Connecting transdisciplinarity – a citation network analysis to reveal the main transdisciplinary scientific communities and approaches

Conectando a transdisciplinaridade - uma análise de rede de citações para revelar as principais comunidades científicas e abordagens transdisciplinares

Beatriz Moraes Murer

São Paulo

2023

Universidade de São Paulo
Instituto de Biociências
Programa de Pós-Graduação em Ecologia

Connecting transdisciplinarity – a citation network analysis to reveal the main transdisciplinary scientific communities and approaches

Conectando a transdisciplinaridade - uma análise de rede de citações para revelar as principais comunidades científicas e abordagens transdisciplinares

Beatriz Moraes Murer

Dissertação apresentada ao Instituto de Biociências da Universidade de São Paulo, para a obtenção de Título de Mestre em Ciências, na Área de Ecologia.

Orientadora: Profa. Dra. Renata Pardini

Coorientador: Prof. Dr. Pedro Luís Bernardo da Rocha

São Paulo

2023

Ficha Catalográfica

Murer, Beatriz Moraes
Conectando a transdisciplinaridade - uma análise de rede de citações para revelar as principais comunidades científicas e abordagens transdisciplinares / Murer Beatriz Moraes ; orientadora Pardini Renata ; coorientador Rocha Pedro Luis Bernardo da -- São Paulo, 2023.
108 p.

Dissertação (Mestrado) -- Instituto de Biociências da Universidade de São Paulo. Ciências Biológicas (Ecologia).

1. Coprodução de conhecimento. 2. Ciência e sociedade. 3. Lacuna ciência-prática. 4. Transformações sociais. 5. Parcerias colaborativas. I. Pardini, Renata, orient. II. Rocha, Pedro Luis Bernardo da, coorient. Título.

Comissão Julgadora:

____

Prof(a). Dr(a).

____

Prof(a). Dr(a).

____

Prof(a). Dr(a).

____

Profa. Dra. Renata Pardini Orientadora

“Sempre soube que de conhecer eu tinha sede
E mais ainda de me conectar com tanta gente
É tão potente quando a gente se faz em rede
Porque a gente é mais igual do que diferente.

Não faz sentido olhar apenas o começo e o fim
Nesse meio tem aprendizado e muita conexão
Que torna esse processo tão maior para mim
Porque é no coletivo que se faz a construção.”

Marina Rosalino Gomes (2023)

Marina escreveu essa maravilha num esforço para estar especificamente aqui nesta página.
Eu tinha certeza que ela traria às palavras o necessário. Obrigada por tudo e tanto.
Te amo, amor da minha vida!

AGRADECIMENTOS

Tem tanta coisa aqui dentro que tá até difícil de verbalizar. Viver é mesmo uma coisa muito louca e potente. Requer coragem e improviso e, sobretudo, boa companhia. Eu não tinha dúvidas de que aprenderia muito no mestrado, mas o processo sempre me surpreende, foi muito além. Foi um percurso intenso. Perdi uma das pessoas mais importantes da minha vida, vivemos uma pandemia, mudança de governo e tantas vivências que eu até me perco em memórias. Com a ressalva de que é necessário ser crítica e não ser toxicamente positiva, eu tive a honra de extrair coisa boa de todo o processo. Cada página que aqui se sucede envolveu processos desafiadores, imersivos e, principalmente, coletivos. Eu aprendi muito sobre coprodução, sobre redes de citação, sobre programar e sobre ciência. Mas nem de longe esses foram os maiores ganhos dessa pós-graduação.

Foram as relações, as autodescobertas, o desfrute do processo, os baques e arremates, as danças e remexos que eu nem sabia que era capaz e fui, graças também e muito a cada pessoa que me atravessou nesses últimos anos. Aprendi sobre mim, sobre meus limites, sobre meus sonhos, sobre a importância dos descansos, dos ócios, das distrações, de todas as emoções e sentimentos vividos em sua integralidade e de sempre valorizar e aproveitar o trajeto. Sobretudo, aprendi sobre o respeito aos tempos e sobre como em última (primeira e em toda) instância, o importante são as conexões com as pessoas. É por isso, e por tudo, que sinto uma imensa felicidade e um alívio verdadeiramente gratificante estar cumprindo a meta de entregar esta dissertação. Obrigada por cada sorriso, colo, ideia, incentivo, olhar, carinho e preocupação manifestados. Uma pessoa querida diz sempre “eu sou, porque somos”. Então, obrigada por contribuírem com quem sou. Sou verdadeira e profundamente agradecida. Que felicidade, que delícia, obrigada! Eu transbordo!

Agradeço ao Instituto de Biociências da Universidade de São Paulo por tantas vivências, conhecimentos e pessoas que mudaram a minha vida; ao Departamento de Ecologia pela oportunidade de conduzir esta pesquisa; e ao Programa de Pós-graduação em Ecologia, que é acolhedor e amplia as possibilidades e a qualidade da produção científica além das caixinhas. Professoras/es, funcionárias/os, representantes discentes, Vera, obrigada!

Agradeço à Renata, minha orientadora, pela potência e parceria contínua. Obrigada por todas as oportunidades, trocas, ensinamentos e vivências únicas que você viabilizou. Obrigada pela paciência, pelo cuidado e pelo empenho por mim e por este projeto. Obrigada principalmente por me mostrar humanidade e enfatizar que viver é o processo!

Ao Peu, meu coorientador, pela energia, pela articulação, pelas representações, pelas contribuições. Obrigada pela emoção manifestada e pela maravilhosidade! Ao meu Comitê formado por Peu, Mark e Paulo Inácio, obrigada pelo esforço conjunto e impecável. Sempre atentos e zelosos. Obrigada por se envolverem desde o princípio até o último momento. Obrigada pelos incentivos, pelas boas ideias e provocações, pelo suporte integral e pela paciência.

Aos parceiros de Lab, que traçaram comigo esse trajeto. Às conversas, compartilhamentos, acolhidas, sugestões, ideias, estímulos. Nossos momentos semanais, especialmente durante a pandemia, todas as trocas que tivemos virtual e presencialmente. Nossa! Como vocês fizeram a diferença! Nossa vivência na Colômbia também foi uma alegria sem fim. Agradecimento e enaltecimento especial à Beá, Marcella, Marina e Diana maravilhosas e João-paixão maravilhoso. Vocês são genialidade, potência e inspiração. Obrigada pela amizade, companheirismo, incentivo e apoios incansáveis. Amo vocês! Um xêro pra Malu, pra Maju, pra Dani, pra Quel, pra Le, pra Lívia, pra Lari (minha gêmea de aniversário) e todas as pessoas queridas que passaram pelo grupo esses anos também. Admiração e carinho demais!

À Margô, Samy, Caren, Gabi e ao pessoal de Siribinha (que tive a breve, mas marcante oportunidade de conhecer), obrigada pelas vivências baianas e tantos aprendizados. Ao Ogro e à Paulinha que me ajudaram a colocar as ideias em prática - nas programações e organização de pensamentos. Ao Fer querido, à DEUSA Gabi e ao Ricardo Pardini pelos apoios nos scripts infinitos. Eu duvidei, mas confiei acima de tudo e sem vocês definitivamente não teria dado!

Ao Paulo Sano, a quem devo incalculáveis aprendizados e carinho. Obrigada por me enxergar, estimular e ser amigo. Ao Ronaldo, à Beca, à Anne, ao Anderson, ao Gabriel, ao Pedro, ao Igor e à Rafa, queridas e queridos do Cajuí, obrigada por tantas contribuições concretas, pelo direcionamento; e também por me confirmarem a potência de fazer no cuidado, na atenção, no diálogo, na empatia. Agradeço também ao pessoal de Pé de Serra, que tanto me ensinou na prática, mesmo que em poucos encontros, sobre a importância do vínculo, do cuidado, do estar e fazer junto.

À Mariazinha, Mari, Dodó, Dani, Tantan, que trouxeram música, dança e leveza ao meu dia-a-dia. Obrigada pela amizade, pela sanfona, pela Chapada e pelas risadas. À Selminha e à Ju tão queridas e parceiras, obrigada por tantos compartilhamentos, incentivos, confiança e potência. À Carlinha amada por tantas compartilhadas, acolhidas, incentivos, conversas profundas, amor e cuidado. À Silzinha querida, pelo carinho, zelo, preocupação e credibilidade que me dedicou. Obrigada por enxergar minhas potencialidades e otimizar meus percalços. Sinto que você é das pessoas que mais acreditam em mim e, sem dúvida, das que mais me colocam pra cima. Não tenho nem palavras. Tenho tanta felicidade de te ter na minha vida e tanto amor e admiração por você que uma das coisas que mais celebro é ouvir que sou cria de Silzinha. Ao Jonny, ao Silvio, ao Ítalo, ao Will, ao Cicerito, à Mi, à Gio, à Re, obrigada por tantos compartilhamentos e especialmente por reiterarem a força do

coletivo. Quanto amor e admiração por essa galera! Fanyzoca, também sou muito agradecida por todos os ensinamentos sobre povos indígenas, sobre o ISA e a vida!

Agradeço também a toda a galera do escritório do ISA SP, que faz tudo valer! Obrigada por cada abraço, sorriso, risada, almoço e acolhida! Ao pessoal do GT Gênero, especialmente Selminha e Carlinha (de novo sim), Karina, Dulce, Aline, Nina, Joãozinho, Mau, Carol, com as e os quais tanto aprendi. Obrigada pela confiança, incentivo e credibilidade dedicados a mim e aos processos equitativos. Sandrinha, Fer, Fábio e Gui, obrigada pelos ensinamentos e compartilhamentos no âmbito do comitê sobre cuidado, parceria e coletividade. Agradeço também à Yas, à Wuara e ao Glaubinho pelos sorrisos, amizade e potência! À Clarinha amada, obrigada demais por ser esse acontecimento que só me agrega e transborda. Amor e admiração infinitos!

Agradeço imensamente à minha galera da restauração. Vocês e as sementes mudaram minha vida! Edu, Má, Edézio, Line, Gi, Codorninha, Mi, Dani, Drea, Luciano, Anabele, Cami, Jimenão, Natanna, Duda, Buzz, Laiane, Silvia, Este, Lilla, Rodrigo, Laura, Bruninha, Larinha, João, Ci, Dé, Nath, Max, vocês são geniais! Me inspiram todo dia. Obrigada por toda paciência, compartilhamentos, ensinamentos e celebração coletiva! Agradeço também a cada coletor e coletora de sementes com o qual eu tenho o imenso prazer de compartilhar saberes e vivências. Parceiros da jornada, que honra e felicidade diária que é trabalhar com vocês! Nessa jangada, nominalmente agradeço à Gisele, à Lena e ao Zé da Lena, por todo carinho, confiança, cuidado e histórias traçadas e compartilhadas.

Ao Anguzinho, cuja companhia e parceria nos estudos viabilizaram literalmente o ingresso nessa pós-graduação. Sempre trilhando caminhos confluentes. Te admiro e agradeço muito! Ao meu Frizão, amor, admiração e torcida infinitas. Obrigada pela relação que me transborda. Te amo! Ao Rob pelos anos de companheirismo, amor e incentivos sem fim. Obrigada por tanto ter me ensinado sobre a vida, sobre mim e por ter feito tantos questionamentos construtivos para este projeto. Você me disse uma vez que tem muito de você neste mestrado e é verdade! Obrigada. O amor é permanente, eu sei que você sabe. Agradeço também à Fe por todo cuidado, conversas, risadas e comida quentinha e deliciosa.

Agradecimento máster também à minha terapeuta, que apoiou demais esses anos em muitos aspectos, sempre trazendo boas provocações e palavras de incentivo. Obrigada, Anelisa!

Às pessoas amadas e maravilhosas que a bio me deu: Inkilino, Fridinha, Pirulita, Cumps, Teté, Ro, Xeninha. Nossos momentos nos últimos anos e especialmente neste ano me deram todo gás, amor, certeza e apoio que eu precisava. Vocês são a definição dos amigos dos sonhos. Amo vocês! Isaurinha, Carol, Xupisca, Di, Cookiezinha, Avatar, Zatts e minhas Piranhas, muita felicidade ter vocês na vida, vocês são sensacionais, obrigada demais!

Às minhas maiores riquezas, que de tão diferentes e complementarmente maravilhosas, me transbordam: meu amô, meu bem, minha couts, minha samambaia, minha amora, minha xu e minha vodol. Amo vocês incondicionalmente! Amô da minha vida, eu não sei nem por onde começar... obrigada por tudo, sempre e todo dia, por cada risada de tirar o fôlego, balanço zeloso, rolê aleatório e colo. Obrigada por ser genial e concretizar a melhor relação que eu poderia sonhar. Você é lar. Não sei o que seria de mim sem você e nem quero! Que felicidade é nossa sincronia. Te amo! Meu bem, é de todas as vidas. Obrigada por todo o amor, por acreditar sempre e por ser você. Te amo! Minha Couts, obrigada por provar sempre que a gente tá sempre uma pela outra. Obrigada por me fazer amar mais o meu nome, só por você carregá-lo. Te amo! Minha samambaia, obrigada por estar sempre tão presente e aquecendo meu coração (você literalmente viabilizou presença mesmo que parte desses últimos anos tenha envolvido milhares de quilômetros de distância física). Obrigada pelo seu interesse em mim e nas minhas questões existenciais. Te amo! Minha Tequinha amorinha, que honra é existir no mesmo mundo que você. Obrigada por ser leveza, amor, parceria e lar. Te amo! Minha xu, você é das pessoas mais sensacionais que existem neste universo. Felicidade é compartilhar a vida com você e saber que somos a mesma pessoa. Sem você eu não teria conseguido. Obrigada por cada doideira, cada compartilhamento profundo e pela parceria infinita. Eu explodo de amor por você! Minha Vodol, obrigada por todo o amor e a pureza que me fazem acreditar que o mundo pode ser melhor, porque nele há pessoas como você. Te amo!

