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Stakeholder engagement in the co-production of knowledge for environmental decision-making

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ABSTRACT

The production of science has generally been understood as primarily a technical endeavor, conducted by a narrow group of knowledge "experts" who ostensibly bring legitimacy and rigor to the process. In recent decades, the speed with which global environmental change has unfolded has pressured the scientific community to engage a broader set of actors in the production of knowledge to inform decision-making. Indeed, calls for societal engagement in the "co-production" of knowledge have proliferated in environmental and natural resource governance, climate adaptation, and land system science scholarship, among many others. We conduct a systematic review of scholarship focused on collaborative engagement between scientists and decision-makers to better understand the nature of stakeholder engagement in science production processes. We analyze collaborative knowledge generation within research that conceptualizes it as co-production and transdisciplinarity. We explore how stakeholders are defined, the processes by which stakeholders are engaged, the societal impacts associated with stakeholder engagement, and the barriers and enablers to stakeholder engagement. We uncover a diverse body of scholarship from around the world that cuts across many environmental issues, and highlights challenges in stakeholder engagement related to unequal and unmitigated power relations. We conclude with a set of recommendations related to how researchers engage in and report on stakeholder engagement in co-production processes.

Contents

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1. Introduction

The production of science has often been viewed as primarily a technical endeavor, conducted by a narrow group of knowledge "experts" who confer legitimacy and rigor to the generation of knowledge. In recent decades, the speed with which environmental challenges from climatic change and resource exploitation have unfolded has created "wicked problems," which are characterized by their complexity and where solutions are contested and change over time (Rittel & Webber, 1973). The nature of these problems has compelled the scientific community to engage with a broader set of actors in the pursuit of solutions. Collaborative knowledge production has become an approach to addressing challenging problems with multiple stakeholder groups. Collaborative knowledge production is seen as particularly useful to engage multiple stakeholder groups when it heeds power disparities and conflict (Turnhout et al., 2020) and differences in technical capacity, resource endowments, and trust (Baker et al., 2020). Similarly, many societal actors have increasingly recognized that the assimilation of science into decision-making is a vital step in the improvement of governance and resource management strategies.

Beyond practicality, societal engagement in the production of knowledge can also be attributed to the growing awareness of social justice issues concerning how research is – or should be – conducted, as well as the importance of decolonizing methodologies and expanding what counts as knowledge. In this context, gaps in data access and availability and scientific information, capacity, and funding accentuate inequities between the Global North and South (Blicharska et al., 2017; Kandlikar & Sagar, 1999; Karlsson, 2002). This North-South gap in the production of knowledge has significant negative implications for science and policy for sustainable development (Karlsson et al., 2007). For the sake of simplicity, we use the term North to refer to countries that are classified as high-income economies by the World Bank, and South refers to countries classified as upper-middle income, lower-middle income or low-income economies (World Bank, 2021). The dominant view of the South as simply adopting norms from the North is being questioned, with some researchers demonstrating how Southern scholars are idea-shifters and agents who shape global norms, for example, in areas of ecology (Mathai), human development (Huq and Sen), and responsible sovereignty (Deng and colleagues) (Acharya, 2016; Fukuda-Parr & Muchhala, 2020).

The participation of diverse actors in research has numerous advantages. Importantly, drawing in diverse views can help research better address (or better account for) socio-political and cultural contexts, thereby leading to relevant policy and practice (Blicharska et al., 2017). This idea has been central to many fields of development theory and practice and has also become an organizing principle to burgeoning disciplines like climate change adaptation and climate services. More than ever, it has become important to ask how knowledge is produced, who is involved in its production, how it is applied to decision-making, and how it serves society. One way to help integrate the practice and scholarship of co-production is to improve collection and reporting on the process of co-production itself in the many case studies of environmental knowledge production and use being prepared and disseminated. Tracking what stakeholders are doing on the ground, with what results, would go a long way towards fostering better decisions related to when and how to co-produce and what strategies can be scaled up to increase impact.

In this review, we systematically reviewed peer-reviewed publications relevant to two main approaches to collaborative knowledge production in the social and environmental sciences – transdisciplinary research and the coproduction of knowledge. We reviewed 109 publications that were published between 2005 and 2020 to analyze how different actors, such as those from local communities, governmental and non-governmental organizations, the private sector, and the general public, are involved in the knowledge production process (hereafter stakeholders), the societal impacts reported from stakeholder participation in research, and barriers and enablers to effective stakeholder engagement.

We use the term stakeholder in this paper to describe the non-academic actors engaged in the research processes we describe. However, we also acknowledge at least two issues with the term. First, "stakeholder" is often overly coarse because so many different actors can be interested in and affected by research efforts; people bring a range of knowledge, interests, capabilities, and investment to a transdisciplinary or co-production effort and this diversity can be masked by the use of one term to describe them all (Wall et al., 2017). Secondly, in the context of Indigenous communities, stakeholder can take on colonialist meanings; many Indigenous communities prefer the term rights holders when describing their relationship to natural and cultural resources (Pomart, 2020). This review uncovers a diverse body of scholarship from around the world that showcases not only the importance of stakeholder engagement but also its substantial challenges.

We conclude this review with a set of recommendations that serve as new frontiers for improving both the theory and practice of stakeholder engagement in co-production processes. Specifically, we suggest better metrics to measure the societal impacts that emerge from stakeholder engagement, greater communication, and facilitation to enable stakeholder engagement in co-production and to mitigate power imbalances, recognition of co-production as more than a methodological challenge, and the need for greater reporting of co-production practices more broadly. The

results from this review make it clear that stakeholder engagement creates benefits for the science production processes and emphasizes a need to better understand and to approach carefully *when and how* stakeholders are engaged.

2. Literature review: stakeholder engagement in co-production

Scholarly work on collaborative knowledge production is scattered over a wide range of disciplines that both intersect and diverge in their conceptualizations of these processes. Within climate change research, for example, collaborative knowledge production has been conceptualized as a process of "co-production" whereby knowledge users and producers interact to develop tailored information fit for purpose. This engagement helps promote the use of information in decision-making (Lemos & Morehouse, 2005); advise on specific actions that result in the creation of usable science (Meadow et al., 2015); or produce knowledge that is salient, credible, and legitimate (Cash et al., 2003) and that leads to changes in norms and structures within society (Jagannathan et al., 2020). Within community-based participatory research, the study of collaborative knowledge production emphasizes the role of community–academic partnerships in formulating research projects and publications and in ensuring the usefulness of information (Kaufman et al., 2014; Keune et al., 2010); citizen engagement in conservation (Jansujwicz & Johnson, 2015); and the enhancement of community capacity (Garzón et al., 2013). Finally, the study of collaboration in knowledge production in the domain of transdisciplinarity emphasizes the integration of knowledge systems and disciplinary traditions to solve complex problems (Priess & Hauck, 2014; Renner et al., 2013; Sarkki et al., 2013) and the envisioning of researchers as "active change agents" (Takeuchi, 2014).

Stakeholder engagement in collaborative knowledge production, defined broadly as co-production for the purposes of this paper, provides the context-specific expertise required for producing socially relevant, usable science (Polk, 2015). Stakeholder knowledge enables better understanding of multi-dimensional sustainability issues, as stakeholders are familiar with decision-making contexts and existing data (Polk, 2015; Frantzeskaki & Kabisch, 2016; Norström et al., 2020; Lemos et al., 2018). Meadow et al. (2015) find that stakeholder participation contributes to the acceptance and use of collaboratively produced knowledge by decision-makers because of greater transparency, perceived legitimacy, appropriateness of scale, embeddedness in the decision-framework, and users' feeling of ownership of the product. Scientists become more accountable when engaging with stakeholders, and co-production processes foster mutual responsibility and commitment to the research (Talwar et al., 2011; Polk, 2015). Beyond the primary goal of producing relevant and actionable information, engagement builds capacity, networks, and social capital, and leads to collective action (Bremer et al., 2019; Norström et al., 2020). While stakeholder engagement in co-production has many potential benefits, the outcomes, or the tangible changes that occur in society because of co-produced research, depend on how stakeholders are engaged (Djenontin & Meadow, 2018).

Several studies have shown that co-production success is dependent on the degree of interaction between groups (Djenontin & Meadow, 2018; Baker et al., 2020; Norström et al., 2020). Meadow et al. (2015) define stakeholders as the users of science. This broad definition can apply to almost any category of person, including representatives from local communities, non-profit organizations, private businesses, universities and schools, government agencies, and other governing bodies. However, co-production scholars question the distinction between producers and users, which reinforces unidirectional scientific methods and power dynamics, and fails to capture the overlap in roles during co-production (Bremer et al., 2019, Vincent et al., 2018). In co-production, stakeholders are also producers of knowledge, so the process must integrate multiple ways of knowing including local and traditional knowledge (Mach et al., 2020). Stakeholder knowledge is grounded in daily experience and practices and is rooted in a particular context or place (Eshuis & Stuiver, 2005).

