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Redefining co-design for social-ecological research and practice: A systematic literature review

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ABSTRACT

Collaborative processes such as co-design are increasingly crucial in generating social-ecological research and practice. Fostering change within complex adaptive systems requires collaboratively working with real-world actors or stakeholders to resolve complicated issues. Co-design is a distinct and fundamental component of the co-paradigm, a collective term for co-design, co-production, and co-creation. However, scientific literature currently provides limited definitions of the key concepts within the co-paradigm, leading to misinterpretations or inconsistent usage. Improving the clarity of these definitions is essential because it permits scientific progress and better implementation of processes and engagement in practice. To address this gap, the following paper presents research which critically examines the practice of co-design through a systematic literature review. Using a systematic approach, this study identifies fifty-two papers with empirical methodologies, which are thematically analysed to understand the purpose and process of the co-design approach within social-ecological research and practice. The paper identifies effective co-design methods and discusses the implications of their utilisation within social-ecological study and practice. The review also identifies and examines definitions of co-design and the challenges of implementing a co-design approach, highlighting potential solutions. The paper concludes by proposing an integrative definition of co-design to further understand and enhance the process's implementation within social-ecological systems. The definition proposed in this paper can serve as a roadmap for researchers and practitioners aiming to use co-design as part of sustainable transformation efforts in social-ecological systems.

1. Introduction

Complex adaptive systems, such as cities (Bettencourt and West, 2010; Moglia et al., 2018; Webb et al., 2018), comprise many interacting layers, components, and relationships with nonlinearity, spontaneity, and unpredictability (Miller and Page, 2007). Therefore, change and transformation within these systems can become challenging because of these multiple interacting dynamic properties and forces. Fostering such

change requires a transdisciplinary framework that works collaboratively with real-world actors or stakeholders to resolve collective issues such as climate and biodiversity crises (Restrepo et al., 2014). Transdisciplinary frameworks, such as the social-ecological systems framework (Ostrom, 2009), Nature Futures Framework (Pereira et al., 2020b), and social-ecological-technological systems framework (SETS) (McPhearson et al., 2022), are beneficial because they provide insights from multiple fields. This may assist in the navigation of interconnected,

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adaptive and emergent properties, which are defining characteristics of complex systems (Tzafestas and Tzafestas, 2018). Another key aspect of navigating complex adaptive systems is recognising that their causality is often shaped by the social construction of realities, a dynamic process in which individuals and groups collectively and informally agree on concepts, values, and principles (Rogers et al., 2013). This construction is not static but evolves over time, reflecting changes in societal norms, priorities, and shared experiences. The social construction of realities underpins many processes within complex systems, as it governs how different actors perceive and respond to challenges. The dynamic nature of shared understanding is particularly evident in collaborative processes such as co-design (Gomes et al., 2016).

Addressing the challenges of navigating, interacting with, and transforming complex social-ecological systems requires active participation from multiple stakeholders, engagement with diverse knowledge systems, and various modes of action (Pereira, 2020a). Collaborative methodologies, including co-design, co-production, and co-creation, have become essential tools for investigating and guiding system transformations (Page et al., 2016). Selecting methodologies appropriately tailored to the specific problem at hand is essential, as this is critical for minimising risks and achieving optimal outcomes. However, conceptual ambiguity surrounding these processes has contributed to confusion and potential conflicts among stakeholders (Heigl et al., 2020). Enhancing the precision of these definitions is crucial for advancing scientific understanding and improving the practical application of collaborative processes (Nguyen et al., 2024).

Based on the importance of co-design within social-ecological research and practice and the lack of a clear definition, this paper seeks to identify the diverse ways co-design may be defined, the challenges faced through its implementation, and the multiple dimensions characterising this participatory process. The study examines co-design practice through a systematic literature review by asking, "How is co-design conceptualised in social-ecological systems?" incorporating keyword and thematic analyses. We identify effective co-design methods and discuss the implications of their utilisation within social-ecological research and practice. The study identifies numerous themes in the co-design process to develop a comprehensive definition of co-design within social-ecological research and practice. The definition proposed in this paper may guide researchers and practitioners seeking to engage in co-design processes and serve as a roadmap for formulating frameworks to facilitate sustainable transformation efforts.

2. The co-paradigm and social-ecological systems

Participation, as a critical theoretical and methodological component of the co-paradigm, is increasingly essential in nature conservation (Nel et al., 2016), the promotion of climate change resilience and urban sustainability (Grove et al., 2015), and the achievement of justice or equity (Martín-López et al., 2020) within social-ecological systems. Collaborative approaches are progressively utilised to facilitate value-based research, enquiring about societies' deeply held ideals, which are vital during decision-making (Ní Shé and Harrison, 2021). Collaborative approaches such as co-design, co-production, and co-creation have evolved to engage diverse stakeholders with varying values and beliefs, making the processes more comprehensive and inclusive, especially within communities which may be difficult to reach (Frantzeskaki and Kabisch, 2016, Pérez Rubi and Hack, 2021).

When discussing co-design, co-production, and co-creation, it is helpful to position them collectively within the broader co-paradigm (Dudau et al., 2019, Mates and Grimshaw, 2024). It is imperative to note that 'co' refers to the term 'collaborative' as these are processes whereby individuals and organisations cooperate. The co-paradigm encompasses collaborative methodologies that prioritise stakeholders' active engagement throughout various phases of an initiative or project, emphasising the principle of collaboration. The co-paradigm emphasises the integration of diverse perspectives to address complex issues,

contrasting with relational paradigms that concentrate on understanding the interconnections and dynamics between entities (Ferreira et al., 2023). The co-paradigm also spans the entire life cycle of a project, encompassing various stages from design through to creation and implementation, contrasting with participatory planning, which aims to engage diverse voices in planning decision-making.

Building upon this, Dudau et al. (2019) break down these processes into tangible directions, including identifying the interfaces between professionals, citizens, and critical stakeholders in the co-paradigm processes and investigating unsuccessful cases of these processes to enhance our knowledge of the co-paradigm. The three terms are differentiated as follows: co-design is the initial step towards co-production, which attempts to identify an issue and develop a solution; co-production endeavours to produce the services of the suggested solution, often equated with co-creation; and co-creation is the process whereby the aim/outcome of co-design and co-production emerges (ibid.) (see Fig. 1). Within the non-peer reviewed or grey literature, these differences are explained succinctly by McDougall (2012) as 'Co-design is an attempt to define a problem and then define a solution; co-production is the attempt to implement the proposed solution; co-creation is the process by which people do both', and it's this overlap which can often cause confusion. While this briefly highlights the distinctions between the terms, there are yet to be widely accepted definitions of the various concepts. Using multiple and abstract definitions for co-design further adds to the need for more clarity. For example, co-design has been described as 'collectively creating through the design process' (Steen, 2013), 'actively involving the experiences, expertise, and knowledge of different actors to imagine better futures' (Zamenopoulos and Alexiou, 2018), 'an action of empowering consumers to develop new ideas' (Kim et al., 2020), and 'the joint formulation of the research problem' (Horlings, 2016). Given how the various processes mutually inform each other while providing feedback to enhance understanding, a more profound comprehension of co-design can inform and improve our understanding of the various stages of the co-paradigm.

