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SPECIAL ISSUE ARTICLE



Knowledge co-production and researcher roles in transdisciplinary environmental management projects

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Abstract

KEYWORDS

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1 | INTRODUCTION

Global climatic change and sustainable development goals demand fundamental, transformative change in various aspects of coupled humanenvironment systems (Diaz et al., 2019; Patterson et al., 2017). Scientists and scientific expertise are widely argued to play an important role in these sustainability transformations—not only by analyzing these change processes but also by actively shaping them (Cornell et al., 2013; Patterson et al., 2017; Schneidewind et al., 2016). This implies that researchers are increasingly challenged to work in

Calls for transformative change and participatory modes of knowledge production

demand researchers to assume new roles. This paper synthesizes the literature on

knowledge co-production and researcher roles to explore challenges for researchers

involved in transdisciplinary environmental management projects. Our research

methods combine a scoping review and reflections on personal experiences with

three transdisciplinary projects. To conceptualize researcher roles in transdisciplinary

knowledge co-production, we distinguish between three spaces: knowledge, formal

policy, and stakeholder. Knowledge co-production requires collaboration between

actors from different spaces and integration of diverse knowledge sources and types.

Depending on whether researchers adopt knowledge-oriented, change-oriented or

intermediating roles, they will experience different challenges. When researchers

combine knowledge development with change-oriented and/or intermediating roles,

they encounter new challenges, such as, maintaining independence or objectivity. To

assist researchers in transdisciplinary projects, we conclude with a checklist of four

elements to reflect upon: orientation, norms and values, expectations and resources.

environmental management, knowledge co-production, knowledge integration, researcher

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role, river management, transdisciplinary research

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transdisciplinary projects where researchers from different scientific disciplines co-produce knowledge with non-scientific stakeholders (Lang et al., 2012; Pohl et al., 2010). Consequently, next to conducting scientific research, researchers are increasingly asked to facilitate learning processes (Hansson & Polk, 2018) or to take positions in societal debates (Crouzat et al., 2018; Pielke, 2007; Pohl et al., 2010).

In recent years, the literature on both knowledge co-production and researcher roles has been burgeoning, especially in the domains of sustainability science and environmental studies. Various frameworks have been developed to guide researchers with the analysis or implementation of transdisciplinary projects that involve the integration of knowledge from science and societal stakeholders (cf. Edelenbos et al., 2011; Hegger et al., 2012; Lang et al., 2012; Norström et al., 2020; Raymond et al., 2010). Also, diverse typologies have been developed to characterize the different ways researchers can relate to decision-makers (Pielke, 2007), policy processes (Stoffels et al., 2018), knowledge co-production (Pohl et al., 2010) or transformative change processes (Fazev et al., 2018; Wittmaver & Schäpke, 2014). On the basis of systematic reviews of both literature streams, we conclude that transdisciplinary knowledge co-production and researcher roles are generally discussed separately from one another. As a result, our understanding of the knowledge co-production setting and the positions and roles of the researchers in such transdisciplinary projects remains limited (Lang et al., 2012; Rogga & Zscheischler, 2021).

We address this knowledge gap for the specific case of transdisciplinary environmental management projects (EMPs). In these projects, researchers co-produce knowledge with responsible governmental organizations and/or other stakeholders (cf. Lang et al., 2012) to keep the state of the environment within desirable boundaries (Pahl-Wostl, 2009). While researcher roles have been explored in the context of environmental management (cf. Crouzat et al., 2018), they have not been discussed in relation to transdisciplinary knowledge co-production. To better understand researcher roles in transdisciplinary EMP's, we assert that knowledge co-production occurs at the interface between the knowledge space, and one or both of the following spaces: the formal policy space where responsible governmental organizations make policies and political choices; and the stakeholder space where societal challenges are addressed with actors who have an interest in the challenge under concern. Our experience is that researchers working at the interfaces between these spaces are not only challenged to integrate knowledge from different scientific disciplines. They increasingly often also need to combine the production of (scientific) knowledge with more actionoriented roles for the design or facilitation of knowledge co-production processes. To support researchers who are involved in EMPs and wish to make informed decisions about their role and position in transdisciplinary research projects, we aim to: (1) conceptualize the knowledge coproduction setting; (2) synthesize insights about researcher roles and positions; and (3) identify key challenges and explore the implications for the researchers involved. We conclude with a checklist to guide researchers who deal with those challenges in transdisciplinary projects.

Our research methods combine a scoping review (Peters et al., 2015) with a reflection on the experiences of the authors in three transdisciplinary EMPs: the PlanSmart project (2016-2022) in Germany and two projects that were embedded in the RiverCare

program (2014-2019) in the Netherlands. Our discussions began as part of a collaborative two-day workshop in June 2018. As input for the workshop, we asked all participants to reflect upon how-in their own experience-researchers can promote or facilitate the coproduction of knowledge in transdisciplinary projects. We also asked to reflect upon the challenges, implications, trade-offs and benefits of adopting a specific role. During the workshop, we discussed contemporary scientific understandings of and our own experiences in transdisciplinary projects. We concluded that we had witnessed tensions and challenges that were hitherto not reflected in the literature that we were familiar with. To verify this finding, we agreed to further review and reflect on the roles of the researchers in EMPs from the lenses of our own projects. We divided ourselves in different working groups and created an online workspace to follow up the action points. One group conducted a scoping review of the literature on knowledge co-production and another group on the researcher roles. For these reviews, we focused on the seminal and most relevant publications. To identify these publications, we searched Scopus and Web of Science databases for publications about researcher roles and knowledge coproduction (cited 50 times or more). In addition, we applied snowball sampling. Following this approach, we identified and reviewed 47 publications that focus on transdisciplinary research, knowledge integration. knowledge co-production and 31 publications that focus on researcher roles (see Appendix). In parallel, we mapped the knowledge coproduction processes that occurred in our projects (i.e., what kind of stakeholders were involved, links to policy processes, types of interaction, joint outputs and outcomes, and available resources). After we reviewed the literature and mapped our cases, we organized another two-day workshop in November 2018. During this workshop, we discussed the results of the working groups and laid the basis for the conceptual framework that is presented in this paper.