Common stakeholder engagement activities include workshops, town meetings, questionnaires and surveys, and scenario exercises (Vincent et al., 2018; Mach et al., 2020; Frantzeskaki & Kabisch, 2016). The engagement activities can reflect different degrees of stakeholder interaction and the chosen activities are influenced by the phase of the research (Schneider & Buser, 2018). Bremer et al. (2019) identify three phases of co-production: (1) the *co-design* of the research; (2) the *co-production* of science that occurs in the process of conducting the research; and (3) the *co-dissemination* (and co-evaluation) of the results, noting that the level of stakeholder involvement can vary between phases. Lemos and Morehouse (2005) maintain that successful co-production processes are favored when stakeholders are involved in multiple stages of research. The implementation phase is the "heart" of the co-production process, according to Djenontin and Meadow (2018), because it is where the research team and stakeholders most actively collaborate to undertake the research. The cycle of co-production should be characterized by continuous monitoring, knowledge exchange and learning that enables reflexive review and refinement of both the process and product as necessary (Vincent et al., 2018).

Despite the theoretical and practical developments of co-production, the concept and the way it is enacted has been critiqued. Turnhout and others (2020) review these critiques and find that co-production processes often fail to meet their stated goals due to a lack of engagement with underlying power differentials between participants. Co-production processes may also be framed in a technical manner which masks the inherently political nature of whose knowledge is seen as legitimate, which can inhibit truly co-produced knowledge and further entrench social hierarchies (Turnhout et al., 2020; Daly & Dilling, 2019; Goldman et al., 2018). Further, there is a recognition that not all actors are equal in participatory processes. Knowledge co-production is often initiated by elites, who shape stakeholder selection and have more time, resources, and perceived legitimacy, politicizing the effort from inception (Edelenbos et al., 2011; Turnhout et al., 2020). Some actors may have more ability to participate while others may lack capacity to or have been excluded from engaging in knowledge production processes (Wilmer et al., 2021). Scholars have called for attention to power dynamics and inclusion in co-production to avoid reinforcing inequities and also improve the outcomes of knowledge production (Wamsler, 2017; Vincent et al., 2018; Norström et al., 2020).

Despite the breadth of directions from which research on collaborative knowledge production has ensued, work is still needed to identify how these areas of research approach stakeholder engagement. Given the explosion of co-production processes in practice, and how stakeholders are central to these processes, interrogating the role of stakeholders in these processes systematically across a broad set of scholarship fills a key gap in the research. One key challenge is that, as the above discussion suggests, diverse disciplinary orientations have used different terms to express the process of engagement in knowledge production. In this review, our emphasis is on identifying the ways in which stakeholders engage in distinct forms of knowledge production, the varied ways stakeholders engage and are represented, and the meaning this diversity of representation has for collaborative knowledge production itself. In addition, we heed calls to better

understand how and why co-production works under certain circumstances, and to avoid highly prescriptive approaches that mostly focus on the process rather than on achieving desired sustainability outcomes (Lemos et al., 2018). Our work here aims to help track what stakeholders are doing on the ground and with what results, with the intention to foster better decisions related to when and how to co-produce and what strategies can be scaled up to increase impact.

3. Methods

We conducted a systematic review to examine the peer-reviewed scholarship around stakeholder engagement in co-production processes. Systematic reviews first emerged in the health sciences scholarship and have been adopted in the environmental social science scholarship more generally (Berrang-Ford, 2015; Cox, 2015). They are used as a means to thoroughly, consistently, and clearly assess a defined series of existing literature (Berrang-Ford, 2015).

Our review drew from the Scopus Database (Scopus, https://www.scopus.com/). Our principal goal was to review relevant empirical work on the co-production of knowledge. As noted above, the ideas of co-production are embedded in different disciplines and approaches that may, or may not, explicitly use the term "co-production." Cognizant of this fact, we searched bodies of literature focused on transdisciplinary and community-based participatory research, as well as on co-production. We used variants of these terms, as well as variants of "stakeholder" and "partner" as denoted in the following three strings:

1. KEY ("stakeholder*" OR "partner*" AND "coproduc*" OR "co-produc*") OR TITLE ("stakeholder*" OR "partner*" AND "coproduc*" OR "co-produc*")
2. KEY ("stakeholder*" OR "partner*" AND "transdiscip*") OR TITLE ("stakeholder*" OR "partner*" AND "transdiscip*")
3. KEY ("stakeholder*" OR "partner*" AND "community-based participatory research" OR "community based participatory research") OR TITLE ("stakeholder*" OR "partner*" AND "community based participatory research" OR "community based participatory research")

Each search queried keywords, abstracts, and titles and was restricted by subject area, the document types "article" and "chapter," the language "English", and the source type "journal." Our initial searches in June 2020 returned 142, 175, and 392 for the search strings based on co-production, transdisciplinary, and community-based participatory research, respectively, for a total of 709 potential publications. The publications spanned 2005 to June 2020.

We then reviewed the abstracts of each publication to assess whether it met all of the following four criteria: (1) provided empirical results, (2) was related to the environment, (3) appeared to include stakeholder engagement, and (4) was not only a review of other research. If we were uncertain whether the publication met these criteria, we included it. This review of abstracts reduced the dataset to 203 publications total, or 66 for co-production, 131 for transdisciplinary, and 6 for community-based participatory research queries. With only six publications in the community-based participatory research category, we decided to omit them from further analysis. This resulted in an initial dataset of 197, from which we further eliminated 10 publications that appeared in both categories.

One member of our research team then reviewed each publication to determine if it actually described the process of stakeholder engagement related to co-production, given that the details of stakeholder engagement are often not evident in the abstract. By applying our criteria for inclusion again, we removed 43 more publications from the dataset due to a lack of description of a specific stakeholder engagement process. This resulted in a dataset of 144 publications (see supplemental materials for the entire corpus).

We reviewed each publication to answer the 15 questions presented in Supplemental Table 1; we have provided the dataset via Zendo. These questions targeted the nature of the stakeholders and the engagement activities, as well as the impacts and outputs resulting from the engagement. Our coding methodology combined established frameworks and a grounded theory approach. All the codes are listed in Table 1 of the supplemental material. We also provide definitions for the codes we refer to commonly in corresponding tables, and we combine all the definitions in Table 2 in the supplemental material. For each question, one member of the author team coded all articles to create consistency in the coding. Questions were independent and did not require an analysis of intercoder reliability.

We attempted to include individual cases that were included in papers summarizing multiple case studies. However, there was a marked difference in the detail of stakeholder engagement described in publications that reported on a single case study compared to publications that reported on more than one case study which prevented comparison between the two groups. Therefore, we chose to principally analyze the publications that reported single cases, which account for 109 of the 144 publications. We include a brief analysis of multi-case publications in the supplemental material. In this analysis, we present both summary statistics of these questions and, where needed, analyses based on group clusters.

Several issues about this systematic review bear on the interpretation of our results. First, our results reflect the discourse of peer-reviewed publications written in English. Scopus is partial to academic literature with about 92.6% of the articles are written in English (Vera-Baceta et al., 2019); had we not restricted the search to English, we would only have had two additional article to review. We recognize, however, that relevant research is found in gray literature and in non-English texts. However, at present there does not exist a parallel database for non-academic research that would provide a broad, representative sample. Second, stakeholder engagement and co-production are practiced in many disciplines, including public health, environmental governance, citizen science, and development. The expertise and experience of the author team lead to the decision to restrict our initial foray to three of the more prominent fields that has informed co-production as it pertains to environmental research: co-production, transdisciplinary, and community-based participatory research (Meadow et al., 2015). As such, this systematic review is not a comprehensive treatment of co-production. Nonetheless, it is a robust representation of the literature surrounding co-production, stakeholder engagement, and the environment. Finally, the academic literature slants toward western industrialized countries, as noted in our sample. The prevalence of these contexts reinforces the framings and discourse around stakeholder engagement and co-production, while isolating valid but less accessible research.

Table 1 summarizes the general characteristics of the 109 case studies. Peer-reviewed articles about stakeholder engagement have been increasing, with a notable acceleration in our dataset beginning around 2014. A majority of case studies (62%) were published between 2017 and 2020. Studies occurred in 39 different countries, with European countries (44%) represented most frequently. Due to the broad dispersal of cases across countries, it was difficult to discern clear trends in knowledge co-production at the country level, and even at the regional level. We found a few notable differences and similarities between cases occurring in the Global North (61%) and the Global South (31%), which are discussed in Section 4.8. Case study topics spanned a variety of

Table 1
General characteristics of the 109 case studies including study region, Global North or Global South, and main environmental issues addressed.

Case Study Characteristics	Percent of Case Studies (n = 109)
Regions of Study	
Europe	44%
Africa	23%
North America & Caribbean	19%
Asia	17%
Oceania	12%
South America	2%
Global North & South	
Global North	61%
Global South	31%
Both	2%
Main Environmental Issues	
Food & Agriculture	43%
Water	26%
Wildlife & Biodiversity	22%
Other	19%
Climate	15%
Land & Soil Conservation	14%
Forests	10%
Urban Planning & Development	10%
Energy	5%
Marine Ecosystems & Coasts	4%

Note: Many studies addressed more than one main environmental issue or occurred in more than one region.

environmental issues, such as food and agriculture (43%), water (26%), and wildlife and biodiversity (22%).