3. The importance of defining co-design

Despite attempts to clarify each term and its position within the co-paradigm, several misunderstandings continue to permeate it (Heigl et al., 2020). This is primarily because of the significant overlaps between the concepts, with the terms often implemented interchangeably and incorrectly (Brandesen and Honingh, 2018, Masterson et al., 2022), leading Nguyen et al. (2024) to call for research to clarify each specific term more clearly. While these processes often occur alongside each other, Nguyen et al. (2024) highlight the lack of clarification between the three approaches and argue for the need for clear and consistent

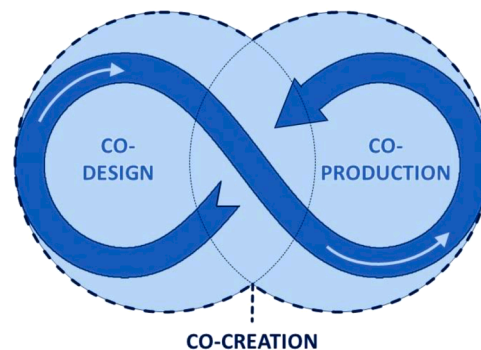


Fig. 1. The co-paradigm consists of three distinct concepts: co-design (first stage) and co-production (second stage). When both stages are combined, this becomes co-creation. The blue arrows represent the iterative and dynamic nature of these processes, which continually provide feedback to each other.

definitions of each. An unclear definition of co-design may lead to several issues, including misalignment of expectations, resulting in potential conflicts (Heigl et al., 2020). It may also cause ineffective collaboration if stakeholders are uncertain about their roles, leading to inconsistent outcomes. Furthermore, ambiguous definitions have the potential to diminish stakeholder engagement by discouraging participation due to a lack of clarity (Podsakoff et al., 2016).

The fragmentation and specialisation of disciplines have led to extraordinary progress in knowledge production, though in practice, siloed approaches may prove an impediment to mainstreaming resilience policies (Frantzeskaki et al., 2020). In addition, siloed approaches, within academia and beyond, tend not to have the capacity to tackle the complex challenges which face today's societies (Mauser et al., 2013). Therefore, improving our understanding of the interface and interrelationship between different groups of actors that engage with the co-paradigm is essential to add clarity to the processes' definition. Due to its relative novelty (Blomkamp, 2018), co-design is often misconstrued as a subsidiary of co-production rather than a separate and distinct process (Batalden et al., 2016, Osborne et al., 2016). As co-design is fundamental to collaborative processes, given its role in defining an issue and developing a solution from the beginning, it is imperative to have a clear definition and pathways for guiding the process and understanding the role of the various stakeholders. Gaining a deeper understanding of co-design may inform the co-production and co-creation processes. Furthermore, it may enhance our capacity for transformative change, understood as a comprehensive overhaul of technological, economic, and social elements, including shifts in paradigms, objectives, and values (IIPBES et al., 2019). Implementing processes such as co-design can contribute to navigating transformations within social-ecological systems (Pereira et al., 2020a).

4. Co-design, co-production and co-creation

Co-design is viewed as an integral component of the co-creation process and emerged as user-centred design during the 1970s (David et al., 2013). The concept has since developed toward a more participatory design approach, incorporating the creativity of experts and people not formally trained in design (Sanders and Stappers, 2008), recently gaining significant traction within sustainability science (Asah and Blahna, 2020, Lähteenoja et al., 2023, Melles, 2019). Given the various global challenges now faced by society, Mauser et al. (2013) state efforts between the human, natural, and social sciences are required to co-design a sustainable future, which necessitates various levels and sources of knowledge to identify problems and solutions to design an enhanced future for all. Part of the attraction of the co-design process is that it incorporates diverse ideologies of expertise and combines these perceptions to develop creative solutions. Therefore, there is an increasing use of co-design within the scholarship of science-policy interactions (Moser, 2016). Furthermore, co-design is now being communicated as an expectation in various international programs, such as Future Earth (Turner II et al., 2016). The importance of engaging with stakeholders outside of academia to build relationships and trust is increasingly highlighted through such international programs, given the necessity for more sustainable societies in the future (Frantzeskaki and Rok, 2018, Nonet et al., 2022, Tembo et al., 2021).

Knowledge co-production has also gained significant traction recently, particularly within the policy and practice of the natural and social sciences (Loeffler and Bovaird, 2021, Masterson et al., 2022, Verschuere et al., 2012). This is despite appearing in literature some time ago (Brudney and England, 1983, Parks et al., 1981). A potential contributor to this increase in prevalence is the rapidly growing field of sustainability science (Clark, 2007). Co-production is one of the most central concepts, theoretically and practically, in advancing knowledge and governance within global sustainability, including ecological and biological conservation (Miller and Wyborn, 2020). This is grounded in the fact that knowledge co-production aims to enhance the significance

and application of science within society (Lemos and Morehouse, 2005, Wall et al., 2017). This contributes to sustainable transformations by improving scientific knowledge's relevance, practical application, and inclusivity, which is crucial for driving systemic changes in governance, conservation practices, and societal well-being.

Co-creation encompasses co-design and co-production and is implemented to create inclusive and innovative processes within industry and research (Lund, 2018). Amann and Rubinelli (2017) define co-creation as "an act of collective creativity, with applications ranging from product and service design to more abstract spheres of value creation taking place between two or more individuals who may or may not belong to the same actor group" (p. 2). The co-creation process has attracted significant attention from academics and practitioners, particularly within the co-creation of values (Ranjan and Read, 2016). Galvagno and Dalli (2014) describe this as a collaborative, peer-like process that creates symbolic and material values. The concept is often found within the business management and marketing literature as a method of interacting companies with consumers to create value (Frow et al., 2015, Galvagno and Dalli, 2014, Payne et al., 2008). However, co-creation has recently begun to emerge in social-ecological and sustainability research through the process of knowledge co-creation (Galafassi et al., 2017, Pereira et al., 2018, Mauser et al., 2013), a process which extends beyond knowledge collaboration by creating new knowledge or ideas through exchanging information (Amann and Rubinelli, 2017).

As a deeper understanding of both co-production and co-creation emerges within social-ecological literature, this study seeks to gain a clear and comprehensive overview of the co-design process within social-ecological research and practice. Despite the increasing expectation to incorporate collaboration into research, communities within science and planning have yet to reach a consensus on the definition of co-design, and there is confusion surrounding its implementation and delivery (Nguyen et al., 2024). Additionally, the need for creative, qualitative research within the ecological realm has increased, as insights into the drivers of behavioural, social, and cultural phenomena are often limited (Sutherland et al., 2018). Keith et al. (2022) highlight how this is caused by ecologists needing more epistemological and methodological preparations, which often require mixed-method study design. The reconceptualisation of human-nature relationships through emerging concepts, such as social-ecological systems, has stimulated a deeper understanding of the social sciences within conservation biology (Teel et al., 2018) and policy (Brehony et al., 2020). To contribute to the knowledge of qualitative research within social-ecological science, this paper systematically reviews the academic literature to examine the research question: *How is co-design conceptualised in social-ecological systems?* By reviewing the co-design process in practice, the paper develops an integrative definition that can help researchers and practitioners implement co-design processes.

5. Methodology

To identify the nuanced debates surrounding the co-paradigm, a systematic literature review was conducted to yield insight into co-design processes in social-ecological research and practice. A systematic review was deemed relevant for this study as the research aims to gain a clear and comprehensive overview of a specific process, co-design. To understand this process and its implementation, the review analyses co-design definitions, the methods and collaboration involved, and identifies potential challenges. Systematic reviews offer the opportunity to increase the breadth of the study while remaining focused on empirical research (Mallett et al., 2012), both vital aspects in bringing clarity to a widely used concept but often defined differently (Victor, 2008). The argument and research question guiding this study stem from understanding social and ecological components and interactions of complex adaptive systems through collaborative research and practice. Understanding complex adaptive systems requires inter and trans-disciplinary collaboration, and as such, providing clarity of concepts and

practices can benefit more expansive goals. This is important to note because the ontological and epistemological beliefs stemming from the positions of researchers influence and shape the research (Holmes, 2020). Holding a constructivist perspective and a holistic view of nature may lead to potential bias while attempting to understand the role of co-design within social-ecological systems research and practice. A reflexive approach was implemented throughout the study to alleviate potential bias within this research. This included regular meetings with all co-authors and continuous revision of and reflection on the material.

