinkin, NT, Australia @sim_patrickwest

These calls are emblematic of the need among problem-driven and applied fields more generally to ensure that research contributes usefully to processes of social and policy change (e.g. Haines, Kuruvilla, and Borchert 2004; Stromquist 2015). However, ideas differ about precisely how knowledge and action are and should be linked. Conventional approaches tend to subscribe, implicitly or explicitly, to an image of "two communities" where researchers (associated with knowledge) and policy actors (associated with action) reside in relatively self-contained domains (van Kerkhoff and Lebel 2006). In these linear models, the researcher is expected to develop objective knowledge which can then be "applied to" action to deliver solutions (Cook and Wagenaar 2012). These commitments are widespread in sustainability science-policy circles, for example as embodied in the intergovernmental panels on climate change (the IPCC) and biodiversity and ecosystem services (IPBES), and in the promotion of evidence-based conservation (Sutherland and Wordley 2017).

Yet sustainability challenges have long been considered "wicked problems" characterized by complexity, unpredictability and inherently contestable facts and values (Rittel and Webber 1973; Ludwig 2001). Here, no objectively "optimal" solutions exist, and linear approaches to linking knowledge and action are considered either insufficient or inappropriate (Stirling 2010). In responding to such challenges, as Kates et al. (2001, 641) note in relation to climate change, scientific exploration and practical application are not ordered linearly and sequentially but occur simultaneously and become entangled with one another. Consequently, sustainability researchers have sought to develop more dynamic, open-ended and collaborative modes of engaging with policy and practice, that recognize a broader range of relevant knowledge including practitioner, experiential and traditional knowledge (Tengö et al. 2014) and seek to foster "learning-by-doing" (Lee 1993). Approaches such as transdisciplinary research (Lang et al. 2012) and knowledge co-production (Miller and Wyborn 2019) have become widely institutionalized in sustainability science-policy fora, such as the global sustainability research platform Future Earth.

Nevertheless, there remains much uncertainty among researchers and policy actors alike about the implications of transdisciplinary research and knowledge co-production for research-policy engagement. Such is the strength of epistemic convention that even these alternative approaches often remain captive to linear assumptions about linking knowledge and action, where knowledge comes first and "underlies" effective action. Such assumptions, embedded in everyday categories of speech and thought and supported by institutionalized practices of professionalism and control, shape our institutions of learning and government. For instance, Future Earth (2014, 7) justifies a potentially radical expansion of knowledge co-production in terms of "delivering the products and services that our societal partners need to meet [sustainability] challenges." One benign interpretation might be that Future Earth is evoking linear (and decidedly neoliberal) models of knowledge and action strategically as a means to obtain political and corporate support for a complexity-oriented agenda. Yet this highlights a crucial dilemma in sustainability research: how to develop approaches sensitive to the contingencies of intervening in a complex world, while maintaining a "can-do," engaged orientation that remains "relevant to the pursuit of more sustainable solutions" (Miller et al. 2014, 240)? The ways in which this dilemma is navigated will affect the transformative potential of transdisciplinary and co-produced research (Wise et al. 2014). There is an important role for theory in helping actors to navigate this dilemma more effectively and ethically, because concepts and language inform "ontologies of action" (Cairns and Stirling 2014, 26). A

vibrant body of literature has introduced social and political theory to sustainability research as a means to better understand the complexities of knowledge-action relationships and inform the strategies and roles adopted by researchers, policy-makers and practitioners engaging in collaborative work (e.g. van Kerkhoff and Lebel 2006; Clark et al. 2016). Nevertheless, there is a need for more work that mobilizes social theory to develop transdisciplinary sustainability interventions that are simultaneously complexity-oriented, critically reflexive and normatively committed (West 2016).

In this paper we contribute by articulating a practice-based approach to knowledge-action relationships. We suggest that contemporary pragmatist theories of practice, initially developed within deliberative policy analysis (DPA), are useful for directly challenging residual linear assumptions about knowledge and action and developing complexity-oriented approaches to intervention (Wagenaar and Cook 2003; Cook and Wagenaar 2012; Griggs, Norval, and Wagenaar 2014). A practice-based approach suggests that the primary task of participants in sustainability interventions is to arrive at workable solutions to situations of dynamic complexity that are fundamentally open-ended and unpredictable (Wagenaar 2007; Connolly 2011). Epistemically, the institutionalized approach of "applying" preconceived, expert knowledge "to" action with the purpose of controlling such situations is largely ineffective when confronted with such dense and continuously shifting interconnectedness. The effectively static character of this professional model is quickly overwhelmed by the multiple feedback mechanisms that dynamic complexity throws up. A practice approach, on the other hand, is more situated, varied and improvisational (Klemp et al. 2008). Knowledge is not applied "to" action, but is drawn upon, produced and used from within the situation at hand, allowing researchers and policy actors to better harness the emergent character of situational developments and outcomes (Axelrod and Cohen 2000; Cook and Wagenaar 2012). We argue that a practice approach reconfigures both the nature of knowledge (as relational, embodied and holistic) as well as the knowledge-action relationship. Consequently, a practice approach: (1) provides a theoretical language that "fits" the complexity of sustainability interventions, (2) reconfigures the value and role of research for those interested in generating "actionable knowledge," and (3) identifies appropriate modes of evaluation for transdisciplinary and co-produced research.