To better understand any observable changes over time in the case studies examined, we compared two discrete periods: 2005–2014 and 2015–2020. The first period is 10 years and accounts for 22% of papers examined, while the shorter second period of 5.5 years accounts for 78% of the papers studied. There is a step change around 2015 in the number of publications we analyze each year from about 2.4 to 15.5 publication per year. Based on this, we analyzed change over time for several variables by comparing averages of these two periods.

4. Results

4.1. Types of stakeholders engaged and environmental issues addressed

Key finding: Several types of stakeholders engage in co-production activities, but most frequently involve university-based researchers and government employees.

A variety of stakeholder groups engaged in co-production activities. University-based researchers were part of all cases except one, an unsurprising result given our analysis of only peer-reviewed publications. Government employees (84%) were the second most prominent stakeholder type. Private sector (55%) and representatives from non-governmental organizations (53%) were both represented in more than half the case studies. Members of the members of the public (31%), local communities (19%), professional associations (17%), Indigenous/tribal communities (14%), and representatives from regional or multinational organizations and development organizations (11%) were less frequently involved.

Across the stakeholder groups, patterns of engagement with environmental issues were evident. Fig. 1 shows the proportion that stakeholder groups engaged in different environmental issues. Engagement was most frequent in issues related to agriculture, water, and biodiversity for all stakeholder groups. Professional associations also engaged relatively more often on issues of land conservation than other environmental issues, and regional, multinational, and development-focused institutions had proportionally more engagement in climate issues than other groups. The data also reveal relatively less engagement in topics surrounding forests, energy, urban planning, and marine/coastal issues.

4.2. Stakeholder engagement throughout the research process

Key finding: Stakeholders are engaged primarily in the data collection phase of research.

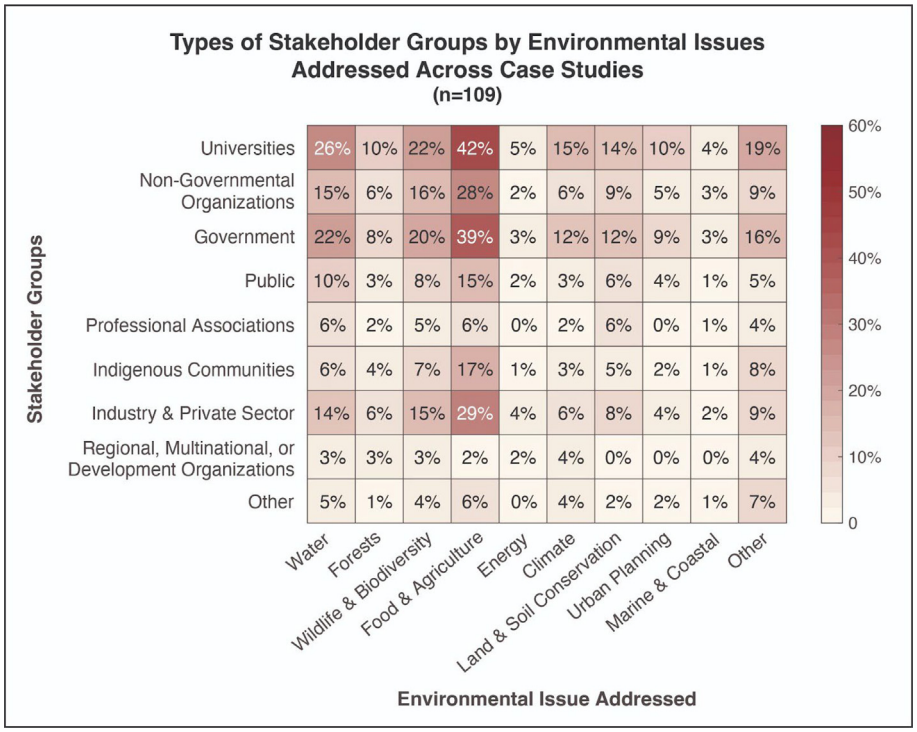

Fig. 1. Percent frequency of each stakeholder group category and environmental issue addressed across 109 case studies.

Stakeholder engagement varied throughout the project lifecycles. Nearly all stakeholders were engaged during data collection (95%), which included participation in surveys, interviews, workshops, or field data collection. This suggests that stakeholders were largely engaged as research subjects, not necessarily as partners. Data collection was the most frequent form of engagement over time; stakeholders were part of data collection in about 95% of the studies analyzed in both the 2005–2014 and 2015–2020 periods.

In contrast, less than a third were engaged in other project lifecycle phases (see Fig. 2). Only 30% of case studies mentioned stakeholder engagement during data analysis, evaluating previously collected information, or prioritizing research findings for decision making. Although many case studies mentioned the desire to engage stakeholders beyond the project period, disseminating post-research findings among stakeholders through an event or electronic circulations were mentioned in 23%. Only 13% included non-university-based stakeholders as paper co-authors.

Although university researchers and government representatives were both well represented in co-production processes, the depth of their engagement differed across cases. For example, in some instances, government representatives were consulted or interviewed by researchers (e.g., Beech, 2015; Lebel et al., 2015), while in others they were included as key participants in multi-stakeholder workshops (e.g., Allen et al., 2017). There were several examples in which government representatives formed working groups or councils with other stakeholders to coordinate on particular issues, such as the impacts of hurricanes and flash floods as described in Aguilar-Barajas et al. (2019). For Miszczak and Patel (2018), the co-production process was more immersive, with university researchers being embedded in relevant government departments and working alongside practitioners on specified urban policies for seven months at a time over a three-year period.

4.3. Ways that stakeholders were engaged

Key finding: Stakeholders were engaged mostly through surveys, interviews, and workshops; more recently published case studies show increased variety in types of engagement activities.

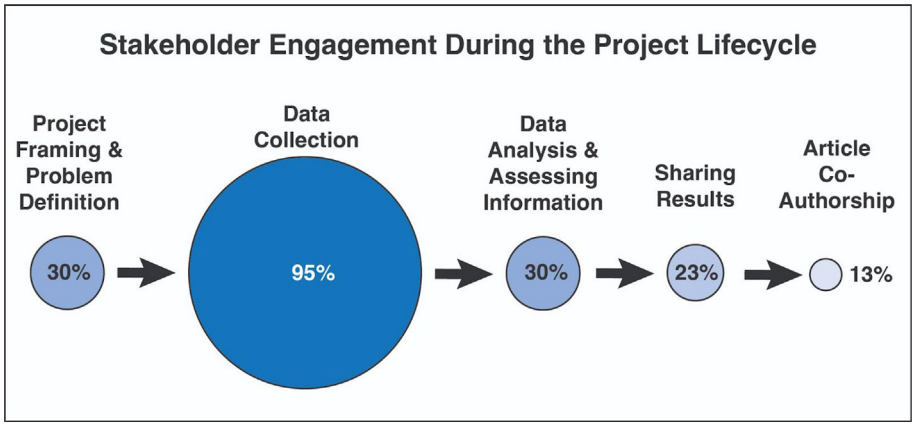

Fig. 2. Percent of stakeholder engagement during various phases of the project lifecycle.

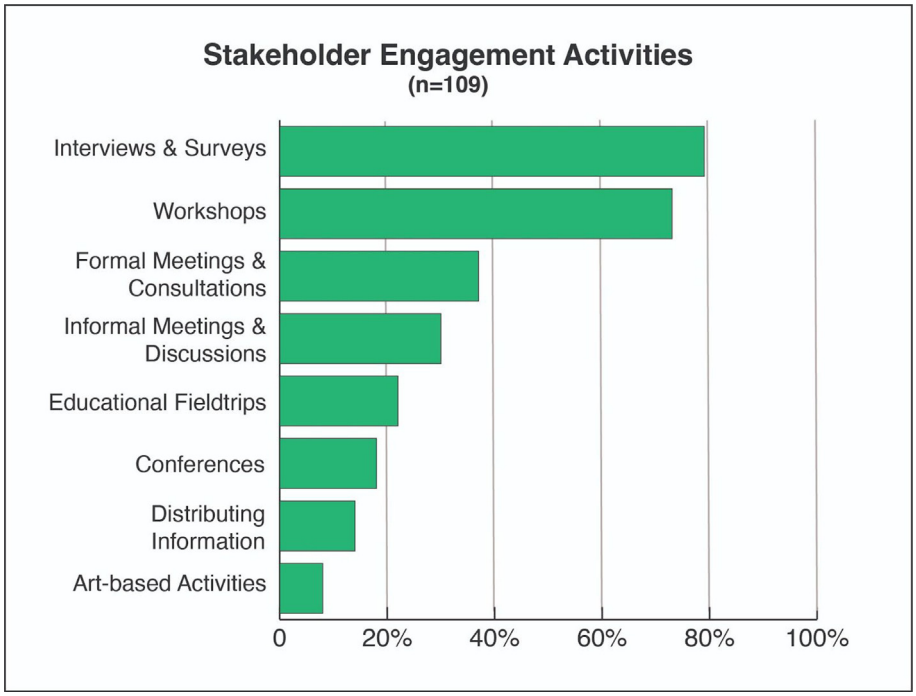

Fig. 3. Percent frequency of activities reported to engage stakeholders across 109 case studies.