À minha família, sem a qual nada sou. Ao meu baby, que é a minha maior inspiração da vida. Por ser a coisa mais genial e maravilhosa que eu já vi e vivi. Te amo mais que mil milhões, que qualquer cinturão de qualquer galáxia! À minha Pichuzinha, que me ensinou sobre amor incondicional e que tanto me inspira com sua inteligência racional e emocional. Eu vivo de amores e orgulho! Eu babo por você! À kirida, que é meu irmão de alma e sempre me prova como dá pra sorrir, cantar e dançar em qualquer tempestade. Você é BABILÔNICA e te amo tanto que transborda! À Ba, que sempre foi minha referência e meu amor e que me deu o maior presente da vida. À mia regina, por ser minha ídola e por me provar que o amor liberta. Obrigada por sempre acreditar e confiar em mim. Sou o que sou porque você me amou. Já disse que te amo? Ao meu veio, que apesar da distância, sempre esteve perto e foi entusiasta. Amo você! Ao meu belo, que é o amor da minha vida, e desde pequenina me mostrou o poder da educação e do amor. Nunca vou estar só ou vazia, você me preenche a vida toda. À minha fofó coruja, que sempre acreditou em mim e estimulou meus sonhos. Me ensinou a ler antes do esperado, era minha professora dentro de casa. Ao seu Nivardo, que corria com o pão quentinho, querido como raramente se vê. A estrela brilha. Sempre e todo dia. À dona Marta, que passava manteiguinha e era a aluna que me incentivou. À vó Maria, por sempre ser colo. Foi sufocante não poder estar fisicamente na despedida, mas sei que sempre estaremos juntas. À

Tata e ao Dadi, que foram os padrinhos-avós dos sonhos. À Lê e ao Né, que me mimaram e ensinaram sempre. O "Bia, meu bem" sempre me fez sentir que eu era capaz e que eu tinha uma torcida e tanto! Ao meu doce, que não poderia ter outro vocativo. Meu pacotinho de amor, que me inspira e me transborda de amor e orgulho. Ao Dokas, que é e sempre foi meu parceiro de vida. Since always, forever! Ao Bru, que me inspira pelo silêncio e calma. À Lô, Ju, Cá e Manuca, ao Be, Tata, Vi, Tom, Nonis, Guigos e Drica, que são amor e suporte. À minha gêmula, à Veli, à tia Pi, ao tio Dinho e à Mone amados, por todo o carinho e zelo. Ao tio Luiz, que pela admiração me faz querer ser melhor. A todos os Moraes e os Murer: todo o meu amor! À tia Giselle, à tia Andrea, ao tio Roger e à Heleninha, que sonharam comigo. Ao Gudi, que tanto me ensinou e transformou. Orgulho de cultivarmos o amor e a torcida.

À Kim pincesa, Sme gudinho, Bergamota turuja, Pérola piciosa, Rasputchas, Bolotinha, Gurdina, Stitch, Jêre, Murzinho, Bijamin, Curidones e Kit, que me definiram confiança e lar. Obrigada por serem minha família. Eu amo vocês pra sempre!

Um salve cheio de agradecimento também a grandes pessoas, as quais pude conhecer um tanto por meio das leituras e das escutas, que mudam mundos e contribuem para jornadas equitativas e coletivas. São muitas e com as quais seguirei aprendendo todo dia.

Por último, e pra reiterar que não há ordem nessa lista de gratidão eterna, a Deus, pela luz, amor incondicional e a toda a oportunidade. Pelos caminhos cruzados com pessoas que me transbordam e fazem de mim quem sou.

Já diz Emicida*: viver é partir, voltar e repartir!*

É tudo sobre o momento, o movimento e o compartilhamento. Porque “*nós somos o começo, o meio e o começo*” (Nêgo Bispo). Obrigada!

TABLE OF CONTENTS

ABSTRACT

Climate change, deforestation, pollution, biodiversity loss, food insecurity, water scarcity, socioeconomic inequality, and threats to ways of life and culture of local and indigenous communities are among the complex interrelated problems we face today. They impose limitations to traditional and discipline-oriented science to support transformative change, given its compartmentalization and detachment from societal pressures. The complexity of societal problems makes articulation across academic disciplines crucial, while the perspectives and values within society challenge problem delimitation and make technocratic solutions insufficient and collaborations with non-academic actors imperative. Among the propositions to deal with these limitations, transdisciplinary approaches focus on collaboratively articulating scientific and non-scientific knowledge and values. Although potentially relevant, transdisciplinary approaches are numerous, spread across different scientific fields, and distinct in how they tackle the multiple challenges of articulating knowledge and values. Hence, identifying and comparing the multiple approaches available in the literature can help by connecting distinct views, uncovering solutions to confront known challenges as well as detecting gaps limiting the advance of transdisciplinary practice. In this dissertation we (i) compiled the names and characterizations of available transdisciplinary approaches; (ii) identified and characterized the distinct scientific communities using them; and (iii) qualitatively compared dominant approaches and described their distribution across scientific communities. We first inventoried and screened approaches related to transdisciplinarity. We then used the names of 55 approaches in an extensive bibliographic search in Scopus that returned 130,279 publications. By conducting a direct citation network analysis and using a clusterization algorithm, we identified the 13 largest scientific communities using transdisciplinary approaches, representing 83.7% of the 55,744 publications in the network. Through the frequency of terms in the title, abstract and keywords of their publications, the title of the most cited and central publications, as well as the names and scientific fields of the journals where they are published, we described the thematic scope and the dominant approaches used by the different transdisciplinary communities. Finally, we characterize all 11 dominant transdisciplinary approach in five dimensions – focal entities under consideration, focal process to be changed, central goals of the change, guiding tenets, and general methodological guidelines. The 13 largest transdisciplinary communities were associated with five interdisciplinary thematic domains: Socio-environmental, Health, Business and management, Teaching and education, and Medicine. These groups of communities sharing themes and focusing on the same broad type of societal issues are linked by shared transdisciplinary approaches rather than by citation. The within-approach linkages between focal entity under consideration, focal process to be changed, central goal, and main tenet create a specific affinity between the characteristics of transdisciplinary approaches and particular types of societal issues and thematic domains. Yet, the four identified types of general methodological guidelines were shared across transdisciplinary approaches and domains. Acknowledging that there is no universally superior transdisciplinary approach, the comparative framework we propose allows for the identification of strengths and complementarities among transdisciplinary approaches, and lays the ground for articulating different approaches to improve transdisciplinary practice.

RESUMO

Mudanças climáticas, desmatamento, poluição, perda de biodiversidade, insegurança alimentar, escassez de água, desigualdade socioeconômica e ameaças aos modos de vida e à cultura das comunidades locais e indígenas estão entre os problemas complexos e interrelacionados que enfrentamos hoje. Eles impõem limitações para que a ciência tradicional e disciplinar apoie mudanças transformadoras, dada a sua compartimentalização e desvinculação das pressões sociais. A complexidade dos problemas sociais torna crucial a articulação entre disciplinas acadêmicas, enquanto as perspectivas e valores na sociedade desafiam a delimitação dos problemas e tornam as soluções tecnocráticas insuficientes e a colaboração com atores não acadêmicos essencial. Entre as proposições para lidar com essas limitações, abordagens transdisciplinares concentram-se na articulação colaborativa de conhecimento e valores científicos e não científicos. Embora potencialmente relevantes, essas abordagens são numerosas, distribuídas em diferentes campos científicos e distintas na forma como enfrentam os múltiplos desafios de articular conhecimento e valores. Assim, identificar e comparar as múltiplas abordagens disponíveis na literatura pode ajudar a conectar pontos de vista distintos, encontrar soluções para enfrentar desafios conhecidos e detectar lacunas que limitam o avanço da prática transdisciplinar. Nesta dissertação (i) compilamos os nomes e caracterizações das abordagens transdisciplinares disponíveis; (ii) identificamos e caracterizamos as distintas comunidades científicas que as utilizam; e (iii) comparamos qualitativamente as abordagens dominantes e descrevemos sua distribuição entre as comunidades científicas. Primeiramente, mapeamos e filtramos abordagens relacionadas à transdisciplinaridade. Em seguida, utilizamos os nomes das 55 abordagens em uma extensa busca bibliográfica no Scopus, que resultou em 130.279 publicações. Por meio de uma análise de rede de citações diretas e usando um algoritmo de clusterização, identificamos as 13 maiores comunidades científicas que utilizam abordagens transdisciplinares, representando 83,7% das 55.744 publicações na rede. A partir da frequência de termos no título, resumo e palavras-chave de suas publicações, do título das publicações mais citadas e centrais, bem como dos nomes e campos científicos dos periódicos onde são publicadas, descrevemos o escopo temático e as abordagens dominantes usadas pelas diferentes comunidades transdisciplinares. Por fim, caracterizamos todas as 11 abordagens transdisciplinares dominantes em cinco dimensões - entidades focais em consideração, processo focal a ser alterado, metas centrais da mudança, princípios orientadores e diretrizes metodológicas gerais. As 13 maiores comunidades transdisciplinares foram associadas a cinco domínios temáticos interdisciplinares: Socioambiental, Saúde, Gestão e negócios, Ensino e educação e Medicina. Esses grupos de comunidades que compartilham temas e focam no mesmo tipo amplo de questões sociais estão conectadas por abordagens transdisciplinares compartilhadas, mas não por citações. As ligações – dentro de cada abordagem – entre entidade focal em consideração, processo focal a ser alterado, meta central e princípio orientador criam uma afinidade específica entre as características das abordagens transdisciplinares e tipos particulares de questões sociais e domínios temáticos. No entanto, os quatro tipos identificados de diretrizes metodológicas gerais foram compartilhados entre abordagens transdisciplinares e domínios. Reconhecendo que não há abordagem transdisciplinar universalmente superior, o esquema comparativo que propomos permite identificar pontos fortes e complementaridades entre abordagens transdisciplinares e estabelece as bases para articular diferentes abordagens visando aprimorar a prática transdisciplinar.

1. INTRODUCTION

The current socio-ecological crisis entangles multiple dimensions, from climate change, deforestation, pollution and biodiversity loss to food insecurity, water scarcity, socio-economic inequality and injustice, and the continued threat to livelihoods, ways of life and culture of local and indigenous communities around the world (Latour & Weibel, 2005; Shiva, 2005; Galeano, 2010). The interconnectedness between these environmental, social-cultural, economic and political problems – and their roots in the expansion of the capitalist structure of modern western societies (Escobar, 1995; Mies & Shiva, 1998; Quijano, 2000; Shiva, 2016) – impose critical challenges to science for supporting and confronting the pressing problems we face today (Hulme, 2014; Bertuol-Garcia et al., 2018). Being a key component of the way modern western societies are structured, science frequently reproduce inequalities and injustice (Carter & Silva, 2011; Metcalf et al., 2018; Diele-Viegas et al., 2022), and research agendas and scientific policies are commonly tied to economic interests (Aronowitz & Giroux, 2000; Busch, 2017). The common perception of science as value-free and a neutral arbiter (Sarewitz, 2004; Sarewitz, 2015; Pardini et al., 2021) allows systems of injustice to persist unchallenged, leads to science politicization and disfavor the consideration of other types of knowledge (Freire, 1971; Wiesel, 1999; Hall & Tandon, 2017; Turnhout et al., 2020).

Indeed, many authors have argued that science has not been effective in helping to solve the pressing problems we face today (Lubchenco, 1998; Sarewitz, 2004; McNie, 2007), nor has fulfilled expectations of serving society by responding to its needs and priorities (Kitcher, 2003; Sarewitz & Pielke, 2007; Dilling & Lemos, 2011). Indeed, researchers in many scientific fields – from those concerned with the governance of socio-ecological systems (Lee, 2001; Kloprogge & Sluijs, 2006) to those focusing on socio-environmental justice in territorialized communities (Eisinger & Senturia, 2001; Berardi, 2002) or equity in relationships between students and teachers (Lewin, 1946; Tripp, 2005) or patients and doctors (Gilliland et al., 2019) - recognize that the traditional way science is organized, and scientific knowledge built, prevent effective support to societal transformations.

There are two main commonly recognized proximate obstacles preventing science to support these transformations. First, the complex and intertwined (social, environmental, economic, and institutional) nature of societal problems (Folke, 2006) requires taking into account multiple dimensions or perspectives (Murer et al., 2018), as actions can have unexpected and undesired consequences through feedback across physical, ecological and social systems (Gardner et al., 2013). Addressing complex systems and problems demands, then, the consideration of multiple areas of expertise (Max-Neef, 2005), despite the current disciplinary orientation of science (Ferrer-Balas et al., 2010). Second, the multiplicity of values and interests within society, and concerns about social equity and justice, make many of the problems we face today difficult to define and to reach agreement on (Rittel & Webber, 1973; Roberts, 2000). Lack of agreement on which is the problem then frequently makes technocratic solutions to be perceived as improper, misplaced, insensitive or unacceptable by different stakeholders. Besides, such strategies tend to keep citizens distanced from relevant and urgent issues, impairing citizenry and democracy (Teixeira, 1988; Roberts, 2000). Thus, confronting the pressing current issues requires articulating not only multiple disciplinary knowledge but also varied knowledge and discourse from outside academia (Scholtz & Steiner, 2015).