We begin by exploring ideas about "linking knowledge and action" in sustainability research, highlighting the progressive recognition of complexity and the integration of social and political theory. We then use the practice dimension of DPA to articulate a practice-based approach to knowledge-action relations, as an avenue to develop complexity-oriented approaches to sustainability interventions. In applying practice theory to research-policy encounters in pursuit of sustainability, we demonstrate – in this Special Issue marking 15 years since Hajer and Wagenaar's (2003) *Deliberative Policy Analysis* – the quite radical implications and possibilities of developing a more inclusive, interventionist approach to DPA (Li and Wagenaar 2019). We continue by illustrating the value of a practice-based approach through a brief case study of a transdisciplinary project intended to "future-proof" conservation in Colombia, and conclude by discussing the implications of our work.

2. Linking knowledge and action for sustainability

In this section we trace some broad currents of thought around knowledge and action in sustainability research. While we base our characterization primarily on the field of

sustainability science – as broadly representative of the array of disciplines involved in sustainability research, and as the field most explicitly tied to sustainability as an organizing concept – we also draw on literature from sustainability-related research more generally. We inevitably make significant simplifications. Our aim is not to provide a comprehensive review of the literature, but to provide a brief summary to illustrate the potential contribution of a practice-based approach.

At the turn of the millennium various strands of research relevant to sustainability issues coalesced into the problem-driven, transdisciplinary field of sustainability science (NRC 1999; Kates et al. 2001). Several common commitments united the emerging field. Firstly, an awareness of a number of interlinked global sustainability challenges, including climate change, biodiversity loss and land-use change, that appeared to threaten the ability of earth's "life support systems" to support human wellbeing (Clark 2007). Secondly, a recognition that these challenges were "wicked problems" characterized by complexity and a fundamental intertwinedness between humans and their environment, informed by complex socio-environmental systems perspectives.[1] And thirdly, a desire to "reconnect" science to the political agenda for sustainable development (Kates et al. 2001, 642), often framed in terms of "linking" or "integrating" knowledge and action (NRC 1999; Cash et al. 2003). The simultaneously descriptive and normative nature of sustainability science – developing holistic understandings of socio-environmental systems and intervening on the basis of these – was considered to necessitate participation across the academic spectrum, including social and natural sciences, the humanities, and applied disciplines like engineering and law, as well as collaboration with policy-makers, practitioners and citizens (Clark and Dickson 2003).

There have always been a variety of perspectives in sustainability science on precisely how knowledge and action should be linked. Views on the role of research in contributing to social and political change are closely related to epistemology. As Hajer and Wagenaar (2003, 19–21) note, a particular conception of epistemology and the purpose of research "simultaneously enables and limits opportunities for collective inquiry and for knowledge thus acquired to contribute to the solution of social problems." In sustainability science, epistemologies range from positivist perspectives, where knowledge is considered a "correct representation of an independent reality" (Taylor 1995a, 3), to post-positivist and constructivist approaches where knowledge is inextricable from the perspective and experience of the knower.

Positivist approaches tend to lead to more linear, "two communities" models of knowledge and action, where the task of producing objective knowledge is conducted by researchers, and the separate task of acting on that knowledge resides with policy-makers and practitioners (Booth 1988; Figure 1). The basic assumption in these models is that accurate knowledge is essential to, and comes before, effective action ("action" and "practice" are generally used synonymously). The primary challenge, from this

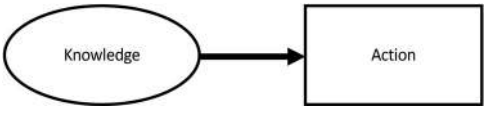

Figure 1. "Two communities." Knowledge is developed by researchers and is then applied to action by policy actors.

perspective, is to "link" the domain of knowledge to that of action in a unidirectional fashion, usually through either "trickle-down" (where good research will be spontaneously taken up by policy-makers) or "transfer and translate" approaches (where research requires translation into lay terms for uptake) (van Kerkhoff and Lebel 2006). These models are widespread in sustainability science-policy circles, with the trickle-down model implicit in ideas of "basic" and "fundamental" research, and the transfer and translate model sitting behind international assessments such as the IPCC and IPBES, as well as the evidence-based policy movement. In such approaches, the sustainability researcher is imagined to play a role akin to a medical doctor providing, as Fang et al. (2018, 12) put it, "diagnostic" and "therapeutic" services to society, while policy-makers and practitioners are portrayed as oft-complacent "practical people" (Lenzer 1998; Sutherland and Wordley 2017).

By contrast, post-positivist and constructivist approaches tend to lead to more complexity-oriented models of knowledge and action, that challenge the idea of two communities conducting their respective tasks in isolation and suggest that researchers and policy-makers are and should be involved in *both* knowledge-making *and* action. The key assumptions here are, firstly, that in a complex world scientific knowledge will inevitably be partial, provisional and uncertain (Berkes, Colding, and Folke 2003); secondly, that practitioners, policy-makers and citizens hold valuable and relevant knowledge (Tengö et al. 2014); and thirdly, that knowledge and action are not ordered sequentially but occur simultaneously and "co-produce" one another (Clark et al. 2016; Figure 2). The challenge is to make these co-productive relationships more generative, effective and equitable, for instance through participation, deliberation and learning (Biggs, Schlüter, and Schoon 2015). These commitments are infused within a growing range of approaches to science-policy engagement, including transdisciplinary research (Lang et al. 2012) and knowledge co-production (Miller and Wyborn 2019). In such approaches, the role of the sustainability researcher shifts from doctor to "facilitator," "knowledge broker" or "change agent" (Milkoreit et al. 2015), and the policy-maker from a complacent practical person to "co-investigator" or "knowledge holder" (Tengö et al. 2014).