Stakeholder engagement mechanisms reflect the activities used to integrate stakeholders in the co-production process. We identified seven different mechanisms in our analysis (see Fig. 3). The most frequent mechanisms were surveys and interviews (79%) and stakeholder workshops (73%), suggesting that stakeholders were largely involved as sources of information. Informal meetings and discussions (30%) as well as formal meetings and consultations (37%) were somewhat frequently used. Case studies published since 2013 more frequently described diverse types of stakeholder engagement activities, such as educational trips and fieldwork, informal meetings, and arts-based activities.

Arts-based activities provide creative methods for stakeholder engagement although they are the least common type of activities. For example, Ruiu et al. (2017) described a theatrical process in which local actors, stakeholders, and researchers participated in a creative process of exchange and learning. In this example, scientists and local artists drafted a theatrical legal trial to resolve a local water conflict. Participants deliberated on the verdict, but its meaning went beyond the performance. It was intended as a "mediating object" to encourage shared acceptance of the outcome by stakeholders. In addition to a collective workshop, Allain et al. (2020) engaged stakeholders in problem structuring through interviews based on a card-sorting game. The game involved interviewees selecting 3–5 cards from at deck of 15 that best depicted their concerns around agricultural water management. In their efforts to understand human-wildlife conflict in Mexico, Castillo et al. (2020) engaged community members in a participatory photo-mapping process, in which local people were trained to operate and manage cameras that would capture the movement of jaguars and other wildlife. Subsequently, a public festival was organized, which included games, short talks, and an arts and crafts competition, all of which helped to raise awareness around wildlife and to establish closer relationships between the researchers and the local community.

4.4. Approaches to stakeholder engagement

Key finding: Researchers tend to hold leadership and decision-making roles in the co-production process; however, consensus and stakeholder leadership is present.

We further categorized each paper into one of five approaches to stakeholder engagement. These categories—contractual, consultative, collaborative, collegial, and Indigenous—reflect different engagement intensities and roles people play in the engagement process. We adapted these categories from David-Chavez and Gavin (2018) and Biggs (1989). Category definitions and frequencies are provided in Table 2. Overall, consultative, collaborative, and collegial are the dominant approaches. The difference between these three approaches lies in who holds leadership roles, decision-making authority, and power in the research process. In most cases, researchers hold leadership positions, make decisions, and drive the co-production process (consultative and collaborative approaches). However, several cases demonstrate a shift in leadership and power in the process toward stakeholders (collegial and Indigenous approaches). We observe no marked change in the relative proportions of the different approaches between the 2005–2014 and 2015–2020 periods.

While a majority of cases (64%) described only one approach to stakeholder engagement, others employed different approaches at different stages of the research process. Two forms of engagement were described in 28% of cases, 7% described three forms of engagement, and one case described four categories of engagement. Contractual forms of engagement never occurred solely on their own; they were always described with at least one other form of stakeholder engagement.

Table 2
Definitions of approaches to stakeholder engagement and the percent that each occurs in the dataset of 109 case studies.

Approach to Stakeholder Engagement	Definition	Percent of Case Studies (n = 109)
Contractual	Stakeholders or researchers are contracted to perform a particular project task whose goals and methods are prescribed.	6%
Consultative	Stakeholders are consulted about the research process and/or about data collection but do not make research decisions.	40%
Collaborative	Stakeholders and researchers work together during one or more parts of the research process; researchers tend to hold project authority and leadership roles.	56%
Collegial	Stakeholders and researchers work together; decisions are made by stakeholders or by consensus of the team.	41%
Indigenous	Research process is centered in indigenous value systems and historical contexts; stakeholders hold decision-making authority.	2%

Grima et al. (2017) describe multiple engagement approaches that occurred over the course of a land management project in the Cuitzmala watershed in Mexico. Stakeholders participated in a series of workshops, which were used to gather participant data and represented a consultative approach. Subsequent workshops were informed by previous workshop outcomes and needs identified by participants, which represented a collaborative approach. At the end of all the workshops, stakeholders and researchers produced an action plan for next steps, concrete actions, and identified the responsible party for implementing those actions, revealing a more collegial approach. Reflecting upon the process, the authors noted, "It is important to mention that throughout the entire process, stakeholders were not only a source of (very valuable) information but were also invited to add their perspectives in the analysis of this information and the validation and acceptance (or rejection) of results" (Grima et al., 2017: 82).

Only two cases reported using an Indigenous approach, both occurring in New Zealand. In one of these cases, a Maori knowledge system and methodology was used to guide the research process and to develop a freshwater management framework (Kitson et al., 2018). In the other case, researchers brought together representatives from multiple stakeholder groups to create a shared understanding around pest management practices across New Zealand, with the goal of developing practices that incorporate a Maori worldview (Allen et al., 2014).

4.5. Outputs reported from stakeholder engagement

Key finding: Stakeholder engagement in co-production leads to a variety of outputs; dialogue is the most frequent output reported.

Outputs from stakeholder engagement processes took several forms (see Fig. 4). The most common output was dialogue, in which stakeholders participated in group discussions (61% of case studies). For example, Hayes et al. (2020) engaged stakeholders to discuss risk reduction from volcanic eruptions. They held multiple discussion forums which allowed stakeholders to communicate with other stakeholders and identify common themes and research avenues for future exploration. Jansujwicz and Johnson (2015) also focused their outputs on dialogue, allowing stakeholders to discuss

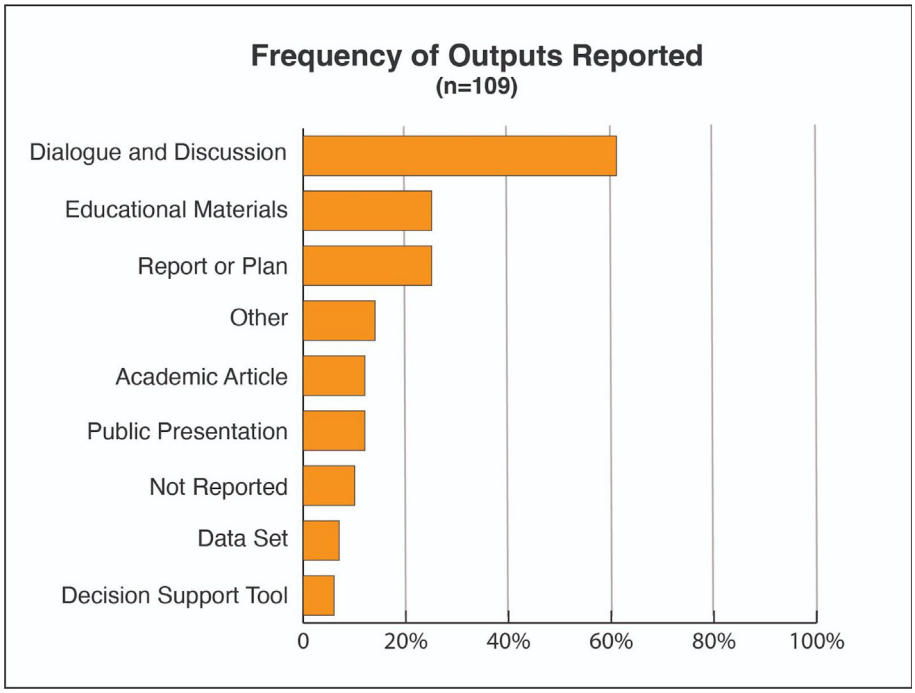

Fig. 4. Percent frequency of outputs reported from stakeholder engagement activities across 109 case studies.

local knowledge, research methodologies, and providing a platform to listen and document community concerns, questions, and informational needs. Several case studies also went beyond facilitating dialogue and included the creation of curricula or educational materials (25%), reports and plans (25%), and presentations (12%). A smaller number of articles mentioned datasets (7%) and decision support tools (6%) as key outputs of stakeholder engagement.

4.6. Societal impacts reported from stakeholder engagement

Key Finding: While all approaches to stakeholder engagement reported a range of societal impacts, collegial approaches (stakeholder-led or consensus driven) reported higher frequencies of instrumental, capacity-building, and connectivity impacts than consultative or collaborative approaches (researcher-led).

In this paper, societal impacts are defined as the changes to people, communities, and/or environments outside of academia that occurred due to the research process or findings. We classified societal impacts into six categories, adapted from Edwards and Meagher (2020), and defined in Table 3. Conceptual, connectivity, instrumental, and capacity building categories are typically shorter-term changes that lead to longer-term impacts of social and environmental change over time (Meadow & Owen, 2021).

