Received: 28 November 2019 | Revised: 8 April 2020 | Accepted: 15 April 2020

DOI: 10.1002/wat2.1450

ADVANCED REVIEW

WIREs WATER WILEY

Communities of practice at the center of circular water solutions

Andrea Fulgenzi[1] | **Stijn Brouwer**[1] | **Kate Baker**[2] | **Jos Frijns**[1]

[1]Resilience Management and Governance, KWR Water Research Institute, Nieuwegein, The Netherlands

[2]Centre for Water Systems, University of Exeter, Exeter, UK

Correspondence
Jos Frijns, Resilience Management and Governance, KWR Water Research Institute, Nieuwegein, The Netherlands.
Email: jos.frijns@kwrwater.nl

Funding information
European Commission, Grant/Award Number: 776541

Abstract

The circular economy (CE) is an emerging system that moves away from the traditional linear view of "make, use, and dispose" to one that is restorative and regenerative to keep resources, such as water, at its highest value and utility at all times. Water is essential to the CE due to its importance for human life and because of the energy and material it contains. However, the move toward more circular water solutions is accompanied by both technological and social challenges for which, this article argues, stakeholder participation and social learning are essential. Enabling diverse stakeholders to engage and share different perspectives, interests, and needs, and ultimately to co-produce knowledge, communities of practice (CoPs) are seen as a suitable approach to discuss CE water technologies in their institutional context. Although CoPs are being used widely in many sectors and disciplines, there is insufficient focus and a lack of consensus on how to evaluate the CoPs to understand whether and how the co-production of knowledge is effective and efficient. This article gives an overview of the importance of water in the CE, explores the rationale for knowledge co-production and CoPs, and proposes a CoP evaluation framework to draw together a consensus on the methods used for evaluating water knowledge co-production and social learning processes in the transition toward the CE.

This article is categorized under:

- Human Water > Water as Imagined and Represented
- Engineering Water > Planning Water
- Water and Life > Conservation, Management, and Awareness

KEYWORDS

circular economy, circular water solutions, co-creation, co-production, communities of practice

1 | INTRODUCTION

Since the industrial revolution, water has predominantly been viewed in a linear way. Water is withdrawn from rivers, reservoirs and groundwater aquifers; used by agriculture, industry, society and the environment; and then returned to

the water basin directly or via a treatment facility (Tahir, Steichen, & Shouler, 2019). This current system is often inefficient as water is lost, polluted and wasted. In recent years, society and business have started to move away from this linear model of "make, use and dispose" and instead developed a system that is closed looped to increase efficiency and optimize reuse (Abu-Ghunmi, Abu-Ghunmi, Kayal, & Bino, 2016; European Commission (EC), 2015; Ness, 2008). The Ellen MacArthur Foundation who are key leaders in the field of the CE define it as the following: "A circular economy (CE) is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles" (Ellen MacArthur Foundation, 2015, p. 2). The overarching idea is to break down the connection between growth and finite resource consumption. Water is considered as essential to the CE due to its importance for human life but also because of the energy and material it contains (Voulvoulis, 2018).

Creating a CE with water presents opportunities and challenges whereby a broad range of stakeholders, including government, industry, and the public need to work together. Communities of practice (CoPs), defined as social learning systems that bring together "people who share a concern or a passion for something they do and learn how to do it better as they interact regularly" (Wenger-Trayner & Wenger-Trayner, 2015, p. 1), are seen as a potential solution to manage these processes as they enable geographically dispersed actors to connect to share insights, practices, frustrations, and ultimately to co-produce knowledge and engage in collective action. Knowledge co-production is one of the steps of conducting transdisciplinary research, characterized by "a continuous exchange among the participating scientists and with the stakeholders" (Mauser et al., 2013, p. 428). The latter are explicitly referred to as nonacademic actors, whose involvement is key for ensuring the societal relevance and scientific quality of research (Brugnach & Özerol, 2019; Lang et al., 2012; Mauser et al., 2013). Although different scholars have made various conceptual distinctions between co-creation and co-production, there is to-date little consistency and agreement within the literature on these distinctions (cf. Brugnach & Özerol, 2019; Lawrence, 2015; Mauser et al., 2013). Accordingly, this article treats the terms as interchangeable.

The goal of this article is to do the following: (a) give an overview of water in the CE and the rationale for co-producing knowledge in the CE, (b) explore the effectiveness of CoPs for co-producing knowledge in the water CE, (c) discuss the need for a CoP evaluation framework and present an experimental framework for evaluating the effectiveness of CoPs in co-producing circular water solutions, and (d) define how CoPs can support the diffusion and upscaling of CE in the water sector.

2 | WATER IN THE CE AND THE RATIONALE FOR CO-PRODUCTION

The Ellen MacArthur Foundation have defined three CE principles applicable to water systems (Tahir et al., 2018). The first principle is to design out waste and pollution, both by optimizing the amount of energy and chemicals used in operation of water systems, and by substituting the need for water itself in agriculture and industry. The second principle is to keep products and materials in use, through the recovery and reuse of energy (heat, biogas) and materials (e.g., nutrients) from (waste)water. The third principle is to regenerate natural systems, by reducing water use and ensuring minimum disruption to natural water systems from human intervention. The challenge is to better align the human water cycle with the natural water cycle through the following measures: Avoid use, reduce use, reuse, recycle, and replenish water.

Lessons learnt from successful transitions from the linear economy to a circular one show that active involvement from all members of society and strong levels of collaboration is key (Ghisellini, Cialani, & Ulgiati, 2016). Harding (2006), for example, suggests that research should take a more holistic approach and from the beginning be co-produced with society, industry, and government. Several initiatives focusing on knowledge co-production have been extensively applied in the water sector to effectively deal with complex policy issues (Pahl-Wostl, Mostert, & Tàbara, 2008). The rationale behind these processes is they stimulate and support social learning, which is believed to improve decision-making functions, relationships among stakeholders and their problem-solving capacity (Cundill & Rodela, 2012).

Indeed, the value generated by circular water systems is likely significantly lower if society and industry are not engaged to become water wise, as their role is instrumental to change (Abu-Ghunmi et al., 2016; Bouziotas et al., 2019; International Water Association (IWA), 2016). Several authors argue that active involvement of society and industry can facilitate the uptake of new technologies (Ormerod & Scott, 2013; Peake, Cherry, Steentjes, Scott, & Pidgeon, 2018), the adoption of resource-saving practices (Hartley, 2006; Peake et al., 2018), and ensure investments in appropriate and

effective technologies (Stahel, 2016; International Water Association (IWA), 2016; Smith, Brouwer, Jeffrey, & Frijns, 2018).

2.1 | Co-production across disciplines and sectors

Integration of the CE concept at the government level and upper management of industry must rely on the coordinated action from a wide range of stakeholders (Ghisellini et al., 2016). As further detailed in Box 1, co-production is not always straightforward, entails many challenges, takes time, even when there is a shared goal and understanding between the parties involved (Dewulf, Craps, Bouwen, Taillieu, & Pahl-Wostl, 2005; Sol, Beers, & Wals, 2013). Nonetheless, examples of co-production can be found in academia, business, and policy. It is important to review the different sectors so that learning can be shared.