5.1. Search strategy and study selection

The systematic literature review reported here implements the PRISMA checklist to ensure transparent literature reporting throughout (Liberati et al., 2009). Three coding levels (See Table 1 for search terms and Boolean operators) were applied to searches of three databases (Scopus, PsycArticles/PscInfo, and Web of Science). The terms used in the searches are based on three concepts: (1) terms often used interchangeably or are related to the methods of co-design; (2) terms that capture social-ecological systems; and (3) terms incorporating an attitudinal dimension. Diverse perceptions are essential to collaborative processes (Nicholas et al., 2019). Therefore, the latter terms were included to acknowledge their importance in this research and to capture multi-perspective approaches during the literature search. This component relates to various areas of co-design, such as understanding diverse stakeholders' perceptions, exploring challenges and solutions, and understanding the co-design process's effectiveness. The search terms were applied to the entire content of the papers to capture academic literature incorporating these three concepts simultaneously.

Database searches were undertaken to include relevant literature published from 2000 to May and October 2023 for the first and second searches, respectively. An additional search was conducted incorporating all of the terms to include literature published between the years of 2024 and 2025 to capture more recent papers. Subsequently, the literature was uploaded to Covidence software to undertake several screening processes. The search period was selected because the role and integration of co-design into social-ecological sciences has not only increased but also altered in diversity and technology since the early 2000s (Grove et al., 2015). Three searches were conducted to capture the entire scope of the paper. The first search returned 2113 papers, the second returned 298 papers, of which 578 duplicates were removed, and the third returned 204 papers with no duplicates. The first screening stage aimed to include peer-reviewed papers in English and the words 'co-design' or 'codesign' in the title, abstract or keywords. These criteria deemed 1830 papers irrelevant, leaving 197 papers for the second screening process. The second screening stage reviewed the full texts to ensure they were empirical research projects based on social-ecological systems, excluding theoretical studies, to understand the co-design process better. Following the double screening processes, fifty-two

Table 1
The search terms and Boolean operators used for three searches of the literature.

	Search terms (1)(3)	Search terms (2)(3)
Concept 1 (i.e., Terms which encompass co-design)	"co-design" OR "co-production" OR "co-creation" OR "citizen science" OR "knowledge collaboration"	"foresight planning" OR "participatory planning" OR "exploratory scenario"
	AND	AND
Concept 2 (i.e., Terms which encompass social-ecological systems)	"ecological" OR "environmental" OR "social-ecological" OR "bioecological"	"ecological" OR "environmental" OR "social-ecological" OR "sustainab*"
	AND	AND
Concept 3 (i.e., Terms which encompass attitudes)	"attitude*" OR "opinion*" OR "perception*" OR "perspective*"	"values*" OR "preferences" OR "trade-offs" OR "conflicts"

papers were included in the study (Fig. 2).

5.2. Data extraction and analytical strategy

The systematic literature review process has its difficulties and drawbacks, mainly when applied to complex or open-ended questions (Westgate and Lindenmayer, 2017). Therefore, this review begins by using simple yet effective questions to understand the co-design process and how it can be implemented in the context of social-ecological research and practice. The fifty-two studies selected for analysis were reviewed to extract essential information regarding the objective of the studies, definitions of co-design, methods implemented, locations of studies, results, and challenges. A keyword analysis was conducted on all the included papers using a 5W1H analysis (Jia et al., 2016, Mosannenzadeh et al., 2017), which is implemented in various fields to frame analysis during literature reviews. A keyword analysis is a method used to identify the most common or significant words within a body of text. This approach considers the context in which words are determined to gain a deeper understanding and provides meaning to a subject by identifying core topics or themes. The framework was utilised to gain a broad overview of co-design processes by asking the following six questions:

1. *Where* was the research conducted?
2. *When* was the research published?
3. *Who* was involved in the co-design process?
4. *Why* was the co-design process carried out?
5. *What* was analysed in the study?
6. *How* was the co-design process conducted?

For question 1, papers were grouped into different geographical locations by continent; for question 2, papers were sorted by their year of publication; and for question 3, stakeholders were classified into three different communities: communities of practice (i.e., planners, designers, etc.); epistemic communities (i.e., academics, policymakers, etc.); and interest groups (i.e., residents, citizens, etc.) (Wagner et al., 2019). Epistemic communities are traditionally involved in decision-making processes. In contrast, communities of interest can often be found placing pressure on these decision-makers, and communities of practice are frequently interested in the field but also engage practically. Placing the participants into these categories aims to distinguish the diversity of participation in the study. Categorising participants based on their discursive actions also provides an opportunity to grasp the power-knowledge dynamics of the process (ibid.). Questions 4 and 5 explored the aims and objectives of the studies, while question 6 focused on the methods employed during the co-design process. To gain a deeper understanding of the co-design process, an iterative thematic analysis was employed to identify and integrate concepts from the literature when asking questions 4-6 (Clarke et al., 2015). In addition, the review explored the challenges faced when using co-design methods and how co-design is defined within the studies. The extraction and harmonisation of keywords and themes were carried out manually, and software was not utilised to derive the keywords or themes from the text.

6. Results

This research encompassed studies that specifically employed a co-design process in order to scrutinise stakeholders' perceptions, values, knowledge and interactions to contribute to the design of outputs and assist in delivering desirable outcomes. The co-design process contributed to outputs such as the development of a tool in the form of a mobile application (Bell et al., 2018), a simulation tool (Buchheit et al., 2015) and a life-cycle assessment calculator (Borrion et al., 2019). However, the results demonstrate that co-design is also employed to assist in developing research agendas (Horlings, 2016), methods (Kim, et al.,

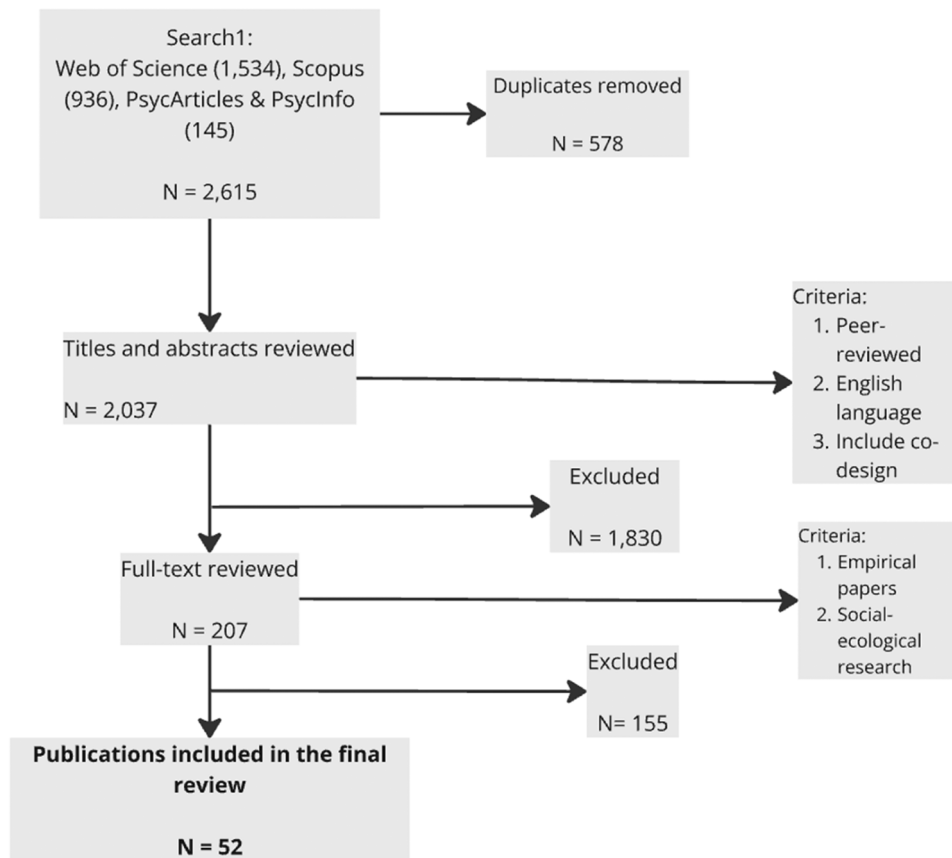


Fig. 2. The PRISMA screening processes were conducted on three literature searches to identify suitable academic papers implementing co-design in social-ecological systems research.

