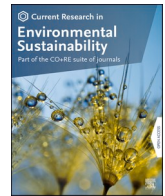




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Placing sustainability at the centre of water, sanitation and hygiene: Knowledge co-production for sectoral transformation

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ABSTRACT

Efforts to expand the delivery of water, sanitation and hygiene (WASH) services are occurring in the context of increasing pressures on the environmental and resource systems on which WASH services depend. As such, it is imperative to explore how sustainability considerations can be made central to WASH initiatives in ways that strengthen both service delivery and environmental systems. This article contributes insights from a transdisciplinary knowledge co-production process designed to bridge conceptual and practical priorities in a sectoral context – the WASH sector – with the intent to inform transformations at multiple levels from local practice through to global discourse. The co-production process was held online with a select group of WASH professionals from 10 countries. The design involved three components: engaging with worldviews and sustainability concepts; discussing the practical relevance of featured research studies in participant's professional roles; and co-creating ideas about desirable futures and transformation pathways. Findings from the process relate to its method, outcomes and implications for future knowledge co-production across four themes: (i) fostering self-reflection and engaging with purpose; (ii) considering sustainability across scales and contexts; (iii) generating ideas for individual and sectoral action; and (iv) reflecting on researcher power and considerations for future co-production processes. The case demonstrates the potential for co-production in a sectoral context to foster generative self-reflection, shared understandings and practical ideas for action towards sustainability transformations. Methodological insights suggest that future knowledge co-production proponents could beneficially emphasize purpose, work across scales and contexts, and take a reflexive approach to power.

1. Introduction

Universal access to safe water, sanitation and hygiene (WASH) services is foundational for human flourishing. Addressing the substantial challenge of expanding access is the 'WASH sector', a global community of diverse professionals. The sector's efforts are focused primarily on low- and middle-income countries, where 2 billion people live without safely managed water services and 3.6 billion without safely managed sanitation services (UN-Water, 2021). As such, the sector is influenced by the history and dynamics of development aid and associated power dynamics (Hargrove, 2019). A wide range of public and private institutions engage in WASH activities at global, national and local levels, with professionals spanning technical, social and regulatory roles. Multiple public agencies are implicated in WASH, including those with remits relevant to public works, health, education, environment and resource management.

WASH is both a public health and environmental concern, yet focus

on 'sustainability' as an environmental rather than service continuity consideration is relatively recent in mainstream sector discourse (Hargrove, 2019; Carrard and Willetts, 2017). Normative directions for the WASH sector are described in Sustainable Development Goal (SDG) 6 (Ensure access to water and sanitation for all) (United Nations, 2015) and the human rights to water and sanitation (United Nations, 2010). Both articulate visions for an equitable and sustainable global community in alignment with sustainability transformation agendas (Scoones et al., 2020), particularly when SDG 6 is viewed as intended within the integrated, interconnected SDG framework (Nilsson et al., 2016; Cerf, 2019). To progress and deepen WASH sector engagement with sustainability, there is opportunity to explore how the WASH sector can foreground planetary sustainability imperatives within and through its ongoing work.

Knowledge co-production is a potentially powerful method for exploring how the WASH sector can strengthen its focus on planetary sustainability. Knowledge co-production – defined as a way to produce

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science that is iterative, collaborative, inclusive of different knowledge types and (increasingly) normative in intent (Wyborn et al., 2019; Norström et al., 2020) – is well suited to a sector characterized by disciplinary and institutional diversity. As both a means to reconfigure knowledge production and a strategy for collective progression of ideals (Schuttenberg and Guth, 2015), co-production promises an integrated vision of research and action that can address societal challenges and move us towards preferred futures. Co-production as a method has been traced to disciplinary traditions in public administration, science and technology studies, and sustainability science (Miller and Wyborn, 2020). In this article, while acknowledging the influence of multiple disciplinary bodies of work, we primarily draw on conceptions of co-production articulated in sustainability science in which, in line with our investigation, co-production is focused on generation of knowledge (or a reimagined ‘science’) in pursuit of sustainable futures (Miller and Wyborn, 2020). As such, our use of the terms ‘knowledge co-production’ and ‘co-production’ (for brevity) should be viewed as interchangeable and reflective of sustainability science conceptions.

Interest in knowledge co-production has increased markedly in recent years, with literature spanning its potential, performance and pitfalls. The potential of co-production stems from its importance for reshaping conceptions of earth system governance (Miller and Wyborn, 2020) and its emergence as the ‘gold standard’ of engaged science (Lemos et al., 2018). Co-production is conceived as a multi-purpose method: for legitimating research outcomes, driving the implementation of knowledge in society, and/or bringing diverse perspectives and knowledge types to bear in the design of problem-solutions (Wyborn et al., 2019; Norström et al., 2020; Chambers et al., 2021). In global sustainability research, knowledge co-production is a key step in scientific integration, a means for science and society to engage in dialogue that produces rigorous, relevant research (Mauser et al., 2013; Schneider et al., 2021).

With the proliferation of knowledge co-production examples, the performance of co-production as a tool for achieving sustainability outcomes has emerged as a critical area for further research. Co-production has been credited with achieving sustainability outcomes across a wide range of sustainable development themes (Lemos et al., 2018; Chambers et al., 2021; Jagannathan et al., 2020; Pohl et al., 2010). However, reported outcomes do not yet attest to the transformative potential of co-production claimed by its proponents (Jagannathan et al., 2020; Oliver et al., 2019). To address the risk that co-production becomes an end in itself rather than a means for effective engagement (Lemos et al., 2018), there is opportunity to strengthen the evidence base about co-production’s achievements and potential. Articulating theories of change about the ways in which co-production can drive transformative change is one means by which to define and assess complex impact pathways (Schuttenberg and Guth, 2015; Oberlack et al., 2019; Schneider et al., 2019). One such an approach has been described by Schneider et al. (2019) who identify three generic mechanisms through which knowledge co-production can lead to impact, namely knowledge generation, social learning and enhancing leadership competencies.

Recent literature also highlights potential pitfalls associated with knowledge co-production and its role in sustainability transformations. Co-production – particularly when normatively framed – has been critiqued as tending towards apolitical conceptions of engagement and knowledge (Wyborn et al., 2019; Jagannathan et al., 2020; Turnhout et al., 2020; Fritz and Binder, 2020). Questions of power are particularly pertinent when co-production occurs in contexts characterized by deep historical asymmetries, such as is the case with South-North collaboration (Vincent et al., 2020). While there is a growing body of work emphasizing the importance of power in shaping co-production and its outcomes, a tendency to suggest ‘balancing’ strategies (Norström et al., 2020; Vincent et al., 2020) could be matched by relational approaches advocating for more nuanced and reflexive perspectives (Fritz and Binder, 2020). Beyond power analysis, relational approaches have been

advocated as a means to develop more situated, diverse knowledge production processes in sustainability science (West et al., 2020), and to challenge dominant linear conceptions in which knowledge production is followed by action (West et al., 2019). Such linear conceptions are evident in many ‘project’ models of co-production, driven by research funding paradigms and a policy-relevant focus on impact pathways (Chambers et al., 2021).