Complexity-oriented approaches have become increasingly sophisticated, informed by burgeoning experience enacting transdisciplinary and co-produced research (Pohl et al. 2010; Hill et al. 2016) and a growing literature that has brought social and political theory to bear on science-policy relationships (van Kerkhoff and Lebel 2006; van Kerkhoff and Pilbeam 2017; Evans and Cvitanovic 2018). Nevertheless, there is a sense that they are still often held captive by linear formulations and received views of the relationships between knowledge and action that are deeply ingrained in language and institutions. For instance, while the focus has shifted from studying two domains of

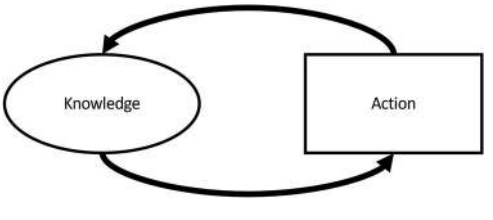

Figure 2. "Co-production." Knowledge and action occur simultaneously and shape one another.

knowledge and action in isolation to the reciprocal relationships between them, ideas of "linking" knowledge and action continue to evoke linear models. As van Kerkhoff and Lebel (2006, 470) note, the notion of "linking" implies "a chain-like, disembodied, somewhat mechanistic relationship … the concept of two communities will persist while we continue to use the language that invokes it." Hulme (2018, 334) argues in relation to global sustainability research programmes that

> too infrequently is there any direct questioning of how knowledge does and should relate to action. Instead, the implicit assumption too often still seems to be that: knowledge leads to action; *more certain* knowledge leads to *more definite* action; and *more integrated* knowledge leads to *more joined-up* action.

This raises a crucial issue for sustainability research: how to develop approaches that recognize the complexities of knowledge-action relations, while still expressing an engaged commitment to intervention.

We suggest that one way of developing complexity perspectives still further, challenging residual linear assumptions while retaining a solutions-focus, is to pay close attention to how those tasked with "linking knowledge and action" attempt to navigate the complex situations they find themselves in. This entails complementing the literature on the institutional characteristics of "knowledge-action systems" (Cash et al. 2003; Muñoz-Erikson 2014; van Kerkhoff and Szlezák 2016) with approaches that begin from human experience, particularly those within the interpretive and performative social sciences, humanities and arts (Bennett and Roth 2018; Duncan et al. 2018; Hulme 2018). In particular, we might ask questions such as: what are the nature of the situations that (sustainability) practitioners, researchers and policy-makers find themselves in? How do they experience these situations, and how do they go about navigating and intervening in them to arrive at satisfying, workable solutions? Do they seek to "apply" knowledge "to" action, or do they do something else? In the following section we turn to one approach that takes up these questions, the practice dimension of deliberative policy analysis (DPA), to articulate a practice-based approach to transdisciplinary sustainability interventions.

3. Towards a practice-based approach to transdisciplinary sustainability interventions

3.1. The practice dimension of deliberative policy analysis

DPA emerged in the early 2000s as an attempt to develop an approach to policy analysis attuned to the complexity, plurality and unpredictability of governance in the network society (Hajer and Wagenaar 2003). DPA drew on critiques that highlighted the limits of positivist policy analysis in providing "actionable knowledge" to policy makers (Fischer and Forester 1993), and on the growing awareness of social complexity indicated by the macro-sociological work of Manuel Castells and Ulrich Beck, to make the case for an action-oriented, interpretive account of governance. Such an account, structured around the three "pillars" of interpretation, deliberation and practice, was intended to capture the centrality of meaning and sense-making in everyday policy situations, the inevitably contested (and increasingly participatory) nature of policy-making in pluralistic societies, and the ubiquitous obligation in policy and administrative work to act on the situation at hand (Hajer and Wagenaar 2003). The role of the researcher was not to

propose solutions that "bring political discussions to an end … [But to] facilitate the citizen's and client's capacity for democratic deliberation and collective learning" (Hajer and Wagenaar 2003, 37); through collaborating "with social groups in a way that combines research, transformative action and participation" (Griggs, Norval, and Wagenaar 2014, 13). Similarly to sustainability science, DPA was formulated as both a descriptive and normative innovation, combining analytic description of contemporary governance with a progressive programme of intervention aimed at social, political and democratic transformation (Li and Wagenaar 2019).

The practice dimension of DPA directly challenges the privileged position often afforded to knowledge in addressing complex policy problems (Wagenaar and Cook 2003). From a practice perspective, solutions are generally not "delivered" through the production of new or more knowledge, but rather arrived at "haltingly, tentatively, through acting on the situation at hand and through the application of practical wisdom in negotiating concrete situations" (Hajer and Wagenaar 2003, 25). Yet while a rich vein of practice scholarship has emerged (Cook and Wagenaar 2012; Nicolini 2013; Arts et al. 2013; Shove and Spurling 2013) the uptake of a practice approach in the policy literature has been relatively limited compared to the interpretive and deliberative dimensions of DPA (Bartels 2019). This may reflect the quite radical challenges posed by practice theory to institutions of knowledge production, governance and public policy. While the term "practice" is widely used in a casual sense to refer to what happens in "the real world," practice *theory* brings into play "a conceptual apparatus, a mode of inquiry, even an ontology … which differs radically from the standard, epistemology-driven world view which has permeated social science, and in general the institutions with which we attempt to know and control the world" (Griggs, Norval, and Wagenaar 2014, 15).