However, the traditional, unidirectional way of conceptualizing the relationship between science and practice assumes that science should be auto-regulated and free from societal pressures, and that accumulated knowledge would automatically flow from science to practice (Bertuol-Garcia et al. 2018; Neff, 2020). Solutions to bridge science and practice within this perspective usually focus on facilitating the flux, access, and use of scientific knowledge in practice within an evidence-based approach to practice (e.g. Sackett et al., 1996; Pullin & Knight, 2001). This view supports current scientific policies that measure academic success and productivity through the number and impact of specialized publications (Neff, 2020). It also disregards the relevance of other types of knowledge to tackle situated problems, as well as the multiplicity of perspectives and values that influence the framing of real-world problems, the need to politically negotiate and mediate interests related to these problems, and - first and foremost - the need to deal with power asymmetries that prevent many from having they worldviews and values considered (Ansell & Gash, 2008; Krenak, 2019).

This complex interplay between science policies and the dominant, unidirectional perspective on science-practice interface underscores the imperative for critical examination of norms and culture in academia that prevent bidirectional, plural and horizontal ways of connecting science and practice (Rocha et al., 2020). Such transdisciplinary approaches are context-driven, problem focused and require the engagement of multiple disciplines and knowledge types (Norström et al., 2020), allowing for the consideration of factors other than those related to science, such as political interests, social values, and feasibility of actions. By focusing on joint knowledge-production processes, this perspective may also favor confronting the potential ambiguity brought about by science and its underlying value positions (Collingridge & Reeve, 1986; Sarewitz, 2004). By allowing to deal with value differences and negotiate value positions, it may lead to more democratic decision-making processes (Collingridge & Reeve, 1986; Albaek, 1995), if power asymmetries are recognized and confronted (Turnhout et al., 2020). Furthermore, transdisciplinary approaches may also potentially foster other types of science uses beyond the instrumental use, such as conceptual and symbolic uses (Amara, 2004; Nutley et al., 2007).

The term transdisciplinarity is frequently adopted to define the articulation between unrelated disciplines and non-academic knowledge (Tress et al., 2005; Reyers et al., 2010), encompassing the combination between interdisciplinarity and participatory approaches (Tress et al., 2005; Jahn et al., 2012). Disciplinary knowledge articulation is useful in the context of the complexity of socio-ecological systems, and participatory approaches are of value for dealing with problem definition accounting for different perspectives and to deal with power asymmetries and equity. A transdisciplinary way of conducting science may then confront the two main proximate obstacles preventing science effectiveness in supporting initiatives to solve the pressing problems we face today, fostering knowledge articulation, joint problem definition, power distribution and negotiation of value positions (Scholtz & Steiner, 2015). As such, transdisciplinary approaches emerged in numerous academic domains (Ludwig et al., 2023), from fields such as conservation biology, health sciences, and policy studies (Bohensky & Maru, 2011; Reyes-García & Benyei, 2019; Ludwig et al., 2023).

This multiplicity of transdisciplinary approaches that arose across a variety of scientific fields received different names (McNie, 2007). For instance, Scholtz & Steiner (2015) identified approaches similar to transdisciplinarity, such as community-based participatory research (Fals-Borda & Rahman, 1991; Leung et al., 2004) or variants of action research (Kemmis et al., 2004). Nevertheless, there has apparently been poor connection and debate among the proponents and users of these approaches, which seem mainly restricted to certain scientific domains, making difficult to understand their similarities and differences and restricting learning and sharing of challenges and solutions. In addition, the term transdisciplinarity has been frequently used with no clear definition, lacking specification of how to conduct these processes in practice (Jahn et al., 2012).

Moreover, despite the growing recognition (e.g. Nature, 2018) of the positive aspects of transdisciplinarity as an adequate scientific response to pressing societal problems, substantial challenges hamper collaborative interactions across multiple actors and hinder processes of knowledge articulation and action (Jahn et al., 2012; Brandt et al., 2013). For instance, Bertuol-Garcia & collaborators (2018) argue there are four main factors preventing transdisciplinarity. The first concerns epistemological issues related to differences between science and practice concerning the nature of knowledge and which process of knowledge generation is considered valid. The second refers to cultural differences between scientists and other actors. The third is related to difficulties associated with organizational and institutional arrangements, such as formal education that does not train scientists for transdisciplinary approaches, professional evaluation systems that focus on the publication of scientific articles, among others. The fourth concerns prevalent models of science-practice interface, such as the idea that a unidirectional flow of knowledge is sufficient to link science and practice, or that only objective, value-free knowledge is relevant to practice.

Given the potential but also the challenges associated with transdisciplinary approaches to link science and practice, fostering learning and sharing on how to effectively put these approaches into practice is key. Identifying and comparing the multiple approaches available in the literature can help in this endeavor, by connecting distinct views, identifying solutions to confront known challenges as well as detecting gaps limiting the advance of this perspective. Bibliometric studies are useful to accomplish that, allowing the description of the development of a topic across scientific communities (Klavans & Boyack, 2016). Coupled with citation network analysis, it has been successful in providing general frameworks that identify the different communities and perspectives on interdisciplinary topics such as resilience (Xu & Kajikawa, 2018) and the role of scientists as policy advisors (Spruijt et al., 2014).

2. OBJECTIVES

By means of a comprehensive literature review and citation network analysis, we aim at:

a) compiling the names and characterizations of available transdisciplinary approaches in the scientific literature, and creating a glossary for the dominant approaches;
b) identifying the distinct scientific communities using transdisciplinary approaches and characterizing them in terms of their domain of interest, degree of connection by citation, and the approaches they use; and
c) compare qualitative differences across dominant approaches as well as their distribution across communities, pointing out how communities could learn from each other.

3. METHODS

To identify and characterize scientific communities using transdisciplinary approaches, we started by inventorying the terms used to name the variety of such approaches in the literature. We then used these terms as keywords in a bibliographic search in Scopus. Results from the search were analyzed through a direct citation network using an algorithm suitable to identify clusters of papers that cite each other frequently. Assuming these clusters represent scientific communities, whose researchers share in some degree literature sources, we characterized the thematic scope and the connections among the 13 largest clusters/communities. We then created a glossary for the 11 dominant transdisciplinary approaches, analyzed their distribution across the largest communities and qualitatively compared them to highlight how communities can learn from each other (Figure 1).

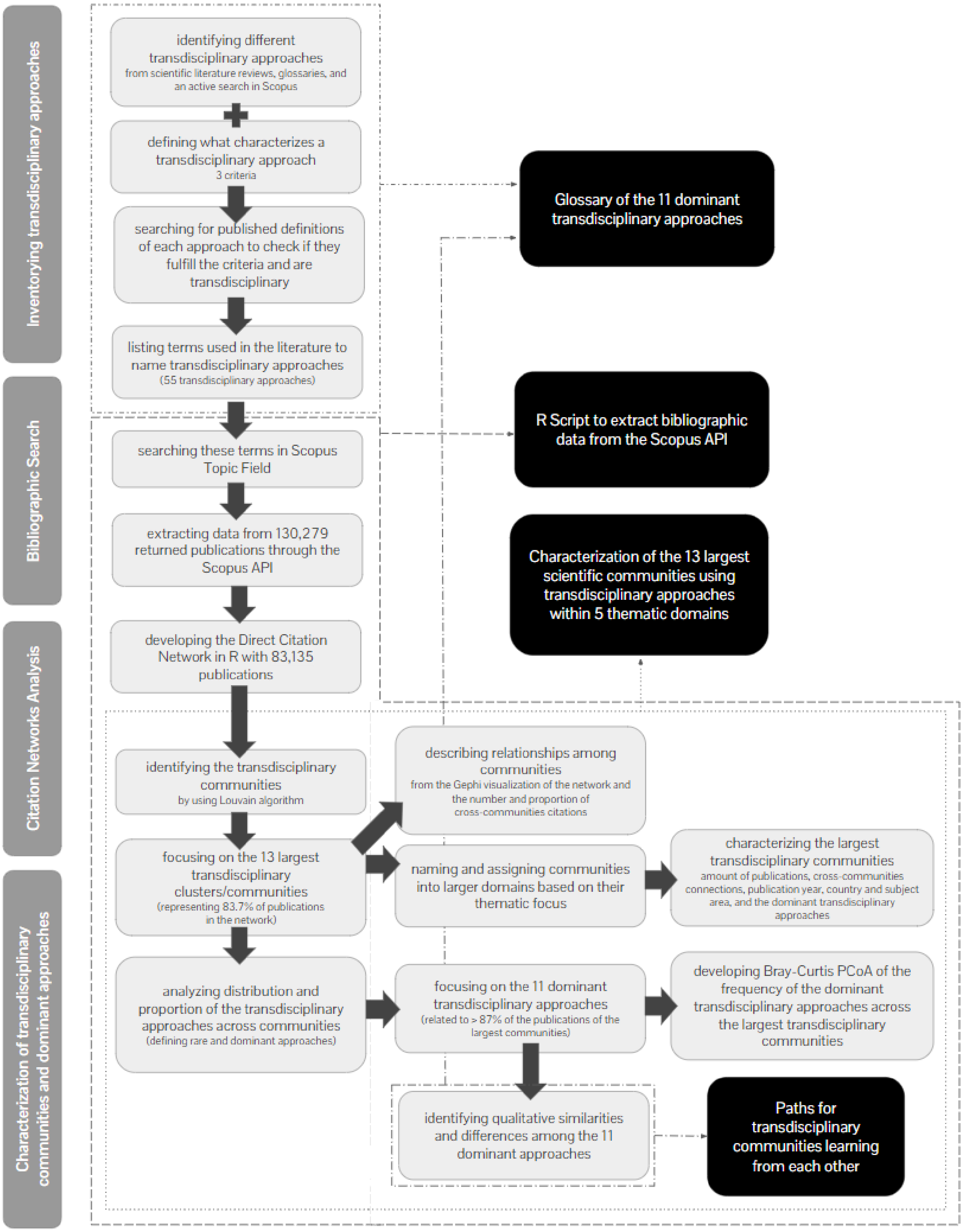

Figure 1 – Schematic representation of the steps used to identify and describe transdisciplinary approaches and communities. Dark and light gray boxes represent methodological steps and black boxes products or results. Dotted and dashed lines circumscribe the steps related to each result/product.

3.1. Inventorying transdisciplinary approaches

We first identified the terms used to name approaches that could potentially be characterized as transdisciplinary (i.e. require the participation of multiple actors/knowledge/values either in research, management or policy) and compiled published definitions/characterizations of each of them. For the identification of terms (Appendix A), we started by relying on published reviews concerning the compilation of different strategies to link science and practice/policy, as well as the definition and comparison of transdisciplinarity to other approaches. Next, we conducted an active search in Scopus for additional terms, and included extra terms known by the authors and/or found while compiling the definitions and characterizations of each approach. Our initial list included 71 terms (Appendix B). For all of them, we searched for and compiled definitions and characterizations from different sources (Appendix A).

Then, we specified a definition of transdisciplinary approaches from which we established the essential elements of such approaches and used them as criteria to evaluate all initially listed approaches to select the final set to be considered here. We defined a transdisciplinary approach as *ways of conducting research, management, planning or decision making, or of producing knowledge or public discourse, that aim at solving real-world problems by linking science and practice (including also organizations designed for, and specific techniques used in, the process of doing so). In such approaches, the linkage between science and practice is based on the sharing of multiple scientific and non-scientific - including experiential - types of knowledge in an iterative, multi-way and influential manner.* From this definition, we derived three criteria (Figure 2) to select the final set of 55 terms naming approaches that fulfill our definition (Appendix B). If a given approach had a broad definition, or more than one definition, suggesting that it can - but not always is - used in a way that includes all the three essential elements to be considered transdisciplinary, we excluded it, or – if available - we retained a specific term given to a particular way of using that approach that fulfill our criteria (e.g. retaining "participatory team science" rather than "team science").

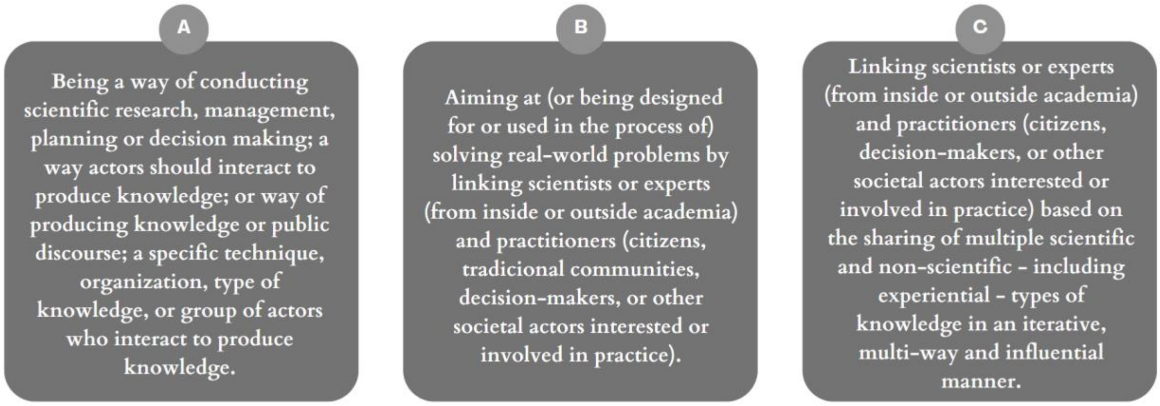

Figure 2 – The three criteria used to screen approaches and decide which were transdisciplinary.