The remainder of this paper is structured as follows. We first introduce the knowledge co-production setting of EMPs as well as some of the key associated challenges. Next, we synthesize existing typologies of researcher roles by distinguishing between three spaces (knowledge, formal policy and stakeholder) that researchers can position themselves in. We then introduce the transdisciplinary projects we reflect upon with a focus on the knowledge co-production setting. In section five, we identify and discuss knowledge co-production challenges that researchers in different roles are likely to experience and the ways in which we addressed these challenges in our own projects. We conclude with our main findings and a checklist as guidance for researchers to reflect and decide upon the suitability of a role.

KNOWLEDGE CO-PRODUCTION IN 2 TRANSDISCIPLINARY ENVIRONMENTAL MANAGEMENT PROJECTS

Key characteristics of environmental 2.1 management projects

Activities in EMPs typically vary from analyzing and monitoring an environmental system to developing and implementing measures

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(Pahl-Wostl, 2009). These activities are often embedded in projects aimed at achieving specific objectives by a certain date, for a certain amount of financial resources and with a temporary group of people (Koskinen et al., 2003). Objectives pursued in EMPs relate to reducing risks (e.g., flooding) and/or improving the management of environmental resources (e.g., biodiversity) at a specific location.

While governments have long been the key decision-makers in pursuing environmental management objectives, it is now widely acknowledged that policy decisions are influenced by a wide range of actors, including knowledge institutes, civil society and private actors (cf. Berkes, 2010; Bressers & Kuks, 2003). This shift is captured in the notion of governance, which refers to the idea that the formulation and implementation of environmental policies and/or management actions involve diverse individuals, organizations and networks (Bressers & Kuks, 2003; Pahl-Wostl, 2009). Thus, in addition to authorities who have a formal role in policy and decision-making processes, EMPs generally involve a wider variety of actors (e.g., researchers, interest groups, other public bodies) who all contribute to the creation of a knowledge base and therefore exert an influence on the policy process.

While governance without government is a common phenomenon in environmental management (Young, 2012), many EMPs are initiated by government organizations and embedded in established and formalized policy networks (cf. Pahl-Wostl, 2009; Parsons et al., 2017). For example, governmental organizations generally still play a dominant and controlling role in river and floodplain management (Fliervoet et al., 2016: Vinke-de Kruiif et al., 2015). Because of this institutional embedding, EMPs are generally oriented toward incremental improvement and maintaining the status quo (Pahl-Wostl. 2009). Yet. EMPs can also be led by stakeholders who do not have a formal role in the relevant policy domain, such as academic institutions, interest groups and private organizations. If this is the case, a transdisciplinary EMP takes place at the interface of the knowledge space and the stakeholder space without any formal connection to the formal policy space. Thus, such an EMP is embedded only in informal actor networks (see Table 1). Compared to government-led projects, informal processes typically develop in a bottom-up fashion and therefore provide better opportunities for exploring alternative approaches and system configurations. Hence, they are argued to play an important role in transformative change (cf. Loorbach, 2010; Pahl-Wostl et al., 2013). Yet, the impacts of

TABLE 1 Characteristics of informal and formal EMPs (adapted from Pahl-Wostl, 2009)

Formal EMPs	Informal EMPs
Embedded in or formally	Developed in bottom-up fashion;
connected to formal policy	no or loose connection to formal
processes; knowledge	policy processes; knowledge
production to inform policy	production to explore alternative
making; oriented toward	approaches and system
incremental improvement	configurations; oriented toward
and maintaining status quo;	transformative change.

Abbreviation: EMPs, environmental management projects.

informal networks on environmental policies and management may be limited (Pahl-Wostl, 2009; Pahl-Wostl et al., 2013). Unless there is coordination and feedback between informal EMPs and policy processes, decision-makers may not be aware of or ignore the outcomes of these projects (Edelenbos et al., 2008).

2.2 | Knowledge co-production in transdisciplinary projects

To develop a better understanding of knowledge co-production in transdisciplinary projects, we reviewed the literature on transdisciplinary research (Lang et al., 2012), knowledge co-production and related concepts in the context of sustainability and environmental management challenges, such as, knowledge integration (Raymond et al., 2010) or joint knowledge production (Edelenbos et al., 2011; Hegger et al., 2012). In these literature streams, two rather different interpretations of knowledge co-production stand out (Harvey et al., 2019): (1) knowledge co-production as an emergent process that challenges existing knowledge systems (cf. Jasanoff, 2004); and (2) knowledge co-production as a means to produce usable knowledge (cf. Dilling & Lemos, 2011). The first interpretation is rooted in sciencetechnology studies and stresses the social construction of scientific knowledge. The second interpretation is particularly relevant to EMPs where the production of knowledge, by definition, takes place against the background of a specific real-world challenge, such as a policy issue, problem at stake, or decision to be made (Harvey et al., 2019). In the literature, the latter interpretation is also referred to as "mode 2 knowledge production" (Gibbons, 1994) or "the co-production of knowledge in and for the context of application" (Pohl et al., 2010, p. 269). In the context of environment management, knowledge co-production in transdisciplinary projects is in our experience best understood as "a collaborative process of bringing a plurality of knowledge sources and types together" (Armitage et al., 2011, p. 996). This involves collaboration between (scientific) experts, representatives of government organizations and/or other societal stakeholders who can each provide different types of knowledge (Edelenbos et al., 2011; Hegger et al., 2012; Hommes et al., 2008). Here, we particularly focus on transdisciplinary EMP's in which researchers from different disciplines produce knowledge in close collaboration with responsible governmental organizations and/or other stakeholders.

In the literature, a wide range of arguments is provided in favor of using transdisciplinary knowledge co-production to effectively address environmental challenges (Norström et al., 2020). One commonly found argument is that diverse disciplines and actor groups hold essential knowledge and their integration is needed to develop a comprehensive knowledge base (Enengel et al., 2012; Lang et al., 2012) or to identify novel or innovative solutions (Johnson et al., 2018; Tengö et al., 2014). Another argument is that knowledge is situated and influenced by views and preferences (Brugnach & Ingram, 2012) which have to be reconciled (Lang et al., 2012). Moreover, co-production is expected to smoothen implementation since it improves stakeholder involvement and support, enhances legitimacy 396 WILEY – Sustainable Development

and creates ownership, both for the problem and solution options (Lang et al., 2012;Lemos & Morehouse, 2005; Schuttenberg & Guth, 2015). Lastly, co-production is more likely to create knowledge that benefits society (Enengel et al., 2012), influences decision-making (Lemos & Morehouse, 2005; Schuttenberg & Guth, 2015) or advances policy or practice (Cvitanovic et al., 2016).

