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ORIGINAL ARTICLE

Perception of interconnectedness: a new typology and tools across disciplines

Maura C. Muldoon[1,2] · **Gillian L. Galford**[1,2] · **Rachelle K. Gould**[1,2]

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Abstract
Increased awareness of human-nature interconnectedness could, according to recent global syntheses, transform the dominant unsustainable systems that threaten our shared future on this planet. We collected and synthesized evidence from the interdisciplinary body of literature on how humans perceive their interconnectedness using a systematic search and thematic coding. Our findings provide three practical additions to the literature and the science-policy interface. First, our typology of six types of interconnectedness lends structure to the interconnectedness concept. It provides an intelligible, operationalizable core of a definition that can serve as goal and guide for efforts to increase interconnectedness. Second, the wide-ranging list of benefits and associations we found can aid practitioners and researchers to understand how diverse the benefits of interconnectedness can be; this may help to broaden coalitions and build support behind the recommended practices of working to increase perceptions of interconnectedness. Finally, our Perception of Interconnectedness Toolkit compiles diverse methods that researchers have used to measure perception of interconnectedness; it provides a menu of options for researchers to adapt to their research goals and contexts. This selection of repeatable methods can help practitioners and researchers to monitor and understand current perceptions of interconnectedness, and whether and how actions (e.g., interventions) may change those perceptions.

Keywords Interconnectedness · Human-nature relationships · Transformative change · Systematic literature review · Science-policy processes

Introduction

A person's conscious awareness of their interconnectedness, the extent to which they recognize their connections with other entities, is a phenomenon with wide-ranging benefits for many of today's complex challenges. Depending on the scale, context, and connections included, this phenomenon, which we refer to hereafter as perception of interconnectedness, can be experienced as an inseparable part of a community's worldview (Behrens 2010), an individual and isolated event (Brumec et al. 2023), a capacity developed through learning (Kos and Celik 2023), and countless other manifestations. Perception of interconnectedness, in all its manifestations, is a valuable topic of study because who and what people feel connected to shapes their sense of responsibility and compassion, which in turn influences their decision-making (Geng 2015).

In the context of the environmental crisis, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) identified the lack of broad understanding of interconnectedness as an underlying driver of biodiversity loss (IPBES 2024). It consequently proposed that recognizing and prioritizing human-nature interconnectedness will likely lead to transformative change because it will address this root cause (IPBES 2024). The report identified multiple important likely outcomes of greater societal understanding of interconnectedness: reduced anthropocentrism, shifts in social norms towards care and reciprocity, and widespread behavior change (IPBES 2024).

Handled by Barbara Schröter, Leibniz Centre for Agricultural Landscape Research, Germany.

✉ Maura C. Muldoon
Maura.Muldoon@uvm.edu

[1] Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, USA

[2] Gund Institute of Environment, University of Vermont, Burlington, USA

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The focus on interconnectedness in these global assessments comes from a combination of knowledge systems. Academic science plays a major role (Boccaletti et al. 2006; Guzmán et al. 2021; Palla et al. 2005; West et al. 2020), and multiple other knowledge systems also identify the centrality of understanding interconnectedness. These include Indigenous and Local Knowledge (Chiblow and Meighan 2024; Gonzalez et al. 2021; Nelson 2008; Redvers et al. 2020) and the major world religions of Buddhism, Confucianism and Daoism (Anālayo 2021; McMahan 2009; Nelson 2009; Weiming 2001), among others. These intellectual traditions provide essential foundations for interconnectedness research; they have centered interconnectedness and articulated its relationship to more-than-human wellbeing and sustainability for millennia (Gould et al. 2023; Hariyanto 2025).

Though scholars in disciplines ranging from biology to religion to business have connected their work to people's perception of interconnectedness, to our knowledge, no systematic review has yet synthesized how it is being conceptualized, what empirical associations have been found, or how it can be measured. In this study, we addressed these questions by conducting a systematic literature review with random sampling (to compile a cross-section of the literature) and concept saturation (to decide when to complete our review). We coded a sample of 100 papers. We noted the types of interconnectedness studied and created a typology of interconnectedness (i.e., how it is conceptualized); the typology contains six broad types with 24 subtypes. We also coded papers by their disciplines and the types of benefits reported (i.e., what benefits have studies found to be associated with perception of interconnectedness). Finally, we collected measurement tools used in the papers and synthesized trends and takeaways to guide future work (i.e., how perception of interconnectedness can be measured).

Within the wider science-policy interface, these three contributions relate to global conversations about how to support thriving systems that support biodiversity and ecosystem services; a primary recommendation of recent science-policy processes is the need for greater societal awareness and recognition of interconnectedness (Fig. 1; IPBES 2024). We recognize that Fig. 1 simplifies a complex system, but it clarifies the science-policy relevance of measuring perceptions of interconnectedness. There is broad global consensus regarding the need to adopt well-being metrics beyond Gross Domestic Product (e.g., Costanza et al. 2025). Our collection of co-benefits of increased perception of interconnectedness makes clear that increased understanding of interconnectedness is a valuable thing to strive for. This evidence, along with increasing calls for interconnectedness measurement, strongly encourage policymakers to support interconnectedness measurement over time, and also implement interventions to bolster those perceptions.

Characterizing the components of perception of interconnectedness—what it is and what it looks like—is arguably crucial to efforts to measure it. Measurement offers multiple important benefits in today's decision-making world. First, it enables us to incorporate metrics that matter into policy. Second, it allows us to measure progress over time and at large scales. Third, it facilitates assessments of whether interventions to increase understandings of interconnectedness are working. Our review thus starts with a typology

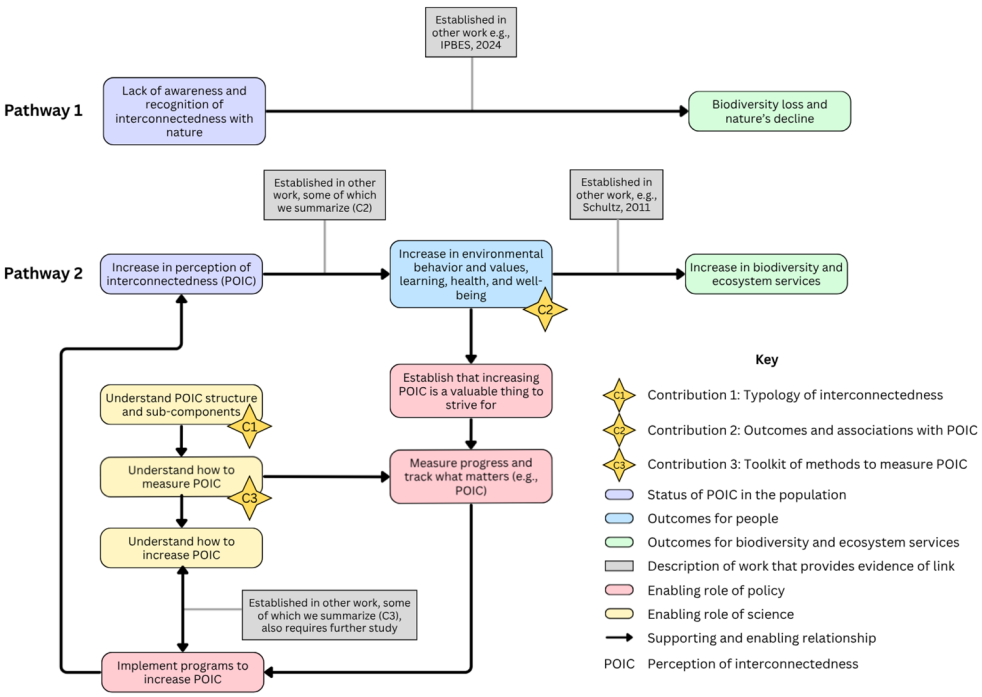


Fig. 1 Situating the three contributions of this study in the wider science-policy interface. This figure should not be interpreted as a causal model with linear relationships. Instead, it represents a conceptual simplification of the science-policy interface with reciprocal or context-specific relationships between elements. The figure demonstrates how this paper's content can be used within the science-policy interface in at least two ways: (1) to increase our collective ability to track what really matters, such as POIC, and (2) to help to design programs that might effectively increase POIC

of the components of interconnectedness perceptions, then provides a catalogue of existing ways to measure those perceptions and a list of co-benefits identified in the literature.