3.2. Bibliographic search

To identify the scientific publications that focus on the conceptual development, application, use, evaluation, and other aspects of transdisciplinary approaches to link science and practice, we conducted a bibliographic search in the Scopus database, with no restriction of scientific fields or period of time, searching for the 55 terms or expressions naming transdisciplinary approaches in either the title, abstract or keywords of publications (i.e. Scopus Topic field; Appendix C).

The Scopus database is one of the largest curated databases covering scientific journals, books and conference proceedings, and one of the most widely used databases for bibliometric analyses (Singh et al., 2021). It includes more indexed publications and unique journals compared to other important databases, such as Web of Science (Visser et al., 2020; Singh et al., 2021), being a large and diverse collection of indexed journals from various disciplines, and helping to identify a considerable number of valuable citations not found in other databases (Yang & Meho, 2006).

The search was completed on May 31st 2022 and returned 130,279 publications. As the Scopus interface (https://scopus.com/) allows downloading information from a maximum of 2,000 publications at a time, we developed in R a script to extract information from the list of returned publications through the Scopus API (Appendix D). An API (Application Programming Interface) is a set of protocols, routines, and tools for building software applications that allow for computer-to-computer interaction (EDP, 2023). APIs can be thought of as a kind of contract between the provider of the API and the user, where the provider specifies the data and functionality that can be accessed through the API. The Scopus API involves citation data, metadata, and abstracts from scholarly journals, as indexed by Scopus (EDP, 2023).

The input was the list of 55 terms or expressions to be searched at Scopus database and the output consisted on data about each of the 130,279 returned publications - authors and their affiliations, title, abstract, keywords, standard references, journal, knowledge area/subject, and year of publication, among others, such as the ID (i.e. number of identification) each publication of Scopus receives - extracted in a table format called bibliographic dataframe - used in developing citation network analysis (Figure 3).

3.3. Citation Network Analysis

Citation network analysis has proved to be useful for studying the dynamics of scientific communities (Vincenot, 2018), and has already been used to identify the scientific communities that depart from distinct perspectives to study the role of scientists as policy advisors (Spruijt et al., 2014) – a topic associated with transdisciplinarity.

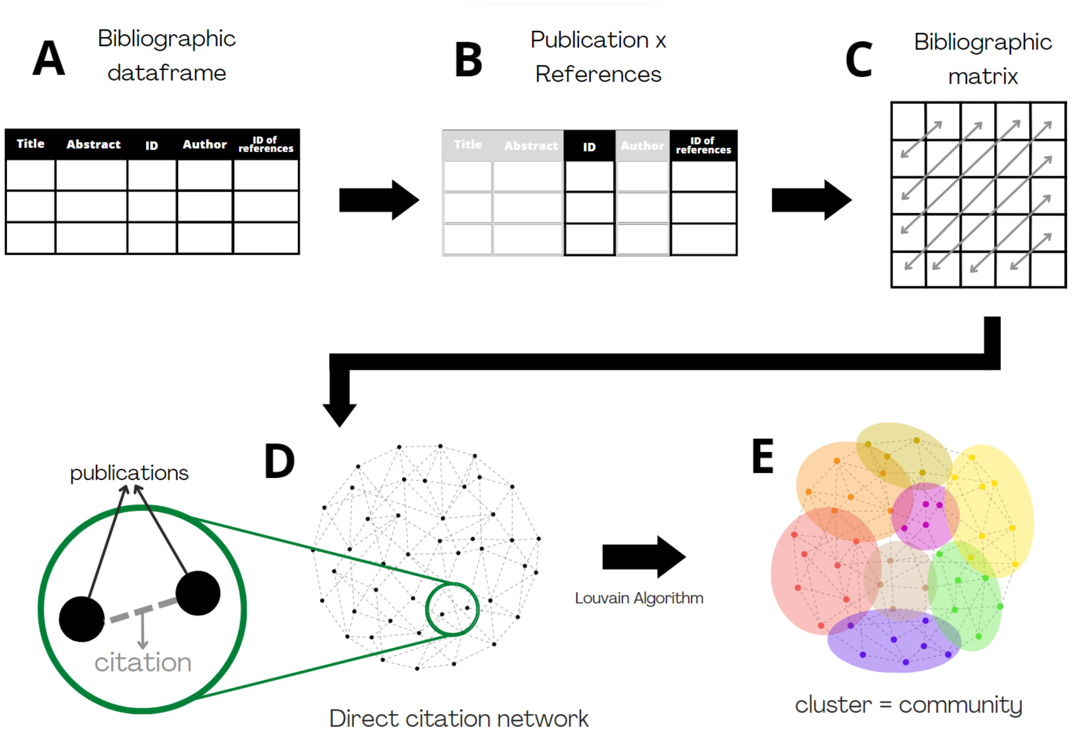

Figure 3 – Schematic representation of the steps and procedures to develop the citation network analysis: from the bibliographic dataframe containing the information on the returned publications in the Scopus search (A), the ID of the publications and the ID of the references of the publications were crossed (B) and a matrix of publications that cite each other - bibliographic matrix - was generated (C). From the bibliographic matrix, the citation network - in which publications are nodes and citations are edges - was built (E). Finally, using the Louvain algorithm, the clusterization of publications was reached and scientific communities identified.

We used the results of the bibliographic search to develop a Citation Network Analysis, through a direct citation network, in which publications are the nodes connected by citations (Figure 3). Among the types of networks representing relationships between authors and/or publications (i.e. direct citation, co-citation, co-authorship and bibliographic coupling), we used direct citation network, as it is considered better for investigating long-term scientific development of a topic (rather than the recent research front), providing a more accurate representation of the classification of scientific knowledge than other network representations (Klavans & Boyack, 2016). To do so, we used the Bibliometrix R package (Aria & Cuccurullo, 2017) and the Scopus ID of returned publications and of their references (Appendices D and E). The result is a correlation matrix with which it is possible to identify which publications are connected through citation (Figure 3).

Then, we used an algorithm to identify groups of papers - clusters - that are more connected through citation among themselves than with publications from other groups – interpreted here as scientific communities that communicate through citation. Using the Louvain algorithm, suitable for identification of clusters (compartments) in large and heterogeneous networks (Yang et al., 2016) as ours (Appendix F), we identified which publications belong to distinct scientific communities that use transdisciplinary approaches (Figure 3). To visualize the network with its clusters/communities, we used a graph layout technique in Gephi (Gephi, 2023), by uploading the network edges and nodes extracted from the Bibliometrix R package (Appendix D).

Direct citation networks frequently encompass a large number (hundreds to thousands) of clusters containing a relatively small proportion of publications, making the description of all of them unfeasible. However, the largest clusters (communities) usually include a large proportion of the total set of papers in the network (e.g. Xu & Kajikawa, 2018). Here, we focused on the 13 largest clusters (with more than 1,500 publications), which encompass 83.7% of the publications in the network and guarantee surpassing the breaking point of the accumulation curve of publications across clusters/ communities (Figure 4).

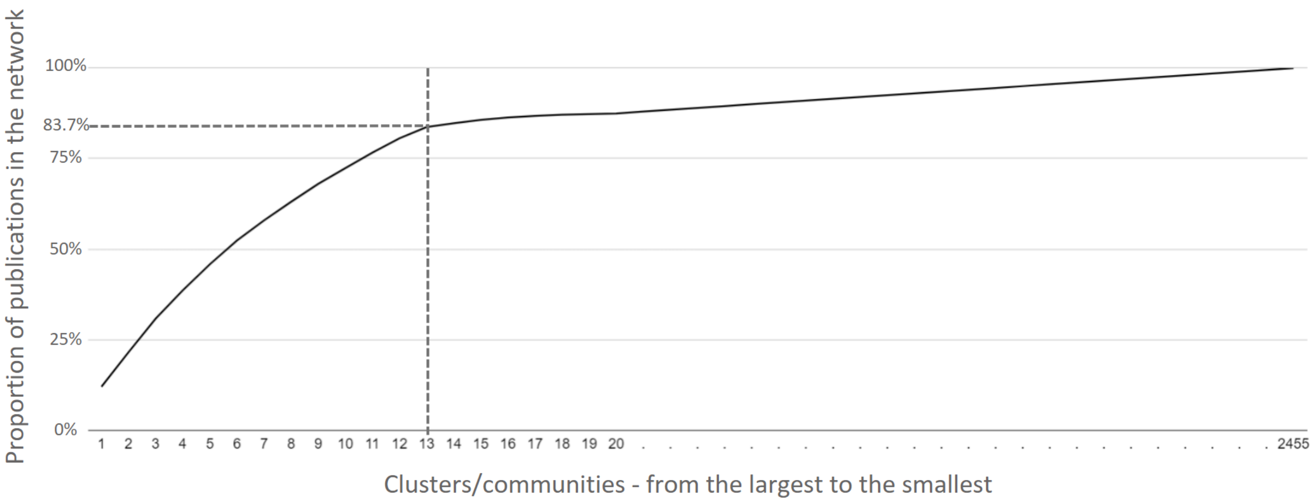

Figure 4 - Accumulated proportion of publications in the network across clusters/ communities ranked by the number of publications.

3.4. Characterization of transdisciplinary communities

Following Xu & Kajikawa (2018), we named and defined the scope of each of the 13 largest communities considering its thematic focus, which was identified by (a) the most used terms in titles, abstracts and keywords of its publications (excluding the terms used to name the 55 transdisciplinary approaches); (b) title of the most common journals where its publications are published; and (c) the titles of the most central and cited publications within each community. We considered as central the publications that simultaneously had the highest values for three indices of centrality within each community - Closeness centrality, Betweenness centrality and PageRank score[1], and as most cited those with the highest number of citations within each community (in both cases, we excluded publications focusing on transdisciplinary approaches whose titles did not contribute to characterize the thematic scope of each community). These three types of information were obtained using the R package Bibliometrix (Aria & Cuccurullo, 2017; Appendix D).

Hence, through the most mentioned terms, the most dominant journals, and the focus of the most central and cited publications, we identified the thematic scope of the 13 communities and named them accordingly. By comparing the thematic scope across the 13 communities, we grouped them into five thematic domains. As such, these domains include communities similar in thematic scope, irrespective of their connections through citations. We also characterized each of the 13 communities in terms of: (a) the number of publications, and the degree of connection within the community (i.e. citations between publications of the community) and between communities (i.e. citations between publications of the community and the rest of the network); (b) the year of its first publication, countries of the affiliation of the first authors of its publications, and the subject areas (as classified in Scopus from the All Science Journal Classification - ASJC) of the journals of its publications; and (c) the dominant transdisciplinary approach - identified by the distribution and frequency of approaches across communities. Finally, we described the relationships among communities from the Gephi visualization of the network and the number of connections (citations) within and between communities and domains.

[1] According to Aria and Cuccurullo (2023), Closeness centrality "measures how many steps are required to access every other vertex from a given vertex"; Eigenvector centrality "is a measure of being well-connected connected to the well-connected"; and PageRank score "approximates probability that any message will arrive to a particular vertex".

3.5. Characterization of transdisciplinary approaches

For each of the 55 approaches, we computed the number of publications in the network and the number of communities and domains that use or mention it. We then tested with a linear model if the variation across approaches in the number of communities mentioning them was explained by the variation across approaches in the number of publications within the network (i.e. whether transdisciplinary approaches with more publications are mentioned in a larger number of communities or otherwise there are approaches less or more widely distributed across communities than expected by the number of publications in the network).

Among the largest 13 transdisciplinary communities, we identified 11 dominant approaches that together are associated with 83.7% of their publications. To create a glossary of these dominant transdisciplinary approaches, we compiled, for each of them, a short description, containing a brief characterization and a short list of key references (Appendix G).

We synthesized the distribution of the dominant transdisciplinary approaches across the largest transdisciplinary communities from a biplot of a Principal Coordinates Analysis (PCoA) - a metric multidimensional scaling method designed to explore and to visualize similarities or dissimilarities of data based on projection (Xia, 2020). PCoA uses spectral decomposition to approximate a matrix of distances/dissimilarities by the distances to reduce dimensions of data points (Gower, 2014). The PCoA analysis was run using the Bray-Curtis dissimilarity of the proportion of total publications of each largest community that correspond to each dominant approach. Finally, we qualitatively compared the similarities and differences among the 11 dominant approaches based on their definitions and key references (Appendix G).

4. RESULTS

We identified 55 transdisciplinary approaches, from which 130,279 publications returned in the search in Scopus, 83,135 of which had their citation references standardized in the database (Appendix E). These publications resulted in a direct citation network composed of 55,744 nodes (publications) and 161,619 connections/edges (citations among them). The Louvain algorithm identified 2,455 clusters/ communities, from which the 13 largest concentrate 46,656 publications (83.7% of the publications in the network) and 149,874 connections (92.7% of the connections in the network), being 84.25% (126,270) of the connections within communities and 15.75% (23,604) between communities. Below we characterize the 13 largest communities grouped into five domains.

4.1. Characterization of transdisciplinary domains and communities

The 13 largest communities were grouped into five domains (different colors in Figure 5) based on the similarity in general thematic scope, as shown by the prevalence of journals in specific combinations of areas of knowledge within each domain (Figure 6a).