While there are strong arguments in favor of transdisciplinary knowledge co-production, there are challenges and barriers to doing so. Alongside 12 design principles for successful co-production processes in transdisciplinary research, Lang et al. (2012) present 12 challenges, varying from discontinuous participation and lack of trust to conflicting methodological standards and lack of integration. Knowledge co-production processes can only take place when relationships and joint starting-points have been established. Even if this is the case, knowledge co-production may still be time-consuming and have high transaction costs for researchers, decision-makers and societal stakeholders (Harvey et al., 2019; Oliver et al., 2019). To better understand what these challenges imply for researchers involved in transdisciplinary EMP's, we propose to combine insights from the literature on transdisciplinary research and the literature on environmental management and governance. Inspired by the latter literature stream (see Table 1), we conceptualize transdisciplinary EMP's as settings that potentially bring together actors from three different spaces: (a) the knowledge space where researchers seek to produce scientific knowledge; (b) the formal policy space where responsible governmental organizations make policies and political choices; and/or (c) the stakeholder space where societal challenges are addressed in interaction between actors who have an interest in the challenge under concern. Examples of such actors in the stakeholder space are citizens, interest groups and representatives of governmental organizations who have an interest in but are not formally in charge of the policy domain under concern. From knowledge co-production literature, we know that the extent to which researchers (as actors in the knowledge space) co-produce knowledge with actors of the formal policy space and/or the stakeholder space is likely to vary not only across projects but also across different project phases (Enengel et al., 2012). In other words, depending on a projects' design and implementation, the three different spaces can be more or less overlapping, coupled or separate.

From the literature on transdisciplinary research, we know that for knowledge co-production to actually occur, it is essential that actors collaborate and interact at different points in time. The design and implementation of these interaction processes comes with-at least-two specific types of challenges. First, transdisciplinary knowledge co-production implies that actors from different spaces have to be brought together and engaged in collaborative working processes. Participation should go beyond the usual suspects. Moreover, processes should be organized and facilitated in such a way that participants remain interested and continue to contribute throughout the process (Lang et al., 2012). This requires finding the right forms of participation, addressing different power relationships, ensuring that different interests and thought styles are made transparent, and advocating the need for co-existence of different views (Pohl et al., 2010). Second, there are challenges related to the actual integration of different knowledge sources. To enable successful knowledge integration, actors need to be sufficiently aware of the problem under study and should be willing to leave their comfort zone to engage in a joint problem framing process (Bergmann & Jahn, 2008). Once actors involved agree upon a shared problem definition and project scope, there may still be a need for mediating between actors with conflicting methodological standards (Lang et al., 2012) and for keeping an eye on subjective and normative aspects that affect, for example, how boundaries are drawn (Leach et al., 2010; Pohl et al., 2010). In the next sections, we further reflect on the role of researchers in dealing with these knowledge coproduction challenges and on how challenges played out in our own transdisciplinary projects.

SYNTHESIS OF THE LITERATURE ON 3 **RESEARCHER ROLES**

A wide range of typologies has emerged to classify the roles that researchers can take on in diverse projects. Based on our scoping review, we conclude that existing studies either focus on: (1) knowledge production and the interface between the scientific knowledge space and formal policy space; or (2) knowledge co-production and the interface between the scientific knowledge space and the stakeholder space. Both perspectives provide insights that are relevant to understanding researcher roles in transdisciplinary projects. In this section, we therefore synthesize the most relevant insights and typologies about researcher roles along these two perspectives.

3.1 Knowledge production and the science-policy interface

Various scholars have developed typologies to describe the different ways in which researchers can relate to government-led policy and decision-making processes. Basically, a researcher can either assume a role inside or outside the formal policy space. When a researcher is positioned inside the formal policy space where policies and political choices are made, a researcher can act as stakeholder or advocate of certain solutions but with "science-led values, expectations and interpretations" (Parsons et al., 2017, p. D). Alternatively, a researcher is positioned outside of the formal policy space in the roles of independent knowledge provider or scientific advisor (Parsons et al., 2017).

These two positions resonate with the widely cited typology of researcher roles developed by Pielke (2007), who describes different ways in which researchers can interact with and relate to decisionmakers. In his typology, he distinguishes between researchers that are: (1) rather disconnected from politics and decision-making (pure scientist); (2) giving advice to decision-makers, for example, in the role of an expert advisory committee (science arbiter); (3) contributing to societal debates (issue advocate); or (4) clarifying the scope for actions (honest broker of policy alternatives). In addition, he introduces (5) the stealth issue advocate whose main interest is increasing knowledge and claims to be disconnected from decision-making. Crouzat et al. (2018) further developed and expanded this typology to assist

researchers who work in the domain of ecosystem services. They added one more role: (6) the *officer* who seeks to use environmental science within policy processes. What both typologies have in common is their focus on the science-policy interface, that is, they only discuss how researchers relate to the spaces where (scientific) knowledge is produced and where governmental decisions and formal policies are prepared and made.

3.2 | Knowledge co-production and the science-society interface

One of the shortcomings of the above-presented typologies is that they assume limited interactions between researchers, policymakers and other societal stakeholders. In response to Pielke's typology, Turnhout et al. (2013) argue that, "even the role of the [honest] broker, which includes the most interaction with knowledge users, is still fairly distant, offering different knowledge-based alternatives to knowledge users, without actively engaging them in the production of these alternatives or in contributing to the solution of problems" (p. 355). The above-presented view on knowledge production (i.e., scientific knowledge is produced at a distance from society and societal actors) is therefore sometimes associated with knowledge-first approaches. These approaches are then contrasted with process-oriented approaches, that is, participatory forms of knowledge production with researchers co-producing knowledge with societal stakeholders or facilitating knowledge co-production processes (Miller, 2013; Wittmayer & Schäpke, 2014) within the context of formal policy processes or informal networks.