We focus on interconnectedness in this review, rather than expanding to include related terms like interdependence, relationality, entanglement, unity, oneness, or wholeness, for four primary reasons. First, the body of literature that encompasses this set of terms together is prohibitively large. Second, each term carries non-relevant or vague uses that have no relevance to human perception; these must be excluded (via search strings or manually). For example, interdependence commonly refers to descriptions of statistical analyses; entanglement commonly refers to quantum physics. Relationality is used in a broad array of ways including as a worldview, practice, psychological orientation, and responsibility towards kin (Tynan 2021). Third, the terms unity, oneness, and wholeness encapsulate a particular flavor of interconnectedness characterized by dissolution of the self or integration of the self into something larger. It is likely that a broad focus on interconnectedness captures the meaning in this conceptual space while limiting the search results to a feasible size. Examples of seminal work in this area include Maslow's peak experiences (1982), Turner's *communitas* or collective joy through action (2012), and the symmetry between inner and outer transformation articulated in the transformative research agenda of Anderson et al. (2011).

Fourth, interconnectedness seems more commonly used in policy documents that refer to changes in understanding. For example, the IPBES Transformative Change Assessment Summary for Policymakers states that increasing awareness of interconnectedness in the context of the environmental crisis will support transformative change (IPBES 2024). The full report uses both interdependence and interconnectedness, sometimes interchangeably, but only interconnectedness is used in key messages and summary sentences (IPBES 2024). We focus on interconnectedness for all of these reasons.

Materials and methods

To identify relevant literature, we searched the Web of Science Core Collection and SCOPUS databases in July 2025. See Table S1 in the Electronic Supplementary Material for the search strings used. Note that we specifically excluded "finance" and "financial" due to the irrelevant, common use of interconnectedness in the context of relationships between financial institutions.

After eliminating duplicates, we identified a total of $n = 5{,}341$ articles. Screening the full set of articles would not only have required a prohibitive amount of time and resources, it would have also limited the depth of analysis possible for the full-article review, since between 30 and 50% of the initial dataset was anticipated to be eligible for the full-article review stage based on a pilot review. We instead used a randomized sampling approach, outlined below and in Fig. 2, prioritizing the feasibility of completing the review in a timely manner and contributing to the pressing research gap outlined in the Introduction.

First, we submitted a pre-registration of our review plan to OSF detailing how we decided when to stop adding articles to the dataset according to the stratification of types of interconnectedness and concept saturation (Muldoon et al. 2025).

Next, we imported the 5,341 unique articles into Rayyan software. Two independent reviewers screened articles (titles and abstracts) in Rayyan for eligibility according to the eligibility criteria shown in Fig. 2 in random order until 100 papers were deemed eligible. The reviewers met regularly with another member of the research team to resolve conflicts and refine the protocol. See Document S1 in the Electronic Supplementary Material for the full reference list and Document S2 for the eligibility and inclusion decisions. Articles were excluded if they did not meet the following inclusion criteria:

Include the article if interconnectedness is used in the context of human perception (or belief, recognition, understanding, awareness, notion, feeling, interpretation, experience, etc.) of interconnectedness.

All excluded articles fell into one of two categories: the article was not about human interconnectedness at all, or it merely described the world as interconnected (e.g., "In today's interconnected world, communications technology is…") rather than addressing people's perception of that interconnectedness (e.g., "People's sense of interconnectedness in the modern world leads to…").

The research team then screened the full texts of the initial, randomly identified set of 100 articles. In an iterative process, articles that failed to meet the inclusion criteria upon reading the full text were replaced with screened papers from the remaining full set until 100 full texts had been screened and included at the full text stage. The following data were then extracted from each article using MAXQDA software:

1. Discipline.
2. Type of interconnectedness (i.e., who/what is being perceived as interconnected).
3. How perception of interconnectedness is being studied (if at all) including methods (if any).
4. Associations of correlations with perceptions of interconnectedness (if any).

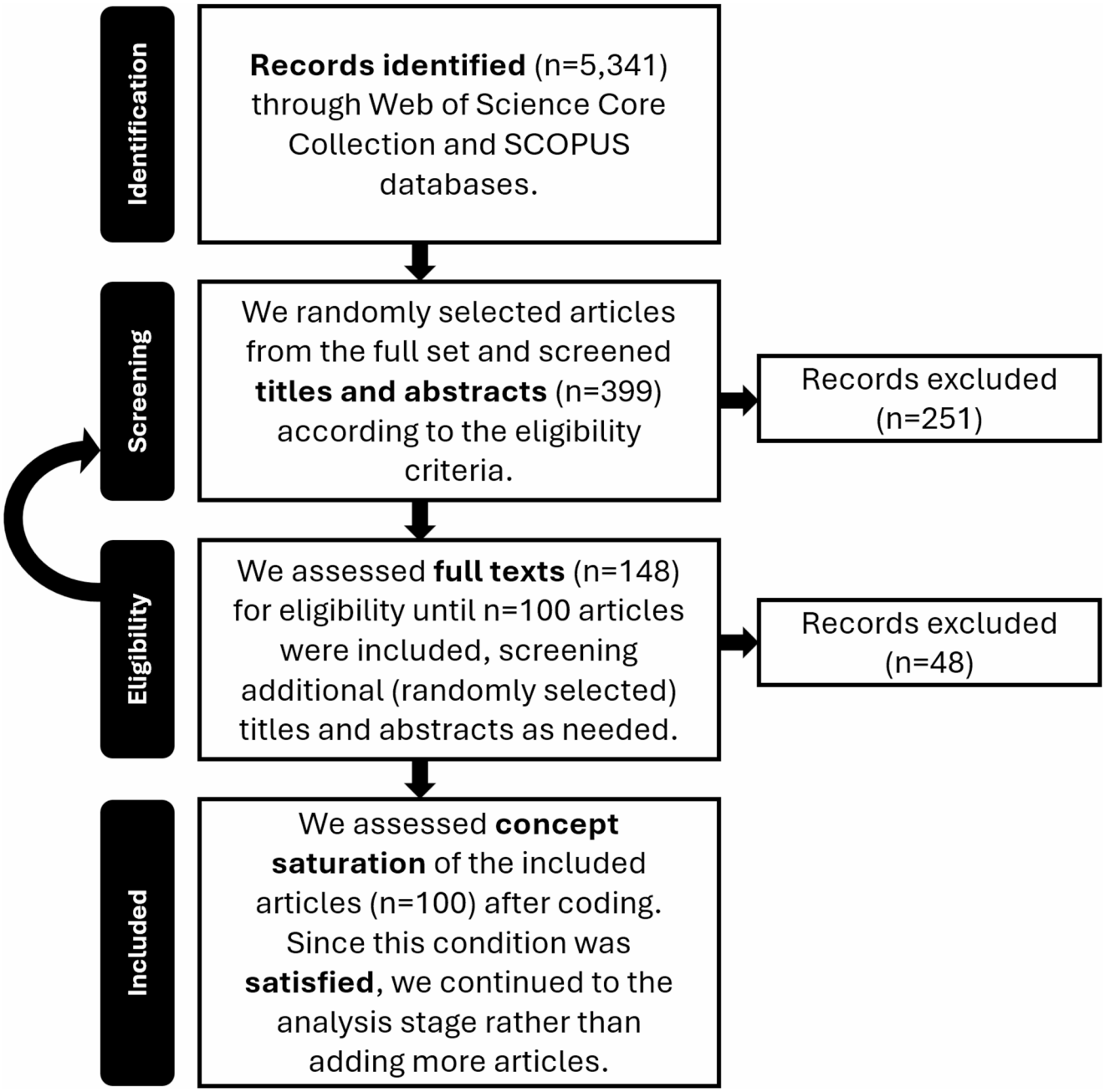


Fig. 2 Systematic review methodology with random sampling

5. Whether these associations were studied empirically or solely stated/assumed.

To code the type of interconnectedness data we used a mixture of deductive and inductive coding. The 24 subtypes of interconnectedness emerged inductively from the data. We then grouped the 24 subtypes into the types of interconnectedness which we had begun developing in pilot work to organize our findings, and the only subtypes which did not fit were related to Self interconnectedness, so we created and added this type to the typology. The rest of the data were coded inductively, using no predetermined set of codes or themes. The coding protocol was refined during pilot work and subsequently throughout the full study by the research team including two independent reviewers and other members who helped resolve screening and coding conflicts. See the pre-registration on OSF (Muldoon et al. 2025) for more details on the coding procedure. See Document S3 in the Electronic Supplementary Material for the full codebook.