As scholarship and practice on co-production has diversified and evolved, co-production researchers have synthesized insights from multiple processes to offer heuristics and principles for future processes. Four principles for high quality co-production have been proposed by Norström et al. (2020), namely that co-production for sustainability should be context-based, pluralistic, goal-oriented and interactive. The authors expound the principles to inform both design and assessment of co-production. They situate the principles within a call for co-production to engage with deep drivers of current unsustainable trajectories and attend to the values, politics and power inherent in transformative change (Norström et al., 2020). As such, the usefulness of the principles is in their nuanced application across the diverse realms in which co-production occurs.

Complementing a principled approach to co-production design, Chambers et al. (2021) offer a heuristic for identifying benefits and trade-offs associated with different approaches. The analysis identifies six distinct modes of co-production based on analysis of the ways in which co-production processes engage with purpose, power, politics and pathways to impact (Chambers et al., 2021). A key outcome of the analysis is the articulation of trade-offs associated with different design choices, for example knowledge-focused processes were more likely to influence policy compared with relational approaches, but had less potential to inspire collective action (Chambers et al., 2021). Whether, and how, co-production can be designed to achieve both actionable knowledge and transformation of norms and structures – characterized as pragmatic scope 1 and transformative scope 2 outcomes by Jagannathan et al. (2020) – is an important question for future endeavors.

Drawing on the history and trajectory of co-production in trans-disciplinary sustainability research, the study presented in this article explores how co-production can contribute to sustainability transformations in the WASH sector. A sectoral focus is novel in knowledge co-production scholarship, with examples tending to focus on specific place- or issue-based questions (Chambers et al., 2021; Jagannathan et al., 2020; Schneider et al., 2019). In this case, we draw on co-production techniques to consider how they might inform a foregrounding of sustainability within a broad professional community. The co-production process involved a diverse group of professionals deliberating the relevance and usefulness of planetary sustainability concepts for WASH. Insights from the process relate to its method, outcomes and implications for future co-production. We first describe the research aims, context and co-production design. We then present and discuss findings from the analysis across four themes: fostering self-reflection and engaging with purpose; considering sustainability across scales and contexts; generating ideas for individual and sectoral action; and reflecting on power and considerations for future co-production processes.

2. Materials and methods

2.1. Aims and scope

The knowledge co-production process sought to engage selected WASH professionals in reflection and deliberation about sectoral engagement with planetary sustainability concepts, with a view to inspiring sustainability-oriented action. Two research questions guided the inquiry:

1. How does engaging WASH professionals in deliberation about planetary sustainability concepts contribute to new knowledge, shared understandings and new competencies?
2. In pursuit of sectoral sustainability transformations, how does knowledge co-production work in practice and what considerations might inform its nuanced application?

This first question explores WASH sector co-production with reference to three generic mechanisms of impact generation associated with transdisciplinary knowledge co-production proposed by [Schneider et al. \(2019\)](#). In Schneider et al.'s theory of change, new knowledge, shared understandings and new competencies are direct activities and outcomes of co-production processes that can drive longer term sustainability transformations by contributing respectively to knowledge promotion, social learning and competence building for reflective leadership ([Schneider et al., 2019](#)).

The second research question seeks deeper reflection about how we conceive and design co-production processes when viewed from the WASH sector perspective. In seeking deeper reflection, the intent is to interrogate our assumptions about how co-production should occur and how it might contribute to sustainability transformations. In responding to this question, we situate WASH co-production process reflections within recent literature on principles and critical considerations for co-production in transdisciplinary sustainability research. As such, evidence underpinning the analysis includes both outputs from the knowledge co-production process with WASH professionals, alongside applications and adaptations of insights from literature on knowledge co-production as a strategy for progressing sustainability transformations generally.

2.2. Positioning co-production within doctoral research

The process was undertaken as the culmination of the lead author's transdisciplinary doctoral research exploring the potential for greater WASH sector focus on global sustainability imperatives. [First author] was therefore the facilitator for the co-production process. The doctoral research built on a 10-year career in applied WASH research, responding to a gap in sector discourse and action about sustainability. Three studies completed in earlier stages of the doctoral research provided input content for group reflection. They included: (i) a systematic review of WASH sector sustainability discourse and the potential for planetary boundary ideas to inform future directions ([Carrard and Willetts, 2017](#)); (ii) analysis of reliance on groundwater as a source of drinking water and emerging resource issues in ten Southeast Asia and Pacific countries ([Carrard et al., 2019](#)); and (iii) analysis of the life-cycle costs of a resource-oriented sanitation system in urban Sri Lanka and implications for advancing a circular economy approach to sanitation ([Carrard et al., 2021](#)). The co-production process sought both engagement with research findings and the collaborative development of pathways for action that may inspire long-term sectoral transformation.

The co-production process, and wider doctoral research, built from the lead and co-authors' established careers as transdisciplinary WASH sector researchers. The co-production process featured in this article is not the only, but rather the most recent, of the authors' co-production practices, and generated insights therefore draw on a longer history of transdisciplinary WASH research. In situating the contribution as transdisciplinary, we adopt a conception of co-production as tantamount to transdisciplinary research that is purpose-driven, problem-focused, collaborative, transcends disciplinary boundaries and involves representatives from public, private and civil society realms ([Pohl et al., 2021](#)). We also note the authors' position as white women living in a high-income country, operating within the asymmetric power structures characteristic of international development research and seeking to reflexively approach applied research in pursuit of a just and sustainable world.

2.3. Design and analysis

Design of the co-production process sought to prioritize voices and experiences from low- and middle-income countries, and to maximize the diversity of WASH domains and contexts represented within a small group size that enabled inclusive discussion. The decision to prioritize low- and middle-income country participants was in effort to counter the historic dominance of high-income country voices in sector leadership ([Worsham et al., 2021](#)). The process was run online with a total of 14 participants across two sequential Zoom videoconferencing forums with the same agenda (nine in the first session, five in the second). The aim was to recruit 12–16 participants in total, such that each session would have a sufficiently small group to enable inclusive, open and meaningful engagement and exchange. Participants were recruited purposively through professional networks: the focus was on those with an expressed interest in the nexus of WASH and sustainability. In targeting participants with interest in the topic, the intent was to capitalize and build on existing knowledge and motivation to act. Participant recruitment also sought diversity in gender, age, level of professional experience, country of origin and aspect of WASH sector focus.

The final cohort included 6 women and 9 men from 10 countries. Of the 14 participants, 11 identified as nationals of low- and middle-income countries, with 8 living in their country of origin. Participants held roles as government officials and policy advisors, researchers, private sector consultants, an international organization advisor and civil society representatives. A number held multiple positions, for example working in both research and consulting roles. Participants had disciplinary backgrounds in engineering, earth system science, social science, and policy and planning. Both water and sanitation expertise were represented across urban and rural contexts. The cohort broadly reflected a mix of skills and roles typical of the WASH sector, with a notable exception that no participants identified as public health experts or having roles focused on hygiene (including for example handwashing or menstrual health). Further, no participants identified as having specialist skills in gender equality, disability, and social inclusion, which are critical considerations for the pursuit of universal, equitable WASH services ([Cumming and Slaymaker, 2018](#); [Workman et al., 2021](#)). Limitations related to group representativeness are discussed in [Section 2.4](#).