2020, Moreno-Llorca et al., 2019), and experiments (Ciaccia et al., 2021, Gottlieb and Schaeffer, 2022). Furthermore, co-design can also be utilised to create grant proposals (Arbogast et al., 2020), management strategies (Enloe et al., 2021) and guide urban planning (Tewdwr-Jones and Wilson, 2022). These contributions assist in the delivery of outcomes such as enhancing accessibility (Chalal et al., 2020), inclusivity (Lennon et al., 2019, Truworthly et al., 2024) and innovation (Herzog et al., 2019).

Each study's location was grouped by continent, which provided context when interpreting this review's findings and highlighted gaps or trends in the geographic distribution of co-design implementation. Thirty-two studies occurred within Europe, eight each in Oceania and North America, five in Africa, three in Asia, and two in South America, with four trans-continental studies. Several core themes emerged from the review when analysing the studies to explore why, what, and how co-design is used.

Decision-making through diverse stakeholder engagement, navigating complex adaptive systems for system transformation through reflexivity, and methods conducive to generating creativity were crucial elements which cut across the studies. Co-design was found to be implemented to enhance the decision-making process through diverse stakeholder engagement. Incorporating diverse perceptions, knowledge, and reflexivity was beneficial for navigating complex adaptive systems. This navigation assisted in systems transformation through reflexivity and connection to place. Methods stimulating creativity also emerged as a critical co-design component, fostering safe and collaborative environments, stimulating multiple senses and encouraging divergent thinking. These themes are expanded upon in the following sections.

6.1. Decision-making through stakeholder engagement

When exploring why the co-design process was being carried out, the theme of decision-making emerged as a critical component within the studies. The co-design approach considers the range of values underpinning decision-making that is not ordinarily encompassed within top-down approaches. This theme of decision-making appears in nineteen studies, from using the methods to guide decision-making for protected area visitor centres (Moreno-Llorca et al., 2019) to informing decisions on energy-saving strategies in residential buildings (Liu et al., 2012). Incorporating stakeholder knowledge into the decision-making process allows for various needs to be met; hence, co-design has been identified as increasing the effectiveness of the decision-making process (Bennett, 2017). Asah and Blahna (2020) provide evidence of this increased effectiveness through co-designing social valuations of biodiversity and ecosystem services. The study indicates that the knowledge gained through the co-design process informs enhanced decisions. This also reveals the significance of diverse stakeholder inclusion as a cross-collaboration component that enhances the co-design process.

6.2. Integrating stakeholder knowledge and perceptions

Exploring why co-design methods are utilised in these studies, twenty-six papers mention using the techniques for collaboration between different communities, organisations, and individuals. For example, Novoa et al. (2018) developed a framework for engaging stakeholders in alien species management. The paper discusses the importance of increasing trust and developing collaborations within research to promote sharing knowledge and information, which are critical aspects of the co-design process. Although co-design aims to create alternative solutions, the recurring theme of knowledge sharing is

inherently built into the process through collaboration (Buchheit et al., 2015, Enloe et al., 2021, Keselman et al., 2012). This occurs when diverse communities converge, bringing various experiences, knowledge, and perspectives. This convergence highlights the importance of stakeholder inclusion across three distinct communities: epistemic communities, communities of practice, and interest groups. The role of social learning is crucial in this context, as it enables the collaborative exchange of knowledge and insights between these groups, fostering mutual understanding and collective problem-solving (Ridder et al., 2005). Social learning in co-design may encourage stakeholders to reflect on their own experiences while engaging with others' viewpoints, facilitating the exchange and co-creation of knowledge grounded in participants' lived realities. This process may assist in uncovering social constructs, such as shared values, norms, and power dynamics, that shape system behaviour. By understanding these constructs, stakeholders may identify underlying barriers and opportunities, enabling the collaborative creation of innovative solutions.

6.3. Enhancing stakeholder diversity

Although twenty-two papers reviewed included participants from all three communities within the co-design process, this result was not uniform. The participants included in the study reflected situation-specific needs and context. For example, the Fumagalli et al. (2020) study co-designed a restorative garden in Milan. The research used snowball sampling to recruit potential end-users, including older user groups between the ages of 65 and 82 who were either district residents or members of local associations. This allowed the researchers to combine the needs and insights of an interest group with the design criteria set out through a literature review.

Asah and Blahna (2020) state the importance of incorporating various communities in the process and assert that it is illogical to assume using knowledge from experts alone is enough to make social valuations. Davidová and Zimová (2018) ascertain that incorporating stakeholders with "highly different interests" strengthened their project. While various co-design methods were implemented within the studies, workshops were the most common method when working with multiple communities. Paddeu et al. (2020) explain how co-design processes support participants in reflecting on their values and trade-offs while negotiating personal values collectively with fellow participants. Focus groups and workshops are often employed to encourage this dialogue as they incite group discussions where such negotiations are supported (Paddeu et al., 2020)

6.4. Navigating complex adaptive systems to enable transformation

Navigating complex adaptive systems emerged as a critical theme when analysing the co-design process. Regarding agricultural systems, co-design is being implemented to re-design food production to become more sustainable. Reckling et al. (2020) practice a combination of participatory and quantitative methods to re-design cropping systems with assistance from farmers, scientists, and agricultural advisors. Webb et al. (2018) explore how a co-design approach supports and progresses whole systems view and transformational change at multiple scales (local to national) within the urban development context. The paper emphasises how no one 'owns the whole system'; therefore, engagement with various stakeholders from communities of practice, epistemic communities, and interest groups is imperative to understand the values and resources of stakeholders to enable systems transformation. The literature reveals that co-design methods are instrumental in driving sustainable transformations across diverse systems such as energy (Krietemeyer et al., 2021, Lennon et al., 2019, Liu et al., 2012, Trueworthy et al., 2024); agricultural (Ciaccia et al., 2021, Cisilino and Vanni, 2019, Enloe et al., 2021, Hossard et al., 2022b, Kargiannopoulou et al., 2020, Mutinda et al., 2024, Reckling et al., 2020, Richard et al., 2020); food (Heitlinger and Houston, 2021, Kim et al.,

2020); and urban systems (Bell et al., 2018, Davidová and Zimová, 2018, Moro and Puerari, 2015, Sharp and Salter, 2017, Webb et al., 2018). These examples from the literature also provide insight into the role of co-design within policy and decision-making contexts through the ability to enhance whole-system thinking and bring about transformational change through bidirectional approaches (a combination of bottom-up and top-down).

6.5. Reflexivity and connection to place

Reflexivity and connection become essential when navigating complex adaptive systems during co-design processes. These systems serve as critical frameworks for understanding how people interact with their environment, shaping and being shaped by place. Place-shaping, a co-created process between individuals and their surroundings (Horlings, 2016), is central to this understanding. Reflexivity allows stakeholders to critically engage with the evolving dynamics of these systems, while connection emphasises the importance of relational bonds between people and the environment. With its capacity to innovate and enable systems transformation, co-design plays a vital role in sustainability transformations. Reflection prompts participants to think critically about the topics being discussed, connect concepts to previous knowledge they have, and recognise gaps in their understandings or skills. Results from Hossard et al. (2022b) depict how debates between the various actors in the study of agrarian systems stimulated reflections, helping adaptively shape their working model to assess the performances of current and alternative agricultural systems. Such reflexive approaches can create learning experiences by encouraging deeper thinking and self-awareness. The findings reveal that reflexivity and connection were intricately linked to the creative methodologies utilised across the studies. Tewdwr-Jones and Wilson (2022) explain that 'creative methods, more so than traditional social science research methods or planning consultation methods, allow for improvisation and messiness, and open opportunities for researchers to wander outside of their disciplinary fields to both reflect and reconnect with the social life they purport to be concerned with' (p. 235).