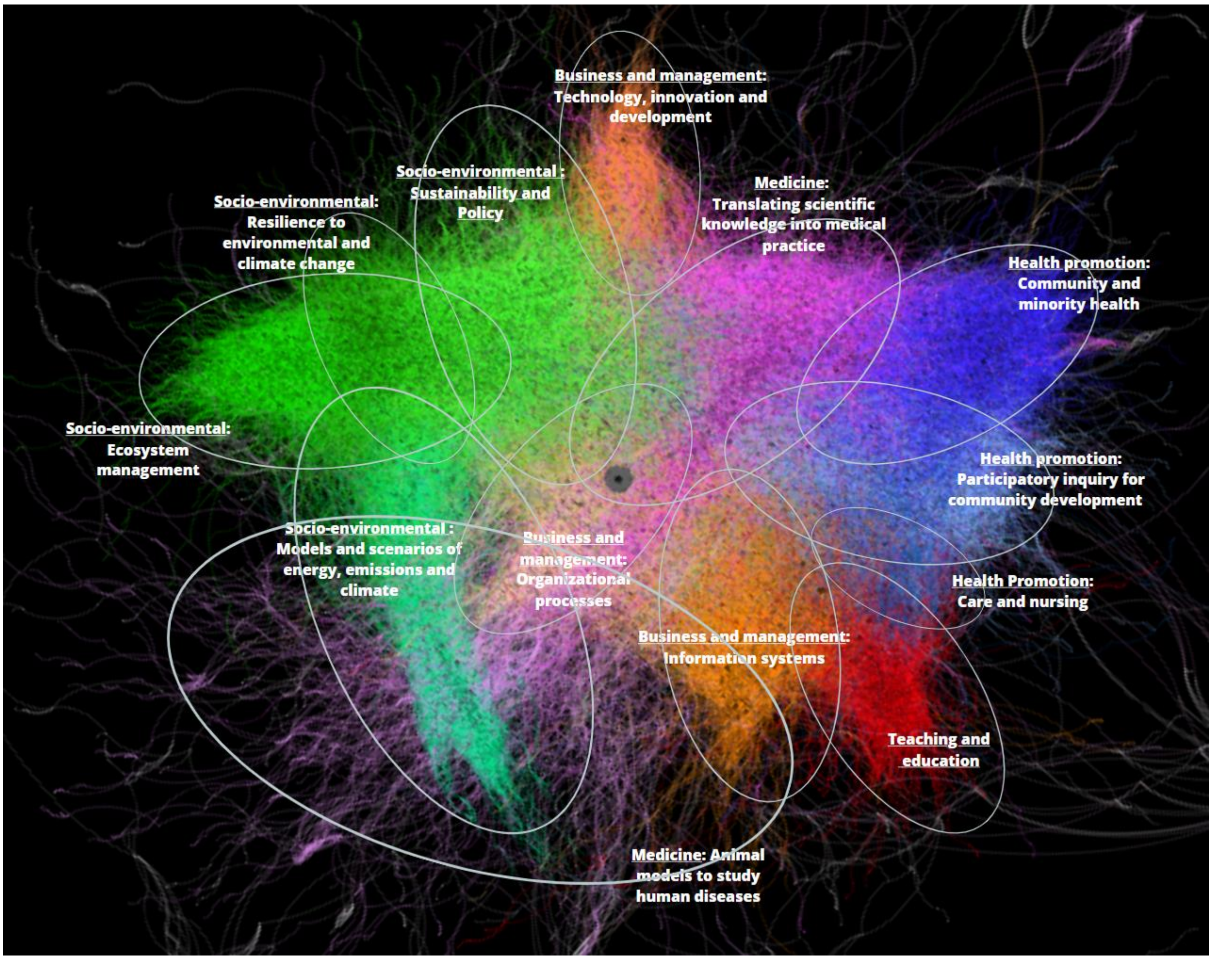

Figure 5 - Visualization of the 13 largest communities of the network. The communities of the same color are related to the same domain - Green: Socio-environmental; Blue: Health; Pink: Medicine; Orange: Business and management; and Red: Teaching and education. Elaborated with Gephi.

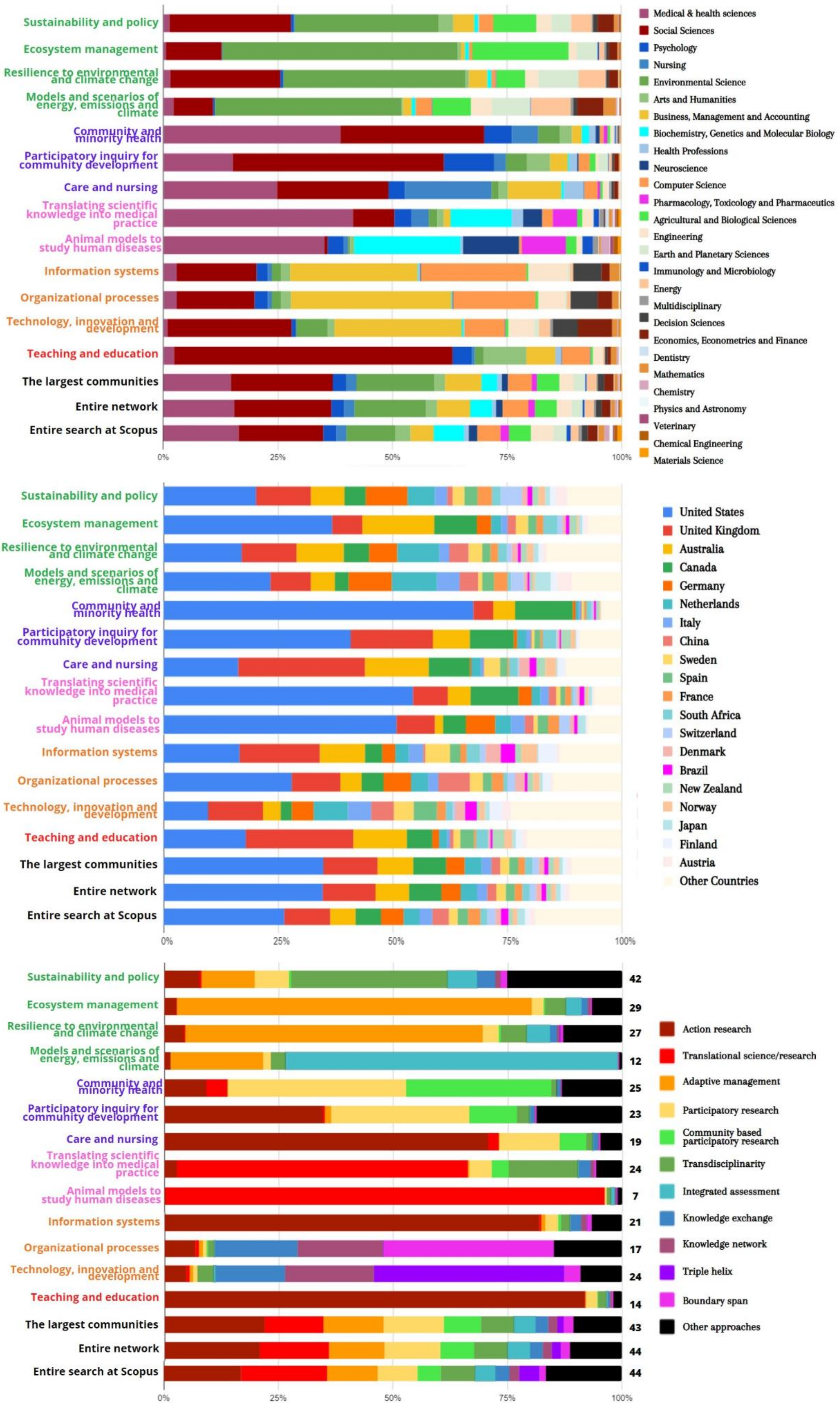

Figure 6 - Proportion of publications within each of the 13 largest communities (and within the entire network) per (a, above) knowledge area of the journals where they are published, (b, middle) country of the affiliation of the first author, and (c, bellow) transdisciplinary approaches mentioned in them.

4.1.1. Socio-environmental domain

The socio-environmental is the largest domain, encompassing four communities and including 28.9% of the publications of the network and 38.7% of its connections (93.3% within communities and 6.7% between communities). All four communities publish in journals from five key areas of knowledge - "environmental sciences", "social sciences", "agricultural and biological sciences", "earth and planetary sciences" and "economics, econometrics and finance" (Figure 6a) - and focus on confronting or managing socio-environmental issues or systems (Figure 7 and Table 1).

4.1.1.1. Sustainability and policy

The Sustainability and policy community has had publications since 1947 (Table 2). The United States, United Kingdom, and Germany are the most frequent countries of the affiliation of the first authors (Figure 6b). This is the second largest community of the network, with 5,168 publications and 25,932 connections - 17,306 within the community and 8,626 between communities (external connections roughly almost half of the internal connections; Table 2). The most frequent terms in the title, abstract and keywords of its publications (Figure 7) indicate that the community is interested in policy, sustainability, management, development of socio-environmental systems (concerning particularly water and climate) through participatory learning processes connecting scientific research, knowledge, assessments, and analysis to stakeholders. The focus on environmental sustainability and policy, together with the emphasis on the links between science and policy/society, ecological economics, agriculture, and land use is evident in the name of the most frequent journals (Figure 7). The most cited and central publications reiterate the emphasis on sustainability science and policy, ecosystem services and land use change, as well as linking science to society (Table 1). The Sustainability and policy community is the one using or mentioning the largest variety of transdisciplinary approaches - 53 out of the 55 included in the network (Fig. 5c). The approach “transdisciplinarity” itself dominates the community being mentioned in 34.2% of its publications, followed by adaptive management (11.6%), action research (7.7%), participatory research (7,5%), and integrated assessment (6.5%).

Figure 7 - Word-clouds of the most common terms in the title, abstract, and keywords (left) and the most common journals (right) of the publications of the four communities within the Socio-environmental domain, respectively, Sustainability and policy; Ecosystem management; Resilience to environmental and climate change; and Models and scenarios of energy, emissions and climate.

Table 1 – Most central (i.e. simultaneously with the highest values in three indices of centrality) and most cited publications within the four communities of the Socio-environmental domain. In bold, the most informative words in the titles of these publications for interpreting the thematic scope of the communities.

Community	Title of the most central publications	Title of the most cited publications
Sustainability and policy	**Science** for the **post-normal age** (Funtowicz & Ravetz, 1993) **Environmental literacy** in **science and society**: From knowledge to decisions (Scholz & Binder, 2011) Reconciling the supply of **scientific information with user demands**: an analysis of the problem and review of the literature (McNie, 2007) **Transdisciplinary** research **in sustainability science**: Practice, principles, and challenges (Lang et al., 2012) **Public participation in scientific research**: A framework for deliberate design (Shirk et al., 2012) **Boundary Organizations in Environmental Policy and Science:** An Introduction (Guston, 2001)	**Science** for the **post-normal age** (Funtowicz & Ravetz, 1993) **Transdisciplinary** research in **sustainability science**: Practice, principles, and challenges (Lang et al., 2012) **Managing ecosystem services**: What do we need to know about their ecology? (Kremen, 2005) Pollination and other **ecosystem services** produced by mobile organisms: A conceptual framework for **the effects of land-use change** (Kremen et al., 2007) **Boundary Organizations** in **Environmental Policy and Science**: An Introduction (Guston, 2001) Categorising tools for **sustainability assessment** (Ness et al., 2007)
Ecosystem management	**Evolution of co-management**: Role of knowledge generation, bridging organizations and social learning (Berkes, 2009) A conceptual framework for analysing adaptive capacity and multi-level learning processes **in resource governance regimes** (Pahl-Wostl, 2009) **Resilience and sustainable development**: Building adaptive capacity in a world of transformations (Folke et al., 2002) Shooting the rapids: Navigating transitions to **adaptive governance of social-ecological systems** (Olsson et al., 2006) Rediscovery of **Traditional Ecological Knowledge** as **adaptive management** (Berkes et al., 2000) Adaptive **comanagement** for building **resilience in social-ecological systems** (Olsson et al., 2004)	**Regime shifts, resilience, and biodiversity** in **ecosystem management** (Folke et al., 2004) Rediscovery of **Traditional Ecological Knowledge** as **adaptive management** (Berkes, 2000) **Ecological resilience** In theory and application (Gunderson, 2000) **Resilience and sustainable development**: Building adaptive capacity in a world of transformations (Folke et al., 2002) **Evolution of co-management**: Role of knowledge generation, bridging organizations and social learning (Berkes, 2009) **Climate change and forests of the future**: **Managing in the face of uncertainty** (Millar et al., 2007)
Resilience to environmental and climate change	**Resilience**: The emergence of a perspective **for social-ecological systems analyses** (Folke, 2006) Linkages between **vulnerability, resilience, and adaptive capacity** (Gallopin, 2006) More evolution than revolution: **Transition management in public policy** (Rotmans et al., 2001) **Vulnerability**: A generally applicable conceptual framework for **climate change** research (Füssel, 2007) Adaptation to **environmental change**: contributions of a **resilience framework** (Nelson et al., 2007) **Adaptive capacity** and its assessment (Engle, 2011)	**Resilience**: The emergence of a perspective **for social-ecological systems analyses** (Folke, 2006) Linkages between **vulnerability, resilience, and adaptive capacity** (Gallopin, 2006) Functions of **innovation systems**: A new approach for analysing **technological change** (Hekkert et al., 2007) **Urban greening** to cool towns and cities: A systematic review of the empirical evidence (Bowler et al., 2010) The **governance of sustainable socio-technical transitions** (Smith et al., 2005) Adaptation to **environmental change**: contributions of a **resilience framework** (Nelson et al., 2007)
Models and scenarios of energy, emissions and climate	Ten iterative steps in development and evaluation of **environmental models** (Jakeman et al., 2006) Selecting among five **common modelling approaches** for integrated **environmental assessment and management** (Kelly et al., 2013) Integrated assessment **modeling** of **global climate change**: Transparent rational tool for **policy making** or opaque screen hiding value-laden assumptions? (Schneider, 1997) Integrated environmental **modeling**: A vision and **roadmap for the future** (Laniak et al., 2013) **Adaptation to climate change and climate variability** in European agriculture: The importance of farm level responses (Reidsma et al., 2010) Learning from integrated assessment of **climate change** (Morgan & Dowlatabadi, 1996)	The representative **concentration pathways**: An overview (Van Vuuren et al., 2011) **Long-term climate change**: **Projections**, commitments and irreversibility (Collins et al., 2013) The RCP **greenhouse gas concentrations** and their extensions from 1765 to 2300 (Meinshausen et al., 2011) A **scenario** of comparatively **high greenhouse gas emissions** (Riahi et al., 2011) **Climate change and food systems** (Vermeulen et al., 2012) The **geographical distribution of fossil fuels unused** when limiting **global warming** to 2°C (McGlade & Ekins, 2015)

Table 2 – Number of publications, as well as of internal and external connections (citations within and between communities, respectively), proportion of internal connections to external connections, and year of - and period of time since - the first publication associated with each of the 13 largest transdisciplinary communities and five domains.