In recent years, various typologies of researcher roles were developed around process-oriented approaches (Fazey et al., 2018; Pohl et al., 2010; Turnhout et al., 2013; Wittmayer & Schäpke, 2014). A common starting-point of these typologies is a study by Pohl et al. (2010) that explored researcher roles in relation to the need of addressing power relations, integrating different perspectives ("thought styles") and enhancing communication in knowledge co-production processes. Based on a comparative study, they identified the following three roles: (1) the reflective scientist who provides scientific knowledge but is also aware of power relations; (2) the intermediary who clarifies and synthesizes perspectives that are shared by different groups; and (3) the (process) facilitator who enhances communication. Turnhout et al. (2013) group the intermediating and facilitating role and refer to this as the role of the knowledge broker. Knowledge brokers may supply knowledge users with relevant expertise, help to bridge the gap between knowledge users and producers, or facilitate the integration of knowledge production and use to create concrete solutions. Wittmayer and Schäpke (2014) elaborated the typology of Pohl et al. (2010) with a focus on sustainability-oriented projects in which researchers can take on an active role in creating and maintaining spaces for societal learning. In addition to power and sustainability, they see ownership, action and reflexivity as important aspects of action-oriented research. These aspects come with additional roles: (4) the change agent who seeks to motivate and empower

participants with the aim of addressing real-world problems; and (5) the *self-reflexive scientist* who engages in reflexive practices about one's own normative orientation and power dynamics. Two additional roles were added by Fazey et al. (2018): (6) the *expert in learning* who assists practitioners or citizen scientists to become better learners and (7) the *reflexive facilitator* who encourages reflexive practices of others by acting as critical friends or sparring partners. What all these roles have in common is that they assume researchers to be increasingly engaged in the co-production of knowledge.

3.3 | Synthesis of existing researcher role typologies

The presented typologies provide complementary insights into the role and position of researchers in transdisciplinary projects. On the one hand, we have seen the emergence of typologies that deal with the science-policy interface and focus on how researchers relate to decision-making and the formal policy space (Crouzat et al., 2018; Pielke, 2007). On the other hand, process-oriented typologies that center on how researchers relate to societal processes emerged (Fazey et al., 2018; Pohl et al., 2010; Turnhout et al., 2013; Wittmayer & Schäpke, 2014). To synthesize the presented typologies, Figure 1 visualizes how researchers can be positioned-at least in theory-in relation to the three spaces that are potentially relevant in transdisciplinary EMPs: (1) the (scientific) knowledge space; (2) the formal policy space; and (3) the stakeholder space. When linking these spaces to the presented typologies, we observe that typologies that focus on the science-policy interface assert that researchers can either stay away from societal norms and values (position A), provide input for the formal policy space (position B) or deliberately engage with and seek to influence the formal policy space (position C). Typologies that focus on the science-society interface assert that researchers focus on producing knowledge while still being connected to society (position D), combine knowledge production with facilitating reflection or change (position E) or focus on synthesizing, integrating and mediating diverse knowledge sources and perspectives (position F).

4 | TRANSDISCIPLINARY APPROACHES OF THE SELECTED PROJECTS

This section provides an introduction to the research projects that we reflect upon in this paper. Specific attention is given to how actors of different spaces were brought together, what role they played in formulating the project scope and the process of knowledge integration.

4.1 | PlanSmart project

Central in the transdisciplinary research project PlanSmart (www. plansmart.info) are the planning and governance of nature-based



FIGURE 1 Illustration of the formal policy, stakeholder and knowledge spaces in environmental management projects, and the relative position (points A to F) of a researcher as described in selected literature (Crouzat et al., 2018; Fazey et al., 2018; Pielke, 2007; Pohl et al., 2010; Turnhout et al., 2013; Wittmayer & Schäpke, 2014). Note that the positions are indications of how a researcher may be positioned at a certain point in time; they are not absolute positions of such roles in reality [Colour figure can be viewed at wileyonlinelibrary.com]

Knowledge space

solutions in river landscape management systems, including studies of potential ecological, economic and social effects. In PlanSmart, researchers cooperate with the integrated EU-LIFE project LiLa (Living Lahn). LiLa aims to develop a long-term strategy for sustainable development of the Lahn river landscape in Hesse and Rhineland-Palatinate, Germany. The LiLa consortium includes representatives of institutions from different governance levels (from state to regional level) and different sectors (science, water management, administration). Coordination between both projects (PlanSmart and LiLa) started before the projects began. After both projects started, PlanSmart researchers came up with suggestions how to organize workshops and other collaboration and knowledge integration processes. The actual organization of the process was negotiated during steering committee meetings of the LiLa project.

Stealth issue advocate

Transdisciplinary cooperation between LiLa and PlanSmart took place in a so-called LahnLab, consisting of a series of five workshops in which diverse participatory methods were used to facilitate knowledge co-production (Albert et al., 2019; Albert et al., 2020). The workshops were change-oriented in the sense that they were meant to provide a space for discussing creative and strategic scenarios for development of the river landscape and exploring extraordinary ideas (Albert et al., 2020). Participants developed a shared understanding and methods for planning and implementing nature-based solutions in river landscapes. PlanSmart researchers tested the methods with the LiLa project partners who enriched them with their local and sector related expert knowledge. The periodical LahnLab workshops and other activities (e.g., interviews, joint conferences and meetings) secured continuous collaboration between actors involved over a period of 5 years.

PlanSmart particularly integrated knowledge from researchers and representatives of actors in the formal policy space, such as, the Environmental Ministries (federal state level) and regional administrative agencies. Other societal stakeholders (such as, interest organizations, municipalities and land owners) did not participate in the workshop series. Their knowledge was integrated indirectly. First, via the governmental actors involved, who had many ongoing interactions with relevant societal stakeholders. Moreover, researchers conducted two short surveys among local stakeholders to investigate placeattachment and the use of ecosystem services along the river.

Self-reflexive scientist

4.2 | Projects in the RiverCare program

The two other projects we reflect upon were part of the recently completed RiverCare program (www.rivercare.nl). The program assessed the effects in the river dynamics, morphology and ecology of newly applied river management interventions to create more space for water in the Netherlands (e.g., side channels and longitudinal training dams). Projects also proposed collaboration approaches and communication tools to support river management (Hulscher et al., 2014). The RiverCare program was initiated by researchers from diverse disciplines of five Dutch universities. The research questions were shaped with more than 20 governmental organizations, other research institutes and consultancies. Thematic projects and user committees were set up to facilitate collaboration and knowledge co-production between researchers and representatives of the formal policy space and the stakeholder space.