The pragmatic, interventionist nature of the practice dimension of DPA makes it particularly well-suited for shedding light on attempts to "link knowledge and action" for sustainability. Practice theory is a broad area of scholarship, constituting less a single theory and more a dispersed family of related theories and commitments spread across organizational theory, science and technology studies (STS), sociology, and human geography, among others (Schatzki, Knorr Cetina, and von Savigny 2001). While there are many ways of categorizing this landscape, Behagel, Arts, and Turnhout (2017) usefully distinguish between sociological, post-humanist and pragmatist traditions. Sociological approaches have used practice to explore patterns of consumer behaviour (Spaargaren 2011) and post-humanist approaches to examine processes of (natural) scientific experimentation (Pickering 1995). The practice dimension of DPA sits within the pragmatist tradition (while also including aspects of post-humanism) and focuses on how policy actors address the complex situations they find themselves in. This emphasis on the experiential landscapes of everyday problem-solving, acknowledgement of complexity, and commitments to learning and progressive social change, makes the DPA practice tradition perfectly positioned to help explain what happens when policy-makers, practitioners and researchers come together to collaboratively solve sustainability problems (Ison 2018). Indeed, there has already been substantial cross fertilization between DPA more generally and sustainability science in fields of urban governance (Wagenaar and Wilkinson 2015), deliberative valuation of ecosystem services (Schoon et al. 2015) and global sustainability policy (Hajer et al. 2015). Infusing a practice-based approach

within sustainability research may therefore contribute to both the sustainability and policy sciences: providing a valuable theoretic repertoire to inform sustainability interventions, while also invigorating a broader, interventionist conception of DPA.

3.2. Key tenets of a practice-based approach

We can define "practice" relatively straightforwardly as any activity or constellation of activity that obtains its meaning from a given collective or group context (Cook and Brown 1999; Cook and Wagenaar 2012; Schatzki 2012). Yet the apparent simplicity of this definition belies the far-reaching epistemological, ontological and ethical implications of a practice-based approach to inquiry and intervention. The central commitment of a practice perspective is that the world we live in, the world we experience as reality – that bangs and bumps and brushes up against us, resists and accommodates our various endeavours, and presents itself as largely "out there" – is a product of our "ongoing practical engagement with the world" (Griggs, Norval, and Wagenaar 2014, 16). This is not to say the world is "constructed," but that the world makes itself known to us through our actions, interventions and exchanges with it (Hacking 1983; Pickering 1995; Cook and Wagenaar 2012). We act because we experience certain situations as worthy of or inviting attention, as momentary episodes of indeterminacy or disruption that need to be addressed with greater or lesser urgency. A practice-based approach proposes "practice" as the primary strategy we use to navigate such situations and arrive at tentative workable solutions to the problems we encounter. Experience, situation and practice are therefore features of the same dynamic ecology. The environment is in our actions and vice versa; in this fundamental sense practice is constitutive of the world. We do not exist outside of practice.

Yet when we engage in practice the world does not fully accede to our interventions – it "talks back." The world's boundless, inexhaustible possibilities for ongoing combination and permutation far exceed our capacity for understanding, let alone control.[2] A number of features illustrate the capacity of the world to frustrate our best intentions. Firstly, the intensely interconnected, interdependent nature of social, ecological, economic and political relationships (Connolly 2011). Secondly, the continually shifting, unfolding nature of these relations through time, and the consequent sense of a world in a perpetual state of process and becoming (Mesle 2008; Pickering and Guzik 2009). Thirdly, the complexity and indeterminacy of these relations, reinforcing our awareness of our inevitably partial and provisional grasp of the world, and the inescapable presence of unpredictability, surprise and rapid change (Schatzki 2012). And finally, pluralism – our experience of the irreducible difference and diversity of the world, for instance in terms of differing ways of being, knowing and flourishing (Wagenaar 2011). We can distinguish between two general kinds of reaction to this predicament. One is denial and rejection, and the consequent search for (ever more sophisticated) forms of control. The other is to embrace the richness and creativity inherent in what Gadamer calls the "surfeit of reality" and to explore the elusive and unprobed relations and connections that harbour ever so many possibilities to extend our understanding and work towards some shared sense of good. This latter direction has given rise to an emergent ethics of practice – captured in notions of "reverent interconnectivity" (Stout and Love 2017, 117–118), "presumptive generosity" (Connolly 2011, 114), and ethics of care and stewardship (Martin, Myers,

and Viseu 2015; Stout and Love 2017) – that respect the fundamental human predicament of interconnectedness and complexity and pursue attendant possibilities for understanding and collective action.

Practice in both its simple and expansive senses has significant implications for attempts to link knowledge and action in pursuit of sustainability. Importantly, a practice perspective does not simply address the "action" dimension of knowledge-action relations but provides an alternative way of thinking about knowledge *and* action, and how they are related, by enfolding both within practice. The concept of practice therefore directly challenges the idea that knowledge precedes, underlies and enables action (Cook and Wagenaar 2012, 26). Instead, a practice perspective suggests that we live and operate in fields of intersecting (material and social; human and nonhuman) agencies, with which we actively engage – activity that is itself a kind of continual act of sense-making or "knowing" (Cook and Brown 1999). Consequently, a practice perspective suggests that this activity or "doing" is primary, and that knowledge may be instead understood as one of the products or tools of practice (Figure 3). In the pragmatist Deweyian tradition, then, practice is an effort to "develop a unified account of knowing and doing. It expresses the insight that knowledge, knowledge application and knowledge creation cannot be separated from action; that acting is the 'high road to knowing'" (Hajer and Wagenaar 2003, 26). In the remainder of this section we identify the key tenets of a practice perspective and draw out the implications for knowledge-action relationships in transdisciplinary and co-produced sustainability research.