Prior to the online forums, participants were invited to complete the Worldviews Test based on Hedlund-de Witt's Integrative Worldviews Framework ([Hedlund-de Witt, 2012](#)). The Integrative Worldviews Framework extends previous measures of environmental values, moving beyond a tendency to focus on binary constructions towards recognition of the human potential for cognitive integration ([Hedlund-de Witt, 2012](#)). Questions in the Worldviews Test explore perceptions of reality, knowledge, values, identity and society ([Worldviews Test, n.d.](#)). In requesting prior completion of the Worldviews Test, the intent was to orient participants towards open, inclusive, reflexive discussion ([Hedlund-de Witt, 2014](#)). As such, the identified mix of worldviews was not given emphasis during forum discussions, with participants instead invited to firstly reflect on what completion of the Worldview test brought up for them, and secondly to be mindful of the importance of diverse worldviews and value systems in shaping a knowledge co-production process.

Each forum ran for 2.5 h with a three-phase agenda. The first phase involved orientation to the purpose and format of the forum, introduction of framing sustainability concepts and a reflection on the Worldviews Test. The idea of a 'safe and just space for humanity' between planetary boundaries and social foundations ([Rockström et al., 2009](#); [Steffen et al., 2015](#); [Raworth, 2017](#)) was introduced to frame WASH-sustainability conversations. Participants were invited to share their thoughts about the experience of taking the Worldviews Test and reflect on how different values and worldviews might inform the content and outcomes of group activities focused on WASH and sustainability.

In the second phase, the facilitator shared brief (3 min) pre-recorded videos about research studies (described in 2.2). Videos told the story of

each study according to a central idea (framed as a future direction or call to action), justification of its relevance to WASH professionals, and selected details of research findings and analytical insights. Participants were then prompted to share responses using the interactive presentation platform Mentimeter or directly in discussion. Prompts invited responses regarding how the content made participants feel (emotional reaction), what it made them think about (relevance to their own experiences), and what it inspired them to do (how they might act in their work). The decision to share research through video storytelling sought to leverage the power of stories as mechanisms for scientific communication and sustainability transformations (Veland et al., 2018; Riedy, 2021). Prompting for feelings sought to link emotional responses (which are foundational for motivation (Riechers et al., 2019)) with reflections on relevance and ideas to inspire action – the ultimate goal of co-production.

The third phase involved a futures-oriented co-creation activity using an adapted form of the Three Horizons framework. The Three Horizons framework is a foresight tool that supports groups to grapple with complex challenges and generate agency in designing viable pathways towards a preferred future (Sharpe et al., 2016; Sharpe, 2013). The tool identifies three horizons: the first representing the current (unsustainable) system; the third the emerging and preferred successor to the current system; and the second the domain of innovations and disruptions that can either perpetuate the existing unsustainable system or be harnessed to achieve the preferred future.

In the forum, the Three Horizons framework was adapted for online, condensed application, using a collaborative whiteboard (Miro) to co-create ideas about each horizon. The activity was scoped to focus on the intended outcome of the forum, which was to prompt a shift in WASH sector activities towards greater focus on sustainability. As such the preferred, viable future was articulated as *a future where water and sanitation professionals pursue the human rights to water and sanitation for all in ways that contribute to (and don't undermine) planetary sustainability*. Participants were invited to continue adding content to the collaborative whiteboard after the forum, allowing time for ideas to emerge beyond the actual time-limited events.

Inductive analysis of forum data identified insights about co-production outcomes (research question 1) and process (research question 2). Data included audio recordings of discussions and outputs from interactive platforms (Mentimeter, Miro whiteboard and Zoom chat). Codes were developed with reference to three relevant frameworks. The first group of codes identified outcomes of the WASH forums linked to Schneider et al.'s (Schneider et al., 2019) mechanisms for impact generation, with a particular focus on the direct activities and outcomes of (i) new knowledge, (ii) shared understandings and (iii) new competencies. To elicit process reflections, a second group of codes drew on Norström et al. (2020) principles that knowledge co-production should be: (i) context-based; (ii) pluralistic; (iii) goal-oriented; and (iv) interactive. A third group of codes sought complementary insights by exploring data through the lens of leverage points for sustainability transformations (Waddock et al., 2020). A list of codes used is provided in Appendix A.

Analysis of forum data was iterative, informed by thematic analysis of knowledge co-production literature and prior doctoral research on WASH discourse (Carrard and Willetts, 2017). The iterative analysis was a deliberate strategy to ensure validity of findings given the small-scale nature of the engagement process and intent to derive general insights relevant to either or both co-production as a method, and strategies for strengthening WASH sector engagement with sustainability imperatives. Strategies to ensure validity (drawing on the framework and definitions of Creswell and Miller (2000)) included peer debriefing between the lead and co-authors to challenge assumptions and interpretations, and researcher reflexivity (elaborated in Section 3.4). The research was approved by the University of Technology Sydney Human Research Ethics Committee (Reference: ETH21-5896).

2.4. Limitations

The co-production process involved a single point of interaction with each group of participants, which is a limitation given the co-production ideal of long-term iterative engagement (Chambers et al., 2021; Jagannathan et al., 2020). The decision to proceed with a single point of engagement was made to ensure timely completion of the research project and minimize participant inconvenience, however opportunities to reflect and revisit discussion points were foregone due to this choice. As one mitigating strategy, engagement before and after the event was encouraged by setting up message groups, email threads and an open collaborative whiteboard. Further, while the short-form nature of the co-production process did not allow for collaborative framing of the design and discussion topics, the researchers' long-term transdisciplinary research in the sector provided a strong foundation for appropriate pitching of content and activities. The limitations and value of short-form co-production are discussed further in Section 3.5.

A further limitation relates to overall representativeness. Representativeness is an important principle, but it is unachievable in small group settings, given the diversity and breadth of the WASH sector. Our objective was rather to ensure indicativeness through diversity in dimensions relevant to the sector and the questions at hand (see Section 2.3). We recognize that alternatively constituted cohorts would have shaped discussions in different ways. The validity of our findings comes from their generality, that is we do not seek to provide definitive insight into the ways in which WASH professionals engage with sustainability concepts. Instead, in keeping with our process and data, our findings are general, and relate to knowledge co-production as a research method and approach to create change.

A final limitation is that the process was run in English, which precluded the inclusion of non-English speakers. Given ongoing knowledge decolonization debates in the sector, and the fact this emerged as a theme for action (see Section 3.3), developing mechanisms to enable multi-lingual processes will be important for future co-production events.

3. Results and discussion

In this section we present and discuss results across four themes: (i) fostering self-reflection and engaging with purpose; (ii) considering sustainability across scales and contexts; (iii) generating ideas for individual and sectoral action; and (iv) reflecting on researcher power and considerations for future co-production processes. The four themes integrate data from the WASH sustainability forums with insights from knowledge co-production literature, and the authors' WASH sector perspective. We conclude by synthesizing findings across the lenses of our analysis and considering the limitations and value of short-form co-production.