4.3 | WaalSamen

The basis for WaalSamen was established in 2011 when the national water authority (Rijkswaterstaat) invited researchers and societal stakeholders to co-design a monitoring plan to evaluate the hydrological, ecological and socio-economic effects of a novel construction (longitudinal training dams) in the river Waal. As part of the user committees of the RiverCare program, Rijkswaterstaat, two interest organizations (for shipping and recreational angling), four universities, and one consultancy signed a partnership for the adaptive management and collaborative monitoring of the longitudinal training dams (Verbrugge et al., 2017). Knowledge co-production aimed to provide a basis for short-term decisions on monitoring and safety issues as well

as evaluation of the large-scale dam experiment. What were the effects of the dams on river processes and the biophysical environment? How to improve the design of the dam? And how could these dams improve the quality of living, working and recreating in the river landscape? The core group of WaalSamen collaborators consisted of representatives of all three spaces (scientific knowledge, formal policy and stakeholder). The WaalSamen group met twice a year to discuss monitoring results and to collectively decide upon changes or additional measurements. In addition, thematic working groups were formed for ecological monitoring, technical design and nautical safety. The researchers involved all operated at the interface of different spaces. However, whereas some researchers primarily focused on coproducing relevant knowledge, others also had a role in facilitating and evaluating co-production processes. One researcher, for example, initiated a citizen science project that helped integrating local knowledge of recreational anglers and boaters into the ecological and safety monitoring.

4.4 | Knowledge communication

To communicate the scientific knowledge developed in the RiverCare program, researchers together with governmental agency Rijkswaterstaat and several hydraulic engineering consultancies decided to develop a serious game and an online knowledge base. For the co-design of the serious game "Virtual River" and the knowledge base, researchers engaged additional actors of both the formal policy space and the stakeholder space via interviews and workshops. Inputs from these actors were used to identify the challenges for integrated river basin management that the serious game could address (den Haan et al., 2019) as well as the potential usefulness of online storylines to communicate river research (Cortes Arevalo et al., 2019). The resulting serious game and online knowledge base were designed to intermediate between different spaces. The virtual river is a participatory environment that uses a physical board as interface to computer models. By interacting with the physical board, players-regardless of background and expertise-can collaboratively explore river interventions while the computational models provide feedback on the impact of players' actions into the costs, biodiversity and flood safety indicators (den Haan et al., 2020). An important element of the online knowledge base are storylines that translate research results in an interactive way for actors in the formal policy space and the stakeholder space (Cortes Arevalo et al., 2020).

5 | RETHINKING RESEARCHER ROLES IN TRANSDISCIPLINARY PROJECTS

This section introduces and discusses three orientations that researchers may have. After introducing the knowledge-oriented, change-oriented and intermediating roles, we elaborate each of these orientations while reflecting upon our own experiences. We end the section with a reflection on cross-cutting challenges for knowledge co-production and researchers involved in transdisciplinary EMPs.

5.1 | Researcher orientations in knowledge co-production settings

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While most researchers are trained to fulfill knowledge-oriented roles, researchers who engage in transdisciplinary projects-such as RiverCare and PlanSmart-often want to, or even need to, play a more active role in the co-production of knowledge. Existing researcher role typologies (Section 3) fail to provide a comprehensive picture of the challenges that researchers may experience in transdisciplinary EMPs since they either neglect the stakeholder space or the formal policy space. In response to this shortcoming, this section links the roles that researchers can take on-intentionally or unintentionally-to knowledge co-production challenges. In doing so, we distinguish between three overarching orientations: (1) the knowledge-oriented researcher who primarily seeks to improve the scientific understanding of (natural and/or social) phenomena but is aware of the formal policy space and/or the stakeholder space; (2) the change-oriented researcher who seeks to produce scientific knowledge and promotes societal change by influencing the formal policy space and/or the stakeholder space; and (3) the intermediating researcher who seeks to combine the production of scientific knowledge with integrating multiple knowledge sources and types. Figure 2 visualizes how researchers with a certain orientation (knowledge, change or intermediating oriented) can take positions in the scientific knowledge space and at the same time be in or interact with the formal policy space and/or the stakeholder space. While the positions and orientations are presented here as singular and stable, the researcher roles are much more dynamic over time. In reality, researchers change positions and/or adopt multiple positions at the same time.

5.2 | The "knowledge-oriented" researcher (orientation 1)

The knowledge-oriented researcher is the role that scientists are probably most familiar with. In its purest form, this role describes



FIGURE 2 Positions of knowledge-oriented (number 1), changeoriented (number 2, arrow represents the change-seeking nature), or intermediating researchers (number 3) in the knowledge space and their relations to the decision space and/or the stakeholder space, which can be connected or disconnected from each other [Colour figure can be viewed at wileyonlinelibrary.com] WILEY-Sustainable Development

researchers who are only concerned with the production of (fundamental) knowledge. Interactions with the formal policy space and/or the stakeholder space are limited (Turnhout et al., 2013) and considered problematic since it reduces independence and objectivity (Crouzat et al., 2018).

According to Pielke (2007), who introduced the pure scientist, this role hardly exists in the real world where funding comes with expectations of impact and relevance. In our experience, the role of pure scientist is particularly difficult to maintain in transdisciplinary EMPs where the timing and framing of scientific outputs is likely to be influenced by collaborative processes. In PlanSmart, for example, even researchers who were primarily interested in generating fundamental knowledge (e.g., about the effects of nature-based solutions on ecosystem services) deliberated with local actors to enhance the contextspecific quality of their results by integrating local stakeholder knowledge and experience. Also in WaalSamen, several researchers were primarily interested in producing fundamental knowledge, for example, about how river interventions affect river morphology and ecology. Yet, also in this project, the production of this knowledge required the integration and combination of knowledge from different disciplines as well as interactions with other actors. The WaalSamen monitoring program, for example, was clearly influenced by the organizations that were in the user committees as well as the members of angling associations who contributed to the monitoring of fish populations by reporting sightings. We also observed that researchers were aware that their results would be used by policymakers. Research played an important role in the evaluation of river interventions, subsequent decisions for adaptive management as well as in decisions about the implementation of similar interventions in the Netherlands. Researchers took the potential influence of results into account, for example, by selectively presenting results for biodiversity indicators to decision-makers or societal stakeholders.