Acting in the situation at hand is the driving force of practice. In the pragmatist tradition, "experience" is not a subjective mental phenomenon, but located relationally in a situation inclusive of individual, social and physical aspects (Parker 1996). "Situation" is a key term in pragmatist philosophy, intended to bridge reality and experience, inside and outside, subject and agency. Paraphrasing Connolly (2011, 97), situations are "lived or felt from the inside," but are also something "you seek strategies to ameliorate or rise above." The experience of a situation as problematic or in need of attention implies that action is needed to address it. Conventional approaches might suggest that at this point knowledge needs to be "applied." However, we live in a world where problem formulations are often unclear and contested, where it is unclear what the materialities of the situation will "afford," where the implications of alternative actions are uncertain, and

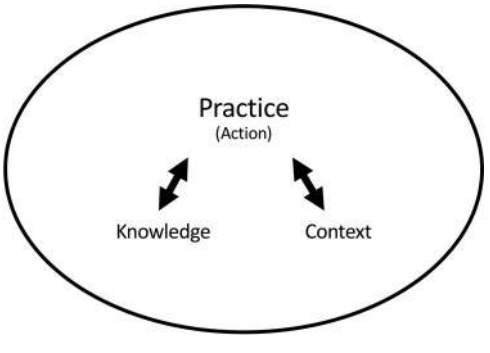

Figure 3. A practice perspective. Practice is primary, action is the driving force of practice. Knowledge and context are artefacts of practice. Adapted from Cook and Wagenaar (2012).

where the utility of various kinds of knowledge is not immediately apparent (Cook and Wagenaar 2012, 17). Therefore, from a practice perspective, the initial task of the actors involved in a transdisciplinary research project is not to apply knowledge but to devise a productive form of practice within which the problem can be addressed. Acting is central here, from interpersonal dialogue to physical tinkering and embodied interaction with the environment, to "get the measure of the situation" and figure out "how to go on" in light of affordances and constraints, purposes and expectations. For sure, knowledge in the sense of concepts, theories and previous experiences will be drawn on at this point – experienced practitioners rarely act in the dark – but the value of that knowledge "lies in its utility within practice, not in a supposed ability to give rise to practice" (Cook and Wagenaar 2012, 20). A practice approach therefore highlights the distinctive value of transdisciplinary research: rather than developing "knowledge outputs" *per se*, its value lies in establishing generative forms of inquiry within which new ways of knowing and doing (and more useful knowledge) may emerge.

Knowledge is a product of practice. To explain this, it is useful to make a distinction between acts of knowing (which reflect the active, embodied processes of navigating and making sense of the world) and the possession of knowledge (as the more static accumulation of abstract concepts, facts and procedures) (Cook and Brown 1999). There has been a general shift in scholarship, instigated by STS, towards viewing scientific knowledge as the "conceptual product" of knowing in practice; as the abstract, transferable product of "real time struggles to make things work" (Pickering 1992, 3–9). Understanding knowledge as a product of practice heightens awareness of the contingencies embedded within all knowledge products. This is a crucial aspect of practice perspectives. Formal knowledge, despite its universalist, rigorous pretensions, is never neutral. An emphasis on practice reveals the presumptions, values and intentions – the "background knowledge" in Taylor's (1995b) words – that are hidden in formal knowledge, framing situations and surreptitiously determining outcomes (Spurling 2014; Wagenaar 2018). An awareness of the contingencies of formal knowledge increases the experiential novelty and diversity of perspectives we bring to bear on a situation. These features are considered key strategies of navigating complexity and may be particularly useful for transdisciplinary research (Biggs, Schlüter, and Schoon 2015).

Knowledge, as the conceptual product of practice, is also used as a tool within practice – for instance where concepts are creatively invoked to help address or "think through" a particular issue (Schwandt 2014). Treating knowledge as a tool of practice emphasizes that the utility of knowledge is determined by the situation, rather than inherent to a knowledge product itself. This highlights that the primary challenge facing transdisciplinary research projects is generally not a lack of knowledge, but rather to make better, more creative use of existing knowledge within particular situations. Consequently, "impactful" projects may be less about generating new knowledge (although this may well happen, and even be required), and more about creating deliberative spaces within which actors can reflect on "why enacting directed change is so hard to accomplish" (Hulme 2018, 335), why we make the same errors over and over again, and why we accept debilitating side effects as an acceptable price to pay for favoured solutions (Holt-Gimenez 2006 , xvii). Actors may then work to reassemble practices that generate knowing and mobilize knowledge in more creative and transformative ways. Such approaches, echoing Stirling's (2016) "knowing doings" and Hulme's (2018) "knowledge thickening," challenge the will to

control inherent in linear models of knowledge to action, and consequently lead to more uncertain, unpredictable, but potentially more transformative transdisciplinary work.

Context is an artefact of practice. At first, this commitment may seem strange. However, while it has long been noted that practice is "indexical" – situated in and directed at a particular material and social world – the nature of this "context" is often taken for granted (Cook and Wagenaar 2012, 14). In much sustainability research, for instance, context is often used as synonymous with "local," or as a kind of "container" for action. In a practice-based approach, context is understood rather as a dynamic set of relations between an actor (or group) and their social and material environment, that become animated in relation to a particular course of action as the situation calls for it (Wagenaar and Cook 2011). In this sense, the relations that become animated – for instance, with colleagues, legal rules, species, tools – may be understood as "artefacts" of a particular practice. Viewing contexts as dynamic sets of relations established *within* practice highlights useful avenues for intervention in transdisciplinary research centred around "re-enacting" social and material relationships as a means to nurture transformative change. Boyd et al. (2015) use a performative approach to encourage researchers to adopt different professional relationships with colleagues and make alternative uses of "props" (e.g. tools) within transdisciplinary research projects. Meanwhile, Nold (2018) uses a practice-based approach to identify the relations between sounds, technologies and administrative procedures at Heathrow Airport that "enact" aircraft noise in particular (inequitable and unsustainable) ways and, together with citizens groups, design technologies that transform these relationships.