2.1.1 | Academic co-production

In academia, the move toward knowledge co-production has started with the growing appreciation of first (a) multidisciplinary research, that is, research that, opposed to monodisciplinary research, draws on knowledge from different disciplines but stays within their boundaries; followed by (b) interdisciplinary research, that is, research that integrates theories or methods from different scientific disciplines; and increasingly, (c) transdisciplinary research, in which knowledge co-production is key, defined as the integration of different disciplinary approaches and contributions from both researchers and nonresearchers (Brugnach & Özerol, 2019; Lawrence, 2015; Pohl, 2011). The same transition can, to a large extent, also be witnessed in the domain of water research (Brouwer, Büscher, & Hessels, 2017). This is especially so for transdisciplinary research which is often regarded as a promising mode to tackle complex challenges (Krueger et al., 2016; Larsen, Hoffmann, Lüthi, Truffer, & Maurer, 2016).

The rationale for academic knowledge co-production can be classified as threefold: (a) substantive, relating to the idea that public participation in the production of knowledge improves the quality of research, for example, as a result of newly raised research questions, alternative solutions, as well as the generation of more information (Reed, 2008); (b) instrumental, rooted in the idea that stakeholders can potentially make large contributions to the quantity of available data, as well as the idea that processes of participation increase the legitimacy and acceptance of the final product (Bonney, Phillips, Ballard, & Enck, 2016; Lidskog, 2008); and (c) normative, relating to the idea that there is an intrinsic

BOX 1 Co-production challenges

Although the involvement of relevant stakeholders dealing with water management, regulation, and consumption is regarded as crucial for supporting the transition toward a circular water economy, co-production is not always an easy process, and entails various challenges.

First, stakeholders may have competing interests and strategies, framing of policy issues, and knowledge bases which may make it more difficult for stakeholders to align and collaborate (Dewulf et al., 2005; Sol et al., 2013). It takes time for stakeholders to build trust and understanding to work successfully together on projects (de Wit-de Vries, Dolfsma, van der Windt, & Gerkema, 2019).

Second, participatory initiatives of co-production entail additional costs for facilitation and community management, which can discourage organizations to adopt such multi-stakeholder approaches (Lemos et al., 2018). Co-production requires a significant amount of investment and, as with any relationship, trust is integral for each party to know that their investment will not be wasted.

The final challenge is to effectively involve all stakeholders in knowledge co-production activities in spite of their power asymmetries. Such differences in issue framings, capacity to participate (i.e., human and financial resources, time), knowledge to be created and communicated can affect the relevance, legitimacy, and scientific quality of transdisciplinary research (Brugnach & Özerol, 2019; Pandya, 2012; Renner et al., 2013). This means that the initiatives do not always increase the legitimacy and acceptability as they are not truly co-produced.

value and a strong moral "ought" for the democratization, through public engagement, of research processes (Haywood, 2016; Stilgoe, Lock, & Wilsdon, 2014). The latter argument is especially dominant in the field of citizen science, referring to any form of active public participation in the process of research to generate science-based knowledge (Brouwer, van der Wielen, Schriks, Claassen, & Frijns, 2018).

2.1.2 | Co-production in business

Co-production of knowledge during innovation processes in business has been identified as a pivotal source of the competitive advantage of businesses. The appreciation that such knowledge creation cannot always take place internally to the firm prompted businesses to increasingly co-produce knowledge with external stakeholders during innovation processes (Kazadi, Lievens, & Mahr, 2016; Mahr, Lievens, & Blazevic, 2014). For instance, well-informed and active customers are increasingly recognized as a crucial external source of knowledge for innovation processes (Prahalad & Ramaswamy, 2004). Firms may benefit from their knowledge, skills, and resources by co-producing knowledge and engaging them in innovation processes and in the development of new products, whereby co-production with customers is found most successful for the creation of highly relevant but moderately novel knowledge (Mahr et al., 2014). Appealing examples of knowledge co-production processes in the private sector include toy company Lego's incorporation of user-designed sets (Antorini, Muñiz Jr, & Askildsen, 2012), as well as crowdsourcing platforms such as InnoCentive, where companies like DuPont and Procter & Gamble pose problems for others to solve in exchange for a reward (Howe, 2006). According to Kazadi et al. (2016), businesses no longer only focus on customers in innovation processes, but increasingly also organize multi-stakeholder co-production processes with various interdependent external stakeholders, such as for instance the logistics provider DHL, who in their efforts to reduce urban traffic and to stimulate a greener economy involved a broad range of stakeholders, including citizens, academics, and public authorities.

2.1.3 | Co-production in public policy

When it comes to stakeholder participation and co-production processes, the public sphere arguably has the longest standing tradition, even if in this domain the traditional premier focus lies on policy and decision-making processes rather than the production of knowledge. It is important to acknowledge the important role heterogeneous stakeholders can have in contributing to effectiveness, efficiency and inclusivity. Over the past decades, in many domains including in water management, traditional top-down approaches to policy design and implementation with "governments" as single decision-making authorities, have been replaced by more deliberative, inclusive, poly-centric and bottom-up governance processes, with the inclusion of a broad range of stakeholders from both the nonprofit and private sector (Akhmouch & Clavreul, 2016). Indeed, it is argued that participation improves the outcome of a project, for instance by including contextual knowledge, or more instrumentally, may promote ownership of decisions, making them easier to implement (Carr, 2015; Irvin & Stansbury, 2004; Renn, Klinke, & Van Asselt, 2011). Stakeholder participation can also be favored from a legal point of view, in cases where participation is practiced because of legal obligations, or from a normative point of view, and the idea that allowing those who will be affected by a decision to have a say has an intrinsic value (Glucker, Driessen, Kolhoff, & Runhaar, 2013).

3 | THE EFFECTIVENESS OF COPS FOR WATER IN THE CE

Alongside the evolution of co-decision making to processes of knowledge co-production, there has also been a development in the range of participatory techniques. The well-known techniques such as public hearings, workshops, and citizen juries, are primarily optimized for the different degrees of participation based on power and co-decision. As further discussed in Box 1, unequal power relations and their reinforcement in participatory initiatives is an important challenge in knowledge co-production processes. New alternative concepts and ideas have emerged around social learning and knowledge co-production processes, including, very prominently, the idea of CoPs (Lave & Wenger, 1991; Reed et al., 2010; Wenger, 1998). Focusing on participation in community life as a basis for learning and identity construction, CoPs are based upon social learning theories, according to which learning involves processes of "interpersonal

relations [...] imitation and modelling [and] observation" (Bandura, 1977 in Wenger, 1998, p. 280). Over time, the usage of the term CoP has shifted substantially and has been used to explain learning and knowledge generation across a variety of work, organizational, and spatial settings (Amin & Roberts, 2008; Cox, 2005).