Table 3
Definitions of six societal impact categories and percentage of frequency across 109 case studies.

Societal Impact Categories	Definition	Percent of Case Studies (n = 109)
Conceptual	Changes to knowledge, awareness, attitudes, emotions, or ideas	65%
Connectivity	Changes in quantity or quality of relationships or networks; changes to trust, mutual understanding, or development of common language	30%
Instrumental	Changes in plans, decisions, practices, or policies	24%
Capacity Building	Changes in skills, expertise, or enhanced capacity to take action	12%
Social Change	Measurable changes to social systems, structures, behaviors, or wellbeing of people	6%
Environmental Change	Measurable changes to natural resources or ecological system function	3%

Stakeholder engagement often led to changes in the way a problem was conceptualized, understood, or framed. Typical examples included: new ways of seeing a given socio-ecological challenge (e.g., Hauck et al., 2016), or new reflections on one's own values and assumptions (e.g., Goven et al., 2015). Conceptual changes frequently took the form of adding new perspectives to a given problem frame, or the way a problem is defined in terms of causes and possible solutions. For example, Brand et al. (2013: 12) described how "place-based knowledge and values of stakeholders were very important elements in broadening perspectives and in developing strategies ... a transdisciplinary approach makes sure that scientists focus on problems that are really relevant for the people in the study regions." In this example, local experiences of declining agriculture and timber industries were integrated with scientific understandings of global climate change to inform the development of possible future scenarios in Visp, Switzerland.

Connectivity and instrumental impacts were also frequently reported. Examples of instrumental impacts included a new management strategy combining scientific and local ecological knowledge in coastal management (e.g., Hastings et al., 2012), securing new sources of funding (e.g, Rosen & Painter, 2019), or the development of new farming practices (e.g., Marshall et al., 2018). Iwaniec et al. (2020: 9) reported connectivity impacts in the following way: "The [research] process helped build relationships among stakeholders from diverse sectors, cities, and scales who do not typically work together."

Other categories of societal impacts were reported less frequently. Capacity building examples included increased ability to collaborate (e.g., Cockburn et al., 2016), or new technical capacities, such as water quality monitoring (e.g., Brasier et al., 2017). Social change and environmental change impacts included examples like shifting power balances amongst stakeholders in marine spatial

planning in Mexico (Paez et al., 2020) and restored mangrove habitat in the Philippines (Farley et al., 2010). Over time, there was a relatively larger focus on instrumental outcomes and environmental change impacts in the 2005–2014 period—about 38 and 8 percent, respectively—compared to the 2015–2020 period—20 and 1 percent, respectively. Conversely, capacity building and society change impacts were reported more frequently in the 2015–2020 period compared to the 2005–2014 period (13 and 8 percent compared to 8 and 0 percent, respectively). We present relationships between stakeholder engagement methods, approach, and societal impact in Figs. 5 and 6.

By analyzing stakeholder engagement approaches and the societal impacts reported, we found that all five categories of approaches show varying degrees of societal impacts (Fig. 6). By focusing on the three most prevalent approaches to engagement in our dataset - consultative, collaborative, and collegial - we see interesting differences in the societal impacts reported. Case studies with collegial approaches reported instrumental impacts more than twice as frequently than cases with consultative approaches and reported capacity building and connectivity impacts more than three times as frequently. This finding suggests that co-produced projects led by stakeholders or by consensus result in more evidence of societal impact than co-produced projects led by researchers.

4.7. Barriers and enablers to co-production

Key finding: Inclusion of diverse stakeholders, building trust, and using dialogue are necessary components of knowledge co-production to help address power imbalances.

Several enabling factors support stakeholder engagement, as shown in Table 4. Operational dynamics, broadly defined as logistical, programmatic, or day-to-day interactions that support engagement activities, were most common. For example, communication among participants was frequently identified (72%) as vital to co-production processes. Some cases also noted that strategic and skillful facilitation (20%) and technical capacity (20%) were crucial components of effective co-production processes.

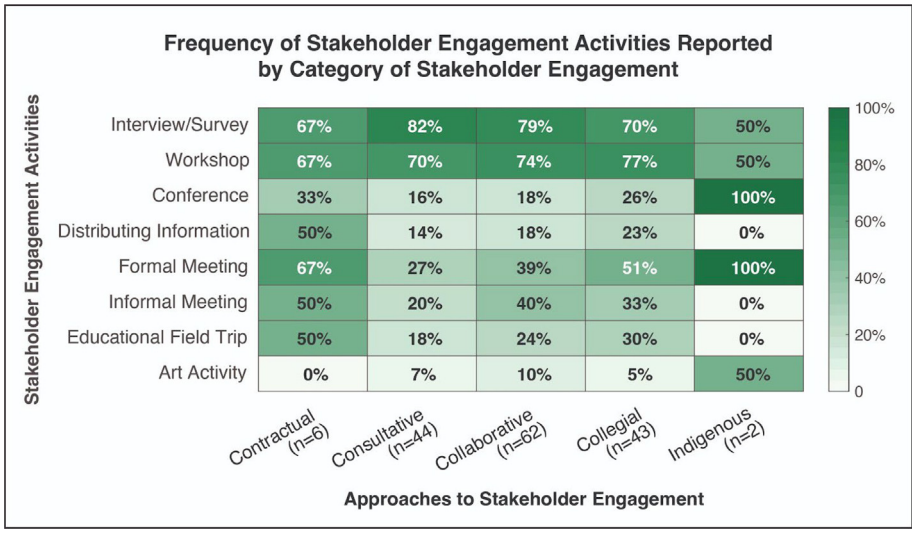

Fig. 5. Percent of case studies divided by categories of approach to stakeholder engagement combined with activities used to engage stakeholders. Note: The sample size for each approach category is noted in the x-axis label.

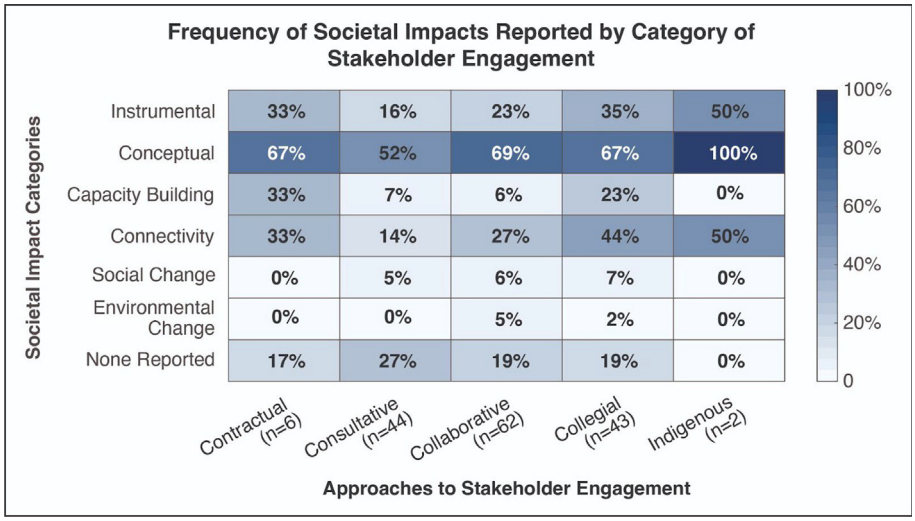

Fig. 6. Percent of case studies in each category of approach to stakeholder engagement combined with reported societal impacts of the engagement. Note: The sample size for each approach category is noted in the x-axis label.

Table 4
Percent of frequency of enablers and barriers to stakeholder engagement across 109 case studies.

Types of Enablers and Barriers to Stakeholder Engagement	Presence as Enabler % of case studies (n = 109)	Presence as Barrier % of case studies (n = 109)	Presence as Enabler and/or Barrier % of case studies (n = 109)
Social Relations			
Power relations & distribution	30%	39%	50%
Stakeholder participation	38%	39%	53%
Trust & accountability	34%	11%	40%
Presence of leadership	6%	1%	6%
Operational Dynamics			
Communication	72%	38%	74%
Human & financial resources	14%	39%	45%
Technical capacity	20%	19%	34%
Coordination & facilitation skills	20%	2%	19%
Structural Components			
Institutional support & capacity	17%	18%	29%
Flexibility & adaptiveness	10%	3%	10%
Partnerships	15%	2%	15%
Transparent & open processes	23%	1%	22%

Case studies also highlighted social relations (defined as the relationship dynamics that support engagement processes) as enablers. Case studies identified enablers such as stakeholder participation and inclusivity (38%); trust and accountability (34%); and power relations and distribution of power (30%). These dynamics were demonstrated by acknowledging diverse forms of knowledge and expertise (e.g., Frantzeskaki & Kabisch, 2016); ensuring the process is meaningful in local contexts (Trimble, 2014; Laborde et al., 2018); building trust (Renner et al., 2013; Schutt et al., 2019) and overcoming power asymmetries (Trimble, 2014; Rosen & Painter, 2019; Adelle et al., 2020) through inclusive practices. For example, Adelle et al. (2020: 63) found that "the emphasis placed on collecting ideas from a wide group of stakeholders shifted the balance of power from traditionally hierarchical relationships between scientists and stakeholders…by empowering traditionally marginalized groups of stakeholders". This work is illustrative of the broader trend we observe of researchers paying greater attention to issues of power in more recent research, or the 2015–2020 period of analysis compared with the 2005–2014 period.