6.6. Methods stimulating creativity

When exploring the question of how the co-design methods were utilised, creativity emerged as a crucial theme. When discussing creativity, this paper refers to the dynamic act of creating original ideas and producing potential alternatives (Walia, 2019). Creativity within this paper is understood as generating novel ideas and solutions that involve exploring innovative tools and methods to leverage approaches that uncover new possibilities and insights (Moran, 2010). Exploring co-design methods is vital to this systematic literature review as it aims to inform how co-design can be implemented in social-ecological research and practice. Transforming existing systems requires creativity, which often occurs through the methods employed. These methods provide the structure, tools, and environment conducive to generating new ideas by encouraging divergent thinking, breaking routine patterns, engaging multiple senses, and fostering a safe and collaborative environment. Workshops, interviews, and surveys are the most common co-design methods implemented within the literature. However, further exploration of how these methods are conducted was essential to understand the process thoroughly.

Tools and methods which stimulate creativity are implemented within the delivery of workshops throughout most of the studies (see Table 2), combined with more formal methods of surveys and interviews. The creative aspects are often delivered in the form of workshop activities and involve methods such as rich picture (Bell et al., 2018), role-play (Buchheit et al., 2015, Heitlinger and Houston, 2021, Hossard et al., 2022a), elicitation process (Nash et al., 2021), LEGO mashup (Tewdwr-Jones and Wilson, 2022) and scenario designing (Cisilino and Vanni, 2019, Hossard et al., 2022b, Jacobs et al., 2024,

Table 2
Examples of the creative methods incorporated into the co-design process.

Literature	Examples of activities incorporating creativity
Arbogast et al., (2020)	Wordplay and storytelling
Bell et al., (2018)	Rich picture and musical interpretation
Buchheit et al., (2015)	Roleplay and gaming boards
Cisilino and Vanni, (2019)	Scenario design
Enloe et al., (2021)	Photo-based interviews
Gottlieb and Schaeffer, (2022)	Teatime design
Hatton et al., (2020)	LEGO serious play
Heitlinger and Houston, (2021)	Roleplay and arts-based methods
Hossard et al., (2022b)	Roleplay game and scenario design
Jacobs et al., (2024)	Speculative scenarios and storylines
Kim et al., (2020)	Word association exercise
Moro and Puerari, (2015)	Tango night and pocket park
Nash et al., (2021)	Scenario development and umbrella drivers
Schröter et al., (2023)	Mapping quiz
Tewdwr-Jones and Wilson, (2022)	LEGO mashup

Nash et al., 2021). Fumagalli et al. (2020) highlight the ability of co-design to foster creativity as one of the critical benefits of the process.

The reason for employing these methods varies throughout these studies. The methods are suggested to encourage more authentic and legitimate discussion, reducing barriers found in traditional debates (Enloe et al., 2021, Tewdwr-Jones and Wilson, 2022). The creative aspects of the activities also lend themselves greatly to problem-solving, a key aspect of co-design (Strobel et al., 2009). The methods may assist in identifying knowledge gaps (Buchheit et al., 2015) and enhance participants to envision alternative solutions to current challenges (Bell et al., 2018, Hatton et al., 2020, Heitlinger and Houston, 2021, Nash et al., 2021). Furthermore, incorporating such methods mobilises the negotiation and translation of diverse knowledge (Schröter et al., 2023) and shares understandings between participants (Hatton et al., 2020, Hossard et al., 2022b, Moro and Puerari, 2015).

A prime example of a method generating creativity is illustrated by Bell et al. (2018) in the use of Rich Picture, a process of drawing pictures to enable participants to think holistically and understand the complexities of systems. Participatory role-play and gameplay are also used within co-design workshops, which can spark creativity by engaging participants in dynamic, immersive and playful interactions. This fosters creativity by encouraging empathy, taking on diverse perspectives, lowering inhibitions, stimulating problem-solving, and breaking down hierarchies. While providing a safe space for experimentation and communication, these elements help participants navigate complex negotiations, leading to more balanced and mutually satisfying decisions. In addition, creativity within co-design mechanisms plays a pivotal role in this process by fostering innovative thinking and encouraging stakeholders to approach challenges from new perspectives. Through creative techniques, such as brainstorming, prototyping, and scenario-building, participants are empowered to explore unconventional solutions and envision transformative possibilities. This emphasis on creativity enhances problem-solving and helps unlock solutions that might otherwise remain obscured within traditional decision-making frameworks. Extending beyond what is typically considered stakeholders, Heitlinger and Houston (2021) implement a live-action role-playing game with a more-than-human element whereby participants play out multispecies relationships. This approach provides a space to challenge human privilege, offering alternative perspectives and values in decision-making. Many forms of gameplay are also employed during workshops to elicit visceral reactions from participants using tools including LEGO (Hatton et al., 2020, Tewdwr-Jones and Wilson, 2022), board games (Buchheit et al., 2015) and arts-based methods (Bell et al., 2018, Heitlinger and Houston, 2021). In other studies, novel tools are explicitly created for the workshops to inspire creativity, such as the dialogical tool 'teatime',

introduced by Gottlieb and Schaeffer (2022).

6.7. Definitions and challenges

While all the papers use the term co-design to describe the process they are implementing, forty studies included in the review do not specifically define co-design. Twelve of the fifty-two papers reviewed describe the co-design process (which is outlined in Table 3). This highlights the various understandings and complexities of the co-design process previously discussed. The need for a robust definition incorporating the process's multiple aspects is reiterated to enhance the effectiveness and relevance of research and practice. The core aims of co-design are to identify challenges and explore solutions with diverse stakeholder involvement.

As with all forms of research, the co-design process comes with challenges for researchers and practitioners. While not every study discussed the challenges of the process, thirty of the studies discuss the difficulties experienced during the co-design process. These challenges include issues with achieving a representative sample, time and resource restrictions, and stakeholder engagement. The most common challenge cited in the literature was obtaining a representative sample, which was reported in fourteen papers. Time restrictions or length of time is the second most common challenge appearing in ten of the papers. Stakeholder engagement and resources are also quoted as significant challenges, appearing in ten and nine papers, respectively. Several papers

Table 3

A list of how the co-design process is described within the reviewed papers.

Literature	Co-Design Description
Asah and Blahna, (2020)	"Co-design involving both expert and stakeholder knowledge in developing research questions and addressing them—is an integral part of the co-creation of knowledge for sustainability." (p. 325)
Borrion et al., (2019)	"end-user requirements were ascertained, and which have directed content and design choices for the Calculator." (p. 1210)
Chalal et al., (2020)	"The involvement of stakeholders and end-users in the design stages of a service or product they might use in the future is referred to as co-design or participatory design" (p. 2)
Fumagalli et al., (2020)	"some benefits can be experienced immediately during the process, like obtaining better knowledge about people's needs or fostering creativity" (p. 5)
Hatton et al., (2020)	"Co-design was a valuable tool that helped understand the perceptions of participants and essential to develop effective interventions and solutions." (p. 2)
Heitlinger and Houston, (2021)	"how they [co-design workshops] generated different modes of knowledge production through inclusive speculative design activity" (p. 2)
Horlings, (2016)	"defined as the joint formulation of the research problem, collaboration between academic and non-academic actors (including NGOs, practitioners and representatives from governments) and the joint formulation of research questions." (p. 33)
Karagiannopoulou et al., (2020)	"The notion of co-design is also conceived as a collaborative knowledge of sharing and creating processes that empowers the design of new ideas and solutions" (p. 6)
Kim et al., (2020)	"Co-design is an action of empowering consumers to develop new ideas during the product/campaign design process" (p. 3)
Paddeu et al., (2020)	"Co-design also allows those people who will be affected by decisions about technology adoption to have a substantive say in the outcome." (p. 5)
Schröter et al., (2023)	"Co-define the setting, understand the challenges, assess potential impacts, and develop solution strategies" (p. 4)
Trueworthy et al., (2024)	"A co-design approach specifically for renewable energy that attends to the complexity and embeddedness of energy systems, prioritizes justice and sustainability, and enables meaningful citizen participation may be able to aid in transitions." (p. 6)

also mention that insufficient knowledge and other limitations, such as institutional support, power dynamics and weather events, are challenging. When obtaining a representative sample, the practicality of identifying and including the pertinent stakeholders is difficult, as some form of representation will ordinarily be omitted from the process (Asah and Blahna, 2020). The review found that Fumagalli et al. (2020) employ the snowball sampling method to identify and recruit participants but highlight its limitation in potentially producing non-representative samples for target populations. The issues of time and resource constraints are also emphasised as a challenge throughout the literature reviewed. Delays during recruitment and engagement of participants are a common occurrence during co-design. They can often cause issues further into the project concerning inclusiveness and collaboration when it is not appropriately considered during the early stages of the project.