Community / Domain	# publications	# internal connections	# external connections	Internal to external connections	Year first publication	Period of time first publication
Sustainability and policy	5,168	17,306	8,626	49.8%	1947	76 years
Ecosystem management	4,345	15,118	5,904	39.0%	1968	55 years
Resilience to environmental and climate change	3,655	8,939	5,243	58.7%	1982	41 years
Models and scenarios of energy, emissions and climate	2,752	8,354	1,870	22.4%	1989	34 years
Socio-environmental domain	15,920	58,437 (8,720)*	4,175	7.1%	1947	76 years
Community and minority health	6,673	23,596	6,806	28.8%	1981	42 years
Participatory inquiry for community development	3,107	7,061	4,267	60.4%	1981	42 years
Care and nursing	2,437	5,270	3,593	68.2%	1967	56 years
Health domain	12,217	39,841 (3,914)*	6,838	17.2%	1967	56 years
Information systems	4,025	9,735	3,834	39.4%	1946	77 years
Organizational processes	2,373	4,809	1,091	22.7%	1975	48 years
Technology, innovation and development	1,731	4,751	969	20.4%	1979	44 years
Business and management domain	8,129	19,953 (658)*	4,578	22.9%	1946	77 years
Translating scientific knowledge into medical practice	5,323	11,637	3,559	30.6%	1979	44 years
Animal models to study human diseases	2,208	3,279	402	12.3%	1978	45 years
Medicine domain	7,531	15,262 (346)*	3,104	20.3%	1979	45 years
Teaching and education	2,859	6,415	2,135	33.3%	1953	70 years
Teaching and education domain	2,859	6,415	2,135	33.3%	1953	70 years

* External connections between communities of the same domain which have become internal connections of the domain.

4.1.1.2. Ecosystem management

The Ecosystem management community has publications dating back to 1968 (Table 2). The most frequent countries of the affiliation of the first authors are the United States, Australia, and Canada (Figure 6b). The community comprises 4,345 publications and 21,022 connections - 15,118 within the community and 5,904 between communities (external connections account for 39% of the internal connections; Table 2). The most common terms in the title, abstract and keywords of its publication suggest the community focus on the governance, restoration, management, planning, monitoring, conservation, and adaptation of ecological systems/ecosystems (especially related to forests, water, natural resources, and species) (Figure 7). The most frequent journals clearly show the emphasis in ecological systems (containing terms related to ecology, biology, natural resources, biodiversity, wildlife, marine/ocean/coastal, forestry) together mainly with terms related to society, management, conservation, restoration, applications, and modelling (Figure 7). The most cited and central publications reiterate the relevance to the community of governance and co-management, as well as the resilience and uncertainty, of ecosystems and socioecological systems (Table 1). The Ecosystem management community uses or mentions 40 transdisciplinary approaches but is highly dominated by adaptive management (77.4% of publications mentioning it) and no other approach reaches 5% of the publications (Figure 6b).

4.1.1.3. Resilience to environmental and climate change

The Resilience to environmental and climate change community has 3,655 publications, with the first of them dating back to 1982 (Table 2). The United States, the United Kingdom, and Australia are the most frequent countries of the affiliation of the first authors (Figure 6b). The community has 14,182 connections, from which 8,939 are within the community and 5,243 between communities - external connections representing 58.7% of the internal connections (Table 2). Both the most common terms in the title, abstract and keywords of its publications (Figure 7) and the most cited and central publications (Table 1) indicate the community emphasizes the research, management, development, and policy considering the future, vulnerability (risks and impacts) and the adaptation of systems and communities to environmental (urban, water) and climate change (Figure 7). While the journals where its publications are published are diverse, the focus on global, environmental, and climate change is evident as the terms are part of the name of many of these journals (Figure 7). The community uses/mentions 38 transdisciplinary approaches, but it is also highly dominated by adaptive management (64.9% of its publications), with transdisciplinarity, integrated assessment, and action research also relevant (around 5% each) (Figure 6c).

4.1.1.4. Models and scenarios of energy, emissions and climate

The Models and scenarios of energy, emissions and climate community has had publications since 1989 (Table 2). The United States of America, Germany, and Netherlands are the most frequent countries of the affiliation of the first authors (Figure 6b). The community contains 2,752 publications and 10,224 connections - 8,354 within the community and 1,870 between communities (external connections around 22.5% of the internal connections; Table 2). The most frequent terms in the title, abstract and keywords of its publications indicate the community focuses on assessing future scenarios and modeling impacts and change in carbon emissions, energy and climate for the management, adaptation, and mitigation of global/environmental systems (land, water and air) (Figure 7). The journals where its publications are published are also varied and include among the most frequent – beside those concerning climate change – some concerning energy policy and economics, economics in general and journals focusing on modeling (Figure 7). The focus on modelling, forecasting and projections for climate change, fossil fuels distribution and greenhouse gas emissions are also emphasized in the most cited and central publications (Table 1). The community uses or mentions 20 transdisciplinary approaches but is dominated by integrated assessment (72.6%) and adaptive management (20.4%) (Figure 6c).

4.1.2. Health domain

The Health domain, which encompasses 22.2% of the publications and 28.9% of the connections of the network (85.4% within communities and 14.6% between communities), is the second largest domain encompassing three communities. All of them share a focus on promoting health, care, well-being, and quality of life (Figure 8) and publish in journals mainly from four key areas of knowledge - "medical & health sciences", "social sciences", "psychology" and "nursing" (Figure 6a; Table 3).

Figure 8 - Word-clouds of the most common terms in the title, abstract, and keywords (left) and the most common journals (right) of the publications of the three communities within the Health domain, respectively, Community and minority health; Participatory inquiry for community development; and Care and nursing.

Table 3 – Most central (i.e. simultaneously with the highest values in three indices of centrality) and most cited publications within the three communities of the Health domain. In bold, the most informative words in the titles of these publications for interpreting the thematic scope of the communities.

Community	Title of the most central publications	Title of the most cited publications
Community and minority health	Review of **community-based research**: Assessing partnership approaches to improve **public health** (Israel et al., 1998) **Community-based participatory** research: **Policy recommendations** for promoting a partnership approach in **health research** (Israel et al., 2001) **Community-based participatory research** from the margin to the mainstream **are researchers prepared**? (Horowitz et al., 2009) **Community-based participatory research** contributions to intervention research: The intersection of **science and practice** to **improve health equity** (Wallerstein & Duran, 2010) **Participatory research** for **environmental justice**: a critical interpretive synthesis (Davis & Ramírez-Andreotta, 2021) **Community-based participatory** research: A promising approach for increasing **epidemiology's relevance** in the 21st century (Leung et al., 2004)	Review of **community-based research**: Assessing partnership approaches to **improve public health** (Israel et al., 1998) **Action-oriented** population **nutrition research**: High demand but limited supply (Pham & Pelletier, 2015) **Community-based participatory research** contributions to intervention research: The intersection of science and practice to **improve health equity** (Wallerstein & Duran, 2010) **Participatory research** in the post-normal age: **Unsustainability and uncertainties** to rethink **paulo freire's pedagogy of the oppressed** (Giatti, 2019) A logic model for **community engagement** within the clinical and **translational science** awards consortium: Can we measure what we model? (Carter-Edwards et al., 2013) **Youth** as **Partners, Participants or Passive Recipients**: A Review of **Children and Adolescents** in **Community-Based Participatory** Research (CBPR) (Jacquez et al., 2013)
Participatory inquiry for community development	The origins and practice of **participatory rural** appraisal (Chambers, 1994) Modifying **Photovoice** for **community-based** participatory **Indigenous research** (Castleden & Garvin, 2008) **Social geography**: Participatory research (Pain, 2004) **Participatory action research**: Theory and methods for **engaged inquiry** (Chevalier & Buckles, 2013) **Photovoice** as **community-based participatory** research: A qualitative review (Hergenrather et al., 2009) The **personal is political**: Developing **new subjectivities** through participatory action research (Cahill, 2007)	An **ecological approach** to creating active **living communities** (Sallis, 2006) The origins and practice of **participatory rural** appraisal (Chambers, 1994) **Photovoice**: A **participatory action research** strategy applied to **women's health** (Wang, 1999) **Qualitative Research Designs**: Selection and Implementation (Creswell et al., 2007) Do attributes in the **physical environment** influence **children's physical activity**? A review of the literature (Davison & Lawson, 2006) **Participatory development** and **empowerment**: The dangers of **localism** (Mohan & Stokke, 2000)
Care and nursing	**Action research** in **nursing and healthcare** (Williamson et al., 2012) Managing change in **healthcare**: Using **action research** (Parkin, 2009) **Action research**: what is it? How has it been used and how can it be used in **nursing**? (Holter & Schwartz-Barcott, 1993) **Community-based participatory research**: Advancing **integrated behavioral health care** through novel partnerships (Mendenhall et al., 2013) **Action research** in **health promotion** (Whitehead et al., 2003) **Participatory design** in **health sciences**: Using **cooperative experimental methods** in developing **health services and computer technology** (Clemensen et al., 2007)	Users' guides to the **medical literature**: XXV. **Evidence-based medicine**: Principles for applying the users' guides to **patient care** (Guyatt, 2000) Testing the reliability and efficiency of the pilot Mixed Methods Appraisal Tool (MMAT) for **systematic mixed studies review** (Pace et al., 2012) A holistic framework to improve the uptake and impact **of ehealth technologies** (van Gemert-Pijnen et al., 2011) **Qualitative research** in **health care** Using qualitative methods in **health related** action research (Meyer, 2000) **Qualitative research**: Grounded theory, mixed methods, and **action research** (Lingard et al., 2008) Factors that influence the implementation of **e-health**: A systematic review of systematic reviews (an update) (Ross et al., 2016)

4.1.2.1. Community and minority health

The Community and minority health is the largest transdisciplinary community in the network with publications since 1981 (Table 2). Most frequent countries of the affiliation of the first authors are the United States (nearly 70%) and Canada (12.6%) (Figure 6b). It contains 6,673 publications and 30,402 connections - 23,596 within the community and 6,806 between communities (external connections account for almost 29% of the internal connections; Table 2). The most common terms in the title, abstract and keywords of its publication suggest a focus on the study, knowledge, research and development of participatory (i.e. community-based) methods, programs, actions and interventions associated with community health and care (Figure 8). The most frequent journals show an emphasis on public, family and community health, community psychology, preventive medicine, environmental health and health education, with many journals specialized in ethnic, poor, underserved, and minority groups (Figure 8). The most cited and central publications reiterate the emphasis on community engagement for health equity and environmental justice (Table 3). The community uses or mentions 35 transdisciplinary approaches but is dominated by participatory research (38.9%) and community based participatory research (31.7%) (Figure 6c). Action research is also relevant with 9.2% of the publications.

4.1.2.2. Participatory inquiry for community development

The Participatory inquiry for community development has had publications since 1981 (Table 2). The United States, the United Kingdom and Canada are the most frequent countries of the affiliation of the first authors (Figure 6b). The community comprises 3,107 publications and 11,328 connections - 7,061 within the community and 4,267 between communities (external connections account for 60% of the internal connections; Table 2). The most common terms in the title, abstract and keywords of its publications indicate the community emphasizes the study and methods (especially photovoice) for the participation of people, students, youth and children in research to promote learning/ education, social development and health (Figure 8). The journals where its publications are published encompass titles focusing on diverse themes, especially community psychology, education, social issues, community development and geography, health promotion, and qualitative methodologies, with some specialized in children and on intellectual and learning disabilities (Figure 8). The most cited and central publications reiterate the emphasis on participatory methodologies (especially photovoice) for engaged inquiry, new subjectivities, living communities and empowerment (Table 3). There are 33 approaches used or mentioned in this community. Among them, action research (34.6%) and participatory research (30.2%) are the dominating, with community based participatory research also relevant, accounting for 10.5% of the total publications (Figure 6c).