3.1. Fostering self-reflection and engaging with purpose

The WASH sustainability forums fostered participant self-reflection and engagement with value-based ideals about future directions. Prior completion of the Worldviews Test (Hedlund-de Witt, 2012) was a novel and useful exercise for participants, enhancing self-reflection and an openness to plural perspectives. Participants appreciated the opportunity for self-reflection, sharing that the test "helped me to understand myself" or "helped me to know myself a little more". The test facilitated an expansion of thinking beyond daily activities into a more reflective mode, moving towards reflexivity by exploring ways of thinking, assumptions and underlying values (Bradbury and Divecha, 2020). One participant reflected that "questions do not relate to my daily activities, so it was interesting to explore myself", while another shared her experience of a different way of thinking: "at the beginning I felt that my thoughts were short-circuiting because it is the first time that I have questioned myself in that way to identify what my worldview is".

Presentation of the group results also elicited reflections about the importance of listening to plural perspectives informed by different values. As one participant expressed, the experience prompted thoughts about “the need to listen more and pay attention to what’s happening in other parts of the world...the need to seek to understand other worldviews because they are equally valid just as much as any other”.

While participants expressed primarily positive reactions to completion of the Worldviews test, they shared concerns relating to its (perceived) dichotomous presentation of science and faith and its appropriateness across diverse cultural contexts. Two participants expressed discomfort with questions about the relative importance of science and spirituality in driving personal perspectives. They had trouble choosing between science-oriented and faith-oriented responses, with one emphasizing the need to respect diverse ways of thinking across cultures and spiritual orientations:

“For many professional people, science only should become the answer to everything. However, I believe...in the different cultures around the world...all of them should be respected...the most important [aspect] for me is respect of thinking, especially...thinking of the spiritual word that everyone believes in.”

The appropriateness of the test for diverse cultural contexts was also questioned by participants, particularly with reference to conceptions of tradition and modernity.

“I don’t know if it takes into consideration the cultural diversity that we all come from, something that is...modern in one part of the world can be considered very traditional in other parts of the world.”

Despite these concerns, participant completion of the Worldviews Test was an effective mechanism for establishing an open, reflective tone. Concerns expressed by participants augmented its value as a reflective exercise, validating the decision to focus on the personal experience of test taking rather than group results. The discussions conveyed interest in, and a safe space for, self-reflection – a foundational skill for competency in reflective leadership (Schneider et al., 2019). Creating space for discussion about worldviews also provided opportunity for the facilitator to share her own epistemic values and motivation for convening the events, fostering reflexivity about facilitator power in shaping co-production processes (discussed further in Section 3.4).

In addition to establishing a safe space for open discussion, reflecting on worldviews, along with introduction of big picture sustainability concepts, oriented participants towards engagement with purpose. The concept of purpose underpinning forum design drew from the foundational transdisciplinary work of Jantsch (1970), in which purpose denotes value-based ideals about human survival in dynamically changing environments. The emphasis on purpose was designed to complement linear conceptions of change implied in goal-oriented co-production processes in which participants agree to a measure of success and “meaningful milestones (that is, stepping-stone goals) to achieve and monitor progress” (Norström et al., 2020). While the complexity of social change and its causal pathways is widely acknowledged in co-production literature (Norström et al., 2020; Jagannathan et al., 2020; Oberlack et al., 2019), linear assumptions about knowledge-action pathways persist (West et al., 2019). In the WASH forums, creating space to reflect on deeply held values enabled consideration about the alignment of goal-oriented actions with purposive imperatives. As one forum participant expressed: “[I’m] thinking about what my life goal is, where I’m going and what my priority is”.

Consideration of the ways in which engaging purpose can inform deeper reflection is particularly pertinent when thinking from a WASH sectoral perspective. The WASH sector is strongly driven by goals and targets articulated in SDG 6 (Ensure access to water and sanitation for all) and the human rights to water and sanitation. While WASH sector goals are shaped by purposive thinking, they risk losing criticality after their adoption if purpose is not continuously re-considered. A failure to

continually reflect on purpose in tandem with the pursuit of goals can result in perverse outcomes, such as occurred when the Millennium Development Goal precursor to SDG6 drove marked efforts to expand sanitation to access in households, with no commensurate focus on safe management of the generated waste (Herrera, 2019; Tortajada and Biswas, 2018) – a critical aspect of WASH for achieving desired public health outcomes.

Discussions in the WASH sustainability forums responded to both sector goals (SDG6 and its targets) and broader purpose (placing the goals within the wider vision of a safe and just space for humanity), yet it was the purposive lens that most effectively elicited reflective contributions. The vision of a safe and just space for humanity (Rockström et al., 2009; Steffen et al., 2015; Raworth, 2017) prompted participants to expand or deepen their thinking about what ‘sustainability’ means for them. For example, as one participant shared:

This concept of planetary boundaries and sustainability boundaries, and this doughnut diagram...it’s a fairly new concept to me to think about it this way. When we think about sustainability...I never really think about it in such big picture, you know, pushing planetary boundaries. I don’t go to that level.

Others were prompted to reflect on human-nature relations, conveying either a perspective of inter-connectedness: “it makes me think about sustainability...the need to imagine ourselves as connected to nature” or reflecting a conception of utility and stewardship towards nature: “natural resources are a gift in our lives, and we should...do our activities trying to replenish after taking advantage of them”. Human-nature connectedness has been identified as a “realm of deep leverage” for sustainability transformations (Abson et al., 2017; Riechers et al., 2021). When seeking to lay foundations for broad and deep change – such as when focusing on sector-wide engagement with sustainability – experiences from the forums therefore suggest value in emphasizing purpose alongside goal-oriented thinking.

Emphasizing purpose in the WASH sustainability forums was particularly valuable given the short-form nature of the process. A pragmatic balancing of goal-oriented discussion and action identification (see Section 3.3), with deeper questioning of purpose, created space for relevance to emerge from the process rather than be predefined. Klenk and Meehan argue for this kind of emergent relevance in trans-disciplinary research, suggesting that shifting our collaborative frames from notions of “engagement” to “encounters” between researchers and stakeholders can helpfully re-orient attention towards more responsive, open forms of relevance (Klenk and Meehan, 2017). Re-conceiving co-production as shaped by purposeful encounters asserts the value of each encounter for shifting conversations towards ideals, even in cases when long term engagement is not feasible. A purposeful approach to co-production encounters also allows for the characteristic messiness of knowledge production and use (Arnott and Lemos, 2021), while maintaining focus on what is ultimately important.

3.2. Considering sustainability across scales and contexts

The cross-context and cross-scale nature of discussions in the WASH sustainability forums is a second theme, with results indicating value in processes that link big picture ideas to diverse local realities. The value of discussions that cross scales and contexts is a particularly relevant finding for sectoral rather than project-focused co-production, given the intent to inform transformations at multiple levels from local practice through to global discourse. Consideration of changes across places and scales is both necessary for a sector such as WASH, which seeks to reconcile universal aims with local realities, and aligned with breadth and depth of transformation required to address sustainability challenges (Linnér and Wibeck, 2019).