3.1 | Introduction to CoPs

The concept CoP was first coined in 1991 by the cognitive anthropologist Jean Lave and the educational theorist Etienne Wenger (Lave & Wenger, 1991) as a new approach to understanding learning, focusing on informal and situated social interaction whereby learning from other learners is central. More recent conceptualizations treat CoPs as the informal relations and understandings that develop in mutual engagement on an appropriated joint enterprise (Wenger, 1998), to groups with the specific purpose to learn, create, and share knowledge (Wenger, McDermott, & Snyder, 2002). The latter define CoPs as "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (Wenger et al., 2002, p. 4).

Accordingly, in this later work, the CoP concept becomes more viewed as a management tool through which geographically dispersed actors can be connected. By being mutually engaged with one another, CoP members share insights, may critique or adopt each other's practices, share frustrations, and co-produce knowledge (Iverson & McPhee, 2002).

Wenger, Trayner, and de Laat (2011) considers three elements as constitutive dimensions of CoPs: The domain, the community, and the practice. To cultivate a CoP, the combination of the three must be developed in parallel.

1. *Domain*: A CoP is different than other stakeholder-engagement networks since its members identify themselves by a shared domain of interest. Membership involves a commitment to the domain and a shared competence, irrespectively of their organizational unit, or professional background.
2. *Community*: While showing their interest in their domain, community members develop, and share information, help each other and join activities and discussions. In this form of sustained mutual interaction, members do not necessarily work together on a daily basis but build relationships in order to learn from and support each other.
3. *Practice*: CoP members do not only share a common interest, over time, through active, and dynamic negotiation of meaning. They produce a common practice where they develop and utilize a shared repertoire of resources. These can be experiences, stories, tools, or ways of addressing recurring problems. To develop this kind of a shared practice it takes time and continuous interaction (Wenger, 2011).

The concept of CoP has found a number of practical applications in business, organizational design, government, education, professional associations, development projects, and civic life (Wenger, 2011). CoPs come in a variety of forms, ranging from quite small to very large, completely informal to formally recognized, and from local to global. Some CoPs meet mainly face-to-face, others mostly online.

3.2 | CoPs and social learning for the water-CE

CoPs can be viewed as a social learning system (Wenger, 2010), whereby members engage in social learning processes. These eventually lead to the building up of (a) a shared problem definition, in particular when the problem is complex and largely ill-defined (but this does not imply consensus building), and (b) trust as the base for a critical self-reflection and to identify interdependencies and potential synergies among stakeholders (Pahl-Wostl, 2003).

Although it cannot be assumed that participation inevitably implies that social learning takes place, there is ample evidence that participatory processes may stimulate and facilitate social learning (Reed et al., 2010). Stakeholder involvement is seen as particularly relevant for managing complex or so-called "wicked" socio-technological problems, difficult to resolve because scientific uncertainty, and value differences are both at the cause (Cuppen, 2010). The water sector has many wicked problems which are predicted to increase in the future with climate change and increasing urbanization. CoPs accommodate diversity and try to realize innovative combinations between highly different stakeholders, representing different knowledge resources, interests, and ambitions (Edelenbos & Van Buuren, 2006).

The move toward a CE includes both technological challenges and social innovations; circular solutions need to take account of both aspects to ensure their successful implementation. Therefore, the implementation of circular solutions can be seen as a complex socio-technological problem, in which stakeholder participation and social learning can be regarded as essential (Pahl-Wostl, 2002). It is fair to hypothesize that CoPs may be of great importance to develop effective solutions toward the CE. In addition, it is of paramount importance to evaluate whether knowledge co-production processes are effective, efficient, and which outcomes can be attributed to stakeholder participation.

However, there is currently no consensus in the literature about the processes that stimulate and support social learning and about which outcomes can be attributable to specific processes. The current literature, in fact, lacks an adequate framework establishing causal relations between processes, outputs, and outcomes of CoPs. There is a need for an evaluation methodology that could be transferred to other governance and socio-technological contexts.

4 | THE NEED FOR A COP EVALUATION FRAMEWORK

Although CoPs are being used widely in many sectors and disciplines, there is insufficient focus and a lack of consensus on how to evaluate their outputs (Lorenz & Barlatier, 2007). This is not to say that no progress has been made, rather current evaluation frameworks present limitations concerning the research methods used. As elaborated in Table 1, two main types of evaluation methods emerge from the existing literature: one relies mostly on qualitative data, collected through ethnographic studies and anecdotal stories; and the second uses quantitative analysis, statistical methods, and modeling to assess the so-called "maturity" of CoPs.

The main limitation with existing qualitative approaches is that they are often resource-intensive and are based on retrospective studies. Qualitative methods such as ethnographic observation require skilled researchers to invest a significant amount of time conducting unstructured interviews and focus groups with CoP-members (e.g., Probst & Borzillo, 2008; Wenger et al., 2011), and the retrospective nature of these studies hampers a definition of how the CoP could improve (e.g., Thompson, 2005). Quantitative evaluation frameworks provide a significant improvement in the evaluation methodology as they work in "real-time" by identifying actions that could potentially "move" the CoP toward higher maturity stages through a roadmap of interventions (e.g., Boughzala & Bououd, 2011). However, these quantitative approaches often overlook the social learning dimension of CoP-development by focusing predominantly on how members score their CoP against a fixed set of criteria (e.g., Lee et al., 2010).

Two other major limitations of current qualitative and quantitative approaches consist in (a) a lack of consensus on the hypothesis, indicators, and preconditions that are believed to support the development of CoPs (e.g., Craps & Maurel, 2003; Wenger et al., 2011); and (b) a poor understanding of the causal relationships between co-production processes occurring within CoPs and their outcomes (Cox, 2005; Wenger et al., 2011). These limitations hamper a clear understanding of the preconditions and processes that make a CoP "effective" in stimulating and supporting social learning. In addition, the complicated and resource-intensive nature of the evaluation frameworks result in a low transferability beyond the knowledge-management sector.

To overcome these limitations, we propose a framework that structures the evaluation of CoPs as the interrelation between social learning outcomes and CoP dimensions, and analyses how and to what extent they contribute to the achievement of specific CoP-objectives. The framework draws together a consensus on the methods used for evaluating water knowledge co-production and social learning processes in the transition toward the CE. It aims at evaluating the added-value of CoPs for creating an adequate multi-stakeholder environment for effectively enabling social learning processes.

The proposed evaluation framework has been developed by reviewing the literature and is at an early experimental stage where additional field-testing will be required to improve its reliability and ease of use among practitioners in the water sector. The following sections provide methodological details of how the framework was constructed, as well as an introduction to the project where it is being applied and tested.

4.1 | A new evaluation framework for analyzing social learning outcomes in CoPs

The development of a CoP, in terms of improvement in its effectiveness and efficiency, can be conceptualized as the parallel development of CoP dimensions (Wenger, 2011) and social learning outcomes (Scholz, Dewulf, & Pahl-Wostl,- 2014). CoP dimensions are defined by Wenger (1998) as:

- Mutual engagement of participants (community)
- Development of a shared repertoire (domain)
- Negotiation of a joint enterprise (practice)

Three outcomes of social learning processes can be identified, based on the definition of social learning by Reed et al. (2010):

- Learning occurs through social interaction (relational outcome);
- Learning is situated within wider social units or CoPs (shared understanding); and
- Learning implies a change in understanding in the individuals involved (substantive outcome).