The coded dataset of 100 articles was then examined to understand how the different types of interconnectedness are distributed, i.e., whether they are evenly distributed or

skewed. Within those types of interconnectedness, or bins, the distribution of recorded measurement approaches and associations were examined to understand whether these results align with the expected distribution. We found that they did align, so we stopped adding more articles.

In total, we screened 399 articles, of which 251 were excluded at the title/abstract stage and 48 were excluded at the full text stage. Of all the excluded articles, two were excluded due to non-English language, one was excluded due to being a full book, and the rest were excluded against the eligibility criteria.

Conceptual saturation in qualitative research refers to the point in data collection at which additional data no longer provides new concepts. It is a widely used and accepted criteria to indicate the point at which further data collection is unnecessary, since more data is unlikely to yield new findings. Figure 3 shows our assessment of conceptual saturation in the review as a relationship between paper number (in chronological order) and the cumulative number of unique types of interconnectedness found over time. This saturation point was reached at paper number eight for the six broad types of interconnectedness and at paper number 84 for the 24 subtypes of interconnectedness. Each of the saturation points in Fig. 3 are followed by periods of validation where we continued to include additional articles but did not find new types of interconnectedness. Had we continued to find additional types of interconnectedness, we would have continued to include additional articles beyond $n = 100$ until we achieved saturation and validation.

For papers that included benefits associated with Traditional Ecological Knowledge, we coded those benefits as explicit benefits due to the credibility of Indigenous wisdom and acknowledging that Indigenous methods for evidence generation differ from those typical of mainstream science. We coded other benefits of perception of interconnectedness reported in the papers we reviewed that were based on traditional empirical methods as explicit benefits. Alongside these explicitly studied benefits, we also coded for "described" benefits which we define as benefits or associations that are merely described or assumed without empirical evidence. The described benefits may represent the zeitgeist of perception of interconnectedness–why people assume that it matters. These described benefits are not included in the Results or Discussion, but are available to view in the Electronic Supplementary Material. See Figure S1 for the distribution of the "described" benefits ($n = 35$) in relation to the types of interconnectedness and Table S2 for a list of the specific described benefits that were coded and lumped together to form the benefits categories.

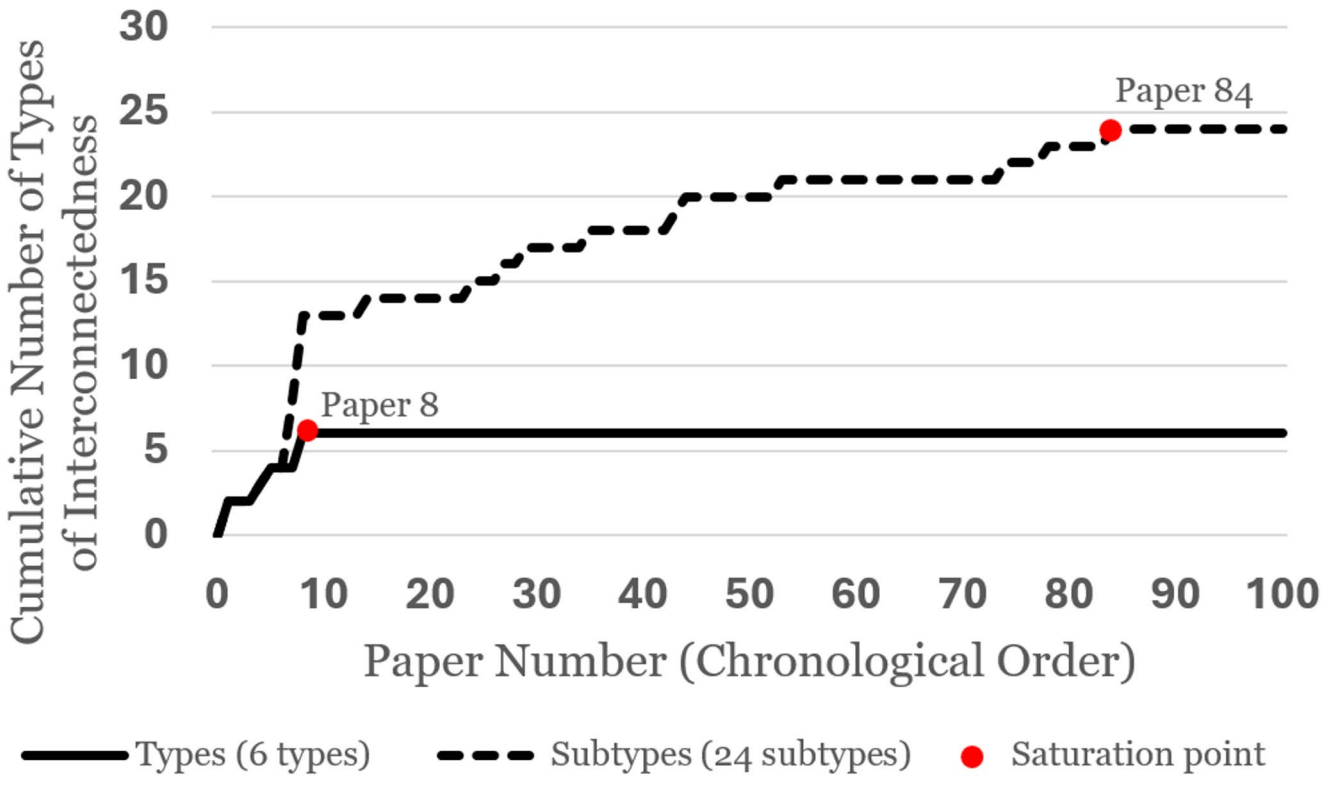


Fig. 3 Saturation curve for cumulative unique types of interconnectedness

Results

A typology of interconnectedness

We created a typology of interconnectedness, shown in Fig. 4, to organize relevant concepts for future work on perception of interconnectedness, with representative quotes for each type shown in Table 1. Through emergent and iterative coding we found six distinct types of interconnectedness that describe the constituents of the relationship (i.e., with who/what a person feels connected). In addition to the interconnectedness categories of Humans (human-human connections) and Nature (human-nature connections), which we expected to find, we also discovered All Beings (human connections with non-human beings), All Things (human connections with everything contained in the cosmos, including events and processes, unfolding across time), Spirit (human connections with the transcendent or sacred), and Self (connections between elements of one human, for example mind-body-spirit connections). These concepts emerged clearly and distinctly in the literature—first in pilot work, where we developed the types of interconnectedness to organize our thinking, and then in the full study, where the only results that didn't fit were related to the inner world, so we added Self interconnectedness to the typology.