Practice unfolds in emergent time. Practice is characterized by its temporal nature; indeed, as Schatzki (2012) notes, time is what makes activity, which sits at the heart of practice, *activity* rather than simply an occurrence. The experience of time unfolding is indelibly bound up with humans acting, linking past and present in a continuous process of becoming (Wagenaar 2011, 287–288). However, while time is often considered in terms of succession (a linear movement from past to present to future), the experiential time of practice places an actor in an "eternally unfolding present," in which past, present and future co-occur (Cook and Wagenaar 2012). Actionable routes forward must be arrived at in the present moment, in light of a continually replenishing past, and an always only partially decipherable future (Cook and Wagenaar 2012, 18). The present is where knowledge and context "take on the form and meaning that constitute them as artefacts of practice" (Cook and Wagenaar 2012, 22). As an actor engages with the situation at hand, abstract concepts and previous experiences are evoked and animated anew, while social and material affordances and constraints make themselves apparent, informing the "next step." Consequently, knowledge is "rarely applied in a literal sense or as a template for action," but creatively interpreted and mobilized in light of continually unfolding relationships (Wagenaar and Cook 2003, 152). The implication for transdisciplinary work is that the ways in which knowledge is evoked in practice – and, potentially, moments of transformative change occur – are inherently improvisational (Klemp et al. 2008; Laws and Forester 2015) and indeterminate (Schatzki 2012; Clark et al. 2016). This indicates the importance of timing in deploying knowledge effectively within practice in ways that echoes the literature on making use of "policy windows" to effect change (e.g. Rose et al. 2019).[3] While the perpetual present of practice therefore frustrates any desire for "controlled transitions" (Stirling 2014), it also ensures the ongoing possibility of fortuitous

encounters with the "surfeit of reality," of new and surprising use of knowledge within practice (Schatzki 2012). In turn, this suggests that the transformative potential of transdisciplinary and co-production research may lie less in developing often over-specified "theories of change" and "pathways to impact," and more about nurturing and being responsive to the evolving relationships through which novel solutions may be happened upon.

Assessment of practice is pragmatic, evaluative and aesthetic. While linear views suggest that practice should be assessed on its fidelity to formal knowledge (or its ability to deliver a predetermined set of outcomes), in a practice-based approach the "rightness" of practice is tied to its ability to navigate or resolve the particular situation at hand in an effective and morally satisfying way. Assessment of practice is therefore, in Wagenaar and Cook's (2003, 150) words, "pragmatic, evaluative and aesthetic," addressed to questions such as "did it work?" and "was it done well?"[4] This has important implications for attempts to develop the appropriate capacities (Wyborn 2015) and associated monitoring and evaluation frameworks to improve transdisciplinary sustainability research (Wall, Meadow, and Horganic 2017). A practice approach provides theoretical justification for recent approaches that have emphasized the importance of embracing the complex, unpredictable and inescapably political nature of using research to influence social change (Clark et al. 2016). Furthermore, a practice approach adds an explicit focus on the everyday situations through which these dynamics play out: the unfolding flow of moral-political-practical dilemmas that demand, "what is the right thing to do in *this* situation, given *these* conditions?" This indicates a need to develop the capacities of transdisciplinary practitioners to improvise and exercise situated judgment; and to develop tailored approaches to evaluation that can evolve in line with the unpredictable courses that true transdisciplinary and co-produced research will take.

4. Case study: "future-proofing" conservation in Colombia

In this section we reflect on the transdisciplinary "Future-Proofing Conservation" project (participated in by LVK) to illustrate both the strengths and challenges of genuine efforts to co-produce practice-based solutions to complex problems. The project sought to create new ways for protected area policy-makers and managers in Colombia to address the challenges posed by climate adaptation within their management strategies, approaches and tools (see van Kerkhoff et al. 2018 for details). Climate change poses a profound challenge to protected areas management, as inevitable ecosystem transformation renders impossible the traditional conservation goals of maintaining current landscapes and their species or ecological communities, or restoring to a previous state. The project emerged from dissatisfaction around existing technical approaches to climate adaptation – including land change scenarios, vulnerability assessments and species movement modelling – that were not "solving the problem." Strategies for tackling climate change were rooted in the linear assumptions of the traditional model – that more science would reduce uncertainty, and that less uncertainty would lead to decisive action in rethinking conservation governance to accommodate climate change. But conservation governance *practice* was not changing (Stein et al. 2013). Despite imperfect but good understandings of climate impacts, impressive frameworks and guidelines, there remained an apparent "gap"

between knowledge and action. Existing conservation interventions were no longer adequate, and the world was indeed "talking back" in increasingly strident tones.

As a team of academics began to challenge the linear assumptions underpinning this gap, a tentative conversation began between researchers, advocacy group staff and protected area managers. All were grappling with the experienced "situation" of ecological instability that many felt was certain to increase. This resulted in an awareness that tried and trusted social and professional responsibilities, practices and deeply held personal values were no longer viable. The group recognized that addressing the situation called for new approaches to conservation governance that could explicitly account for the temporalities of a changing world and open up practice options to enable "future-oriented" conservation policy, planning and management. The diverse partnership that emerged (spanning four continents) included advocacy partners WWF-Colombia; the government agency Parques Nacionales Naturales de Colombia; academic partners from the Australian National University, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Luc Hoffmann Institute and international conservation consultants. The goal was to create a methodology, or "a productive form of practice," that could be called upon in different protected area management settings to guide practitioners in meaningfully exploring the implications of climate change for long-term planning.