By associating the two concepts of CoP dimensions and social learning outcomes, it is possible to identify three key elements: (a) engagement and interaction of stakeholders, (b) change in stakeholders issue frames, and (c) stakeholder awareness of their own role and competence and of those of other members. As shown in Figure 1, these three elements support knowledge co-production processes and connect CoP dimensions with their related social learning outcome.

TABLE 1 Overview of existing CoP evaluation frameworks

Predominant approach	Author(s) and scope of the study	Data-gathering method	Strengths of the method	Weaknesses of the method
Qualitative	Wenger et al., 2011: Conceptual framework to assess "value creation cycles" (maturity model).	Creation of "value creation stories" demonstrating value of CoP outcomes (anecdotal evidence).	Systematic collection and construction of stories; Division in value creation cycles (maturity stages).	Retrospective study on the added-value of CoP outcomes; Resource-intensive evaluation method.
	Probst & Borzillo, 2008: Assessment of CoP leaders' perception of "governance mechanisms determining the success or failure of CoPs in intra-organizational networks.	Likert-type questionnaire, focus group, and semi-structured interviews.	General governance mechanisms (transferability potential); Identification of best-practices.	CoPs used as knowledge management tool in business setting; Focus on management theory and organizational performance.
	Thompson, 2005: Evaluation of the relationship between a CoP and the parent company establishing it.	Non-participant observation and unstructured in interviews.	In-depth analysis of the relation between structural and epistemic components;Ethnographic observation allows for identification of causality between activities and outcomes of a CoP.	CoPs used as knowledge management tool in business setting; Retrospective and resource-intensive evaluation method.
Quantitative	Lee, Suh, & Hong, 2010: Prescriptive assessment of CoP evolution stages based on critical success factors (maturity model).	Likert-type questionnaire.	Maturity stages built upon literature review;Relative weight assigned to critical success factors.	Prescriptive, based on fixed maturity stages and success factors.
	Boughzala & Bououd, 2011: Prescriptive assessment of the capability of a CoP to manage knowledge (maturity model).	Likert-type questionnaire.	Systematic framework building upon review of existing maturity models; Transferability potential.	Prescriptive, relevance of criteria based on evaluator's perception; Evaluation focused on ICT tools (online fora and communities).

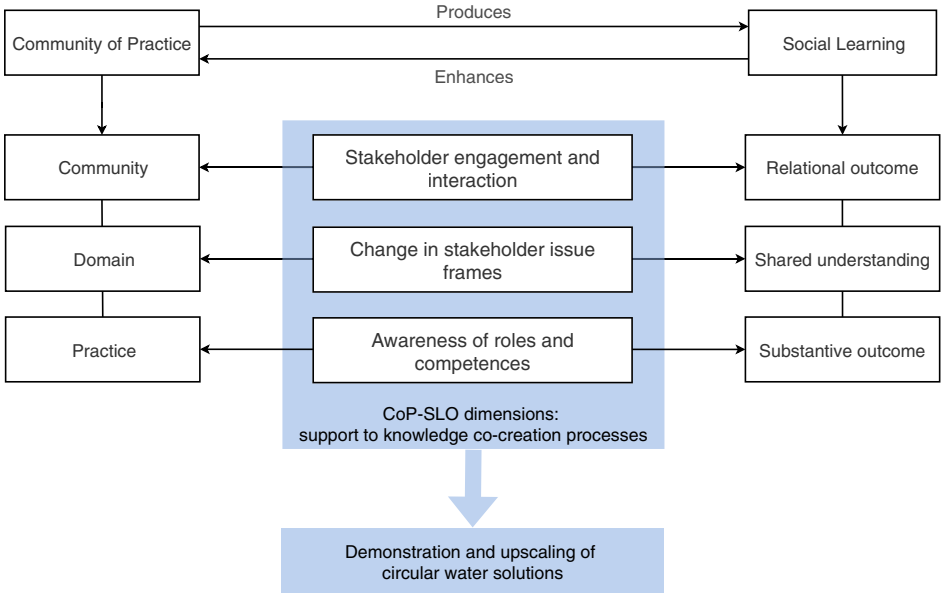

FIGURE 1 Schematic representation of the conceptual framework. The development of the three dimensions of a CoP (community, domain, and practice) is interrelated with the achievement of social learning outcomes (relational outcome, shared understanding, substantive outcome). The parallel development of these dimensions supports knowledge co-production processes, which are crucial for upscaling the CE framework in the water sector

Analyzing this interrelation can give insight into how CoPs can stimulate social learning, and how this contributes to the upscaling of the CE framework into the water sector.

The evaluation of CoPs should therefore consist of assessing the extent to which the development of CoP-dimensions and the achievement of social learning outcomes supports the overall objective behind the establishment of knowledge co-production processes. The proposed evaluation framework consists of an assessment of six key success factors (KSFs) and 30 indicators (Table 2).

4.1.1 | Key success factors

Six KSFs were formulated following the same methodology of previous studies adopting success factors and indicators. Specifically, a first literature review led to the identification of which skills and resources may lead to improved performance (Grunert & Ellegaard, 1992); then, these causal relationships were further specified to distinguish between so-called "failure preventers" (Matthyssens & Vandenbempt, 1998, p. 342) and actual success factors; finally, in order to acquire additional information and practical implications of the KSFs for the water CE and preliminarily test the validity of the framework, four CoP facilitators were asked to provide constructive feedback on the relevance of the success factors and indicators (Koop et al., 2017).

The six KSFs are (1) organizational support, (b) atmosphere of the meeting, (c) representation and engagement, (d) convergence on a shared perspective, (e) identification of opportunities and challenges, and (f) generation of knowledge. As depicted in Table 2, all three social learning outcomes and CoP dimensions are assessed against two KSFs, one measuring CoP structural components (S) CoP and the other the epistemic ones (E). Structural and epistemic components are two sides of the same coin of "CoP-development," and are therefore interdependent: there is a certain degree of organizational control on the structural aspects of a CoP, and investing in these provides support to epistemic activities; at the same time, epistemic activities require some degree of structure to support stakeholder engagement and interaction and members identification with the joint enterprise of the CoP (Dessne & Byström, 2015; Thompson, 2005).