While we think typologies and frameworks are useful for synthesizing and communicating concepts (Partelow 2023), we also acknowledge that they can be overly proscriptive, or reinforce false assumptions of separateness between related ideas and entities in a particularly Western and dualistic manner (Gould et al. 2025; West et al. 2020). This is

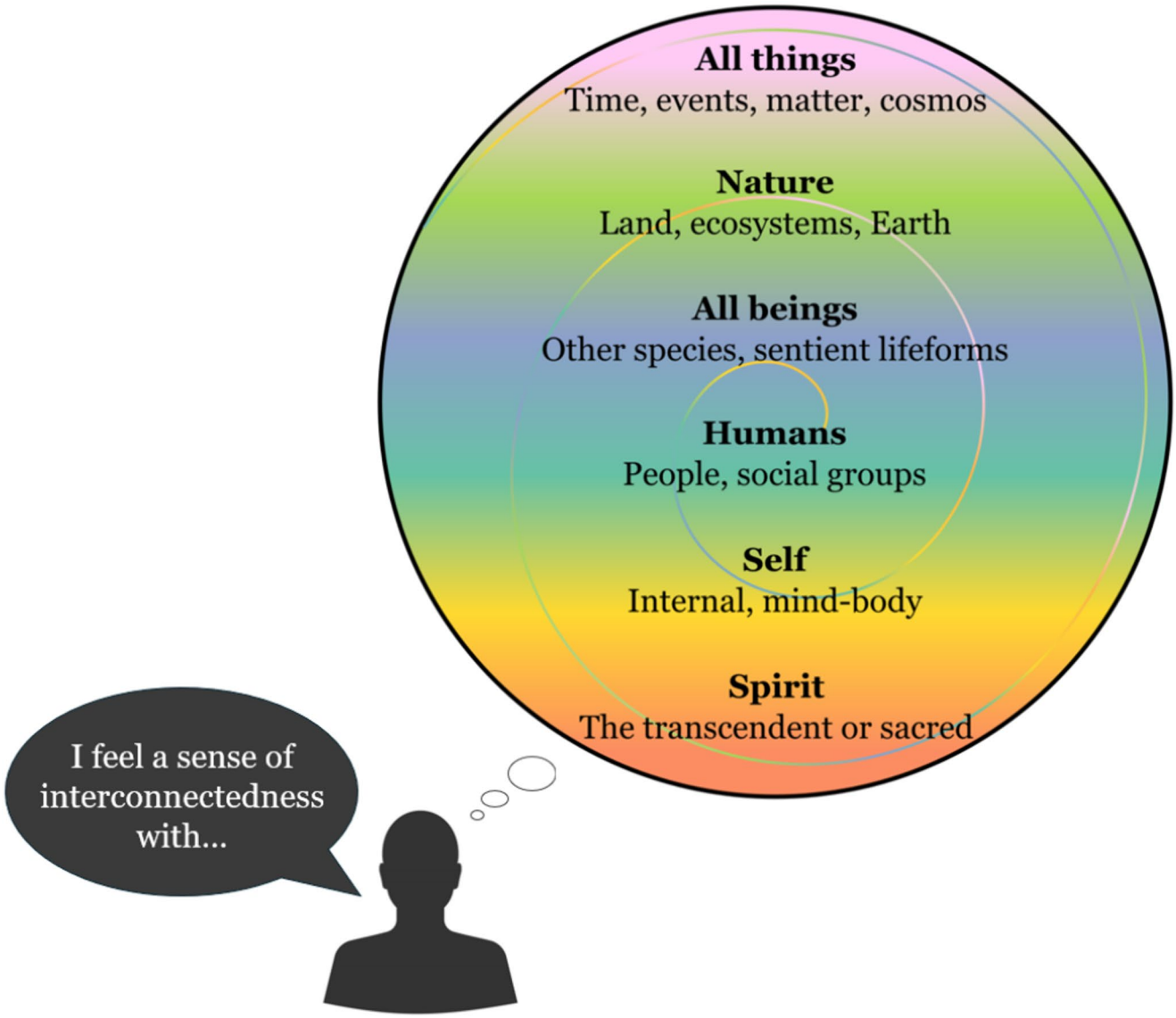


Fig. 4 Typology of interconnectedness with six types. This review focuses on human perception of interconnectedness

Table 1 Representative quotes from the review for the six types and 24 subtypes of interconnectedness

Type of Interconn-ect-edness (num. of papers)	Subtype of Interconn-ect-edness (num. of papers)	Representative Quote	Citation
Humans (73)	Other humans (58)	'Relationships with family and community members, as well as building relationships with Elders, was an evident part of interconnectedness and social connection, supporting health, well-being and positive health outcomes.'	(Ginn et al. 2025, p. 6)
	Human groups and communi-ties (16)	'More-than-coping: Restoring the Creole Sea Interconnectedness: How can we restore our connections? if we have a border dividing our ancestral territory? if no one listens to the arguments of the Creole people living amid the nation's conflict?'	(Ch 2024, p. 14)
	Human sys-tems (10)	'Here we argue that when…interrogating the supposed rationalities of the clinic and use of antimicrobials therein, we must consider the interconnectedness of clinic to the broader social and material world.'	(Broom and Doron 2022, p. 2)
	Socio-envi-ronmental problems (10)	'Reflecting the interconnectedness of social and environmental concerns in the SDGs will strengthen their universal relevance.'	(Hajer et al. 2015, p. 5)
	Ancestors (6)	'I contrast this transgenerational responsibility to inherited guilt and related ideas of genera-tional interconnectedness, which follow the logic of spondeo.'	(Elgabsi 2024, p. 4)
	Future genera-tions (4)	'Yet, although promoting a loving relationship between people and planet, hooks's anthro-pocentric standpoint positions humans as custodians to "redeem", "rescue", and "preserve" nature for future human generations.'	(Godden 2017, p. 3)
	Language (3)	'The poetic alertness with which…the indissoluble entanglement of humans and nature are registered nourishes an explicit awareness in Chihuailaf's cosmologically embedded poetry that the lyrical voice and its environment are transcendentally interconnected.'	(Haase 2024, p. 12)
	Relatives (1)	[Indigenous kinship systems are] 'most often understood as the interconnectedness to land, relatives, animals, and spirits'	(Roy 2022, p. 2)
Nature (59)	Nature (39)	'One's ecological worldview entails their interconnectedness with nature and their perspec-tives regarding sustainable development.'	(Herman et al. 2021, p. 601)
	Land (11)	'This perspective illustrates how the Western ideas of profitization view other-than-human entities merely as a means to an end, disregarding their inherent value and the interconnect-edness between land and Indigenous cultures.'	(D'Ambrosio 2024, p. 72)
	Ecological systems (11)	'By fostering a supportive and collaborative environment, akin to the interconnectedness of a forest garden ecosystem, a thriving community can be cultivated where there is continual learning, reflection, and growth.'	(Gordon 2025, p. 91)
	Socio-envi-ronmental problems (10)	'Reflecting the interconnectedness of social and environmental concerns in the SDGs will strengthen their universal relevance.'	(Hajer et al. 2015, p. 5)
All beings (37)	All beings (23)	'Though we normally think of the environment as being distinct and disassociated from us, Nichiren Buddhists realize the concept of "oneness of life and its environment," and that one universal law lies beneath everything in this universe, and hence all of life is interlinked.'	(Choudhury 2025, p. 186)
	Non-human beings (19)	'Early modern recipe books provide a valuable glimpse of how seventeenth century viewers might have pictured the interconnectedness of human and animal bodies, in health and in sickness.	(Nunn 2022, p. 1)

Table 1 (continued)

Type of Interconn-ect-edness (num. of papers)	Subtype of Interconn-ect-edness (num. of papers)	Representative Quote	Citation
All things (27)	All things (18)	'Realising one's interconnectedness with all things speaks to the significance of the individual not only as an agent of the deities but in a shared responsibility for creation'	(Eruera et al. 2024, p. 29)
	Events (5)	'Interconnectedness reflects the confluence of events or people and their contemplation and integration by the nurses into their lives and relationships.'	(Glynn et al. 1996, p. 37)
	Time (4)	'… the/Xam not only viewed themselves as 'the people who kill springbok' (//Kabbo in LL42: 3244v–3245v), but believed that they once were springbok — in a cosmos made up of permeable boundaries and fluid ontologies, a world in which past and present, legend and reality, and humans, animals and landscapes are all interconnected.'	(Parsons and Lombard 2025, p. 4)
	Cosmos (2)	Mythical stories about creation and the interconnectedness of humans, nature, and the cosmos play a central role in depictions of contemporary issues (Heith 29).	(Indriyanto and Syahfitri 2024, p. 8)
	Matter (1)	'Instead, we propose to include 'matter' and ideas into the sphere of the social as agents in their own right to form a *relational ontology of multi-species assemblages (ROMA).'*	(Kubes and Reinhardt 2022, p. 95)
	Material objects (1)	'We should emphasize the pivotal role of humans in fostering harmony, balance, and interconnectedness with fellow beings as well as with the machines. That's what Tri Hita Karana, a Balinese indigenous wisdom, is about. I also think that teachers, students, and the AI systems should collaborate, not to compete.'	(Purnawan and Prilyasinta 2025, p. 14)
	Visions of the future (1)	'…working with educators and young people to move beyond the crisis of imagination that renders apocalyptic visions central, toward more caring, affective and interconnected visions of future societies in the present.'	(Doyle 2024, p. 4)
Spirit (19)	Spiritual and transcendent realm (19)	'Pope Francis, then, invites us to pay serious attention to the interconnectedness of God, humans, and nature.'	(Joseph 2021, p. 288)
Self (11)	Mind-body-spirit and intrapersonal (10)	'Understanding the essence of interconnectedness of body–mind–spirit'	(Chan et al. 2006,pp. 8, Table 1)
	Internal-external (1)	'This amalgamation of philosophy and science enables us to perceive plant biology as a continuum of processes unfolding over time, accentuating the interconnectedness of internal and external events.'	(Souza et al. 2024, p. 3)