4.1.2.3. Care and nursing

The Care and nursing is a community with publications since 1967 (Table 2), with the most frequent countries of the affiliation of the first authors being the United Kingdom, the United States and Canada (Figure 6b). The community comprises 2,437 publications and 8,863 connections - 5,270 within the community and 3,593 between communities (external connections accounting for almost 70% of the internal connections; Table 2), being the community most connected to other communities. The most frequent terms in the title, abstract and keywords of its publications indicate the community focuses on the study, methods, learning, education, practice, development and implementation of services of care, nursing and health (Figure 8). The journals where its publications are published (Figure 8) include many concerned with health and social care, occupational therapy, interprofessional care, action research and various aspects (e.g. education, practice, and management) of nursing. The most cited and central publications reiterate the emphasis of the community in healthcare and nursing, in action research and other participatory methodologies, as well as in e-health services (Table 3). Regarding the 29 used or mentioned transdisciplinary approaches within it, action research is the most prevalent (70.7%), followed by participatory research (13.2%) (Figure 6c).

4.1.3. Business and management domain

The Business and management domain, which represents 14.8% of the publications of the network and 15.2% of its connections (81.3% within communities and 18.7% between communities), has three communities. All of them publish in journals from "business, management and accounting", "social sciences" and "computer science", with "engineering", "decision sciences", "economics, econometrics and finance" and "environmental science" also relevant (Figure 6a) - and focus on managing information, people, and organizations (Figure 9; Table 4). It is also the oldest domain, with its first publication dating back to 1946.

Figure 9 - Word-clouds of the most common terms in the title, abstract, and keywords (left) and the most common journals (right) of the publications of the three communities within the Business and management domain, respectively, Information systems; Organizational processes; and Technology, innovation and development.

Table 4 – Most central (i.e. simultaneously with the highest values in three indices of centrality) and most cited publications within the three communities of the Business and management domain. In bold, the most informative words in the titles of these publications for interpreting the thematic scope of the communities.

Community	**Title of the most central publications** considering the three indices of centrality	**Title of the most cited publications**
Information systems	**Action Research** and **Minority Problems** (Lewin, 1946) Frontiers in **Group Dynamics**: II. **Channels of Group Life** (Lewin, 1947) Systemic **action research**: A strategy for **whole system change** (Burns, 2007) **Advancing scientific knowledge** through participatory **action research** (Whyte, 1989) **Action research**: Exploring perspectives on a **philosophy of practical knowing** (Coghlan, 2011) **Action research** for **management research** (Eden & Huxham, 1996)	**Action Research** and **Minority Problems** (Lewin, 1946) **Qualitative research** in **information systems** (Myers, 1997) **Action research** for **operations management** (Coughlan & Coghlan, 2002) Coping with **systems risk**: **Security planning models** for **management decision making** (Straub & Welke, 1998) The new **dynamics of strategy**: Sense-making in a **complex and complicated world** (Kurtz & Snowden, 2003) Building **theoretical and empirical bridges** across levels: **Multilevel research** in **management** (Hitt et al., 2007)
Organizational processes	The **emergence of boundary spanning competence** in practice: Implications for implementation and use of **information systems** (Levina & Vaast, 2005) **Organizational/environmental interchange**: a model of **boundary spanning activity** (Leifer & Delbecq, 1978) **Life in the trading zone**: Structuring **coordination across boundarie**s in **postbureaucratic organizations** (Kellogg et al., 2006) The strength of **weak ties** you can **trust**: The mediating role of **trust** in effective **knowledge transfer** (Levin & Cross, 2004) Preparing an **organization** for **sustainability transitions**—the making of **boundary spanners** through design training (Yström et al., 2021) **Institutional work** in the transformation of an **organizational field**: The interplay **of boundary work and practice work** (Zietsma & Lawrence, 2010)	**Beyond local search**: **Boundary-spanning**, exploration, and impact in the **optical disk industry** (Rosenkopf & Nerkar, 2001) It is what one does: **Why people participate and help others** in **electronic communities of practice** (Wasko & Faraj, 2000) All in **a day's work: Boundaries and micro role transitions** (Ashforth et al., 2000) **Knowledge exchange and combination**: The role of **human resource practices** in the **performance of high-technology firms** (Collins & Smith, 2006) Knowledge networks: Explaining effective **knowledge sharing in multiunit companies** (Hansen, 2002) Post-adoption variations in usage and value of **e-business by organizations**: Cross-country evidence from the **retail industry** (Zhu & Kraemer, 2005)
Technology, innovation and development	The **dynamics of innovation**: From National Systems and "mode 2" to a **Triple Helix** of **university-industry-government relations** (Etzkowitz & Leydesdorff, 2000) Re-thinking **new knowledge production**: A literature review and a **research agenda** (Hessels & Van Lente, 2008) Emergence of a **Triple Helix** of **university-industry-government relations** (Leydesdorff & Etzkowitz, 1996) The **Triple Helix** and **new production of knowledge**: **Prepackaged thinking** on **science and technology** (Shinn, 2002) The **future of the university** and the **university of the future**: Evolution of **ivory tower to entrepreneurial paradigm** (Etzkowitz et al., 2000) Overcoming the **triple helix boundaries** in **an environmental research collaboration** (Rosenlund et al., 2017)	**Knowledge Networks as Channels and Conduits**: The Effects of **Spillovers** in the Boston **Biotechnology Community** (Owen-Smith & Powell, 2004) The **future of the university** and the **university of the future**: Evolution of **ivory tower to entrepreneurial paradigm** (Etzkowitz et al., 2000) The **triple helix**: **University-industry-government innovation** in action (Etzkowitz, 2008) **Innovation in innovation**: The Triple Helix of **university-industry-government** relations (Etzkowitz, 2003) The **selective nature** of **knowledge networks** in clusters: Evidence from the **wine industry** (Giuliani, 2007) The exaggerated death **of geography: Learning, proximity and territorial innovation systems** (Morgan, 2004)

4.1.3.1. Information systems

The Information systems community has had publications since 1946 (Table 2), which makes it the oldest community in the network. The United Kingdom, the United States, and Australia are the most frequent countries of the affiliation of the first authors (Figure 6b). It has 4,025 publications and 13,569 connections - 9,735 within the community and 3,834 between communities (external connections account for around 39.5% of the internal connections; Table 2). The most frequent terms in the title, abstract and keywords of its publications (Figure 9) indicate the community focuses on theory, models, research, methodology and analysis concerning the implementation and design of knowledge, data and information systems and processes for management practice and learning, and change and development in business. The journals where its publications are published are varied and include those specialized in action research, computer and information science and systems, information and communication technology and knowledge management, human relations and behavioral sciences, sustainability, and project and performance management, management learning, production planning and control and organizational change and development (Figure 9). The most cited and central publications (Table 4) indicate a focus on action research specialized in whole system change and multilevel management, qualitative research in information systems, and system risk in management decision-making. The community uses or mentions 32 transdisciplinary approaches and the most dominant approach is action research, accounting for 81.8% of the publications (Figure 6c).

4.1.3.2. Organizational processes

The Organizational processes community has had publications since 1975 (Table 2). The most frequent countries of the affiliation of the first authors are the United States, the United Kingdom, Germany, Canada, and Australia (Figure 6b). The community contains 2,373 publications and 5,900 connections - 4,809 within the community and 1,091 between communities (external connections account for almost 23% of the internal connections; Table 2). The most common terms in the title, abstract and keywords of its publication (Figure 9) suggest the community focuses on the study, research, model, and analysis for the practice and learning of management, innovation, development and performance of organizations and firms in business as well as their networks and boundaries (including managing communication and exchange/sharing of knowledge). The most frequent journals clearly show the emphasis in management (of information/knowledge, innovation, and marketing), organization science and studies, business research, marketing science, and applied psychology and human relations (Figure 9). The most cited and central publications show the emphasis of the community in boundary spanning and coordination across boundaries for organizational interchange, knowledge transfer and sustainability transitions (Table 4). The community uses or mentions 28 approaches and the dominant ones are boundary spanning (37.2%), knowledge network (18.7%) and knowledge exchange (18%) (Figure 6c). It is worth pointing out that this is the only community in which the boundary spanning approach is dominant.

4.1.3.3. Technology, innovation and development

Technology, innovation and development is the smallest community among the 13 largest transdisciplinary communities. It has had publications since 1979 (Table 2), with a total of 1,731 publications connected by 5,720 citations - 4,751 within the community and 969 between communities (external connections account for around 20% of the internal connections; Table 2). The United Kingdom, the United States, and Netherlands are the most frequent countries of the affiliation of the first authors (Figure 6b). The most common terms in the title, abstract and keywords of its publications (Figure 9) indicate the community emphasizes research, models and analysis for policies and management of regional networks/collaborations between universities, industries and governments for knowledge, technology, innovation, and economic development. The journals where its publications are published are varied and focused on regional studies, science and development, knowledge economy and management as well as knowledge-based development, technology and innovation transfer and management, but also on scientometrics, public policies, industry and higher education, and sustainability (Figure 9). The most cited and central publications reiterate the focus of the community on knowledge networks and dynamics of innovation across university-industry-government relations and collaborations, as well as rethinking the role of universities (Table 4). The community uses/mentions 35 transdisciplinary approaches and it is the community with the highest percentage of publications (38.1%) related to the 44 less common approaches (Figure 6c). Nevertheless, it is dominated by the triple helix (41.6%), knowledge network (19.4%) and knowledge exchange (15.2%) approaches.

4.1.4. Medicine domain

The Medicine domain, with 13.7% of the publications of the network and 11.4% of its connections (83.1% within communities and 16.9% between communities), is the youngest domain, with its oldest publication dating back to 1978. It encompasses two communities, both of which publish in journals mainly from "medical & health sciences'', "biochemistry, genetics and molecular biology", "pharmacology, toxicology and pharmaceutics", and "neuroscience" (Figure 6a), and have a focus on medicine, clinical practice, and human disease (Figure 10; Table 5).

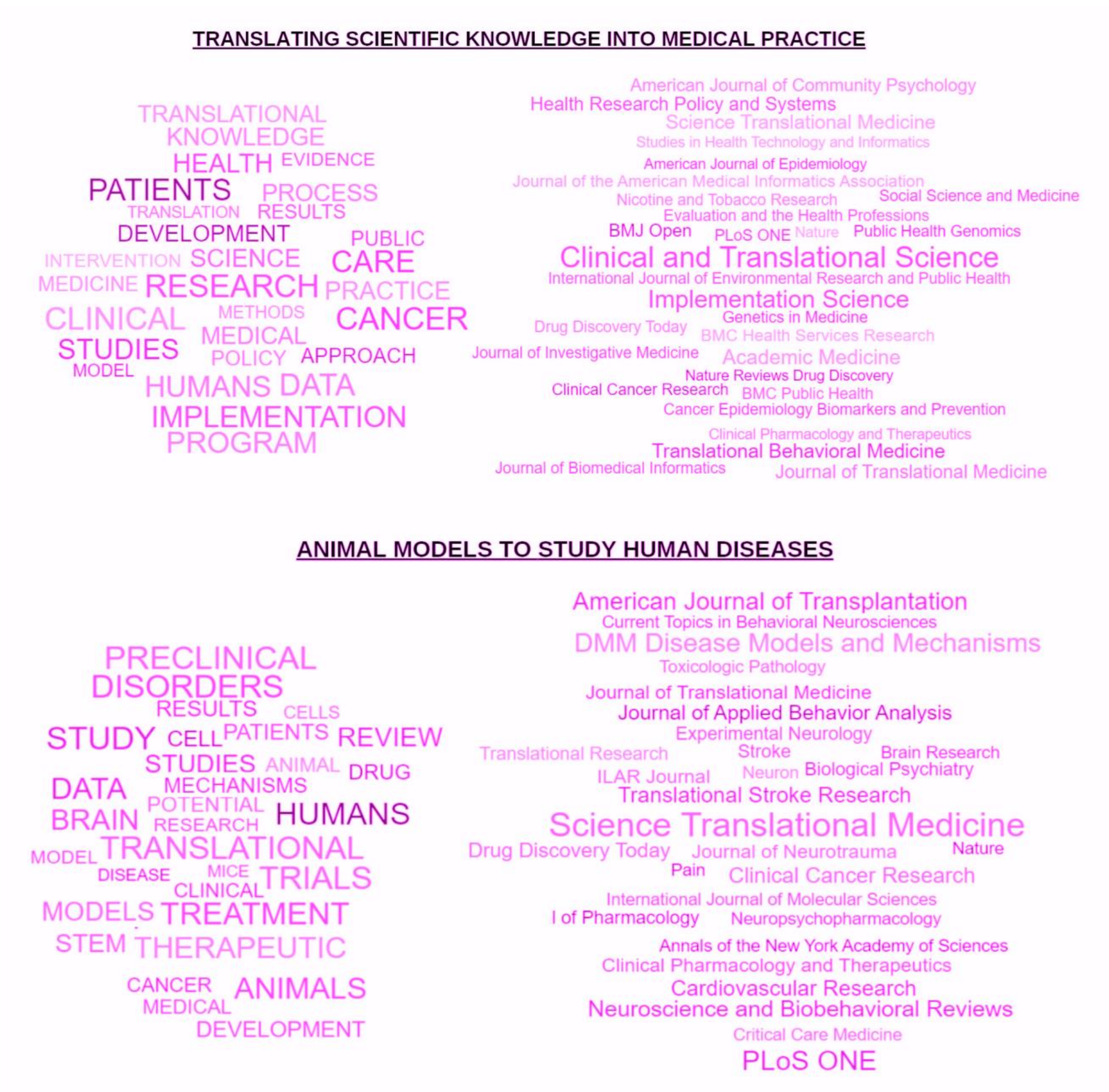

Figure 10 - Word-clouds of the most common terms in the title, abstract, and keywords (left) and the most common journals (right) of the publications of the two communities within the Medicine domain, respectively, Translating scientific knowledge into medical practice; and Animal models to study human diseases.