4.1.2 | Indicators

Each KSF is measured by a set of indicators, which include specific CoP dynamics and characteristics that provide an overall assessment of each CoP dimension and social learning outcome. The indicators were selected, through a literature review, from a pool of existing indicators from the water resource management, CoPs, and social learning literature

TABLE 2 List of the six KSFs and their related indicators

Key success factors (KSFs)	Indicators
1. Support to stakeholder engagement and interaction from organizational aspects, tools, and other artifacts. (S)	1.1 Advance provision of meeting information and materials 1.2 Adequacy of the meeting venue 1.3 Adequacy of the duration of the meeting 1.4 Presence of outputs/materials acting as culturally symbolic infrastructure 1.5 Presence of leadership figures
2. Adequacy of the meeting atmosphere for enabling stakeholder interaction mutual engagement. (E)	2.2 Improvement in working relationships with other participants 2.2 Existing relationships and new connections 2.3 Clarity of presentations and speakers 2.4 Spontaneous behavior and communication 2.5 Trust in others' openness in communicating own opinions, concerns, interests, goals
3. Inclusion and engagement of all relevant stakeholders and interest groups in relation to the issue(s) at hand. (S)	3.1 Opportunity for individual participation and input 3.2 Participation and inclusion of newcomers 3.3 Constructive management of (potential) conflicts and differences 3.4 Representation of all relevant stakeholders and interest groups 3.5 Inclusion of all relevant perspectives in the discussion
4. Convergence on a shared perspective on the issue(s) at hand. (E)	4.1 Agreement on what will be discussed 4.2 Awareness of interdependencies of actions and desired outcomes 4.3 Awareness of presence/lack of resources available to the community 4.4 Changes in own perspective 4.5 Quality of the moderation of the discussion
5. Identification of opportunities and challenges for implementing joint action. (S)	5.1 Opportunities to reflect and talk about collective experiences and processes of the project 5.2 Formulation of conclusions to the discussion and the meeting 5.3 Formulation of actions to address problems and capitalize on opportunities 5.4 Inspiration for follow-up/embedding in own organization 5.5 Ability of participants to influence agenda or procedures
6. Generation of useful knowledge in relation to the topic at hand. (E)	6.1 Increased knowledge on the issue(s) at hand 6.2 Generation of new terms and language 6.3 Creation of new expectations 6.4 Awareness of own role and role of other participants 6.5 (potential) improvement in personal/organizational performance

Note: Each evaluation item is assessed against two KSFs, one measuring CoP structural components (S) CoP and the other the epistemic ones (E).

(e.g., Craps & Maurel, 2003; Wenger, 1998). The current set of indicators contains specific CoP dynamics and characteristics that provide a quantitative measurement of each KSF, as shown in Table 2. The indicators are measured through a Likert-type questionnaire administered to CoP-participants, ranging from 1 to 5. The score of each KSF corresponds to the average of its indicators (Box 2). Annex 1 provides an example of the measurement of one KSF and its related indicators (Table 3).

BOX 2 CoPs for the diffusion of circular water solutions: Brief overview of the NextGen project

The H2020 project "NextGen: Toward a next generation of water systems and services for the CE" aims at demonstrating innovative technological, business, and governance solutions for water in the CE in 10 demonstration cases across Europe (www.nextgenwater.eu). In NextGen, 10 CoPs have been established for each demonstration case, with the aim of involving and engaging stakeholders from the whole water value chain and offering an engagement environment around the innovations demonstrated. They bring together representatives from the water industry (operators), authorities (regulators), engineering companies, consultants, research institutes, representatives of non-governmental organizations, and potential end-users. CoPs in NextGen cover four key topics: setting the scene, closing the loop, implementation, and upscaling and evaluation. The proposed evaluation framework will be further used in NextGen to test and improve its reliability among practitioners in the water sector.

5 | DISCUSSION: HOW COPS CAN SUPPORT WATER IN THE CE

The development and upscaling of the CE creates many positive opportunities but also challenges of uncertainty resulting from the increasing complexity of circular systems of materials and nutrients. These challenges are particularly relevant for the water sector, which has traditionally been characterized by "sectorial" engineering-technocratic approaches (Rotmans & Loorbach, 2009; van de Meene, Brown, & Farrelly, 2011). New technologies and actors like end-users and citizens are assuming more predominant and powerful roles, which challenge the traditional top-down, command-and-control governance approaches and a clear division of responsibilities and functions (van Vliet, Chappells, & Shove, 2005). Water management institutions, research institutes, and technology developers are realizing the importance of co-producing interdisciplinary research with the aim of developing more integrated and circular resource management and governance approaches (Ferguson, Chan, Santelmann, & Tilt, 2018; Renner et al., 2013).

The establishment of CoPs to stimulate and support social learning and knowledge co-production offers promising new ways to deal with issues of complexity and uncertainty arising from the upscaling of water-CE (Cuppen, 2010; Pahl-Wostl, 2002). There are three dimensions through which CoPs can support knowledge co-production processes for upscaling CE in the water sector. This includes the following:

5.1 | Support participation and interaction of all relevant stakeholders

This first dimension is the establishment of an effective and efficient CoP. It is also necessary for upscaling the CE concept in the water sector, because it can allow for the identification of synergies and interdependencies that can further close the loop of water, materials, and nutrients (Pahl-Wostl, 2002; Wenger, 2010). This is materialized in practice through processes of "vertical and horizontal integration" (Ghisellini et al., 2016), which presupposes some level of agreement and trust among stakeholders at different scales and levels.

The degree of organizational support available to CoPs can support stakeholder participation and equal representation (Reed et al., 2010; Wenger, 1998). Measures of organizational support include technical aspects such as meeting venue and duration of the meeting, but also includes other aspects such as the creation of a safe space to help initiate collaborative relationships and understanding (Ferguson, 2016; Reed et al., 2010). Measuring these two factors can therefore ensure that participating stakeholders are willing to collaborate, and that there is adequate structural support.

However, as earlier discussed, stakeholder participation and interaction does not directly result in all stakeholders being represented, or that the CoP develops an identity that members share (Thompson, 2005). In addition, the classification of stakeholders as *relevant* depends on the governance and technological context of the CoP, which can result in some stakeholders having more decision-making power than others.

5.2 | Bridge gaps in stakeholders' knowledge bases through facilitating alignment

The second dimension is the extent to which stakeholder engagement and interaction leads to some degree of alignment of issue frames and knowledge bases. Alignment can be hampered in numerous ways. First, differences in stakeholder issue frames can hamper the knowledge co-production process and decrease the potential of the CoP in effectively upscaling the CE framework in the water sector, especially when stakeholders' perspectives on the specific issue(s) at hand are conflicting (Cuppen, 2010; Ferguson, 2016). Second, uneven knowledge bases can lead to different expectations among stakeholders on the outputs and outcomes of the CoP (Djenontin & Meadow, 2018). This in turn can decrease the motivation of stakeholders to be active members of the CoP and their perception of the value created by its outputs and outcomes.

The alignment of stakeholders' issue frames can be measured by the level of representation and engagement of relevant stakeholders in the CoP and by their convergence toward a shared perspective on the issue(s) at hand. These two factors are interdependent, because CoP-members may prefer to only involve stakeholders with similar issue frames, which could make it easier to share resources among them and reach for agreement (Lemos et al., 2018; Porter & Dessai, 2017). The alignment of stakeholders' issue frames and their fair representation does not always result in agreement and collaboration, especially when conflicts among stakeholders may hinder the policy- or decision-making process (Dewulf et al., 2005). The literature gives much importance to the need for a shared culture that is constructed among CoP-members through iteration and negotiation (Pahl-Wostl et al., 2007).