Drawing from pragmatist scholarship, the team adopted an overarching philosophy of evolutionary learning (Ansell 2011). Evolutionary learning has three guiding principles. First, it emphasizes the need to apply a problem-driven perspective, where all activities are embedded in the policy and decision-making context. Second, it supports processes and structures that enable reflexivity at both individual and institutional levels, thereby recognizing different possibilities for change and transformation, as well as constraints – recognizing the "policy mud." Third, it seeks to create spaces for deliberation that include consideration of personal and social values, historical processes of change, and aspirations for positive futures. The project team interpreted these guiding principles as best implemented through a co-production approach, which focused on creating processes and forums for deliberation in which everyone brought experience, expertise and knowledge, regardless of formal role. For example, of the three workshops that were eventually included in the process, one was developed by academic partners, one by international consultants and one by advocacy partners. Shared experimentation occurred throughout, where ideas were tried and evaluated, refined and reformulated. In these processes knowledge was not applied but treated as a tool of practice. Participants engaged in a continual dialogue between abstract ideas and the grounded realities of practice, where both could be challenged and recast. Even where tools and methods were rejected, all enriched the deliberation and helped the group to arrive at a shared understanding of what might be useful. By maintaining a commitment to face-to-face discussion and crafting spaces where practitioners were not only participants but informed and knowledgeable actors, personal relationships were established and critical analysis was shared equally throughout the group (Figure 4).

Over two years a series of workshops were conducted, where new ideas and activities were tested, evaluated and (often) rejected or (otherwise) adapted to the specific context. Interestingly, when the group first started working together, one of the first requests from practitioners was for "science." This indicates that policy actors and

Figure 4. The 'Future-Proofing Conservation' project in Colombia. Participants generated productive practice through face-to-face discussions and deliberation, and worked with a graphic artist to help them develop shared practical understandings of the challenge at hand.

practitioners were not immune to the idea, well-entrenched in the social and professional discourse of climate adaptation, that the possession of knowledge would solve their problems. Their request was not, however, as simplistic as that. Rather than a "solution," the science report that the researchers dutifully produced became a launch pad for deliberation over the challenge of climate adaptation for management and governance. The report served to ground those discussions in the highly imperfect scientific understanding of the reality of ecological change. This in turn helped to define the relevant context of practice (the relations between the group and their social and material environment) which all participants had to navigate and make sense of.

Through this combined effort the group created a "product" that is a "process" – a multi-stage suite of activities that engages participants in a series of deliberations around conservation, culminating in a dialogue event to connect the pieces. The process encourages and guides participants along a series of transitions (towards anticipation of change, governance, learning, social benefits) that accumulates in new ways of thinking about protected areas management that challenge some of the fundamental tenets of conservation. This included a shared understanding that conservation may not, in the future, be based on goals related to maintaining current species or ecological communities, and recognition that preserving community benefits may be a viable alternative. It also supported a new understanding of the role of climate science, not as a solution-provider ("let's wait until the scientists tell us what to do"), but as a

knowledge base that conservation governance practitioners needed to act upon ("we are knowledgeable actors"). As such, the final methodology can be regarded as encouraging practitioners to think about climate adaptation as a practice, rather than a task. As a practice it is ongoing, deliberative and potentially transformative, framed by learning and dialogue rather than the application of technical solutions. This was reflected in our final activities, where participants noted the wider range of actors to whom they could (or should) extend this dialogue, such as water management agencies and indigenous communities.

While as researchers we can craft a reasonable narrative of the process and its outcomes, this belies the messy, often difficult, highs-and-lows of a practice-based approach. The project required the tolerance of funders who allowed participants to avoid the tyranny of the project logframe and were trusting enough to provide resources when the collective outcome was unknown. And the researchers needed trusting partners who were willing to go on a journey of shared "becoming." Deliberative co-production approaches can be unfamiliar and resisted – expectations from non-academic partners can subscribe to the linear knowledge-action-solutions model as much as scientists. Finally, of course, a practice approach demands humility, tolerance of uncertainty and unclear outcomes, and genuine recognition of the value of sharing and co-creating (Clark et al. 2016).

5. Conclusion

In this paper we have explored the assumptions underpinning calls to "link knowledge and action for sustainability" through transdisciplinary and co-production research. We have argued that while these are highly promising attempts to rethink inquiry and intervention in a complex world, they often remain captive to linear assumptions about what "knowledge" and "action" are and how they relate to each other. These assumptions, embedded in patterns of communication and institutionalized in processes of governance, hinder the transformative potential of transdisciplinary interventions. We have therefore contributed a complexity-oriented, relational model of knowledge and action where both are enfolded within practice. The driving force of practice is the imperative to act on the situation at hand, within which knowledge is evoked as a tool or generated as a product. A practice-based approach is not simply relevant to the "practice" aspect of conventional distinctions between "research and practice." Indeed, practice theories have been employed to explain the "pure" research practices of laboratory scientists, through to the policy practices of "street-level bureaucrats." By cutting across such distinctions, a practice perspective is particularly suited to explore the hybrid transdisciplinary spaces where researchers and policy actors meet. We conclude by drawing out the broader significance of a practice-based approach for sustainability research.

Firstly, we believe that a practice-based approach provides a theoretical language that better "fits" the complexities experienced by participants in transdisciplinary interventions. Rather than external observers seeking to "apply knowledge" to a complex world, participants are situated as actors *within* the complexity that they seek to influence (van Kerkhoff 2014), operating in dynamic, indeterminate worlds of perpetual becoming. They are faced with an unfolding flow of moral-political-practical choices and dilemmas that require resolution in one way or another, the effects of which are unclear but which

will fundamentally shape possibilities for future action. Workable solutions are not simply "delivered" by the production of new or more knowledge, but arrived at haltingly by exercising practical judgment and creatively invoking knowledge in the course of acting on concrete situations. A practice-based approach therefore moves the "action-orientation" of sustainability research from rhetorical flourish to the heart of understanding how we navigate and arrive at solutions within complexity, and provides one example of how the interpretive and performative social sciences can contribute to "instrumental," applied fields such as sustainability science.