ironic given our focus on interconnectedness. Though we ascribe to the view that it is conceptually impossible to explain humans and nature as separate entities, we separate them in our typology to help organize existing research on perception of interconnectedness—which at present refers to humans and nature as separate but connected (as we found clearly demonstrated in our sample). We therefore offer an interpretation of our typology in which the types are not mutually exclusive. Instead, they are often nested and, appropriately, interconnected. Interconnectedness with Spirit, for example, may be synonymous to interconnectedness with Nature or All things to certain people, but they may also be distinct in other cases; therefore, the categories may be helpful to understand the myriad ways in which people describe their perception of interconnectedness.

Another helpful note for interpreting the typology is that Humans are inherently included in all the papers in our sample, since we are focused on *human* perception of interconnectedness. We coded papers that look at perception of human-human interconnectedness as "Human" because humans are the sole focus (e.g., Muñoz-Laboy 2008). All other code names indicate the ways of understanding the more-than-human entities that are involved in the connection.

We found that many articles included more than one of the six types of interconnectedness. Figure 5 shows co-occurrences between the six types of interconnectedness in the 65 papers that included more than one type, demonstrating the high degree of interconnectedness within the typology and our sample. Each of the six types were connected to every other type, with the largest connection (i.e., co-occurrence of two types in a paper) between Humans and Nature (35 papers), and the smallest connection between All beings and Self (2 papers). The 35 papers that only included one of the six types of interconnectedness are distributed as follows: Humans (16 papers), Nature (12), All beings (4), All things (2), Spirit (0), and Self (1). See also Table S3 in the Electronic Supplementary Material for the full matrix of co-occurrence values.

Perception of interconnectedness varies beyond the types of entities to which a person feels connected; it also varies widely across scale. For example, a sense of

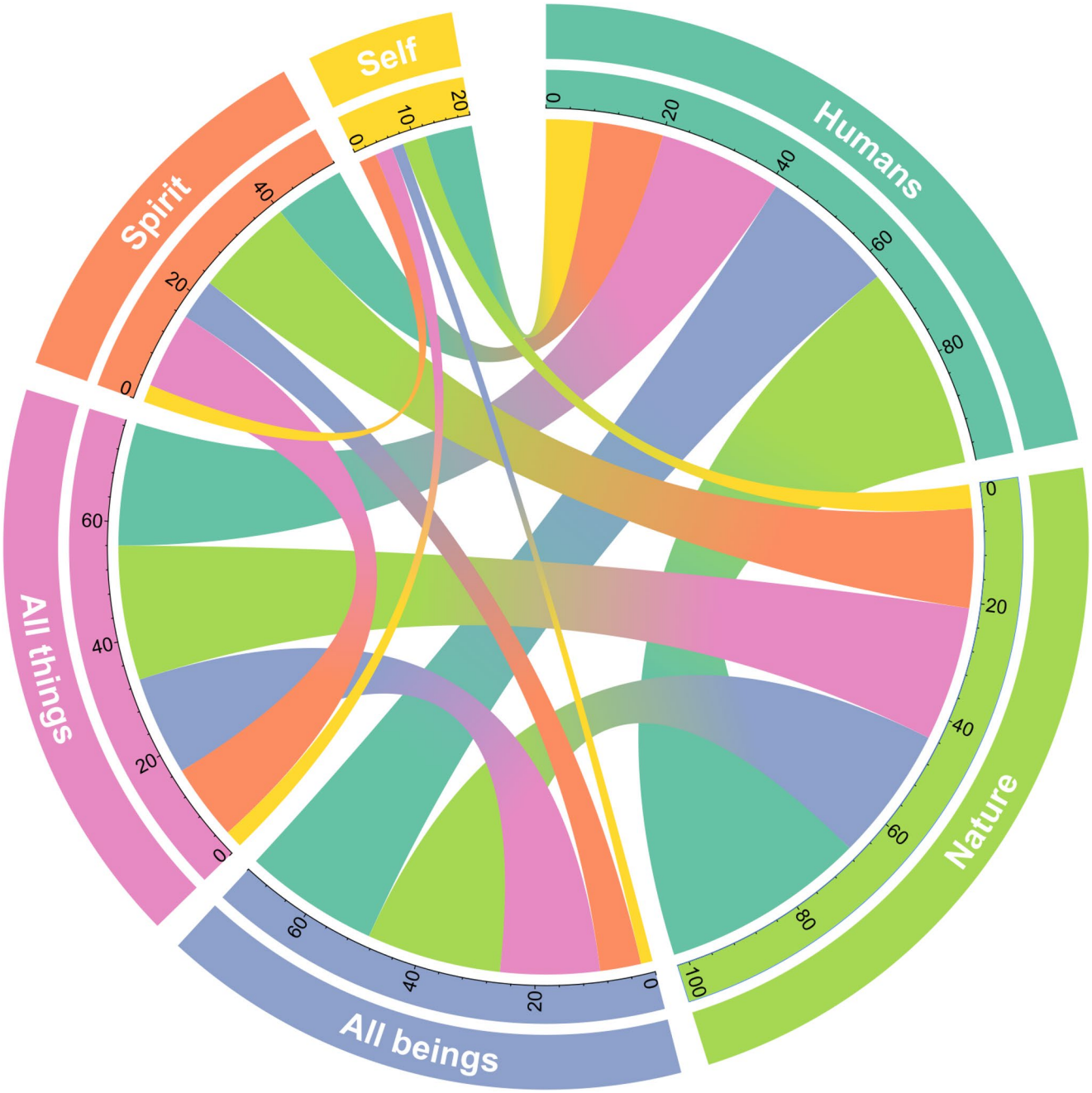


Fig. 5 Co-occurrence of types of interconnectedness in the sample

interconnectedness with Humans may be felt on the individual, person-to-person level (Wolf et al. 2024), expand to a specific community like one's nation (Ho 2025), or be felt towards all humanity as in Ubuntu philosophy's notion of "I am a person because you are"[1] (Chigangaidze et al. 2022, p. 320). The other types of interconnectedness vary similarly across scale. There is also variation in the type of perspective studied. For example, Zhang et al. (2023) collected individual perspectives through a self-report scale, while Ginn et al. (2025) asked leaders, Elders, and community members to reflect on their shared experiences and relationships. All scales of interconnectedness (individual, community, global, or beyond) and types of perspectives (individual or collective) are meaningful to understand in different contexts.

The six types of interconnectedness and 24 subtypes in our typology emerged through thematic coding (representative quotes in Table 1). We reached concept saturation in

[1] Ubuntu philosophy also extends understandings of interconnectedness to non-humans.

the review for both the types and subtypes of interconnectedness before article 100, meaning that we stopped finding new types of interconnectedness with each subsequent paper that we included and coded (see Methods). Subtypes were coded to form the six types as shown in Table 1. Given this use of random sampling and conceptual saturation, the proposed typology represents a synthesis of the sampled literature rather than an exhaustive classification of the entire field or body of literature.

Types of interconnectedness by discipline

To understand how perception of interconnectedness is studied and how it can be measured, i.e., the epistemologies and perspectives represented in the dataset, we coded each paper by discipline. Figure 6 shows the distribution of the types of interconnectedness by discipline, along with the number of articles in each discipline out of the sample of 100 randomly selected articles. Articles may fall into more than one disciplinary category and are counted in each discipline.