5.3 | Facilitate the identification and definition of role and responsibilities

The third dimension focuses on stakeholders' identification and awareness of their role and responsibilities and that of other members. It assesses how this contributes to the development of a shared (organizational) culture and willingness to build collaborative agreements or partnerships based on shared opportunities and challenges. Inherent to this CoP-dynamic are processes of negotiation and sustained mutual interaction, which in turn lead to the co-generation of knowledge (Wenger, 1998). Even when conflicts emerge, these processes are critical for supporting the construction of a water-CE practice shared among and accepted by CoP-members (Cuppen, 2012).

The formulation and identification of opportunities and challenges should deliver useful knowledge to support the integration of the CE framework into the current water management regime of specific governance contexts (Wenger, 1998). This process relies upon a shared understanding on the current water management context and a shared vision for the future circular water system. CoP-members should therefore be engaged with in workshops or feedback sessions where they have the opportunity to evaluate whether the information they gathered is useful and usable, if new expectations were created, and if their perspective on the issue(s) at hand has changed after participating to the CoP.

6 | CONCLUSION

The participation of stakeholders across policy sectors and geographical scales, and the inclusion of different perspectives, interests, and needs, are important requirements to effectively upscale the CE framework in the water sector. Engaging in knowledge co-production initiatives can increase stakeholder capacity of dealing with complex and interrelated issues, such as the diffusion of the CE in a highly technical sector, support policymaking functions in potentially conflicting situations, and stimulate the establishment of collaborative decision-making platforms. This article has highlighted that CoPs are of great importance to develop these effective solutions toward the CE. However, it is of paramount importance to evaluate knowledge co-production processes to understand which outcomes can be attributed to stakeholder participation.

This article has evaluated the literature to understand and evaluate what makes CoPs effective and efficient in stimulating and supporting knowledge co-production processes. The proposed evaluation framework is based on the interrelation between the development of CoP-dimensions and the achievement of social learning outcomes. It evaluates the activities and outcomes of CoPs to improve stakeholders' willingness to collaborate, facilitate a fair representation of all relevant stakeholders, support the convergence toward a shared issue frame, and improve the quality of the knowledge co-produced through stakeholder engagement and interaction in CoPs. Future research to test the validity of the framework is welcomed, which could potentially expand its application beyond the water sector.

ACKNOWLEDGMENTS

This research was conducted as part of the NextGen project "Towards a next generation of water systems and services for the CE." The consortium has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 776541.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

AUTHOR CONTRIBUTIONS

Andrea Fulgenzi: Conceptualization; methodology; project administration; supervision; visualization; writing-original draft; writing-review and editing. **Stijn Brouwer:** Conceptualization; methodology; project administration; supervision; writing-original draft; writing-review and editing. **Kate Baker:** Conceptualization; project administration; supervision; writing-original draft; writing-review and editing. **Jos Frijns:** Funding acquisition; methodology; project administration; supervision; writing-original draft; writing-review and editing.

ORCID

Andrea Fulgenzi https://orcid.org/0000-0001-6111-9791
Stijn Brouwer https://orcid.org/0000-0003-1441-2930
Jos Frijns https://orcid.org/0000-0001-5612-8503

RELATED WIREs ARTICLE

Stakeholder and public participation in river basin management: An introduction.

FURTHER READING

Waughray, D. (2010, November 10). *Why Worry About Water? A Quick Global Overview, 2030 Water Resources Group*. Washington, DC: The World Bank Group.

REFERENCES

Abu-Ghunmi, D., Abu-Ghunmi, L., Kayal, B., & Bino, A. (2016). Circular economy and the opportunity cost of not 'closing the loop' of water industry: The case of Jordan. *Journal of Cleaner Production*, *131*, 228–236.

Akhmouch, A., & Clavreul, D. (2016). Stakeholder engagement for inclusive water governance: "Practicing what we preach" with the OECD water governance initiative. *Water*, *8*(5), 204.

Amin, A., & Roberts, J. (2008). Knowing in action: Beyond communities of practice. *Research Policy*, *37*(2), 353–369.

Antorini, Y. M., Muñiz, A. M., Jr., & Askildsen, T. (2012). Collaborating with customer communities: Lessons from the LEGO group. *MIT Sloan Management Review*, *53*(3), 73.

Bonney, R., Phillips, T. B., Ballard, H. L., & Enck, J. W. (2016). Can citizen science enhance public understanding of science? *Public Understanding of Science*, *25*(1), 2–16.

Boughzala, I., Bououd, I. (2011). *A community maturity model*: *An application for assessing knowledge sharing in the field*. 2011 Proceedings of the PACIS, Paper 30. Retrieved from http://aisel.aisnet.org/pacis2011/30.

Bouziotas, D., van Duuren, D., van Alphen, H.-J., Frijns, J., Nikolopoulos, D., & Makropoulos, C. (2019). Towards circular water neighborhoods: Simulation-based decision support for integrated decentralized urban water systems. *Water*, *11*(6), 1227.

Brouwer, S., Büscher, C., & Hessels, L. K. (2017). Towards transdisciplinarity: A water research programme in transition. *Science and Public Policy*, *45*(2), 211–220. https://doi.org/10.1093/scipol/scx058

Brouwer, S., van der Wielen, P. W. J. J., Schriks, M., Claassen, M., & Frijns, J. (2018). Public participation in science: The future and value of citizen science in the drinking water research. *Water*, *10*(3), 284. https://doi.org/10.3390/w10030284

Brugnach, M., & Özerol, G. (2019). Knowledge co-production and transdisciplinarity: Opening Pandora's box. *Water*, *11*(10), 1997. https://doi.org/10.3390/w11101997

Carr, G. (2015). Stakeholder and public participation in river basin management—An introduction. *WIREs Water*, *2*(4), 393–405.

Cox, A. (2005). What are communities of practice? A comparative review of four seminal works. *Journal of Information Science*, *31*(6), 527–540.

Craps, M., & Maurel, P. (Eds.). (2003). *Social learning pool of questions, HarmoniCOP combined WP2/WP3 deliverable*. Leuven, Belgium: KU Leuven, Centre for Organisational and Personnel Psychology.

Cundill, G., & Rodela, R. (2012). A review of assertions about the processes and outcomes of social learning in natural resource management. *Journal of Environmental Management*, *12*, 7–14.

Cuppen, E. H. W. J. (2010). *Putting perspectives into participation: Constructive conflict methodology for problem structuring in stakeholder dialogues*. Oisterwijk: Uitgeverij BoxPress.

Cuppen, E. H. W. J. (2012). Diversity and constructive conflict in stakeholder dialogue: Considerations for design and methods. *Policy Sciences*, *45*, 23–46. https://doi.org/10.1007/s11077-011-9141-7

de Wit-de Vries, E., Dolfsma, W. A., van der Windt, H. J., & Gerkema, M. P. (2019). Knowledge transfer in university–industry research partnerships: A review. *The Journal of Technology Transfer*, *44*, 1236–1255. https://doi.org/10.1007/s10961-018-9660-x

Dessne, K., & Byström, K. (2015). Imitating CoPs: Imposing formality on informality. *Journal of the Association for Information Science and Technology*, *66*(11), 2277–2284.