The presented examples underline that researchers in transdisciplinary EMPs are unlikely to produce knowledge without interacting or being influenced by one of the other spaces. While knowledge-oriented researchers are likely to avoid an active role in the design or facilitation of collaborative processes, they are still likely to be confronted with knowledge integration challenges. This implies that even knowledgeoriented researchers should reflect upon the way in which knowledge is produced and on their own role and power in shaping the process and knowledge outputs (Wittmayer & Schäpke, 2014). In the role of reflective or self-reflexive researcher, they can seek to provide scientific expertise that is validated as objective or intersubjective (Pohl et al., 2010) while staying in an observing role (Wittmayer & Schäpke, 2014). In doing so, researchers should be aware that other actors may frame seemingly objective elements, such as boundaries, key elements or outputs of a system, differently (Leach et al., 2010). An example of how researchers dealt with this in the WaalSamen project is that researchers considered the results of different monitoring methods and experimental set-ups to create a knowledge base. In the PlanSmart project, one social scientist was explicitly asked to take on a reflective role. During workshops, this researcher had an observing role and examined how interactions contributed to knowledge co-production.

5.3 | The "change-oriented" researcher (orientation 2)

The change-oriented researcher, that is, the researcher as intervener, plays a central role in action-oriented, solutions oriented or transformation-oriented research (Fazey et al., 2018; Wittmayer & Schäpke, 2014). Wittmayer and Schäpke (2014) explain that researchers with this orientation do not only initiate and facilitate experiments or learning processes, but also take on a proactive role in addressing real-world problems. In the role of change agent, a researcher can initiate and participate in change processes or support societal stakeholders in achieving change by motivating and empowering them (Wittmayer & Schäpke, 2014). Researchers who are change-oriented may also seek to influence change processes, for example, by selecting participants (e.g., in the role of process facilitator) (Wittmayer & Schäpke, 2014), stimulating reflexive practices of others (e.g., in the role of reflexive facilitator or expert in learning; Fazey et al., 2018) or making a case for a specific solution (e.g., in the role of issue advocate: Pielke, 2007).

When researchers in transdisciplinary EMPs adopt-consciously or unconsciously-a proactive role in addressing real-world problems, they inherently also take on an active role in the management of participatory process. Yet, combining the role of knowledge producer and change agent comes with challenges. One of them is that participants may question the credibility and legitimacy of the researchers and their research results. This might especially happen when researchers implicitly promote a specific solution (Hegger et al., 2012). In PlanSmart, the research team realized during workshop preparations that they should not put too much focus on the term "naturebased solutions." This term is not commonly used in Germany and may give the impression that the researchers involved only advocate the interests of nature. Hence, to avoid misunderstandings, the team decided to rephrase the project focus. Instead of focusing on the question of how to promote nature-based solutions, they adopted a more open frame-and a broader solution space-around options and scenarios for the future development of the river landscape. In this way, a nature-based solution vision was only one of several alternatives to be discussed. Being reflexive and clear about one's role, especially in a change-oriented role, is of critical importance (Hegger et al., 2012; Wittmayer & Schäpke, 2014).

Another challenge that change-oriented researchers are likely to experience is their own limits to change. In WaalSamen, several researchers became more "embedded" in government agencies as they regularly worked at these agencies. Because of their embeddedness, they were better positioned to identify concrete opportunities to structurally improve, for example, the WaalSamen monitoring or project management. Yet, they also learned over time that actually bringing structural organizational change is beyond the scope of their research projects as well as their scale of influence. Another challenge that was experienced by WaalSamen researchers is related to the continuation of newly established informal collaboration processes, for example, via the citizen science initiative. Trust between the partner organizations and long-term and direct relationships between people played an important role in the longterm success of the WaalSamen partnership (Verbrugge et al., 2017). Yet, researchers involved in WaalSamen also witnessed that support for these informal collaboration processes decreased significantly after the RiverCare program ended despite efforts of the researcher to give guidance and distribute these tasks among others involved. These two examples draw attention to the fact that transformative change processes take time and may not fit within the scope of a research project. This has implications for researchers who adopt change-oriented roles and, for example, bring together new actor groups. In doing so, they might raise expectations on the side of participants, perhaps so that participants are willing to invest time and effort. Yet, these high hopes may turn into disappointment when a project ends and informal learning is not taken up in formal policy processes (Van Stokkom, 2005). The researchers involved in Waalsamen realized, for example, that researchers who design and implement participatory processes need to think beyond project timelines and identify conditions and ways of working that enable and support longterm cooperation in order to ensure continuity.

5.4 | The "intermediating researcher" (orientation 3)

To allow for successful knowledge co-production, researchers who mediate and bridge within and between different spaces are essential. This orientation is referred to as *knowledge broker* or *intermediary* role (Fazey et al., 2018; Pohl et al., 2010; Turnhout et al., 2013; Wittmayer & Schäpke, 2014). A researcher in this role focuses on the process; on mediating between different perspectives (Pohl et al., 2010; Wittmayer & Schäpke, 2014), bridging between different disciplines or knowledge types, communication and networking, and so on (Turnhout et al., 2013).

In our experience, transdisciplinary EMPs require every researcher to-at least partly-take on an intermediating role, that is, to achieve the desired project aims and outcomes each team member has to communicate and bridge different disciplines and knowledge types. In addition, an intermediary role is often required when the scientific knowledge space meets the formal policy space, for example, when research results are presented to decision-makers. All researchers working in transdisciplinary EMPs are-at least to some extent-challenged to take on timeconsuming tasks that they are not necessarily trained for. Yet, researchers are not always the best candidates to take on an intermediating role. On the basis of their experiences with previous transdisciplinary projects, the PlanSmart team, for example, decided to hire an external professional facilitator to moderate the LahnLab workshop series that were organized to facilitate interactions between researchers and actors of the formal policy space. This approach allowed researchers to remain more independent and to focus on providing scientific insights into the joint knowledge co-production process.