7. Discussion

This systematic literature review examined fifty-two papers to clarify how the co-design process is understood and investigate the central themes of the process to develop a more refined definition. Decision-making through diverse stakeholder engagement, navigating complex adaptive systems for transformative change via reflexivity, and using innovative methods which generate creativity were crucial elements throughout the studies. Co-design was consistently applied to enhance decision-making by involving diverse stakeholders. Incorporating varied perspectives and knowledge was instrumental in decision-making, navigating complex adaptive systems, and supporting transformation through critical reflection and a connection to place. Methodologies stimulating creativity also played a crucial role in co-design, fostering inclusive, collaborative spaces which encouraged divergent thinking and stimulated multiple senses. These themes will be further elaborated upon in the following sections, reflecting on the key findings, leading to a working definition of the co-design process within social-ecological systems for researchers and practitioners.

7.1. Implementing co-design for the empowerment of communities

From the outset, it is evident that the distinct characteristic which defines the co-design process is the participation of key stakeholders in design activities to achieve desired outcomes. While it is important to note that a fundamental limitation of this research is that the extraction process only includes papers written in English, which may impact the locations of these studies, the variation in results highlights the difference in how co-design can be interpreted and the role it may play in various locations worldwide. As previously discussed, the term co-design can be ambiguous, and in addition to the other terms within the co-paradigm, 'participatory research' and 'local stakeholder engagement' may also be used as alternative terms for co-design.

However, the contrast in study locations may also be a result of co-design being "inherently designed to the needs of the Global North" (Surá and Kun, 2021) (p. 98). Parsons et al. (2016) highlight the colonial foundations of research methods that must be considered when incorporating co-design methods. In addition, Western science, culture, and norms can further weaken collaborations between Global North and Global South researchers regarding language, authorship, interests, and needs (Mahajan et al., 2022). Although this research discusses the novelty of the term co-design, it is imperative to highlight that collaborative processes are essential to social-ecological research, such as biodiversity conservation, in many regions worldwide, particularly biodiversity-rich regions such as Latin America. While the communities in these regions may not define the process as co-design, it can be found to be inherently built into the scientific practices of the areas. Therefore, it is still essential to clearly define co-design to ensure that those involved clearly understand its goals and processes to encourage consent, avoid confusion, enhance collaboration and allow for consistent

application. Enhancing the precision of these definitions is crucial for advancing scientific understanding and improving the practical application of collaborative processes (Nguyen et al., 2024).

Further research and discussion on how participatory design is implemented in different contexts is necessary to understand these differences more thoroughly. This aspect highlights the integrative nature of the co-design process, indicating that it may be essential to consider the nuances of a representative sample when implementing co-design to ensure the specific goals of a context-sensitive co-designed process are achieved. Therefore, actively involving the participation of various stakeholders in the design process, co-design ought to ensure that diverse perspectives and lived experiences are integrated into the final solutions or ongoing governance practices. Furthermore, co-design may also incorporate multiple disciplines, such as social sciences, environmental studies, design and engineering. This leads co-design to be understood as an integrative process whereby participants combine their diverse skills, knowledge and perceptions towards a common goal, creating innovative solutions.

Participatory methods such as co-design are often acknowledged as approaches to empower local communities. They may provide a voice to stakeholders who are typically left out of the decision-making process. Calvès (2009) describes empowerment as 'principles, such as the ability of individuals and groups to act to ensure their well-being or their right to participate in decision-making that concerns them, that have guided research on and social intervention among poor and marginalized population...' (p. 2). This systematic review identifies that a variety of stakeholder knowledge and perceptions is required for it to be a genuinely co-designed process and to enhance the outcomes. Approaches which only involve one community of stakeholders may impede co-design processes by offering restricted perspectives, unequal power dynamics, and limited diversity, potentially leading to overlooked opportunities for innovation. This study shows that to ensure a fairer and just process and outcome, the inclusion of a broad range of stakeholders is required. To affirmatively address this issue, it is recommended that diversity between the various communities be enhanced where possible by adopting enhanced stakeholder screening methods such as stakeholder mapping (Gray et al., 2012). Techniques such as initial stakeholder mapping may prove valuable for identifying a broad range of participants, their respective roles, and their influence within the system. This approach helps uncover relationships among stakeholders, assess their impact on one another, and analyse the overall power dynamics (Littman et al., 2021).

The literature demonstrates that co-design provides a platform for knowledge holders that extends beyond Western science and can empower communities and create transformative change. Amri (2020) discusses the changing urban landscape, considering that the Global South houses much of the global urban population. This further accentuates the importance of emphasising co-design processes within low-income countries when facilitating global collaborations to tackle new issues that come with the changing urban environment, many of which are social-ecological in context. As the utilisation of co-design methods within social-ecological literature is increasing considerably, we argue that researchers and practitioners must ensure the inclusion of participants from a broad range of communities, including but not limited to communities of practice (i.e., planners, designers, etc.); epistemic communities (i.e., academics, policymakers, etc.); and interest groups (i.e., residents, citizens, etc.) (Wagner et al., 2019).

While the importance of co-design for decision-making processes is highlighted, this study cannot identify the specific decision-making components within co-design, such as the power-knowledge dynamics, yielding these results. However, the analysis did identify some common challenges which impact this decision-making process. Reckling et al. (2020) highlight specific individuals may dominate the process, with less dominant personalities potentially being overlooked, while power imbalances within the existing structures is also referenced as challenge (Heitlinger and Houston, 2021, Jacobs et al., 2024, Lennon et al., 2019,

Trueworthy et al., 2024). Furthermore, several papers outline the financial cost of the process to both the project organisers and the participants (Alfonso et al., 2022, Ciaccia et al., 2021, Novoa et al., 2018, Schröter et al., 2023). This challenge impacts the recruitment of participants as the project may rely on voluntary participation if compensation is unavailable. This can create a further imbalance between the participants, which is a vital consideration from the beginning. Involvement from various stakeholder groups lacks consistency, which makes it challenging to analyse the power-knowledge dynamics within this study. Therefore, in-depth research into the co-design process using case study examples is highly recommended to provide insights into how participation within co-design impacts decision-making and how the challenges outlined above can be addressed. Such research may further assist in identifying opportunities and challenges based on local conditions.