Dewulf, A., Craps, M., Bouwen, R., Taillieu, T., & Pahl-Wostl, C. (2005). Integrated management of natural resources: Dealing with ambiguous issues, multiple actors and diverging frames. *Water Science and Technology*, *52*(6), 115–124.

Djenontin, I. N. S., & Meadow, A. M. (2018). The art of co-production of knowledge in environmental sciences and management: Lessons from international practice. *Environmental Management*, *61*(6), 885–903.

Edelenbos, J., & Van Buuren, A. M. W. (2006). Innovations in the Dutch polder: Communities of practice and the challenge of coevolution. *Emergence: Complexity and Organization.*, *8*(1), 42–49.

Ellen MacArthur Foundation. (2015). *Towards a circular economy: Business rationale for an accelerated transition*. Cowes: Ellen MacArthur Foundation.

European Commission (EC). (2015). *Closing the loop—An EU action plan for the circular economy*. Brussels: European Commission.

Ferguson, L. (2016). *Collaborative science-stakeholder engagement*. Corvallis, OR: Oregon State University Press Retrieved from https://seagrant.oregonstate.edu/sgpubs/collaborative-science-stakeholder-engagement

Ferguson, L., Chan, S., Santelmann, M. V., & Tilt, B. (2018). Transdisciplinary research in water sustainability: What's in it for an engaged researcher-stakeholder community? *Water Alternatives*, *11*(1), 1.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32.

Glucker, A. N., Driessen, P. P., Kolhoff, A., & Runhaar, H. A. (2013). Public participation in environmental impact assessment: Why, who and how? *Environmental Impact Assessment Review*, *43*, 104–111.

Grunert, K. G., & Ellegaard, C. (1992). *The concept of key success factors: Theory and method. MAPP Working Paper No. 4*. Aarhus, Denmark: Centre for Market Surveillance, Research and Strategy for the Food Sector.

Harding, S. (2006). *Science and social inequality: Feminist and postcolonial issues*. Champaign, IL: University of Illinois Press.

Hartley, T. W. (2006). Public perception and participation in water reuse. *Desalination*, *187*(1–5), 115–126. https://doi.org/10.1016/j.desal.2005.04.072

Haywood, B. K. (2016). Beyond data points and research contributions: The personal meaning and value associated with public participation in scientific research. *International Journal of Science Education, Part B*, *6*(3), 239–262.

Howe, J. (2006). The rise of crowdsourcing. *Wired Magazine*, *14*(6), 1–4.

Irvin, R. A., & Stansbury, J. (2004). Citizen participation in decision making: Is it worth the effort? *Public Administration Review*, *64*(1), 55–65.

Iverson, J. O., & McPhee, R. D. (2002). Knowledge management in communities of practice: Being true to the communicative character of knowledge. *Management Communication Quarterly*, *16*(2), 259–266.

International Water Association (IWA). (2016). *Water utility pathways in a circular economy*. London: International Water Association.

Kazadi, K., Lievens, A., & Mahr, D. (2016). Stakeholder co-creation during the innovation process: Identifying capabilities for knowledge creation among multiple stakeholders. *Journal of Business Research*, *69*(2), 525–540.

Koop, S. H. A., Koetsier, L., Doornhof, A., Reinstra, O., Van Leeuwen, C. J., Brouwer, S., ... Driessen, P. P. J. (2017). Assessing the governance capacity of cities to address challenges of water, waste, and climate change. *Water Resources Management*, *31*, 3427–3443.

Krueger, T., Maynard, C., Carr, G., Bruns, A., Mueller, E. N., & Lane, S. (2016). A transdisciplinary account of water research. *WIREs Water*, *3*(3), 369–389.

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., ... Thomas, C. J. (2012). Transdisciplinary research in sustainability science: Practice, principles, and challenges. *Sustainability Science*, *7*(1), 25–43.

Larsen, T. A., Hoffmann, S., Lüthi, C., Truffer, B., & Maurer, M. (2016). Emerging solutions to the water challenges of an urbanizing world. *Science*, *352*(6288), 928–933.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, MA: Cambridge University Press.

Lawrence, R. J. (2015). Advances in transdisciplinarity: Epistemologies, methodologies and processes. *Futures*, *65*, 1–9.

Lee, J., Suh, E., & Hong, J. (2010). A maturity model based CoP evaluation framework: A case study of strategic CoPs in a Korean company. *Expert Systems with Applications*, *37*(3), 2670–2681.

Lemos, M. C., Arnott, J. C., Ardoin, N. M., Baja, K., Bednarek, A. T., Dewulf, A., ... Wyborn, C. (2018). To co-produce or not to co-produce. *Nature Sustainability*, *1*, 722–724. https://doi.org/10.1038/s41893-018-0191-0

Lidskog, R. (2008). Scientised citizens and democratised science. Re-assessing the expert-lay divide. *Journal of Risk Research*, *11*(1–2), 69–86.

Lorenz, E., & Barlatier, P.J. (2007). Report on methods for studying Communities of Practice. Network of Excellence, Dynamics of Institutions and Markets in Europe (DIME), July 2007. Retrieved from http://www.dime-eu.org/wp12/workshop2006/add-papers.

Mahr, D., Lievens, A., & Blazevic, V. (2014). The value of customer cocreated knowledge during the innovation process. *Journal of Product Innovation Management*, *31*(3), 599–615.

Matthyssens, P., & Vandenbempt, K. (1998). Creating competitive advantage in industrial services. *The Journal of Business and Industrial Marketing*, *13*(4/5), 339–355.

Mauser, 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. *Current Opinion in Environment Sustainability*, *5*, 420–431. https://doi.org/10.1016/j.cosust.2013.07.001

Ness, D. (2008). Sustainable urban infrastructure in China: Towards a factor 10 improvement in resource productivity through integrated infrastructure system. *International Journal on Sustainable Development and World Ecology*, *15*, 288–301.

Ormerod, K. J., & Scott, C. A. (2013). Drinking wastewater: Public trust in potable reuse. *Science, Technology & Human Values*, *38*(3), 351–373.

Pahl-Wostl, C. (2002). Towards sustainability in the water sector–the importance of human actors and processes of social learning. *Aquatic Sciences*, *64*(4), 394–411.

Pahl-Wostl, C. (2003). The importance of the human dimension in integrated assessment models and processes: Actor based analysis and modeling approaches. Paper presented at the Proceedings of the Modelling and Simulation Society of Australia and New Zealand, MODSIM.

Pahl-Wostl, C., Craps, M., Dewulf, A., Mostert, E., Tabara, D., & Taillieu, T. (2007). Social learning and water resources management. *Ecology and Society*, *12*(2), 5.