Over half of the dataset comes from either the Social Sciences or Humanities. Health represents around a quarter of the dataset and Education represents around a fifth. See also Figure S2 for a breakdown of the subdisciplines that were coded and lumped together within each of the eight disciplines in Fig. 6.

Spirit interconnectedness was not confined to religious studies in the Humanities, and the Social Sciences, Humanities, and Health disciplines contained each of the six types of interconnectedness, while Education, Sustainability, and Environmental Science were only missing Self interconnectedness. Business and Biology were uncommon across the dataset with 3 and 2 papers included, but they contained three or four types of interconnectedness, respectively. Spirit interconnectedness was missing in both Business and Biology.

Methods to study perception of interconnectedness

We created a Perception of Interconnectedness Toolkit of the measurement tools and instruments used to assess perception of interconnectedness from the sample of papers we reviewed, which is included in Document S4 in the Electronic Supplementary Material and freely available on Open Science Foundation (Muldoon et al. 2025). The Toolkit consists of 28 tools: 17 survey/questionnaires, seven interview protocols, two focus group guides, a coding typology and a role-playing activity. Only 26 papers included a repeatable measurement tool or instrument, which was our criteria for

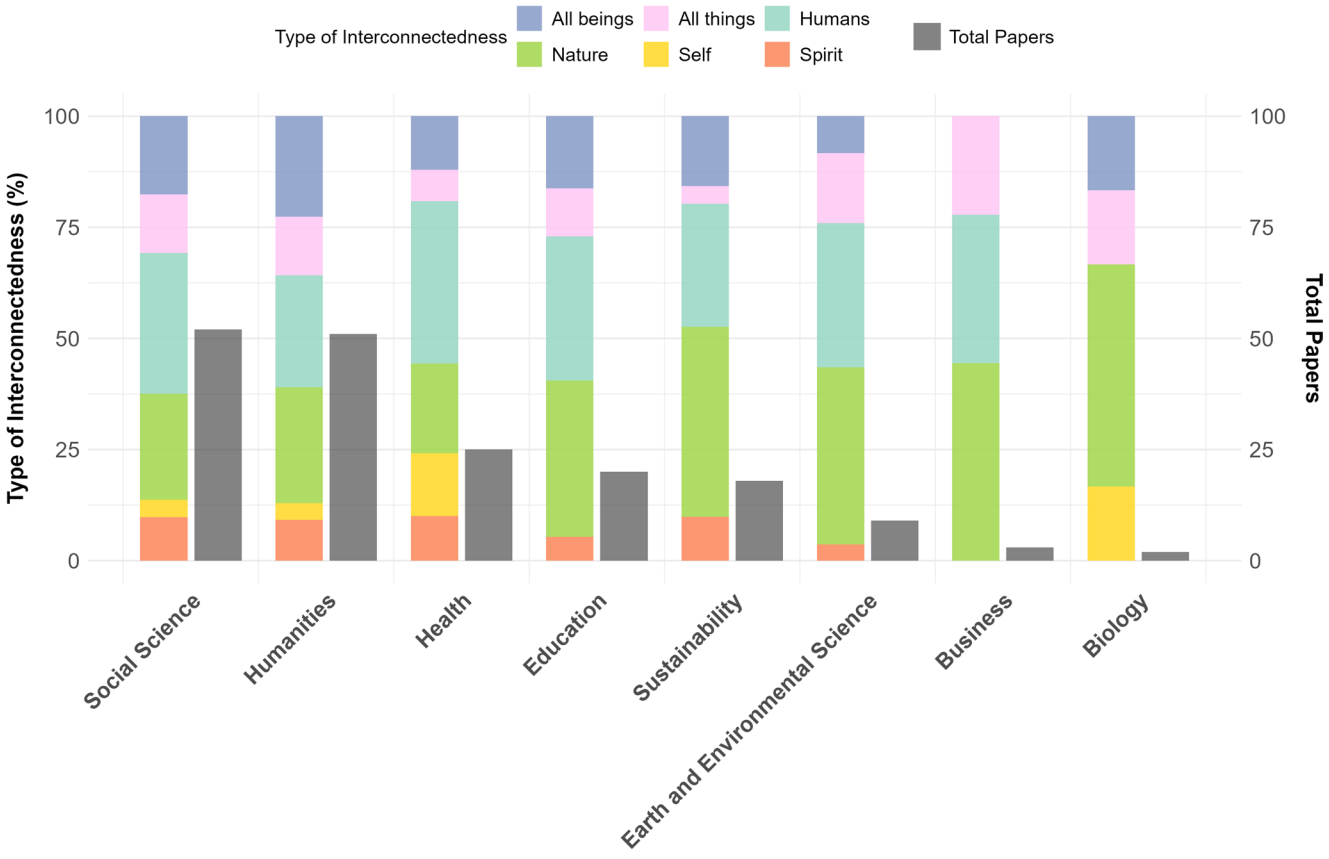


Fig. 6 Types of interconnectedness by discipline

inclusion into the Toolkit (including two papers that used more than one tool to assess perception of interconnectedness), as most papers in the sample were thought-pieces or perspectives ($n=43$) or employed another non-tool-based or interpretive method like review, literary analysis, or case study, as shown in Table 2. There were also several papers which used a tool-based method like interviews or surveys but did not provide enough (or any) information about the questions asked to enable another researcher to replicate their method, so these were not added to the Toolkit.

Note that none of the review papers counted in Table 2 focused on perception of interconnectedness. Rather, perception of interconnectedness emerged as a subtopic or finding, as in Sahoo's review of ecocriticism in poetry which explores how portrayals of interconnected and reciprocal relationships with nature can raise eco-consciousness (2025). Papers that used more than one method were counted in each method in Table 2.

The Perception of Interconnectedness Toolkit in Document S4 contains the full set of measurement tools; it includes details about each tool such as the study population for which it was developed/deployed and whether it was used to test the effect of an intervention. Only four studies in the review were intervention-based; these interventions included nature placemaking programs (Benjumea et al. 2022), a soil-plant interaction role playing activity (Van Nuland et al. 2019), personal development workshops (Wahbeh et al. 2022), and introducing the One Health concept into an existing Veterinary Public Health course (Yanmaz 2024).

In Fig. 7, we present surveys and interview instruments most likely to aid other researchers, organized based on which types of interconnectedness they mainly address. We indicate whether each tool is likely to be useful in a wide variety of cases or in more specific cases. We also indicate the one tool we found outside of the systematic review. We suggest that the tools we indicate as most widely relevant might be used to measure progress towards increasing societal values of interconnectedness.

Table 2 Methods used to study perception of interconnectedness

Method	Number of Papers
Perspective or thought piece	43
Survey/questionnaire	20
Interviews	19
Review	7
Literary analysis	7
Focus group	6
Case study	4
Workshop	3
Content analysis	3
Ethnography	3
Narrative	3
Participant observation	2
Image analysis	1
Document analysis	1
Participatory art practice	1
Public storytelling	1
Deep listening	1
Role playing	1
Psychobiography	1

Figure 7 contains the 8 survey tools and one interview tool we identified which were developed for a broad/general audience. For the survey tools, we did not identify a tool developed for a general audience that specifically measures a sense of interconnectedness with All beings, and only one scale, the Inclusion of the Other in the Self (IOS) Scale developed by Aron et al. (1992) that is adaptable to any of the 6 types of interconnectedness, due to its generic use of "other" that can be replaced with other words like "my parents", "nature", "moths", etc.

For the interview and focus group tools, only three of the tools identified explicitly asked about or probed for a sense of interconnectedness, and only one of these three targeted a broad/general audience. This tool, the Socioscientific Orientations interview, was developed by Herman et al. and deployed in conjunction with the Socioscientific and Environmental Engagement Survey (SEEDS 2021) to test the impact of a place-based education program. The other two interview tools which asked explicitly about sense of interconnectedness targeted ESG experts (Meiden and Silaban 2023) and Indigenous stakeholders and public service managers in Mato Grosso do Sul, Brazil (Grande et al. 2024). In the remaining six interview and focus group tools, perception of interconnectedness emerged but was not a primary research question. These include an interview tool about encounters with death (Dearmond 2013), coproduction value (Forcino et al. 2024), nurse's life experiences (Glynn et al. 1996), intellectual athletes (Lehtonen et al. 2025), HIV stigma in the workplace (Rao et al. 2008), and college student's perceptions of wellness (Ward et al. 2025).