In the RiverCare program, a rather different approach was opted for. In the knowledge communication project, two researchers were explicitly asked to take on intermediating roles. In these roles, they had Sustainable Development 🐭 🚁 – WILEY

to address challenges such as: (1) making domain-specific expert knowledge accessible and transparent to actors of the formal policy and stakeholder spaces; (2) deciding upon which knowledge types and sources to include; and (3) considering all potentially relevant communication tools. One researcher was tasked with the development of a serious game while another researcher had develop an online knowledge base. For both researchers, how to best intermediate between different actors eventually became a research question in itself. For example, for the online knowledge base, the usefulness and effectiveness of storylines for practice was explored. One of the findings was that to be useful, such storylines should be co-created, as much as possible, with representatives of the intended audience (i.e., professionals coordinating the implementation of EMPs: Cortes Arevalo et al., 2020). The development of the serious game started out with a wide range of stakeholder interviews. These interviews made the researchers involved realize that non-experts do not understand hydrodynamic models and perceive them as black boxes. In the design process, the researchers therefore focused on questions related to how to actually integrate advanced models into a low-threshold, easy-to-use interface that enables a wide group of players-regardless of background, expertise or position in spaces-to collaboratively explore river interventions (den Haan et al., 2020). These examples show that one way of being a productive researcher while taking on an intermediating role is to further develop our scientific understanding intermediating processes. approaches and methods.

While the above examples show that researchers can combine intermediating roles with knowledge-oriented roles, this combination can be challenging. First, while intermediating roles and tasks are unavoidable in transdisciplinary projects, they can also be time-consuming, leaving researchers with insufficient time for producing (other types of) scientific knowledge (Turnhout et al., 2013). PlanSmart researchers indeed perceived the integration of knowledge as an indispensable but time-consuming add-on to their own personal, more discipline-oriented, knowledge production aims. Secondly, as researchers are generally trained to be a reflective scientist, they do not necessarily possess the skills to facilitate knowledge co-production processes (Wittmayer & Schäpke, 2014) unless they can fall back on, for example, competences they acquired when working as practitioner (Pohl et al., 2010). Thirdly, persons in an intermediary role have to carefully consider whether societal stakeholders are given the opportunity to participate or just consulted (Mobjörk, 2010) as well as whose knowledge is actually being used and privileged (Raymond et al., 2010). When they fail to do so, knowledge integration may further entrench unequal power relations (Bohensky & Maru, 2011). Therefore, when researchers take on an intermediating role, being reflexive of power relations and dynamics is of paramount importance (Pohl et al., 2010; Wittmayer & Schäpke, 2014). In the RiverCare knowledge communication project, interactions with societal stakeholders made the researchers involved realize that making knowledge accessible to a wide range of stakeholders can play an important role in addressing unequal power relations. The storylines and the serious game that were developed therefore really focused on providing non-experts with a better understanding of research results and modeling outputs. In addition, the virtual river was eventually

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developed in such a way that diverse stakeholders could-regardless of their prior knowledge and expertise-collaboratively explore river interventions.

5.5 Cross-cutting challenges for researchers and knowledge co-production

Knowledge co-production is an integral part of transdisciplinary projects (cf. Enengel et al., 2012; Lang et al., 2012). They require collaboration of actors from different spaces, which comes with challenges for any researcher involved. While knowledge-oriented researchers can often stay away from initiating and organizing collaborative processes, they are-just like change-oriented or intermediating researchersalways confronted with knowledge integration challenges. The EMP's we reflect upon all share a key feature of sustainability-oriented projects: they incorporate all kind of subjective and normative elements (cf. Leach et al., 2010; Wittmaver & Schäpke, 2014). This implies that regardless of the role you opt for as a researcher, you may need to leave your comfort zone to engage in joint problem framing processes (Bergmann & Jahn, 2008). As the PlanSmart experiences show, these processes may involve compromises.

Given the need for knowledge integration, researchers can never completely avoid intermediating roles in transdisciplinary projects. Yet, as intermediating roles are time-consuming (Turnhout et al., 2013) and require specific skills (Wittmayer & Schäpke, 2014), PlanSmart researchers decided to leave process facilitation to an external process facilitator. In contrast to this, RiverCare researchers who were tasked to develop tools decided to invest in co-creating these tools with relevant stakeholders. For these researchers, how to intermediate between different actors became a task and a research topic of its own. Thus, while intermediating roles are highly important for successful knowledge co-production, researchers can opt for more or less intense intermediating roles.

Researchers who adopt change-oriented or intermediating roles are likely to encounter additional knowledge co-production challenges that are related to bringing together and engaging all relevant actors over a longer period of time (Lang et al., 2012). For example, a researcher may wish to guide knowledge co-production toward desired norms of sustainable development or may realize that the collaborative process does not address power relations (Pohl et al., 2010). In our experience, steering a project in the right direction can be a complicated task since the researchers who carry out most of the actual research often become involved only after a project has been granted. Yet, projects take place in a specific context and history. They are often embedded in existing networks or partnerships and important choices about the project scope (e.g., whom to involve, what solutions to consider or budget for facilitation or stakeholder involvement) are often made during the design phase. As a result, researchers may find themselves in a position where they have to actively lobby for incorporating new actors or lack the means or skills to organize a process in the best possible way. Depending on the circumstances, these challenges can be dealt with in different ways.

Regardless of their role, researchers should be critically aware of these challenges and be reflective and self-reflexive, both of their own position and role as well as knowledge co-production dynamics (Pohl et al., 2010; Wittmayer & Schäpke, 2014).

The presented roles and orientations are rather stereotypical and ideal-type. In real-life projects, a researcher does not necessarily take on and keep a specific orientation and role. In fact, orientations and roles are likely to change and researchers can have multiple orientations and roles at the same time. For example, in PlanSmart most of the researchers switched between knowledge-oriented (e.g., conducting a literature review) and intermediating roles (e.g., preparing and facilitating the LahnLab workshops). As researchers in transdisciplinary EMPs, such changeovers tend to happen unconsciously. This is problematic when a researcher-unintentionally-becomes an advocate of a specific solution, that is, scientific understanding and advocacy are mixed (Hegger et al., 2012) or when a change-oriented or intermediating role comes at the cost of independence, credibility and scientific guality (Boezeman & de Coninck. 2018: Turnhout et al., 2013). Yet, in the experience of Pohl et al. (2010), shifting from a knowledge-oriented to a facilitating role does not need to be problematic as long as participants also value nonscientific knowledge or researchers limit their facilitating role. What is key here is that researchers are aware and open about the way in which knowledge is produced and communicated to the various knowledge users (Miller & Wyborn, 2018). When researchers are more aware of their own-often divided-identity, role and position, they can pursue their goals more consciously and purposefully (Pohl et al., 2010).