Pahl-Wostl, C., Mostert, E., & Tàbara, D. (2008). The growing importance of social learning in water resources management and sustainability science. *Ecology and Society*, *13*(1), 24.

Pandya, R. E. (2012). A framework for engaging diverse communities in citizen science in the US. *Frontiers in Ecology and the Environment*, *10*(6), 314–317.

Peake, L., Cherry, C., Steentjes, K., Scott, K., & Pidgeon, N. (2018). *By popular demand: What people want from a resource efficient economy*. London: Green Alliance.

Pohl, C. (2011). What is progress in transdisciplinary research? *Futures*, *43*(6), 618–626. https://doi.org/10.1016/j.futures.2011.03.001

Porter, J. J., & Dessai, S. (2017). Mini-me: Why do climate scientists' misunderstands users and their needs? *Environmental Science & Policy*, *77*, 9–14. https://doi.org/10.1016/j.envsci.2017.07.004

Prahalad, C. K., & Ramaswamy, V. (2004). Co-creating unique value with customers. *Strategy & Leadership*, *32*(3), 4–9.

Probst, G., & Borzillo, S. (2008). Why communities of practice succeed and why they fail. *European Management Journal*, *26*, 335–347.

Reed, M., Evely, A. C., Cundill, G., Fazey, I. R. A., Glass, J., Laing, A., ... Raymond, C. (2010). What is social learning? *Ecology and Society*, *15*(4), r1.

Reed, M. S. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation*, *141*(10), 2417–2431.

Renn, O., Klinke, A., & Van Asselt, M. (2011). Coping with complexity, uncertainty and ambiguity in risk governance: A synthesis. *Ambio*, *40*(2), 231–246.

Renner, R., Schneider, F., Hohenwallner, D., Kopeinig, C., Kruse, S., Lienert, J., ... Muhar, S. (2013). Meeting the challenges of transdisciplinary knowledge production for sustainable water governance. *Mountain Research and Development*, *33*(3), 234–247. https://doi.org/10.1659/MRD-JOURNAL-D-13-00002.1

Rotmans, J., & Loorbach, D. (2009). Complexity and transition management. *Journal of Industrial Ecology*, *13*(2), 184–196.

Scholz, G., Dewulf, A., & Pahl-Wostl, C. (2014). An analytical framework for social learning facilitated by participatory methods. *Systemic Practice and Action Research*, *27*, 575–591.

Smith, H. M., Brouwer, S., Jeffrey, P., & Frijns, J. (2018). Public responses to water reuse—Understanding the evidence. *Journal of Environmental Management*, *207*, 43–50. https://doi.org/10.1016/j.jenvman.2017.11.021

Sol, J., Beers, P. J., & Wals, A. E. J. (2013). Social learning in regional innovation networks: Trust, commitment and reframing as emergent properties of interaction. *Journal of Cleaner Production*, *49*, 35–43.

Stahel, W. R. (2016). Circular economy [Comment]. *Nature*, *531*, 435–438.

Stilgoe, J., Lock, S. J., & Wilsdon, J. (2014). Why should we promote public engagement with science? *Public Understanding of Science*, *23*(1), 4–15.

Tahir, S., Steichen, T., & Shouler, M. (2018). *Water and circular economy: A white paper*. Cowes, UK: Ellen MacArthur Foundation, Arup, Antea Group.

Thompson, M. (2005). Structural and epistemic parameters in communities of practice. *Organisation Science.*, *16*(2), 151–164.

van de Meene, S. J., Brown, R. R., & Farrelly, M. A. (2011). Towards understanding governance for sustainable urban water management. *Global Environmental Change*, *21*, 1117–1127.

van Vliet, B., Chappells, H., & Shove, E. (2005). *Infrastructures of consumption, environmental innovation in the utility industries*. Earthscan: Routledge.

Voulvoulis, N. (2018). Water reuse from a circular economy perspective and potential risks from an unregulated approach. *Current Opinion in Environmental Science & Health*, *2*, 32–45.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge, MA: Cambridge university Press.

Wenger, E. (2010). Communities of practice and social learning systems: The career of a concept. In C. Blackmore (Ed.), *Social learning systems and communities of practice* (pp. 179–198). London: Springer.

Wenger, E. (2011). Communities of practice: A brief introduction. Retrieved from http://www.ewenger.com/theory/communities_of_practice_intro.htm.

Wenger, E., McDermott, R. A., & Snyder, W. (2002). *Cultivating communities of practice: A guide to managing knowledge*. Cambridge, MA: Harvard Business Press.

Wenger, E., Trayner, B., & de Laat, M. (2011). *Promoting and assessing value creation in communities and networks: A conceptual framework*. Amsterdam: Ruud de Moor Centrum, Rapport 18.

Wenger-Trayner, E., & Wenger-Trayner, B. (2015). *Communities of Practice—A brief introduction*. Retrieved from https://wenger-trayner.com/wp-content/uploads/2015/04/07-Brief-introduction-to-communities-of-practice.pdf.

How to cite this article: Fulgenzi A, Brouwer S, Baker K, Frijns J. Communities of practice at the center of circular water solutions. *WIREs Water*. 2020;e21450. https://doi.org/10.1002/wat2.1450

ANNEX 1: Example of the measurement methodology

TABLE 3 Example of the measurement of KSF #6 and its related indicators

KSF #6: Generation of useful knowledge in relation to the topic at hand	
Indicator	**Predefined Likert-type statement(s)**
6.1 Increased knowledge on the issue(s) at hand	The meeting helped me to increase my knowledge on circular water solutions.
6.2 Generation of new terms and language	I got acquainted with the new terms and language used during the meeting.
6.3 Creation of new expectations	Participating to the meeting inspired me with new expectations from the outcomes of the project.
6.4 Awareness of own role and role of other participants	I have a clearer understanding of how I can contribute to the objectives of this community. I am aware of what is the role of the other people participating to the meeting.
6.5 (potential) improvement in personal/organizational performance	I believe that participating to this community will improve my personal/organizational performance.
Likert-type level for indicator 6.4 Awareness of own role and of other participants' role	
Level (highest to lowest score)	Description
Complete definition and high awareness (5)	Participants know how their competences can contribute to the objectives of the CoP, and they know when/how contribution from other members is needed.
Partial understanding and definition of own and others' role (4)	Participants have a general understanding of how each of them could potentially contribute to the objectives of the CoP, but they are not sure about how they could help each other.
Ongoing negotiation of own and participants roles (3)	Participants are still defining how they can put their own competences to use for achieving the objectives of the CoP.
Awareness of own contribution but no understanding of others' roles (2)	Participants know what they could do for the CoP, but they are not aware of what the role of other members is or how the CoP could benefit from their competence.
No awareness of own contribution to the practice (1)	Participants do not know how they could help the CoP, nor how other members could help achieving the objectives of the CoP.

Note: For the KSF in the example, each indicator is presented together with its related Likert-type statement(s), followed by an example of the description of the Likert-type level (score from 1 to 5) for the indicator 6.4 Awareness of own role and role of other participants.