Prior to conducting this study, we were aware of a handful of measurement tools for assessing perception of interconnectedness including the Inclusion of the Other in the Self (IOS) Scale (Aron et al. 1992), the Inclusion of Nature in the Self (INS) Scale (Schultz 2002), the Cloninger Self-Transcendence Scale (Cloninger 1993), the Connectedness to Nature Scale (CNS) (Mayer and Frantz 2004), the Interconnectedness Scale (Yu et al. 2020), and the Watts Connectedness Scale (Watts et al. 2022). Each of these tools except the Interconnectedness Scale and the Watts Connectedness Scale (which we still included in the Toolkit) were used by papers in our review. The only measurement tool which appeared more than once in the review was the IOS Scale (Aron et al. 1992), which was used by three studies in

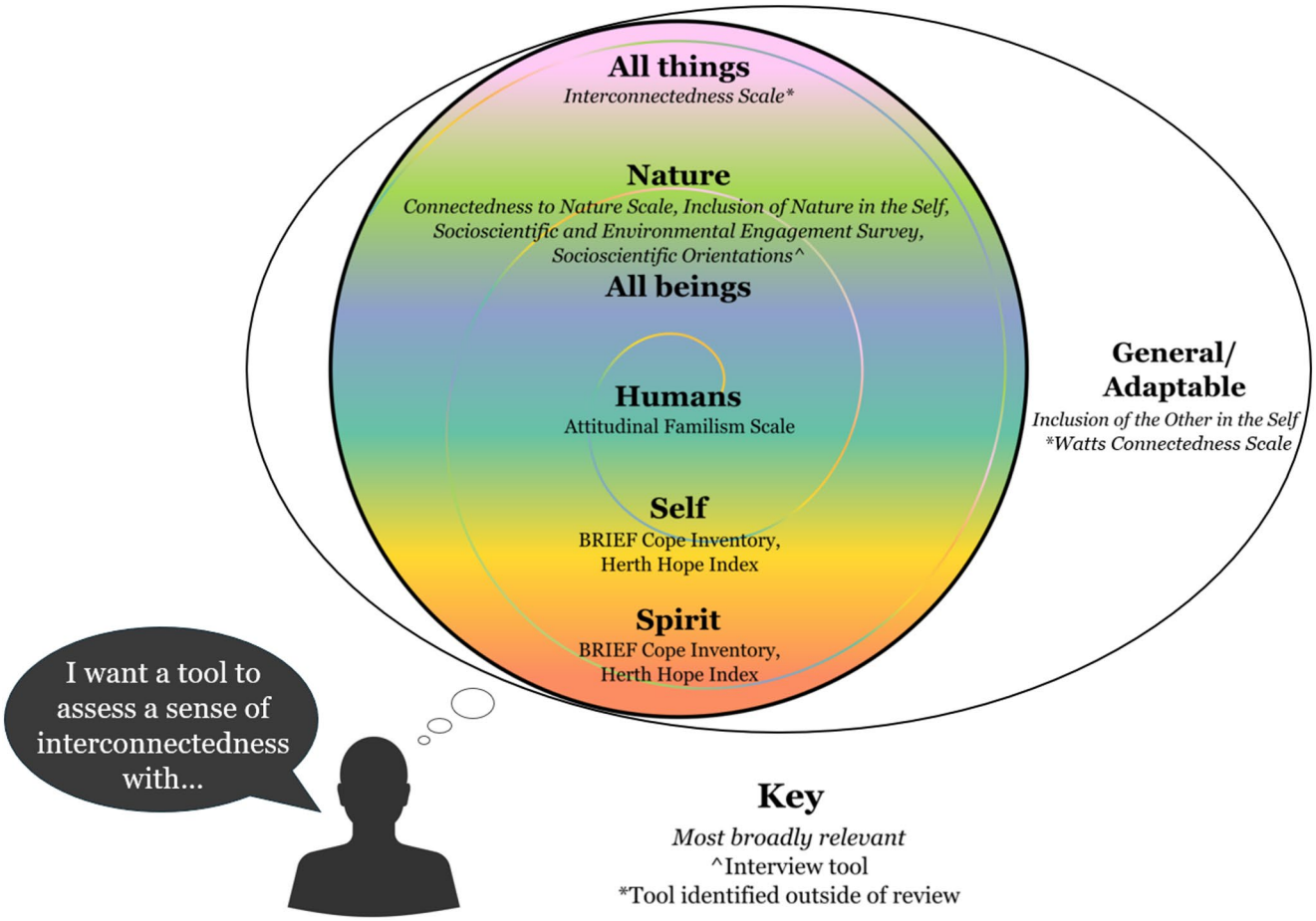


Fig. 7 Survey and interview tools to measure the types of interconnectedness in the typology

the sample (Krueger and Forest 2020; Helané Wahbeh et al. 2022; Wolf et al. 2024).

In our sample of 100 papers, the subtypes of Mind-body-spirit/Intrapersonal (Self) interconnectedness and Ecological systems (Nature) interconnectedness were overrepresented in the papers that contributed a measurement tool. Interconnectedness with Non-human beings and All things were significantly underrepresented in papers with specific tools but did appear. Interconnectedness with All beings, on the other hand, appeared in 23% of the full sample and still did not appear in any of the papers in the Toolkit. All the other types of interconnectedness appeared in similar proportions in both the full sample and the papers in the Toolkit.

Co-benefits of perception of interconnectedness

We found 37 articles that reported explicitly studied (empirical) benefits or associations with perception of interconnectedness, and coded those benefits thematically into the six categories on the right side of Fig. 8, in order of prevalence: Health and Wellbeing, Environmental, Social Cohesion and Belonging, Justice, Learning and Problem-Solving, and Miscellaneous. We found that the co-benefits of perception of interconnectedness extend well beyond environmental sustainability. Table 3 provides the inductive thematic coding we applied to group the benefits into these 6 categories. Not all the articles in the full dataset explicitly studied empirical benefits or associations with perception of interconnectedness, since 43 articles were thought pieces, and the remaining 20 used non-empirical methods like review (Table 2). These non-empirical benefits and associations are not considered in the Results or Discussion of this paper, but are included in Table S2 and Figure S1 in Document S1 of the Electronic Supplemental Materials. We did not observe a pattern of difference between the distribution of explicit and described benefits, but the described benefits can help understand the zeitgeist of perception of interconnectedness–why people assume that it matters.