In the forums, participants both asserted the importance of place-based context and moved fluidly in their reflections between global

(sector-wide) issues and local realities. Initially, when discussing future directions for WASH informed by planetary boundaries, participants demonstrated a preference to prioritize local perspectives and skepticism about the meaning of global concepts for local contexts. As one participant expressed, “national and local context and culture is very important in putting forward these future directions”. As discussions progressed, participants began sharing their perspectives on how the ideas under discussion manifested in their local areas, and what that might mean for their professional practice. One participant spoke about government leadership and the opportunities and risks presented by digitalization in the management and monitoring of water and sanitation services. Another linked sustainability concepts to the need to focus on women’s empowerment and leadership development. Ultimately, encouraging reflections that span places and issues brought to light interconnections that may have been lost with a narrower focus.

Moving from the conceptual to empirical, engagement with WASH-sustainability studies focused on groundwater reliance and resource-oriented sanitation provided space for participants to reflect on the relevance of each for their own context, and draw on their contextualized experiences to enrich shared understandings about sector-wide challenges. Responding to the groundwater study, one participant shared an expansion of focus: “I’m intrigued because as a water practitioner...of course the focus has always been piped water to households and it’s quite intriguing to learn that it’s also important to focus on the water source”. The groundwater study elicited reflections about the cultural significance of wells in some contexts, the potential for groundwater depletion to cause conflict in areas with large refugee populations, the relative costs of different water sources, the ways in which access to water resources drive inequalities, groundwater pollution from heavy metals, climate change impacts and data (un)availability. Discussions about resource-oriented sanitation spanned reflections on how policy frameworks can drive technological innovation, the importance of mindset change for achieving circular economy visions, the affordability of alternative sanitation models, and the distribution of responsibilities between citizens and state. The breadth of ideas discussed spanned environmental, social, technical and governance considerations, each grounded with contextualized examples.

The importance of context in shaping co-production activities and outcomes is self-evident and rightly reflected in co-production literature (Norström et al., 2020). Yet while a broad conception of context as “not synonymous with local” is presented (Norström et al., 2020), in practice co-production literature is dominated by local examples (Wyborn et al., 2019; Schneider et al., 2021; Moallemi et al., 2020). When seeking sectoral transformation, equal focus is warranted on the ways in which the local connects to the global in mutually informative ways. An explicit focus on identifying interconnections encourages a systemic perspective that can generate potentially catalytic ideas and actions across places and scales. As such, sectoral co-production can benefit from the more general call for exploration of how co-production can work across scales with globally powerful actors (Chambers et al., 2021; Schneider et al., 2021).

3.3. Generating ideas for action: Individual intentions and sectoral priorities

A third theme is the generation of ideas for action, which encompassed both individual intentions and identifying sectoral priorities. Action towards sustainability is a core objective of co-production (Norström et al., 2020; Miller and Wyborn, 2020) and the generation of action ideas is therefore an important area of analysis. It is important to note that the focus here is on *ideas* for action rather than action itself, given the pathways from intention to action would take more time and likely require further engagement to both bolster intentions and measure outcomes. Nevertheless, two forms of action ideas emerged from the forums that warrant critical reflection: actions that can be taken within each participant’s individual realm of influence; and priorities for

sector-wide focus.

Individual ideas for action were generated during both discussions about presented research studies and the Three Horizons visioning activity. When prompted ‘what are you inspired you to do in your work?’, participants shared ideas for actions in policy, education, technology and community engagement. For example, one participant shared a motivation to train university students in resource-oriented sanitation, while another was inspired to advocate for groundwater policy formulation in their jurisdiction. Participants also expressed a general intent to include a stronger sustainability orientation in their work, for example to “think more on sustainable and circular solution”, “think of complex interconnected issues of resources, access, governance” and to “go beyond the technical responsibilities of building... infrastructure, to foresee consequences for the inappropriate use of natural resources or polluting them”.

The individual action ideas constitute seeds of transformation knowledge – knowledge about how to make change from the current to preferred situations (Schneider et al., 2019). However, action ideas expressed at the individual level do not equate to the impact pathway of shared understandings leading to coordinated, joint action in project framed co-production processes (Schneider et al., 2019). The focus on individual actions can be attributed to the single round of engagement, the diversity of participant interests and locations, and prompts linking discussion content to participants’ own work. Yet ideas were shaped by group discussion about common interests informed by diverse experiences and plural perspectives, so are reflective of the ideal of co-production in which interaction is foundational for learning and action (Norström et al., 2020). The expression of meaningful action ideas relevant to participants’ own work indicates that in addition to driving joint action, co-production may forge a path to impact through ‘enabling’ transformation approaches in which “individually smaller actions...over time...shift system states in ways which may be unexpected but which reflect the values and visions of mobilized agents” (Scoones et al., 2020). Further exploring, and finding ways to measure, these kinds of changes is an important area of future focus.

Beyond individual intentions, sectoral transformation knowledge was generated through the Three Horizons visioning activity, with two themes emerging: the importance of building networks to drive collective action for sustainability; and the imperative to decolonize development knowledge. When asked about future directions and actions following the visioning activity, participants shared their intentions to “connect with more networks”, “build even more than before strategic alliances”, “look for innovative partnerships”, “build more bridges” and “build solidarities”. One participant focused particularly on fostering collective action with young people, harnessing their local knowledge and making use of the connective potential of open-source technologies to co-develop strategies that address local sustainability concerns. The focus on building networks and solidarities suggests participant intent to further explore sustainability-WASH connections by moving towards collective action in their own contexts, in ways that strengthen their diverse individual intentions.

A second action theme identified through the Three Horizon discussions concerned the redressing of power imbalances in knowledge contributing to WASH sector priorities and plans. When reflecting on horizon three – trends taking us in the direction of our preferred future – participants highlighted that “decolonization debates [are] driving different voices in the conversations”. One participant reflected on the influence of established power structures in shaping decision-making:

Historical models...pertain not only to technology of centralized supply or centralized management of wastewater, but there are also historical models of power sharing. There are also historical models of decision-making processes, which obviously the people in power have interesting continuing status quo and any change in that.

Participants asserted the importance of valuing ‘community’

knowledge to address inequities, for example the “incorporation of traditional knowledge to ensure local communities have a greater voice”. Others spoke more generally about changes in education curricula stressing diversity of voices, and “a change in perception about knowledge and knowledge creation [such that] traditional knowledge from Global South will be central moving ahead”. The emergence of knowledge decolonization as a theme relevant to WASH-sustainability visions reflects wider sector discourse highlighting and challenging the dominance of Global North voices in shaping conversations (Worsham et al., 2021; Luseka, 2020; Kapur, 2020). As sustainability conversations continue across the sector, a power-reflexive approach will be essential to address critical questions about whose voices carry influence (discussed further in Section 3.4).