7.2. Envisioning future scenarios through creativity

Co-design is a bidirectional decision-making approach, i.e. combining bottom-up and top-down processes; therefore, creating a space for stakeholders' voices typically overlooked or left out of the decision-making processes is crucial for justice-oriented solutions. The co-design process may also provide a voice to under-represented stakeholders through its methods. For example, role-playing games allow participants to step into the frame of mind or position of others who do not typically have a role in decision-making. For example, a multispecies role-playing game can encourage empathy from participants by considering the needs and desires of both human and non-human species. It also provides a safe space to debate how those needs and desires can be met during decision-making. Such methods still require further exploration; however, they offer considerable insights into potential solutions for the complex challenges currently within social-ecological systems and their impact must be considered. Complex challenges are often understood and addressed through obscure, subjective judgements (Pearson, 2022). To support sustainable transformation, Kagan (2011) argues for artistic approaches such as those found within the workshop activities in this study. Furthermore, due to the unpredictability and complexity of modern society, an exploration into humans' more creative side is imperative to address uncertainties during the decision-making processes and build foresight capacity.

This study reveals that creativity is a fundamental aspect of the co-design process within social-ecological research and practice to achieve the core aims of co-design, which are identifying challenges and exploring solutions. While there are various understandings of creativity, such as a cognitive view focused on the mental processes involved in generating novel and useful ideas (Dietrich, 2004) or a developmental view emphasising how creative abilities evolve, influenced by individual growth, learning experiences, and environmental factors (Runco, 2014), this research employs a more social view of creativity whereby factors such as collaboration, communication and cultural influences shape creativity (Sawyer, 2017). Social interactions within collaborative processes such as co-design allow individuals to exchange ideas, perspectives and feedback. The activities identified within this research as contributing further to creativity, such as scenario design and development (Cisilino and Vanni, 2019, Nash et al., 2021, Hossard et al., 2022b, Jacobs et al., 2024) and roleplay (Buchheit et al., 2015, Heitlinger and Houston, 2021, Hossard et al., 2022b) promote active engagement and exploration of alternative perspectives thus contributing further to the understanding of creativity outlined in this research. The definition of scenarios in the context of creativity relates to the definition of scenarios set out by IPBES (2024) in terms of their shared focus on exploring possible futures and understanding the consequences of different development pathways. Both understandings emphasise exploring possibilities, considering various perspectives, and comprehending the implications of alternative futures. Whether implemented through creative activities or scientific assessments, scenarios provide valuable tools

for fostering imagination, critical thinking, and informed decision-making in addressing complex challenges and uncertainties. Addressing complex societal challenges requires creating opportunities for diverse knowledge and perspectives to converge, enabling societies to develop shared understandings of current conditions and explore potential alternative futures, including bold and previously unimagined possibilities (Cork et al., 2023).

In this context, creativity permits participants to defy the status quo and reveal innovative solutions when anticipating unknown pressures and obstacles. This is also why co-design can be a vital tool for enhancing resilience. Muñoz-Erickson et al. (2021) discuss the role of anticipation within resilience and suggest using shocks and disasters as 'windows of opportunity' to transform urban environments sustainably. To date, anticipation relating to the strength of our cities has taken the form of scientific models and projections, which rely on patterns and information from past events to inform future solutions. While this form of anticipation is undoubtedly beneficial, it is far more challenging to anticipate how systems and their various elements will be impacted. Muñoz-Erickson et al. (2021) also call for increasing the use of tools incorporating reflexivity and self-awareness into long-term foresight planning. The activities explored within this systematic incorporate elements of long-term foresight planning, such as visioning and scenario planning and development.

7.3. Co-design for systems transformation

Policy and decision-makers are increasingly challenged by the complexity of whole-system views when attempting to implement sustainability transformation at multiple scales. This review has unpacked how co-design is a practical process for navigating the challenges of complex adaptive systems, showing how the cross-sectoral collaboration of various stakeholder groups allows the values of a range of different profiles to be provided for consideration from the outset. There is an increasing need to incorporate complex systems thinking into the planning and designing of our urban spaces. The review argues that the co-design process encourages systems thinking and allows space to consider various aspects of systems not typically present within traditional, siloed planning and designing approaches.

Because we aim to inform co-design processes within social-ecological research and practice, the typical challenges associated with co-design processes have been explored to identify potential issues and consider their mitigation measures. Co-design was found to be a time and resource-intensive process, given the many facets of its undertaking. By acknowledging and considering these challenges before implementation, researchers and practitioners can plan for allowances to alleviate these issues. As discussed earlier, obtaining a representative sample was the most common challenge when implementing the co-design process. Simple random sampling is often employed in research to achieve a representative sample. However, this may not be a practical approach when implementing a co-design process, given the diversity of cultures and social hierarchies. Including participants from the previously discussed stakeholder groups is imperative to achieve the desired co-design outcomes. This is due to the multiple stakeholders of a project possessing knowledge which is novel to experts and vice versa (Asah and Blahna, 2020). Therefore, in the case of co-design, targeted participation may be the more representative approach, as it provides knowledge from the various stakeholders, which is not typically addressed during the conventional design phase of projects. This approach, combined with snowball sampling to increase the volume of participation, may alleviate many of the challenges associated with obtaining a representative sample when implementing co-design. Additionally, appropriate time management and financial planning before beginning the process is recommended to ensure researchers and practitioners achieve the desired benefits of co-design. These are important considerations when implementing a co-design process to assist with sustainable transformations.

7.4. Co-Design: A definition for social-ecological research and practice

Co-design requires a clear, universal definition within social-ecological contexts to enhance the effectiveness and relevance of research and practice. [Mimbs \(2007\)](#) discusses the importance of definitions for explicit communication purposes, and it is vital to understand the definition itself and the concepts behind it. As co-design becomes increasingly prevalent within social-ecological research and practice, it is critical to recognise the reasoning behind choosing this approach over alternative options. The study aims to clearly define co-design to enable an understanding of how the process contributes to sustainable transformations within social-ecological systems. Based on the results of this study and the points raised so far in the discussion, co-design within social-ecological research and practice may now be defined as *an integrative participatory decision-making process incorporating reflexivity and creativity while using diverse stakeholder perceptions and knowledge to determine challenges and explore solutions for navigating complex adaptive systems and enabling their transformation*. This definition includes the major themes identified within the literature during this systematic review and subsequent discussion (see [Fig. 3](#)).

Based on his study, we propose that co-design unfolds iteratively with reflexivity, allowing for continuing ideation, prototyping and refinement cycles. [Fig. 3](#) is designed to demonstrate how the process may work in practice. Initially, by integrating diverse perspectives and knowledge from communities of practice, epistemic communities and interest groups, co-design fosters innovation, creativity and systems thinking. The participatory nature of the process ensures stakeholders have a voice, agency, and ownership over the design process and outcomes from the beginning stage of the co-design process and the overall co-paradigm. By actively engaging stakeholders, co-design empowers participants to contribute their expertise and values to promote inclusivity and democratic governance. Through its methods, the proposed process encourages stakeholders to tap into their creativity and imagination to envision innovative responses to complex challenges, driving transformative change. By leveraging stakeholders' diverse perceptions and knowledge, co-design ensures the solutions are inclusive and contextually relevant, fostering resilience and equity in complex issues.

The proposed process now feeds into co-production and co-creation by laying the foundation for collaborative solutions development and implementation. The reflexive, integrative and participatory nature of co-design aligns closely with the principles of both co-production and co-creation. By engaging diverse stakeholders in decision-making processes and leveraging their knowledge and perceptions, co-design lays the groundwork for co-production, where stakeholders collaborate to implement and evaluate solutions. Working in tandem, the co-creation process is developed, whereby novel solutions are created from conception to implementation and evaluation with input from key stakeholders throughout each stage. Although decision-making is a key

theme identified in this paper, it may be considered part of a broader and more complex dynamic when considering the other themes identified in the co-design process. Co-design may serve as a mechanism for developing new social constructs by fostering the creation of shared values and rules that assist in driving systemic change by accessing typically inaccessible levers. In this sense, co-design transcends traditional decision-making functioning as a process of social construction within specific contexts. Considering this, we recommend further investigation into the role of co-design in cultivating shared values and its implications for system transformation.