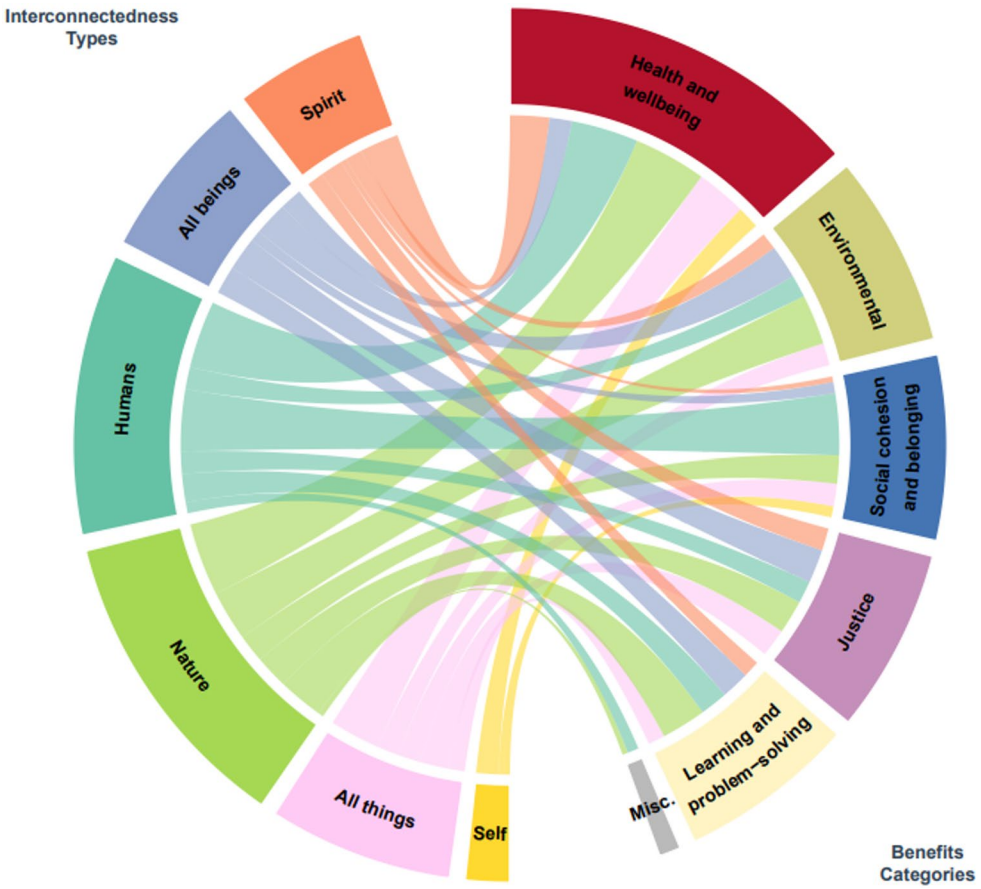


Fig. 8 Explicit benefits by benefit category and interconnectedness type

Table 3 Benefits and associations with perception of interconnectedness (explicitly tested or measured, not merely described or assumed)

Benefit category	Benefits (explicitly tested or measured) in order of prevalence
Health and wellbeing	Wellbeing, health outcomes, mental health disorders, nature connectedness, happiness, grief, hope, sense of self/identity, and spiritual awareness
Environmental	Sustainability, eco-centrism, pro-environmental behaviors, and shared responsibility for creation
Social cohesion and belonging	Social support, compassion, positive relationships, unity, empathy, ethos, mutuality, solidarity, relationship satisfaction, sense of community, social acceptance, and stigma reduction
Justice	Justice, decolonialization, and pluralism
Learning and problem solving	Learning, holism, and holistic problem-solving
Miscellaneous	Dyadic displays on social media, reminiscence for intimacy maintenance, and the spatial characteristics of a space

Discussion

Scholars and practitioners interested in transformative change need to be able to measure progress and organize work related to relevant concepts. This review is the first formal synthesis of how perception of interconnectedness is conceptualized, what empirical associations have been found, and how it can be studied. This paper offers three additions to the literature and the science-policy interface: a typology of interconnectedness; a compilation of benefits of understandings of interconnectedness; and a Perception of Interconnectedness Toolkit of methods to measure perception of interconnectedness. These contributions are synthesized from the sampled literature rather than representing an exhaustive classification of the entire field. We elaborate on each contribution below. Methodological constraints described in Limitations such as focusing on a sample of the literature shape the representativeness of the results. However, our organizing effort to characterize the body of literature related to human perception of interconnectedness can galvanize and steer future study.

First, our typology of six types of interconnectedness with 24 subtypes lends structure to the interconnectedness concept, across the diverse disciplines that study it.

We identified 36 disciplines that study perception of interconnectedness, and grouped these within the categories of Social Science, Humanities, Health, Education, Sustainability, Environmental Science, Business, and Biology. This finding demonstrates that study of perception of interconnectedness is already an interdisciplinary project. Yet our review also found little cross-pollination between disciplines (e.g., every paper used a different definition of interconnectedness, if any definition was used at all). This lack of communication is likely connected to the lack of a clear research agenda or conceptual clarity across the studies we reviewed. Future work should prioritize building connections between disciplines to advance understandings across disciplinary boundaries. This review provides a structure for this diverse work and an intelligible, operationalizable core of a definition that can serve as goal and guide for efforts to increase interconnectedness.

Second, the wide-ranging list of empirical benefits and associations we found can help practitioners and researchers understand how diverse the benefits of interconnectedness can be; this may help to broaden coalitions and build support for working to increase perceptions of interconnectedness. Though the IPBES Transformative Change Assessment (IPBES 2024) focuses on the benefits of perception of interconnectedness for biodiversity and ecosystem services, our results show that perception of interconnectedness has benefits in multiple other realms. This suggests that interested parties from many other causes, including justice, human health, and social cohesion, should consider investigating perception of interconnectedness in their work. As the One Health perspective makes clear, problems related to justice, human health, environmental health, and social cohesion are all intertwined, so it makes sense that a benefit to one would have co-benefits to others (OHHLEP et al. 2022). These empirical associations, such as pro-environmental and pro-social behavior, also support the idea that perception of interconnectedness is not merely a perception but can lead to meaningful action and behavioral change.

Finally, our Perception of Interconnectedness Toolkit compiles diverse methods that researchers have used to measure perception of interconnectedness; it provides a menu of options for researchers to adapt to their research goals and contexts. This selection of methods can help practitioners and researchers to monitor and understand current perceptions of interconnectedness, and whether and how actions (e.g., interventions) may change those perceptions. We note the interventions we found in Results and in the Toolkit, however, a focused review of interventions or experiential pathways should be undertaken in the future. We identified an imbalance in the availability of tools to assess different types of interconnectedness, such as the absence of a tool identified to assess interconnectedness with All beings. The implication of this imbalance is that the underrepresented types of interconnectedness will not be measured if tools to assess people's perception of them are not available. As presented in Fig. 1, to bring about an increase in perception of interconnectedness, we must be able to measure progress and track what matters.

The three advances this paper makes, outlined above, have the potential to aid our collective ability to implement core recommendations from recent United Nations science-policy processes. Chapter 5 of the IPBES Transformative Change Assessment (Gosnell et al. 2024) provided knowledge gaps related to each of the five key strategies proposed for transformative change. For Strategy 5, "shifting societal views and values to recognize and prioritize the fundamental interconnections between humans and nature", the gaps include "exploring inner transformation", "methodologies for inclusive collective action", "actions to phase out views that contribute to nature decline", and the "role of Indigenous worldviews" (Gosnell et al. 2024, p. 266). Our results can help to fill these gaps—especially the first. It seems clear that "exploring inner transformation" toward greater recognition of interconnections will be difficult without a shared framework and tools that address how people understand these interconnections. Our results provide an option for such a shared framework (our typology of types of interconnectedness) and a repository of possible tools. In this way, they help to elevate and center a concept.

Limitations

We only examined a subsample of the entire body of literature pertaining to human perception of interconnectedness. It is possible that if we had looked at the entire body of literature, we may have found different results. However, as detailed in Materials and methods, we used concept saturation to track when we stopped finding new types of interconnectedness in the review. Concept saturation is a widely used and accepted criterion in qualitative research to indicate the point at which further data collection is unnecessary, since more data is unlikely to yield new findings. Since we stopped finding new types of interconnectedness at paper $n=8$, yet included 100 papers in the study, we are confident that our results are an adequate *characterization* of the body of literature, while acknowledging that we did not conduct a comprehensive review. If we had continued to find new types of interconnectedness, we would have continued to add randomly selected articles to the sample. Our use of random sampling in selecting articles for our subset strengthens our confidence in the assertion that our review is an adequate characterization since articles in the entire body of literature had an equal chance of being chosen for the review. Given these limitations, the proposed typology

represents a synthesis of the sampled literature rather than an exhaustive classification of the entire field.

We acknowledge that our focus on English-language peer-reviewed articles is another limitation of this review. We are also aware that our positionality as white women working in academic contexts in the United States may have influenced our methodological decisions and our interpretation of the results.

Resource availability

The full list of articles which were included in the review is included in Document S1 in the Electronic Supplementary Material. The full list of identified literature with inclusion/exclusion decisions is included in Document S2. The full codebook is included in Document S3. The Perception of Interconnectedness Toolkit is included in Document S4. All files in the Electronic Supplementary Material section are also archived on Open Science Foundation associated with our pre-registration (Muldoon et al. 2025) with no embargoes or conditions for access.

Requests for further information and resources should be directed to and will be fulfilled by the lead contact, Maura Muldoon (maura.muldoon@uvm.edu).

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Declarations

Conflict of interest No conflicts of interests to declare.

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