3.4. Researcher power and considerations for future co-production processes

In this final section we build on the action-theme of addressing WASH sector power imbalances by considering researcher power, and how researcher-reflexive approaches might inform future co-production activities. We reflexively acknowledge the extent of researcher influence over the WASH sustainability forums and discuss the tensions and trade-offs associated with alternative strategies. In doing so, we acknowledge the facilitator’s position of privilege as a high-income country researcher working within South-North research collaborations.

In these WASH sustainability forums, the lead researcher determined who to invite, the agenda, and how participation was managed. A targeted set of actors were invited – WASH professionals primarily from low- and middle-income countries with an interest in sustainability – to the exclusion of others. While the inclusion criteria were justified with reference to the aims and ethical considerations of the research, it is important to consider the extent to which this decision shaped the process. Equally, in framing the topic and using previous work as input knowledge for reflection, the facilitator scoped which sustainability and WASH issues (from a potential plethora) were given focus. While participant reflections and discussion could in theory have diverged to a wider set of issues, they tended to stay close to the topics on the agenda, reflecting the truism that ‘the questions you ask determine the answers you get’. This was the case despite the participants being professionals with capacity to critically challenge how discussions were framed.

Power is increasingly acknowledged as important in co-production (Wyborn et al., 2019; Norström et al., 2020; Schuttenberg and Guth, 2015; Chambers et al., 2021; Vincent et al., 2020). Yet to date, power has dominantly been conceived as something to be identified and ameliorated, such that imbalances do not lessen the quality of engagement and its outcomes (Norström et al., 2020; Vincent et al., 2020; Bréthaut et al., 2019). A more reflexive approach to power in transdisciplinary research has been advocated by Fritz and Binder (2020) who draw on theories of power as relational, and participation as constructed by societal contexts, to elucidate the ways in which power shapes transdisciplinary research. In this model three types of power are at play in transdisciplinary research: instrumental power in which one actor influences another; structural power, which describes the conditions (both material and structural) influencing actors’ decision-making; and discursive power in which subtle forms of influence – through values, norms and ideas (such as sustainability) – influence an agenda or process (Fritz and Binder, 2020). Researchers, funding bodies and practitioners exercise these three types of power in different ways, with researchers having substantial instrumental and discursive power in their choice of who to include, setting the agenda, and dictating the rules of engagement (Fritz and Binder, 2020).

For future co-production processes seeking sustainability transformations, recognition of the multiple ways in which researcher-facilitator power manifests demands reflexively sitting with, rather than trying to solve, power dynamics. In other words, it means challenging the tendency for researchers to consider themselves as neutral or

objective facilitators whose role is “identifying positions of power...and developing ameliorative strategies” (Norström et al., 2020). A researcher-reflexive approach is needed (Fritz and Binder, 2020) in which the aim is to recognize and be explicit about the profound ways in which researcher power shapes process, and in doing so to consider “the possibility of moving from power over to power with” (Bradbury and Divecha, 2020). This is particularly true for processes involving collaborations between Global South and Global North researchers and participants, which are shaped by historical and perpetuating power imbalances.

In seeking sectoral transformations for sustainability, a researcher-reflexive approach could pursue different strategies for co-production. One strategy is to cede researcher power in determining the agenda and mode of engagement within a process, taking a purposive approach but leaving space for participants to determine what is worthy of discussion and how those discussions should happen (though it is important to acknowledge that this initial process is in itself shaped by the researcher). An open, purposive approach is more likely to achieve a sought-after feature of co-production: the recognition and valuing of diverse knowledge types (Norström et al., 2020; Blythe et al., 2018) that researchers may not have allowed space for given assumptions they bring to the agenda and process design. This plurality is particularly important in the pursuit of sustainability transformations given a dominance of positivist epistemologies in environmental sustainability discourse (Blythe et al., 2018), a feature also characteristic of the WASH sector given the importance of engineering and public health disciplines in expanding WASH services.

A second strategy is one of open acknowledgement, rather than ceding, of researchers’ instrumental power. It is not always appropriate to redistribute or balance power, for example participants may not want the responsibility of shaping a process and taking on decision making roles (Turnhout et al., 2020), particularly if their participation is not remunerated or in situations where participation fatigue is a risk (Lemos et al., 2018). Yet power must be acknowledged and addressed if co-production is to fulfil its aim to contribute to sustainability transformations that do not inadvertently reinforce existing unequal power relations (Turnhout et al., 2020). For researchers, investing in the development of reflexive skills that enable responsiveness to positionality will support co-production processes in which friction can be productive, and relevance (and therefore impact) can be emergent (Klenk and Meehan, 2017).

3.5. Synthesis of findings and reflections on the value of short-form co-production

In this final section, we synthesize insights from previous themes with reference to the analysis frames that informed their development, namely Schneider et al.’s generic mechanisms of impact generation (Schneider et al., 2019), and Norström et al.’s principles for co-production in sustainability research (Norström et al., 2020). Reflecting on the cross-theme synthesis, we conclude by considering the limitations and value of short-form co-production processes when working in a sectoral context.

Exploring outcomes with reference to Schneider et al. (2019) theory of change for co-production identified ways in which the process generated (i) new knowledge, (ii) shared understandings and (iii) new competences – the direct activities and outcomes of co-production that can lead to impact. Systems and target knowledge were developed through cross-scale and cross-context discussions, as well as purposive reflections that prompted critical consideration of goals. The seeds of transformation knowledge were identified in visioning and action-oriented discussions, generating individual action-intentions and priority sectoral themes of knowledge decolonization and building solidarities for collective action. The focus on collective action arose from activities designed to build shared understandings of sector challenges and future possibilities, which emphasized joint learning and the need

for deliberation about values and how they drive actions. Finally, new experiences of self-reflection, in particular reflection about worldviews, provided an initial step towards development of reflective leadership skills, though building such experiences into competencies would require long-term personal development beyond a single co-production event.

Analyzing the process through the lens of principles for co-production in sustainability research (Norström et al., 2020) identified three considerations for the nuanced application of co-production ideals, particularly when working towards sectoral change. First, a goal-orientation can be enriched by an emphasis on purpose, such that goals are critically questioned and shared visions that transcend goals can emerge. Second, to complement the dominance of locally situated co-production examples, there is scope to consider how future co-production can work across scales and contexts to foster system-wide perspectives. Finally, a reflexive focus on researcher power is essential for co-production to engage meaningfully with the ways in which power shapes the plurality and interactivity of co-coproduction processes.

The short-form nature of the WASH co-production process was a limitation given the strong emphasis placed on long-term engagement in co-production scholarship, yet there was demonstrable richness in the conversations that suggests value in co-production even when long-term engagement is not feasible. Short-form engagement is certainly constrained in its capacity to achieve and demonstrate impact, and claiming impact from the WASH sustainability forums is unrealistic. Similarly, multiple points of interaction would be required to cement trusting relationships, bridge different levels of expertise across relevant concepts, and allow for iterative building of knowledge over time. Nevertheless, the data shows there was depth of engagement in the WASH forums that attests to the value of short-form co-production if well designed and facilitated, and the process generated potentially catalytic ideas for action. Three design features underpinned the richness of WASH forum discussions: working from values to connect with deep motivations for change; using engaging narratives to incorporate research insights and elicit reflections on their relevance for each participant; and including visioning to foster imagination about possible preferred futures and pathways that move us towards them. While longer-term engagement would strengthen WASH forum outcomes, findings demonstrate the value of well-designed co-production of shorter duration when timelines and funding models preclude more established approaches.