Case studies also identified structural components as enablers, defined as institutional or organizational processes, partnerships, and flexibility. Some case studies highlighted the importance of transparent and open decision-making procedures (e.g., Rose et al., 2017; Fernández-Giménez et al., 2019). Others described how the presence of strong partnerships made co-production easier, as group dynamics helped build the foundation to engage in knowledge exchange (Rose et al., 2017).

Key finding: A lack of operational and structural support can inhibit inclusion, communication, and capacity building for knowledge co-production.

Social relations were frequently reported as barriers and were mainly concerned with issues around participation (39%) and with imbalanced power (39%). In looking at changes over time, we observe researchers paying greater attention to power as a barrier in more recent years (2014–2020 period as opposed to 2005–2014). In terms of both barriers and enablers, researchers are paying greater attention to issues of power in the later period.

Here, power is seen in terms of the power to define the problems being addressed (Hauck et al., 2015; Moran et al., 2019; Zscheischler et al., 2019); the power to decide whose priorities should guide the process (Jansujwicz & Johnson, 2015; Healy, 2019); and the power and privilege of Western science and expertise (Schuttenberg & Guth, 2015; Foley et al., 2017). Legacies of exclusion from decision-making represent a particular challenge in engaging stakeholders (Rosen & Painter, 2019).

Operational dynamics were also frequently reported as barriers to engagement, and mainly referred to barriers in human and financial resources (39%) and communication (38%). Communication issues included the lack of a shared vision (e.g., Doble & King, 2011; Ferguson et al., 2018; Zscheischler et al., 2019) and challenges in reconciling diverse perspectives, backgrounds, and opinions (Henze et al., 2018). Henze et al. (2018: 17) found that, "the different perspectives of the representatives in the case study project gave insights into the variety and complexity of the stakeholders in a planning and governance process of a river landscape. It became clear that the stakeholders from different sectors and governance levels with different individual knowledge backgrounds faced some major challenges concerning the cross-institutional collaboration and the mutual understanding of the project".

Other issues included failure to bring different knowledge systems (ontologies) and ways of knowing (epistemologies) together (Edelenbos et al., 2011; Allen et al., 2014; Schuttenberg & Guth, 2015); misunderstandings of information (Schutt et al., 2019); insufficient translation of data (McGreavy et al., 2013; Frantzeskaki & Kabisch, 2016); and failures to create common understandings (Castellanos et al., 2013; Gebhardt et al., 2019; Holzer et al., 2019). For example, Gebhardt et al. found that "…finding a common language within the team that includes the same understanding of the terminology and methods was a challenge that required mutual learning…. The different perspectives of participants from different disciplines within the team of researchers also became evident when deciding on concepts, methodologies, and working methods" (2019: 14). Barriers around power imbalances and communication are not always separate issues and co-production is often challenged by the confluence of these dynamics. This confluence may present itself as challenges to facilitating dialogue between actors at multiple scales of decision-making (Wever et al., 2015; Eden et al., 2016; Frantzeskaki & Rok, 2018).

The most common structural barrier reported was lack of institutional support and capacity (18%). As Thompson et al. explained, "Support for and agreement with the idea of transdisciplinarity is strong…, yet actors who desire to participate feel hindered by the existing institutional structures they work within, which were built to support and reinforce traditional knowledge production modes" (2017: 37). This description applies to academics in their respective disciplinary traditions, but also to government officials or others in positions of power who may feel disincentivized from participating in co-production due to cultural or administrative contexts.

4.8. Co-production in the Global South versus Global North

Key finding: Characteristics in co-production processes are largely similar among studies in the Global South and in the Global North despite their diverse geographic and socio-cultural contexts.

We compared results from the 67 papers on the Global North to the 34 papers on Global South across several variables of interest, including the types of environmental issues addressed, the types of stakeholders involved, engagement activities, timing of collaboration, and enablers and barriers in the engagement. We expected that the socio-economic contexts of studies in these two regions

would be associated with differences in these variables. However, the distributions for each of these variables were largely similar. A few noteworthy differences are highlighted here.

In the Global South, there was a greater focus on food and agriculture and land and soil conservation than in the Global North. These two issues accounted for 59% and 24% of the studies in the Global South compared to 35% and 10% in the Global North, respectively.

With respect to the stakeholders engaged, studies in the Global North reported engaging twice as often with the public as studies in the Global South (40% compared to 21%, respectively), but nearly 4.5 times less frequently with communities (13% compared to 58%, respectively). Studies in the Global North engaged more often in conference settings (24%) compared to the Global South (2%).

Some differences between the Global North and South also emerged in respect to enablers and barriers (see Table 5). Regarding enablers, the largest difference is found in the category of trust and accountability. Cases in the Global South reported these social dynamics as enablers approximately 2.5 times more often than cases in the Global North. Regarding barriers, the largest difference between the two regions were found in stakeholder participation which refers to buy-in, inclusivity, and representation. Cases in the Global North were more than 3 times as likely to report issues of participation as barriers than cases in the Global South. For example, Goven et al. (2015) emphasized that despite active efforts, attracting and retaining a diversity of participants posed challenges. This project drew on established community organizations to identify stakeholder participants, which led to a higher proportion of participants who had extra time for volunteer activities.

Power relationships and the distribution of power among participants was more frequently reported as a barrier (47%) and as an enabler (35%) in the Global South. Pre-existing power dynamics among stakeholders at local levels often became evident in participatory processes. Sometimes these acted as obstacles to the emergence of equitable engagement processes. For example, Barnaud and van Paassen (2013) noted in context of communities negotiating with a national park that "villagers and village leaders were not aware of the proactive role they could or should have played in the negotiation with the national park" and that "community members had unequal access to information and unequal opportunities to participate in decision making at the village level" (Barnaud & van Paassen, 2013: 6).

5. Discussion and conclusions

Overall, this review reveals significant interest in and growing understanding of the importance of stakeholder engagement in knowledge co-production for environmental decision-making. Dialogue is a consistent theme across the studies we examined, which suggests that people are communicating and iterating more in co-production processes than in standard disciplinary focused research. Nonetheless, the balance toward more conceptual impacts in our dataset might suggest that we are in the early stages of documenting the impact of co-production. Impacts often build on one another (Meadow & Owen, 2021). Conceptual impacts tend to be reported at high frequencies (Meagher & Martin, 2017) and are often the first to emerge from new research, thereby laying the early groundwork from which other types of impacts can grow. In our dataset, we see increased and more diverse types of societal impacts appear in the collaborative and consensus-based approaches to co-production. This trend suggests that addressing power dynamics, through communication and facilitation, is key to effective stakeholder engagement. Unequal and unmitigated power relations may ultimately prevent advancement in co-production processes. In the next wave of co-production research, we argue that the social dynamics of the engagement processes deserve greater attention.

5.1. Articulating the tenets of stakeholder engagement

Across a diversity of circumstances, we report numerous characteristics that either have enabled or have acted as a barrier to stakeholder engagement (Table 5). We consider these to represent the key tenets of stakeholder engagement, and we describe them in Table 6 based on our iterative, inductive coding. Some of the characteristics were reported more often than others, as we show in Table 5. For example, "Communication" was identified in 73% of the papers as either an enabler or a barrier, whereas "Flexibility and Adaptiveness" and the "Presence of Leadership" were less frequently identified. Despite differences in their presence in our corpus, each is important to consider. The unique circumstances of the engagement, along with the broader social, political, and cultural context will determine which characteristics weigh more heavily as enablers or barriers.

We note that there are numerous frameworks for stakeholder engagement. Gardner et al. (2009), for example, described 10 principles of effective stakeholder engagement in climate adaptation. Our list of 12 is similar to those 10, with a few notable differences. The notion of power dynamics features prominently in the studies we reviewed, with 50% reporting the presence thereof. More recent frameworks for stakeholder engagement acknowledge growing concerns with power imbalances and dynamics (van den Broek et al., 2020), calling for power-sharing in the engagement process (Kliskey et al., 2021). Additionally, the ways and stages in which stakeholders participate is a key feature in many of the studies

Table 5
Percent frequency of enablers and barriers reported for case studies in the Global South (n = 34) and the Global North (n = 67).