Secondly, a practice-based approach usefully reconfigures the value, contribution and role of research (and researchers) for those interested in producing "actionable knowledge." Knowledge is useful not so much in terms of an ability to "give rise to" practice, but rather in terms of its utility *within* practice. The usefulness of any particular concept, method or body of experience is determined by the unfolding relationships within which it is invoked, and therefore is inherently multi-dimensional and unpredictable. For instance, participants in the Future-Proofing Conservation project ostensibly rejected "futures thinking" tools, yet these tools *were* useful in the sense that they enabled participants to articulate more appropriate alternatives. Moreover, concepts may be quite radically reinterpreted to address the demands of particular situations. This suggests that the primary task for participants in impactful transdisciplinary projects may be to spend time developing effective modes of "productive inquiry," including an ethics of interaction and joint exploration, rather than seeking to rigidly "apply knowledge." While conventional approaches may recognize the importance of these aspects, they are often subservient to a final knowledge output. Put metaphorically, this reworks ideas of "the signal and the noise": rather than excluding noise to find a "true" signal, a practice approach proposes embracing noise to develop a "useful" signal.

Finally, a practice-based approach helps to identify skills and appropriate modes of evaluation for effective transdisciplinary and co-produced research. A practice perspective suggests that "core competencies" for transdisciplinary research (Wiek, Withycombe, and Redman 2011) are not simply individual, cognitive and transferable, but rather relational, embodied and situated accomplishments realized in the collective navigation of practical dilemmas (Cook and Brown 1999). This highlights the value of nurturing skills for transdisciplinary research through collective, interactive forms of problem-solving in "real-world" situations, fostering improvisation, interpersonal relations and situated judgment (Trencher et al. 2018; van Kerkhoff and Lebel 2015). Moreover, the role of evaluation shifts from an "add-on" at the end of a project, to an integrated, ongoing part of a transdisciplinary project and an important mechanism of social change itself. For instance, the integration of video diaries into a project offers the opportunity to engage in real-time evaluation that reflexively informs the purpose and use of a project as it progresses and, importantly, offers opportunities for "deliverables" to evolve along with the project. A practice-based approach therefore challenges the desire for control and professionalism that characterizes managerialist approaches to sustainability; opening up tools such as core competencies, indicator frameworks and monitoring and evaluation to more unruly and emergent approaches, where the "uncontainable" aspects of the world are embraced as sources of ongoing learning and transformation.

Notes

1. Following Clark et al. (2016) we use this term to encompass research that refers to, among others, socio-ecological systems, social-ecological systems, nature-society systems and coupled human-environment systems.
2. The immanent elusiveness of the world has been commented on by a number of theorists who inspire or work within the practice tradition. For example, William James speaks of "litter" to indicate the parts of the universe that escape our attempt at conceptualising and modelling, Hans-Georg Gadamer of a "surfeit of reality," Andrew Pickering of the "agency" of things, and Gilles Deleuze of "abundance." While this permutational surfeit can be a source of frustration and defeat – for example, Donald Schön and Martin Rein (1994) refer to "backtalk" in their pragmatist-inspired *Frame Reflection* – all of the theorists above see it instead as an inexhaustible source of creativity and learning (Connolly 2011, 119).
3. Although there is a sense that this literature often treats policy windows as purely objective phenomena that occur "out there," rather than also intrinsically related to experience and practice.
4. This focus on "did it work?" as a means of assessment among participants within a particular practice should be distinguished from the "what works" agenda in UK science-policy circles, which focuses on identifying "successful" projects and replicating them elsewhere (Spurling 2014).

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Notes on contributor

Simon West is a postdoctoral researcher at the Stockholm Resilience Centre, Stockholm University, and a visiting fellow at the Fenner School of Environment and Society (Australian National University) and the Northern Institute (Charles Darwin University). His research explores how people create, share and use knowledge in the everyday practice of biodiversity conservation. His PhD thesis, completed in 2016, introduces interpretive social science – including practice theory – to the emerging field of sustainability science.

Lorrae van Kerkhoff is an Associate Professor at the Fenner School of Environment and Society, The Australian National University. Her research examines how science is used in decision-making for complex environmental issues. She is particularly interested in the social, political and cultural dimensions of knowledge systems, across diverse Western and non-Western contexts.

Hendrik Wagenaar (https://hendrikwagenaar.com) is senior academic advisor to the International School for Government at King's College London and Adjunct Professor at the University of Canberra. He publishes in the areas of participatory democracy, interpretive policy analysis, deliberative

policy analysis, prostitution policy and practice theory. He is author of *Meaning in Action: Interpretation and Dialogue in Policy Analysis* (M.E. Sharpe, 2011), and editor of *Deliberative Policy Analysis* (with M. Hajer, Cambridge University Press, 2003). In the area of prostitution research, he published *Designing Prostitution Policy: Intention and Reality in Regulating the Sex Trade* (with Helga Amesberger and Sietske Altink, Policy Press, 2017).

ORCID

Simon West http://orcid.org/0000-0002-9738-0593
Lorrae van Kerkhoff http://orcid.org/0000-0003-0247-1511
Hendrik Wagenaar http://orcid.org/0000-0001-7275-6761

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