4. Conclusion

In the context of global environmental challenges, it is imperative to consider how different actors and groups can contribute to sustainability transformations. As a sector united by human rights ideals and shaped by resource management realities, the WASH sector is well-placed to contribute novel thinking and practices towards sustainable futures. Knowledge co-production – with its potential to both diversify and integrate knowledge and action – offers a mechanism for progressing WASH sustainability discourse, as the co-production case profiled in this article demonstrates. The co-production process, although short in duration, generated rich discussions that fostered self-awareness and connected deeply held values with sustainability imperatives and ideas for practical action. The process articulated priority themes for strengthening the sector's focus on sustainability: solidarity building for collective action; and knowledge decolonization. Progressing these themes through further engagement and action, including during future sector co-production processes, will be important.

The co-production experience also highlighted considerations for the nuanced application of co-production principles, particularly the opportunity to enrich a goal-orientation by emphasizing purpose, to explore how co-production can work across scales and contexts, and to strive for power-aware processes by strengthening and enacting researcher reflexivity. The findings of this analysis can inform future co-production activities, particularly those seeking to generate knowledge

and catalyze action in a sectoral context. The findings also show the value of short-form co-production when the ideal of longer-term engagement is not feasible. Well-designed processes can engage, inspire, and offer a strong foundation for further research and action.

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Appendix A. Supplementary data

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References

- Abson, D.J., Fischer, J., Leventon, J., Newig, J., Schomerus, T., Vilsmaier, U., von Wehrden, H., Abernethy, P., Ives, C.D., Jäger, N.W., et al., 2017. Leverage points for sustainability transformation. *Ambio* 46, 30–39.
- Arnott, J.C., Lemos, M.C., 2021. Understanding knowledge use for sustainability. *Environ. Sci. Pol.* 120, 222–230.
- Blythe, J., Silver, J., Evans, L., Armitage, D., Bennett, N.J., Moore, M.L., Morrison, T.H., Brown, K., 2018. The dark side of transformation: latent risks in contemporary sustainability discourse. *Antipode* 50, 1206–1223.
- Bradbury, H., Divecha, S., 2020. Action methods for faster transformation: relationality in action. *Action Res.* 18, 273–281.
- Bréthaut, C., Gallagher, L., Dalton, J., Allouche, J., 2019. Power dynamics and integration in the water-energy-food nexus: learning lessons for transdisciplinary research in Cambodia. *Environ. Sci. Pol.* 94, 153–162.
- Carrard, N., Willetts, J., 2017. Environmentally sustainable WASH? Current discourse, planetary boundaries and future directions. *J. Water Sanit. Hyg. Dev.* 7, 209–228.
- Carrard, N., Foster, T., Willetts, J., 2019. Groundwater as a source of drinking water in Southeast Asia and the Pacific: a multi-country review of current reliance and resource concerns. *Water (Switzerland)* 11.
- Carrard, N., Jayathilake, N., Willetts, J., 2021. Life-cycle costs of a resource-oriented sanitation system and implications for advancing a circular economy approach to sanitation. *J. Clean. Prod.* 307, 127135.
- Cerf, M.E., 2019. Sustainable development goal integration, interdependence, and implementation: the environment–economic–health nexus and universal health coverage. *Glob. Challenge.* 3, 1900021.
- Chambers, J.M., Wyborn, C., Ryan, M.E., Reid, R.S., Riechers, M., Serban, A., Bennett, N. J., Cvitanovic, C., Fernández-Giménez, M.E., Galvin, K.A., et al., 2021. Six modes of co-production for sustainability. *Nat. Sustain.* 49.
- Creswell, J.W., Miller, D.L., 2000. Determining validity in qualitative inquiry. *Theory Pract.* 39, 124–130.
- Cumming, O., Slaymaker, T., 2018. *Equality in Water and Sanitation Services*. Routledge.
- Fritz, L., Binder, C.R., 2020. Whose knowledge, whose values? An empirical analysis of power in transdisciplinary sustainability research. *Eur. J. Futur. Res.* 8.
- Hargrove, A., 2019. Global aid in the water sector: a descriptive analysis of international development effectiveness. *Int. J. Soc. Sci. Stud.* 7, 19.
- Hedlund-de Witt, A., 2012. Exploring worldviews and their relationships to sustainable lifestyles: towards a new conceptual and methodological approach. *Ecol. Econ.* 84, 74–83.
- Hedlund-de Witt, A., 2014. Rethinking sustainable development: considering how different worldviews envision “development” and “quality of life.”. *Sustain* 6, 8310–8328.
- Herrera, V., 2019. Reconciling global aspirations and local realities: challenges facing the sustainable development goals for water and sanitation. *World Dev.* 118, 106–117.
- Jagannathan, K., Arnott, J.C., Wyborn, C., Klenk, N., Mach, K.J., Moss, R.H., Sjöström, K. D., 2020. Great expectations? Reconciling the aspiration, outcome, and possibility of co-production. *Curr. Opin. Environ. Sustain.* 42, 22–29.
- Jantsch, E., 1970. Inter- and transdisciplinary university: a systems approach to education and innovation. *High. Educ.* 1, 403–428.
- Kapur, D., 2020. Decolonisation of WASH Knowledge: Addressing Institutional Bias. IRC WASH Blog. <https://www.ircwash.org/blog/decolonisation-wash-knowledge-addressing-institutional-bias>. accessed 27 September 2021.