Types of Barriers and Enablers to Stakeholder Engagement	% Frequency as Enabler		% Frequency as Barrier	
	South (n = 34)	North (n = 67)	South (n = 34)	North (n = 67)
Communication	65%	75%	29%	40%
Stakeholder participation	44%	34%	26%	43%
Trust & accountability	47%	28%	15%	10%
Power relations & distribution	35%	27%	47%	36%
Transparent & open processes	26%	22%	0%	1%
Coordination & facilitation skills	26%	16%	0%	1%
Technical capacity	21%	21%	21%	18%
Partnerships	12%	16%	0%	3%
Institutional support & capacity	18%	18%	18%	21%
Flexibility & adaptiveness	12%	10%	6%	1%
Human & financial resources	15%	13%	29%	40%
Presence of leadership	12%	3%	0%	1%

Table 6
Key tenets of stakeholder engagement for co-production processes.

Characteristic	Description
Communication	• Appropriateness of communication tools and approaches • Use of boundary objects to develop common understandings • Use of dialogue to promote social learning • Use of digital technical tools to reach desired audiences
Stakeholder Participation	• Ways that stakeholders participate • Stages in which stakeholders are engaged • How ownership in the process develops and is sustained • Effects of who participates and who is excluded • Impact that stakeholder group diversity has on outcomes
Trust & Accountability	• How perceptions of trust among participants affect group dynamics • Considerations to foster trust, accountability, and respect
Power Relations & Distribution	• Influence of status and power on group dynamics • Role of authority and power relations in shaping participation
Transparent & Open Process	• Degree to which processes are persistently transparent and open to modification
Coordination & Facilitation Skills	• Consideration of the skills and tailored approaches needed for effective coordination and facilitation
Technical Capacity	• Degree to which the level and diversity of skills, awareness, and technical ability conditions the engagement • Levels of technical support needed
Partnerships	• Influence and roles of networks and partners
Institutional Support & Capacity	• Degree to which engagement has institutional support and resources
Flexibility & Adaptiveness	• Degree of openness to modification and changes during the engagement process
Human & Financial Resources	• Constraints of time, finances, and human resources of participants in the design of appropriate engagement strategies
Presence of Leadership	• Role of leadership in creating a positive and respectful dynamic

we examined in this review, but is emphasized less in other frameworks (e.g., Gardner et al., 2009; Talley et al., 2016). We elaborate on these two points in sections 5.2 and 5.3.

5.2. Communication is key to enabling stakeholder engagement and mitigating power imbalances

We identified communication as the most frequent enabler of stakeholder engagement while also finding that the inclusion of diverse stakeholders, building trust, and facilitating dialogue are enablers. These results suggest that the structure and management of stakeholder engagement activities need careful design. In fact, other research has found that effective and frequent communication is vital to negotiate different values and perceptions (Sterling et al., 2017; Reed et al., 2018), while effective communication also addresses language gaps between and among the stakeholders and researchers (Djenontin & Meadow, 2018; Turnhout et al., 2020).

It is not surprising that many enablers are also reported as barriers. The publications we analyzed identified power imbalances, a lack of diversity of stakeholders, a lack of human and financial resources, and communication as barriers to effective stakeholder engagement. To address these barriers, projects with co-production ambitions should first assess the time and resources available for communication and determine if this is adequate. Both our review and research from other disciplines calls for open and iterative communication through the various phases of collaborative knowledge generation (Young et al., 2014; Tinch et al., 2018; Podestá et al., 2013). Communication that is clear and transparent about how knowledge will be used and shared can also help mollify external factors that reinforce the uneven distribution of power, like laws, regulations, or agency rules (Kliskey et al., 2021).

Grappling with who gains and who loses, and how power dynamics evolve and are negotiated, is vital for avoiding coercive or marginalizing power relationships. Although this aspect is gaining attention in fields like climate adaptation, it remains underemphasized in this and other environmental fields. In fact, it is suggested that climate scientists reframe their inquiries in co-production from understanding what makes science more usable, to understanding how science can reduce the most inequitable impacts of global environmental changes (Jasanoff, 2021).

5.3. Facilitation supports effective communication and equitable engagement

An important aspect of communication, particularly during events that bring people together, is to reduce conflict and identify common goals. While these are core outcomes of engagement activities, they are goals advanced by skilled facilitation. Facilitation not only sets the groundwork for good communication, but it can help address other obstacles to engagement like stakeholder time constraints (Polk, 2015), participation fatigue (Newton & Elliott, 2016), and even discomfort in interactions (Lemos et al., 2018). Conveners of stakeholder engagement processes may not be able to address all contextual issues, such as those involving histories of violence, prejudice, or discrimination. However, it is important that efforts are made to ensure equal footing between participants through facilitation and open communication. This finding resonates with the work of other scholars who argue that power dynamics need to be managed to ensure every person's contributions are valued and to prevent dominance by one group over another (Brandt et al., 2018; Reed et al., 2018).

In the review conducted here, we find a diversity of stakeholder types engaged in co-production processes in our dataset, yet we see government employees (84%) most prominently engaged. This can be worrisome in light of earlier research suggesting that stakeholders with certified scientific credentials are seen as having authority in comparison to experts versed in other epistemological systems (Nadasdy, 2003; Turnhout et al., 2020; Norström et al., 2020). In cases where research is tightly wedded to the interests of policymakers and these actors narrowly define what counts as useful knowledge, innovative policy solutions may be stymied (Lövbrand, 2011), ultimately limiting potential social and environmental impacts. There is a fundamental tension raised by Wyborn

and others (2019) who suggest that research accountable to decision makers may be incommensurable with that which seeks to challenge the status quo.

Increasingly, we are better understanding how, under the right conditions, collaboration in knowledge production can create empowerment, such as for marginalized communities and knowledge systems (Bremer et al., 2019). Researchers suggest that successful participation is dependent on cultivating a collective sense of ownership, common goals, trust, and innovative ways to interact that take institutional and power structures into account (Vincent et al., 2018; Wamsler, 2017). Some researchers suggest that those actors who yield more power based on the nature of their position or responsibility in a co-production process should intentionally step back to become observers or facilitators and allow marginalized groups to define roles, responsibilities, objectives, and priorities (Akpo et al., 2015; Kraaijvanger et al., 2016; Turnhout et al., 2020; Chilvers & Kearnes, 2016). Others argue that research on mechanisms for empowerment in co-production should include how processes are situated within broader social movements (Turnhout et al., 2020). Others still caution that empowering intentions are "bound to unleash processes of disempowerment and political struggle" (Avelino et al., 2019: 203). While many co-production processes seek to integrate knowledge, more effective and responsive knowledge co-production processes instead recognize that integration may not be possible and therefore, allow for knowledge production to occur along alternative pathways (Chilvers & Kearnes, 2016; Klenk et al., 2017).

5.4. Co-production is not just a methodological challenge but also an epistemological one

Co-production is directly tied to the methodologies and approaches used to engage stakeholders to address a societal problem. However, when and why stakeholders are engaged are also deeply important. As our findings show, the vast majority of stakeholder engagement occurred during the data collection phase of the research process (95% of cases), while engagement during other phases like problem definition, analysis, sharing findings, or co-authorship were each reported in 30% or fewer cases. Only 13% of our cases studied included non-university-based stakeholders as co-authors of articles. However, in looking at changes over time, we observe a slight uptick in authorship in papers published from 2015 to 2020. The relative absence of authorship over time raises questions with regards to how deeply stakeholders are engaged by researchers, and therefore how meaningful their contributions ultimately are to the project. If stakeholders participate in data collection but do not help with data analysis and co-authorship, then they have little say in terms of how the data are interpreted by authors, and which issues become the focal points of the final output. Similarly, when stakeholders are not engaged in the problem framing stage then there is a risk of the research problem being shaped by factors such as the researcher's interests or funding obligations, rather than community needs or policy priorities.

Other researchers show similar trends in which planned engagement activities tended to shift toward data collection over time; stakeholders provided information or data but did not participate in project design or knowledge generation (Boaz et al., 2021). While surveys, interviews, and workshops may be sufficient to gather multiple viewpoints and experiences, they do not inherently create a shared knowledge or understanding of an environmental problem or develop shared products or actions to address the problem. This trend in knowledge co-production to date suggests deeper issues than using the right mechanisms to engage people in a research process.

To practice co-production more authentically, researchers need to move beyond engaging stakeholders during data collection. Organizers of stakeholder engagement in co-production processes need to include stakeholders as early as possible and throughout the process. Engaging stakeholders from the start of the effort builds mutual trust (Edelenbos et al., 2011; Frantzeskaki & Kabisch, 2016). Researchers exploring a diversity of engagement case studies agree that the power to jointly define the issues being addressed, the priorities, and the objectives, can go a long way toward achieving trust and ensuring inclusivity (O'Brien et al., 2013; Reed et al., 2018), and mitigating power inequities that may serve as barriers to stakeholder engagement. Coming to a shared understanding about the value and purpose of stakeholder engagement is a key way to expand engagement into other parts of the research process. Further, engagement processes must begin by acknowledging that stakeholders and communities are not homogenous entities. According to Eaton (2022), this entails better understanding of intersectional and multidimensional publics as opposed to presuming homogeneity within or among groups of participants.