While shifting roles does not need to be problematic, it can be when researchers lack the personal competences and skills to fulfill certain roles. What is important to note here is that knowledge coproduction generally requires a wide variety of skills and competences. In some cases, these roles can be fulfilled by one person yet, oftentimes, they will be hard to mix in a single person. Therefore, it may be better to approach a colleague or to divide roles across a team (Boezeman & de Coninck, 2018; Wittmayer & Schäpke, 2014).

CONCLUSION AND 6 RECOMMENDATIONS

Over the past decades, we have seen growing recognition of the need for transdisciplinary research approaches in which researchers co-produce knowledge with societal actors. In this paper, we reflect upon the literature and our own experiences with three transdisciplinary EMPs, to draw attention to the knowledge co-production challenges that transdisciplinary projects may bring, particularly for the researchers involved.

Our first objective was to conceptualize the knowledge coproduction setting of transdisciplinary EMPs. Inspired by the literature on environmental management and governance, we argue that these EMPs potentially bring together actors from the knowledge space, the formal policy space and/or the stakeholder space. Depending on the design and implementation of a project, these spaces can be more or less overlapping, coupled or separated. Yet, to actually co-produce knowledge, it is essential that actors collaborate and interact at different points in time. This comes with challenges that are associated with bringing together actors from different spaces and engaging them in collaborative working processes. It also comes with challenges associated with the actual integration of knowledge.

Our second objective was to synthesize the rich but fragmented literature on researcher roles in EMPs. While one literature stream focuses almost exclusively on knowledge production and the sciencepolicy interface, another literature stream concentrates on knowledge co-production and the science-society interface. As a result, both literature streams provide complementary insights with regard to how researchers can be positioned in transdisciplinary projects. Yet, existing typologies of researcher roles either neglect the need for academic actors to co-produce knowledge with non-researchers or fail to explicitly acknowledge the need for creating a connection between a knowledge co-production process and formal policy and decisionmaking. Yet, only if such a connection exists can knowledge coproduction actually influence policies and practices and thereby contribute to reducing environmental management problems.

Our third objective was to identify and explore key challenges for researchers who seek to combine the development of knowledge with more change-oriented and/or intermediating roles. We conclude that for any researcher who is involved in transdisciplinary projects, being reflective and self-reflexive is a key competence. Yet, on the basis of literature and our own project experiences, we conclude that researchers in transdisciplinary EMPS especially run the risk of: (1) failing to maintain their independence and objectivity; (2) raising too high expectations among participants (or for themselves); and (3) being caught in time-consuming mediation or facilitation tasks for which they lack resources, such as, time, knowledge or skills.

6.1 | Recommendations

Based on our findings, we identify four elements that researchers working in transdisciplinary EMPs should be aware of and reflect upon. The first element to consider is your "orientation" and relates to how you, as a researcher, are positioned in and contribute to the knowledge space, the formal policy space and the stakeholder space. We observe that researchers who engage in transdisciplinary research are likely to experience more professional, philosophical, methodological, projectrelated and personal challenges compared to researchers who choose to do research within traditional disciplinary boundaries (Patterson et al., 2013). Therefore, we encourage researchers to reflect not only on how they relate to formal policy and stakeholder spaces, but also on the knowledge domain or discipline they want to contribute to. The second element is your own "norms and values" in relation to societal and political values and preferences. Within this context, reflection on your own normative orientation as well as knowledge production processes and outcomes (Wittmayer & Schäpke, 2014) is critical to avoid that knowledge becomes compromised. The third element is your own ability to clearly communicate your own objectives (including normative orientation) and expected impacts. This element is basically about managing "expectations": it should be clear to non-academic actors what they can expect from you as a researcher, not only in terms of scientific **TABLE 2**Overview of elements that researchers should reflectupon when engaged in transdisciplinary research projects

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Ele	ements to reflect upon	Check
1. a.	Orientation: My primary role as a researcher is to provide decision makers and other stakeholders with relevant objective, scientific knowledge (knowledge- oriented):	
b.	to be influential and promote societal change (change- oriented);	
c.	to integrate multiple knowledge sources and types in support of decision-making processes (intermediating).	
2	Names and values I are avous of	
2. a.	my personal opinions about my research topic (such as solution types, need for action):	
b.	how my own values and norms influence my decisions during the research process (for example related to stakeholder involvement, open or closed agenda, top- down or bottom-up);	
c.	the potential societal impacts of my research, including the political and societal values and norms that play a role	
3.	Expectations: I have adequately informed my research collaborators and stakeholders about	
a. b.	the objectives and orientation of my research project; the potential impacts of my research project.	
4.	Resources: I have or have access to	
a.	capacities and skills (e.g., research, organizational, communication) to fulfill required role(s);	
b.	resources (e.g., time, financial, support) available to fulfill required role(s).	

knowledge, but also in terms of promoting and supporting transformative change during and after the project. The fourth element is whether you possess the skills and resources to fulfill the role(s) you intend to fulfill. This involves reflecting on available "resources" including your own capacities and skills, for example, to deal with unequal power relations, as well as the resources available for project implementation and follow-up. The more diverse the knowledge types and sources involved, the more likely it is that researchers either should have experience working as a practitioner or should seek additional training. When intermediating tasks become very challenging and time-consuming, it may be a better idea to approach colleagues or involve third parties. As knowledge co-production generally comes with high transaction costs, a programmatic and longer-term vision might be more fruitful than short-term, project-based initiatives. To help researchers navigating these considerations in relation to transdisciplinary EMPS, we summarize these in Table 2 in the form of a check-list. We call upon fellow researchers-and early career researchers in particular-to use this checklist prior to the start of and throughout their research project to consider their orientation(s) and role(s) and-if needed-adapt them.

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