- Klenk, N.L., Meehan, K., 2017. Transdisciplinary sustainability research beyond engagement models: toward adventures in relevance. *Environ. Sci. Pol.* 78, 27–35.
- Lemos, M.C., Arnott, J.C., Ardoin, N.M., Baja, K., Bednarek, A.T., Dewulf, A., Fieseler, C., Goodrich, K.A., Jagannathan, K., Klenk, N., et al., 2018. To co-produce or not to co-produce. *Nat. Sustain.* 1, 722–724.
- Linnér, B.-O., Wibeck, V., 2019. *Sustainability Transformations: Agents and Drivers across Societies*. Cambridge University Press.
- Luseka, E., 2020. Initiating de-colonisation of WASH sector knowledge. Medium. https://medium.com/@euphresia_luseka/initiating-de-colonization-of-wash-sector-knowledge-c8ad0a9f8d6 (accessed 27 September 2021).
- Mausser, W., Klepper, G., Rice, M., Schmalzbauer, B.S., Hackmann, H., Leemans, R., Moore, H., 2013. Transdisciplinary global change research: the co-creation of knowledge for sustainability. *Curr. Opin. Environ. Sustain.* 5, 420–431.
- Miller, C.A., Wyborn, C., 2020. Co-production in global sustainability: histories and theories. *Environ. Sci. Pol.* 113, 88–95.
- Moallemi, E.A., Malekpour, S., Hadjidakou, M., Raven, R., Szetey, K., Ningrum, D., Dhiaulhaq, A., Bryan, B.A., 2020. Achieving the sustainable development goals requires transdisciplinary innovation at the local scale. *One Earth* 3, 300–313.
- Nilsson, M., Griggs, D., Visbeck, M., 2016. Map the interactions between sustainable development goals. *Nature* 534, 320–322.
- Norström, A.V., Cvitanovic, C., Löf, M.F., West, S., Wyborn, C., Balvanera, P., Bednarek, A.T., Bennett, E.M., Biggs, R., de Bremond, A., et al., 2020. Principles for knowledge co-production in sustainability research. *Nat. Sustain.* 3.
- Oberlack, C., Brey, T., Giger, M., Harari, N., Herweg, K., Mathez-Stiefel, S.-L., Messerli, P., Moser, S., Ott, C., Providoli, I., et al., 2019. Theories of change in sustainability science: understanding how change happens. *Gaia* 28, 106–111.
- Oliver, K., Kothari, A., Mays, N., 2019. The dark side of coproduction: do the costs outweigh the benefits for health research? *Heal. Res. Policy Syst.* 17, 1–10.
- Pohl, C., Rist, S., Zimmermann, A., Fry, P., Gurrung, G.S., Schneider, F., Speranza, C.I., Kiteme, B., Boillat, S., Serrano, E., et al., 2010. Researchers' roles in knowledge co-production: experience from sustainability research in Kenya, Switzerland, Bolivia and Nepal. *Sci. Public Policy* 37, 267–281.
- Pohl, C., Klein, J.T., Hoffmann, S., Mitchell, C., Fam, D., 2021. Conceptualising transdisciplinary integration as a multidimensional interactive process. *Environ. Sci. Pol.* 118, 18–26.
- Raworth, K., 2017. A doughnut for the Anthropocene: humanity's compass in the 21st century. *Lancet Planet. Heal.* 1, e48–e49.
- Riechers, M., Henkel, W., Engbers, M., Fischer, J., 2019. Stories of favourite places in public spaces: emotional responses to landscape change. *Sustain* 11.
- Riechers, M., Balázs, Á., García-Llorente, M., Loos, J., 2021. Human-nature connectedness as leverage point. *Ecosyst. People* 17, 215–221.
- Riedy, C., 2021. Discursive entrepreneurship: ethical meaning-making as a transformative practice for sustainable futures. *Sustain. Sci.* <https://doi.org/10.1007/s11625-021-00978-z>.
- Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., et al., 2009. A safe operating space for humanity. *Nature* 461, 472–475.
- Schneider, F., Giger, M., Harari, N., Moser, S., Oberlack, C., Providoli, I., Schmid, L., Tribaldos, T., Zimmermann, A., 2019. Transdisciplinary co-production of knowledge and sustainability transformations: three generic mechanisms of impact generation. *Environ. Sci. Pol.* 102, 26–35.
- Schneider, F., Tribaldos, T., Adler, C., Biggs, R.O., De, Bremond A., Buser, T., Krug, C., Loutre, M., Paulavets, K., Moore, S., et al., 2021. Co-production of knowledge and sustainability transformations: a strategic compass for global research networks. <https://doi.org/10.1016/j.cosust.2021.04.007>.
- Schuttenberg, H.Z., Guth, H.K., 2015. Seeking our shared wisdom: a framework for understanding knowledge coproduction and coproductive capacities. *Ecol. Soc.* 20.
- Scoones, I., Stirling, A., Abrol, D., Atela, J., Charli-Joseph, L., Eakin, H., Ely, A., Olsson, P., Pereira, L., Priya, R., et al., 2020. Transformations to sustainability: combining structural, systemic and enabling approaches. *Curr. Opin. Environ. Sustain.* 42, 65–75.
- Sharpe, B., 2013. Three Horizons: The Patterning of Hope.
- Sharpe, B., Hodgson, A., Leicester, G., Lyon, A., Fazey, I., 2016. Three horizons: a pathways practice for transformation. *Ecol. Soc.* 21.
- Steffen, W., Richardson, K., Rockstrom, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., de Vries, W., de Wit, C.A., et al., 2015. Planetary boundaries: Guiding human development on a changing planet. *Science* (80-) 347, 1259855.
- Tortajada, C., Biswas, A.K., 2018. Achieving universal access to clean water and sanitation in an era of water scarcity: strengthening contributions from academia. *Curr. Opin. Environ. Sustain.* 34, 21–25.
- Turnhout, E., Metz, T., Wyborn, C., Klenk, N., Louder, E., 2020. The politics of co-production: participation, power, and transformation. *Curr. Opin. Environ. Sustain.* 42, 15–21.
- United Nations, 2010. General Assembly Resolution 64/292, UN doc. A/Res/64/292.
- United Nations, 2015. General Assembly Resolution 70/1, UN doc. A/Res/70/1.
- UN-Water, 2021. Summary Progress Update 2021 - SDG 6 - Water and Sanitation for All.
- Veland, S., Scoville-Simonds, M., Gram-Hanssen, I., Schorre, A.K., El Khoury, A., Nordbø, M.J., Lynch, A.H., Hochachka, G., Bjørkan, M., 2018. Narrative matters for sustainability: the transformative role of storytelling in realizing 1.5°C futures. *Curr. Opin. Environ. Sustain.* 31, 41–47.
- Vincent, K., Carter, S., Steynor, A., Visman, E., Wågsæther, K.L., 2020. Addressing power imbalances in co-production. *Nat. Clim. Chang.* 10, 877–878.
- Waddock, S., Waddell, S., Goldstein, B., Linner, B., Schöpke, N., Vogel, C., 2020. Transformation: How to spur radical change. In: *Our Future on Earth Report*. Edited by Scrutton A. Future Earth.
- West, S., van Kerkhoff, L., Wagenaar, H., 2019. Beyond “linking knowledge and action”: towards a practice-based approach to transdisciplinary sustainability interventions. *Policy Stud.* 40, 534–555.
- West, S., Haider, L.J., Stålhammar, S., Woroniecki, S., 2020. A relational turn for sustainability science? Relational thinking, leverage points and transformations. *Ecosyst. People* 16, 304–325.
- Workman, C.L., Cairns, M.R., De Los Reyes, F.L., Verbyla, M.E., 2021. Global water, sanitation, and hygiene approaches: anthropological contributions and future directions for engineering. *Environ. Eng. Sci.* 38, 402–417.
- Worldviews Test. <https://wvtest.com/> last accessed 06/01/2022.
- Worsham, K., Sylvester, R., Hales, G., McWilliams, K., Luseka, E., 2021. Leadership for SDG 6.2: is diversity missing? *Environ. Health Insights* 15.
- Wyborn, C., Datta, A., Montana, J., Ryan, M., Leith, P., Chaffin, B., Miller, C., Van Kerkhoff, L., 2019. Co-producing sustainability: reordering the governance of science, policy, and practice. *Annu. Rev. Environ. Resour.* 44, 319–346.