Another related way to expand engagement into other parts of the research process is to address epistemological differences - or different knowledge cultures - represented by researchers and stakeholders. Ferguson et al. (2014) suggest that in the beginning stages of a research collaboration, participants typically have very different ways to frame and approach the issue at hand. Through communication and relationship building, participants can develop a shared framing of the problem, leading to a co-developed project, including data collection, analysis, and knowledge production. Ferguson et al. (2014) conceptualize this process as shrinking the epistemological gap between ways that researchers may understand and address an environmental issue and the ways that stakeholders understand and address that issue.

Cultural or administrative contexts that fail to incentivize co-production may inhibit full commitment to the process of engagement. Baker et al. (2020) explores barriers to participation in co-production from a researcher perspective, highlighting lack of time, barriers to establishing relationships with decision makers, and financial constraints. Academic researchers may not be recognized for stakeholder engagement work, or there may be little institutional support for co-production activities (Cvitanovic et al., 2015a; Foster, 2010). There are also particular risks for early career academics where tenure requirements don't recognize or reward co-production which may require more time and produce fewer high-impact publications and citations (Hegger & Dieperink, 2015; Cvitanovic et al., 2019).

Addressing this barrier requires that institutional cultures and perceptions about co-production change. It also requires that co-production activities be formalized. Yet, most stakeholder engagement efforts are short-term in nature (Van Epp & Garside, 2019), despite the fact that there is broad recognition that co-production often takes a long time to come to fruition (Lemos et al., 2018). Long-term funding and full institutional support for coordination activities (through capacity building workshops, provision of venues, support for information dissemination) could help co-production projects more successfully meet their goals. Furthermore, incentivizing stakeholder engagement for co-production by formalizing it as an important academic skill—as is done with publishing and grant-writing—would promote co-production activities in research (Rozance et al., 2020). Forming and maintaining ethical partnerships demands new skills in project management and communication that requires adequate resources to coordinate diverse teams over long distances or across long periods of time (Wilmer et al., 2021). Recognizing the meaningful impact that stakeholder engagement has on the researchers is an important first step (Allen et al., 2017; Di Franco et al., 2020).

5.5. Co-production research requires better documentation of societal impact

Our findings suggest that the societal impacts of co-produced research are connected to the approach taken toward stakeholder engagement. Societal impacts are more frequently reported from stakeholder-led processes, like collaborative and collegial approaches. Therefore, the approach to engaging stakeholders matters and more iterative approaches to stakeholder engagement can lead to a greater number and more diverse types of societal impacts.

However, we found considerable variability in the ways authors reported societal impacts, which obscures the mechanistic links between the research processes, activities, and resulting impacts. Some cases reported explicit processes to document impact. For example, Goodess et al. (2019) detailed their evaluation of climate services for the European renewable energy sector. They analyzed Google Analytics; conducted interviews, a survey, and interactive polls; and gathered stakeholder feedback. Other publications, however, only tangentially or tacitly mentioned impacts, based on reflections of the researchers or a subset of stakeholders. For example, Allain et al. (2020) described a new methodology that integrated quantitative modeling and stakeholder insights. They mentioned "new understandings" as an impact from testing the methodology that they developed (Allain et al., 2020: 12). In this and many other papers, impacts such as changes in understanding are noted, but explicit explanation on *how* such changes occur is absent.

The fact that measures and metrics for stakeholder engagement are under-reported in our dataset is not surprising, as there are several known difficulties in evaluating impact and measuring success. Evidence that co-production activities have been effective in achieving their goals, at either a project or conceptual level, can be difficult to track (Jagannathan et al., 2020). One explanation for this challenge is that, particularly in the climate and environmental science, co-production of knowledge means different things to different people (Meadow et al., 2015; Bremer & Meisch, 2017). Not surprisingly, then, it is nearly impossible to evaluate something when one lacks a clear understanding of what is to be evaluated (Holzer et al., 2018). Another challenge is that, although many frameworks and sets of metrics exist, no single one will meet the needs of all co-production projects. Evaluation must be tailored to the specific contexts in which the activities occur. The contexts may include factors such as who participates, who leads, the social norms of the participating groups, local politics, and overarching culture. Moreover, project participants should decide what constitutes success (Mach et al., 2020; Norström et al., 2020; Fazey et al., 2014), which can be a challenging process to facilitate. Dilling et al. (2021: 2) suggest: "starting from a place of humility, asking communities what outcomes are most valued (NOT what science they need), asking how they have been affected by previous interventions, and listening to what is most wanted--would be a good starting place." Finally, even when success is defined, it can be difficult to say with certainty whether that success can be directly attributed to a particular piece of research or research process (Meagher & Martin, 2017; Hansson & Polk, 2018; Morton, 2015). Rather, success is often influenced by many factors, with the research contributing a portion of that success.

Despite these challenges, several frameworks exist to evaluate the societal impacts of research (see Louder et al., 2021 for a review). While they vary in approach and indicators, there is some agreement around a common set of impact categories, similar to the ones used in our codebook (e.g., instrumental, conceptual, capacity-building, and connectivity). Researchers highlight how the degree to which the public participates in the research process, as well as the quality of that participation, are closely aligned to outcomes and should be a key element in how researchers design projects (Shirk et al., 2012). Having a common, yet flexible set of impact categories, as opposed to strict metrics that can be constraining, provides a mechanism to compare impacts across research projects and programs and better understand key trends in practice. Many evaluation frameworks have been scaled up for use in European research institutions, such as the Research Excellence Framework in the United Kingdom and the Standard Evaluation Protocol in the Netherlands.

Other challenges of identifying indicators and impacts can be met by documenting and evaluating the engagement process within co-production projects (Spaapen & van Drooge, 2011; Meagher & Martin, 2017). Assessing impacts by tracking the engagement process, such as activities and outputs, allows participants to explore how effective their engagement practices have been and to track impact over the course of a project. This type of assessment requires some additional time and resources (Bell et al., 2011; Arnott et al., 2020), however, it does not have to be onerous. A recent guidebook provides researchers some tools to start documenting and planning for societal impacts in their research (Meadow & Owen, 2021). The guidebook follows a cyclical logic model format and asks researchers to document a few key items: the societal problem they intend to address; engagement activities and research activities; outputs; changes observed in a set of impact categories and for whom things changed; and how these impacts address the societal problem. Ultimately, greater transparency in project framing and measurement, and in the broader project monitoring and evaluation processes, is not only critical for addressing key methodological questions for researchers but it allows participants in these engagement and efforts to better assess their roles, opportunities, and risks in engagement. Understanding these risks for participants is a critical part of the ethical dimension and training for researchers that is desperately needed (Wilmer et al., 2021).

6. Pathways Forward: There is a need for greater reporting of practices by researchers

Conducting this systematic review presented several challenges. We quickly learned that there are multiple ways that researchers define and practice co-production. But ultimately, the challenges we encountered relate less to this diversity of definition and application, and more to the lack of a standardized way of documenting the co-production process. Given this, we suggest that detailing the engagement methods, approaches, and outcomes of co-production processes become standard practice.

As the research community builds skill in documenting impacts, we will improve our understanding of the most effective approaches and methods within various societal and environmental contexts. To aid this effort, we propose that researchers report on their co-production process using a standardized set of categories. While there is great diversity across the definitions, practices, and approaches to co-production, much work has been done to synthesize this diversity across environmental research (e.g., Singh et al., 2022; Chambers, Wyborn, & Ryan, 2021). Categories should be well-defined and rigorous, but flexible enough to allow for diverse definitions, practices, and approaches. Categorization will allow for better assessment, classification and ultimately, comparability of approaches.

Researchers could add a section to their published paper, similar to metadata that are reported when new datasets are published. Metadata categories could include: geography, funding, project leadership, stakeholder involvement, engagement activities, main outputs produced, and outcomes categories. Because outputs and outcomes may take longer to materialize, researchers can note that they are still in development. Ultimately, this type of documenta-

tion may help organize co-production research data in ways that will make it more usable and replicable by others. It will also allow for more granular comparison regarding effective co-production at various scales, such as countries or regions, or across environmental issues.

While the categories in our codebook offer a place to start, we recognize that there are several other ways to document and categorize co-production processes and impacts. Several scholars have developed frameworks, heuristics, or guiding principles to conceptualize and implement better practices to support co-production (e.g., Chambers et al., 2021; Singh et al., 2022; Yua, Raymond-Yakoubian, Aluaq Daniel, & Behe, 2022), and ways to explore the effectiveness of co-production outcomes (e.g., Karcher et al., 2021; Dilling et al., 2019). We recommend that the co-production research community, including researchers and stakeholders, come together through collaborative workshop venues and through online survey processes to develop the appropriate set of metadata, definitions, and categories.

Going forward, it is less about *if* stakeholders should be involved, but rather *when and how* to enhance more meaningful and long-standing engagement that is impactful. As researchers develop better metrics to make outputs and impacts more explicit, and work to standardize their practices, we might expect to see some further advancement in understanding how various approaches to stakeholder engagement and co-production lead to tangible improvements in global environmental challenges and help produce a more sustainable and just world for all.

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.worlddev.2023.106336.

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