When undertaking co-design, trial and error often facilitates the discovery of new iterations throughout the process while integrating various perceptions and knowledge of the stakeholders. The reflexive nature of co-design is crucial when enabling systems transformations, given the complexity of social-ecological systems and the need for adaptability due to the dynamism. Furthermore, sustainable transformations require input from stakeholders with unique perceptions and values. Co-design's reflexive and integrative processes enhance the incorporation of diverse viewpoints and allow for continuous engagement. Co-design embodies the principle of enabling equitable opportunities for diverse perspectives, ultimately providing a platform for knowledge transfer between the various communities/actors involved in the process. The element of creativity within the methods encourages blue-sky thinking, i.e. innovative concepts which deviate from conventional norms, when developing unique and efficient solutions for complex challenges. Incorporating creativity into the process is essential to cater to communities' diverse needs and preferences, thus enhancing community engagement and empowerment.

The end goal of systems transformation must be considered throughout the process to ensure pathways are developed for its application. The process does not end there, as collaborative processes are also required for ongoing governance and mainstreaming. The proposed definition provides a clear and tangible purpose for the co-design process while ensuring the critical themes identified throughout this paper are embedded. However, this definition may be missing components or at variance with other conceptions of co-design; therefore, this paper underscores the need for further research and discussions for additional refinement and validation. Given the limitations of this study (discussed further in [Section 7.5.](#)) and that co-design is an initial step in the co-paradigm, further research incorporating additional languages, cultural perspectives, and experiences is recommended for a more comprehensive understanding of the global perspective. Furthermore, understanding what constitutes a successful co-design process is crucial and is missing from this research. Therefore, we recommend further investigating the mechanisms contributing to the different themes and how they facilitate transformative outcomes. Additionally, future research should focus on developing robust monitoring and evaluation frameworks to assess and enhance the effectiveness of co-design

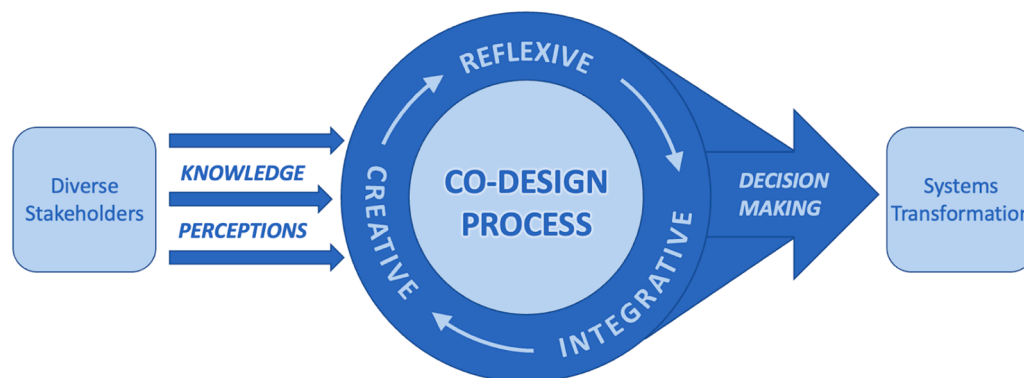


Fig. 3. The proposed definition of co-design is an integrative participatory decision-making process incorporating reflexivity and creativity while using diverse stakeholder perceptions and knowledge to determine challenges and explore solutions for navigating complex adaptive systems and enabling their transformation.

processes within social-ecological research and practice. Nevertheless, the definition developed within this paper may guide the development of frameworks for researchers and practitioners seeking sustainable transformations within social-ecological systems.

7.5. Limitations

Systematic reviews tend to carry certain challenges, such as limited use of a broader range of literature and the possibility that relevant research may be located outside of formal peer-reviewed channels (Mallett et al., 2012), in addition to the associated labour intensity of the approach (Westgate and Lindenmayer, 2017). Language is a fundamental limitation of this systematic literature review because it only includes publications in the English language due to language limitations within the research team and the specificity of a systematic review. This can result in overrepresenting literature based on Western, Eurocentric values. To alleviate these challenges, we explored academic and grey literature outside the formal search while writing this paper to enhance the overall research. Another critical limitation of this paper was the restrictiveness of a systematic literature review when conducting qualitative analysis. As the inclusion criteria adopted during the screening stages are defined in advance, this can lead to relevant data being excluded from the study (Dixon-Woods, 2010). To alleviate this limitation, potentially relevant papers excluded during the screening stages were saved and reviewed for additional depth within the introduction and discussion of this paper.

8. Conclusion

This paper explores the co-design process within social-ecological research and practice through a systematic literature review, incorporating a keyword and thematic analysis. It highlights the significant confusion surrounding the term, having different meanings depending on context. This study identifies numerous themes in the co-design process and develops a comprehensive definition of co-design for utilisation within social-ecological research and practice. The themes revealed in this study encompass the involvement of various stakeholders in shaping the co-design process and outcomes. The process is influenced by insights and perspectives from multiple stakeholders, including those not typically involved in decision-making.

The thematic analysis identifies the role of co-design in decision-making processes to assist the transformation of systems. Co-design approaches benefit policy and decision-making and can significantly enhance whole systems thinking, bringing about transformational change through cross-collaboration. This review finds that co-design is inaccurately defined within social-ecological systems. Given its continued and increased use in social-ecological research and practice, it is necessary to strengthen the understanding of the process. This study proposes a redefinition of co-design to acknowledge and emphasise the various components involved in the process.

Taking this into consideration, along with the other key themes of the process, co-design is defined in this paper as *an integrative participatory decision-making process incorporating reflexivity and creativity while using diverse stakeholder perceptions and knowledge to determine challenges and explore solutions for navigating complex adaptive systems and enabling their transformation*. This definition encompasses the major themes found throughout the analysis and provides direction on utilising co-design within social-ecological research and practice. However, we recommend further investigation into the role of co-design in cultivating shared values and its implications for system transformation to understand its potential role as a process of social construction. We also suggest further research into robust monitoring and evaluation frameworks to examine and improve the effectiveness of co-design processes. Nonetheless, the definition proposed in this paper may serve as a roadmap for social-ecological researchers and practitioners formulating frameworks to facilitate sustainable transformation efforts.

CRedit authorship contribution statement

Mairéad O'Donnell: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Melissa Pineda-Pinto:** Writing – review & editing, Visualization, Validation, Supervision, Formal analysis. **Marcus Collier:** Writing – review & editing, Validation, Supervision, Funding acquisition, Formal analysis, Data curation. **Fiona Nulty:** Writing – review & editing, Visualization, Validation. **Clair Cooper:** Writing – review & editing, Validation. **Natalia Rodriguez Castañeda:** Writing – review & editing, Validation.

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.

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Non-technical summary

Collaborative processes, like co-design, are becoming increasingly important in addressing complex challenges. These processes involve working with various people and groups, known as stakeholders, to solve shared problems and foster meaningful change. Co-design is a central component of the "co-paradigm", which also includes co-production and co-creation. However, misunderstandings and inconsistencies in how these terms are used make it harder to apply these methods effectively.

This study takes a closer look at the concept and practice of co-design through a systematic review of research. By analysing 52 studies utilising co-design in real-world situations, the authors identify common themes, challenges, and effective methods for employing co-design in social-ecological research and practice. We also explore how unclear definitions of co-design and related concepts create confusion and propose a clearer definition.

According to this study, co-design is a collaborative decision-making process that combines creativity and reflection while drawing on the knowledge and perspectives of diverse groups to identify problems and find solutions. The process assists in navigating complex, adaptive systems while simultaneously enabling their transformation. The definition aims to make the concept easier to understand and apply in real-world projects.

The research also highlights the importance of including perspectives from different cultures, languages, and lived experiences to make co-design approaches more inclusive and effective. It emphasises the need to address power dynamics among stakeholders to ensure fair and meaningful collaboration.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.envsci.2025.103998](https://doi.org/10.1016/j.envsci.2025.103998).

Data Availability

I have shared the data at the Attach File stage (Supplementary

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