Table 5 – Most central (i.e. simultaneously with the highest values in three indices of centrality) and most cited publications within the two communities of the Medicine domain. In bold, the most informative words in the titles of these publications for interpreting the thematic scope of the communities.

Community	Title of the most central publications considering the three indices of centrality	Title of the most cited publications
Translating scientific knowledge into medical practice	The potential **of transdisciplinary research** for sustaining and extending **linkages between the health and social sciences** (Rosenfield, 1992) The **Ecology of Team Science**. Understanding Contextual Influences on Transdisciplinary Collaboration (Stokols et al., 2008) **Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy**: 1. Definitions, objectives, and evidence of effectiveness (Choi & Pak, 2006) **Knowledge exchange processes** in **organizations and policy arenas:** A narrative systematic review of the literature (Contandriopoulos et al., 2010) Enhancing **Transdisciplinary Research** Through **Collaborative Leadership** (Gray, 2008) In vivo studies of **transdisciplinary scientific collaboration**: Lessons learned and implications for active living research (Stokols et al., 2005)	**Research electronic data capture** (REDCap)-A metadata-driven methodology and workflow process for providing translational research **informatics support** (Harris et al., 2009) The REDCap consortium: **Building an international community of software platform partners** (Harris et al., 2019) Lost in **knowledge translation**: time for a map? (Graham et al., 2006) Enhancing **treatment fidelity in health behavior change** studies: **Best practices and recommendations** from the NIH Behavior Change Consortium (Bellg et al., 2004) Making sense of **implementation theories, models and frameworks** (Nilsen, 2015) The meaning of **translational research** and why it matters (Woolf, 2008)
Animal models to study human diseases	Translational paradigms in **pharmacology and drug discovery** (Mullane et al., 2014) **Can animal models** of **disease reliably** inform **human studies**? (Van der Worp et al., 2010) **Magnetic resonance imaging** for translational research in **oncology** (Fiordelisi et al., 2019) **Humanized mice** in translational **biomedical research** (Shultz et al., 2007) Can **animal data** translate to **innovations** necessary for a new era of **patient-centered and individualized healthcare**? Bias in **preclinical animal research** (Green, 2015) **Animal models of human disease**: Challenges in enabling translation (McGonigle & Ruggeri, 2014)	Progress and challenges in **translating the biology of atherosclerosis** (Libby et al., 2011) **Vascular contributions to cognitive impairment and dementia**: A statement for **healthcare professionals** from the American Heart Association/American Stroke Association (Gorelick et al., 2011) **Genomic responses** in **mouse models** poorly mimic **human inflammatory diseases** (Seok et al., 2013) **Membrane vesicles**, current state-of-the-art: Emerging role of **extracellular vesicles** (György et al., 2011) **Modeling Tissue Morphogenesis and Cancer in 3D** (Yamada & Cukierman, 2007) Relationships between **preclinical** cardiac electrophysiology, clinical QT interval prolongation and torsade de pointes for a broad range of **drugs**: Evidence for a provisional safety margin in **drug development** (Redfern et al., 2003)

4.1.4.1. Translating scientific knowledge into medical practice

The Translating scientific knowledge into medical practice community has publications dating back to 1979 (Table 2). The United States, Canada and the United Kingdom are the most frequent countries of the affiliation of the first authors (Figure 6b). The community has 5,323 publications and 15,196 connections - 11,637 within the community and 3,559 between communities - external connections roughly 30% of the internal connections (Table 2). The most common terms in the title, abstract and keywords of its publication (Figure 10) and the most cited and central publications (Table 5) suggest the community focuses on translating research, knowledge, science, evidence and data into implementation, development and practice of health, care, clinical and medical programs and policies. The most frequent journals include general journals such as Nature, Science and Plos

One, many concerning translational science and medicine, some concerning health services, policy, technology, and informatics, as well as a range of topics from community psychology and epidemiology to drug discovery, pharmacology and genetics (Figure 10). The community uses or mentions 35 approaches and is dominated by translational research (63.6%) followed by transdisciplinarity with 15.1% of the publications (Figure 6c).

4.1.4.2. Animal models to study human diseases

The Animal models to study human diseases is a community with publications since 1978 (Table 2). The most frequent countries of the affiliation of the first authors are the United States, United Kingdom, and Germany (Figure 6b). It contains 2,208 publications and 3,681 connections - 3,279 within the community and 402 between communities. With external connections representing only 12% of internal connections (Table 2), this is the most isolated community. The most frequent terms in the title, abstract and keywords of its publications (Figure 10) indicate the community focuses on studies and research of animal models to understand the mechanisms and the therapeutic effects of drugs in the treatment of human diseases and disorders. The journals where its publications are published include general journals such as Plos One, Science and Nature, and journals focused on translational medicine, disease models and mechanisms, drug discovery, toxicology and pharmacology, transplantation, and cancer, as well as stroke, neurosciences, and psychiatry (Figure 10). The most cited and central publications reiterate the focus of the community in animal models, drug discovery and development, and translational research (Table 5). The community uses/mentions 17 transdisciplinary approaches and it is strongly dominated by translational research (95.7%) (Figure 6c).

4.1.5. Teaching and education domain

Finally, the Teaching and education domain encompasses only one community and includes 5.2% of the nodes of the network and 5.3% of its connections (75% within communities and 25% between communities). The educational scope is the essence of the domain (Figure 11; Table 6) and its journals are from the "social sciences", "arts and humanities" and "business, management and accounting" areas of knowledge. "Psychology" is also important in this domain.

Figure 11 - Word-clouds of the most common terms in the title, abstract, and keywords (left) and the most common journals (right) of the publications within the Teaching and education domain/community.

Table 6 – Most central (i.e. simultaneously with the highest values in three indices of centrality) and most cited publications within the community of the Teaching and education domain. In bold, the most informative words in the titles of these publications for interpreting the thematic scope of the communities.

Community	Title of the most central publications considering the three indices of centrality	Title of the most cited publications
Teaching and education	**Professional, personal, and political dimensions** of **action research** (Noffke, 1997) **Teacher action research**: Building **knowledge democracies** (Pine, 2009) **Action research** for **educational reform**: Remodelling action research theories and practices **in local contexts** (Somekh & Zeichner, 2009) The **action research story of a student–teacher**: Change is not easy and it takes time, effort, and critical reflection La historia (Eriksson et al., 2017) Different Types Of **Action Research** To Promote **Chemistry Teachers' Professional Development**-A Joined Theoretical Reflection On Two Cases From Israel And Germany (Mamlok-Naaman & Eilks, 2012) **Curriculum development** through **action research**: A model **proposal for practitioners** (Saban, 2021)	A **Motivational Science Perspective** on the Role of **Student Motivation in Learning** and **Teaching Contexts** (Pintrich, 2003) **Professional** development and reform in **science education**: The role **of teachers' practical knowledge** (van Driel, 2001) Guidelines for Quality in **Autobiographical Forms** of **Self-Study Research** (Bullough & Pinnegar, 2001) **Genre pedagogy**: **Language, literacy and L2 writing i**nstruction (Hyland, 2007) CALL Past, present and future (Bax, 2003) **Authentic assessment of teaching** in context (Darling-Hammond & Snyder, 2000)

4.1.5.1. Teaching and education

Teaching and education is a community with publications since 1953 (Table 2). The most frequent countries of the affiliation of the first authors are the United Kingdom, United States and Australia (Figure 6b). This community encompasses 2,859 publications and 8,531 connections - 6,415 within the community and 2,135 between communities (external connections account for 33.3% of the internal connections; Table 2). The most common terms in the title, abstract and keywords of its publication (Figure 11) suggest the community focuses on the research, study, and practice of education, teaching and learning in universities, schools, and classrooms. The most frequent journals where its publications are published show clearly the emphasis in teaching and education, as well as in action research (Figure 11). The most cited and central publications reiterate the emphasis of the community in action research applied to teachers' professional development, students' motivation, education reform and curriculum development (Table 6). The community uses or mentions 25 approaches and is strongly dominated by action research (81.8%) (Figure 6c).

4.1.6. Connections among transdisciplinary communities

Communities within the Socio-environmental domain sum up 8,720 connections between each other, which represents twice the connections with communities of other domains (4,175 connections; Table 2). The Socio-environmental domain is mainly connected with the Health and Business and management domains, with respectively 36.4% and 28.7% of its external connections (Figure 5). Indeed, the communities of the domain are among the most well-structured (high number of within-community connections) and well-connected to other communities (Figure 12), especially the Sustainability and policy and Ecosystem management communities.

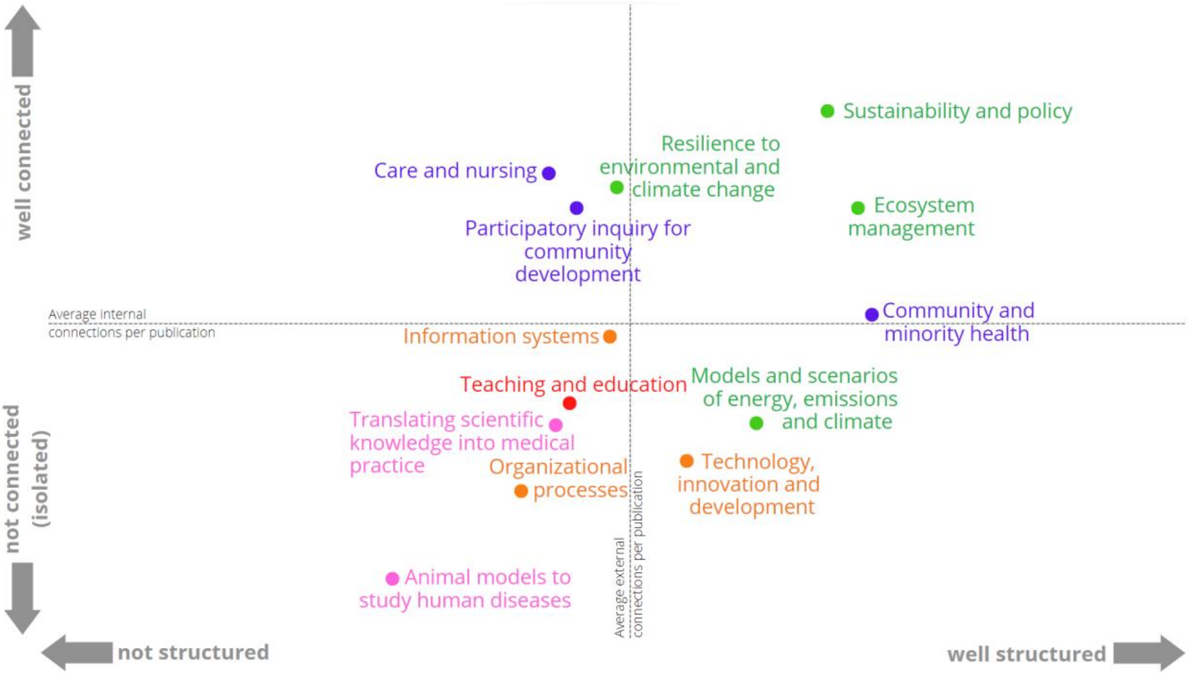

Figure 12 - Structuring and connection of the 13 largest communities. The x axis is the average internal connections (within community citations) per publication and the y is the average external connections (citations to other communities) per publication. In the first quadrant (top left), communities are well-connected to other communities but not structured (relatively fewer connections within the community). In the second quadrant (top right), communities are both well-connected and well-structured. In the third quadrant (down left), communities are not structured and isolated, while in the fourth (down right), they are well-structured but isolated.

Communities in the Health domain sum up 3,914 connections between communities within the domain, half the number of external connections (6,838; Table 2). The Health domain is mainly connected to the Business and management and Medicine domains (Figure 5), with respectively 31.7% and 25.7% of its external connections. Care and nursing and Participatory inquiry for community development are well-connected but relatively unstructured communities, while Community and minority health is more isolated, but well-structured (Figure 12).

The Business and management domain sum up 658 connections between each other, which represents less than 15% of the 4.578 (Table 2) external connections. The domain is mainly connected with the Health and Socio-environmental domains (Figure 5), with respectively, 47.4% and 26.2% of its external connections. Indeed, none of the three communities are well-connected, although Technology, innovation and development is more structured than the other two (Figure 12).

In the Medicine domain, connections between the two communities (346) represent only 11.1% of its 3,104 (Table 2) external connections. The few connections of the domain are mainly with the Health and Socio-environmental domains (Figure 5), with respectively, 56.7% and 29.7% of its external connections. Indeed, its communities are among the least connected and well-structured (Figure 12).

Finally, the only community of the Teaching and education domain has 2,135 external connections that represent 33.3% of its internal connections (Table 2), 53.3% with the Health domain and 37.6% with the Business and Management domain (Figure 5). The community is relatively isolated and not structured (Figure 12).

4.2. Characterization of transdisciplinary approaches

The distribution of publications per transdisciplinary approach (Figure 13) allowed the identification of 11 dominant approaches – those with more than 1,200 publications, encompassing 87.3% of the publications of the 13 largest transdisciplinary communities described above. All remaining 44 transdisciplinary approaches were mentioned in 1,041 publications or less.

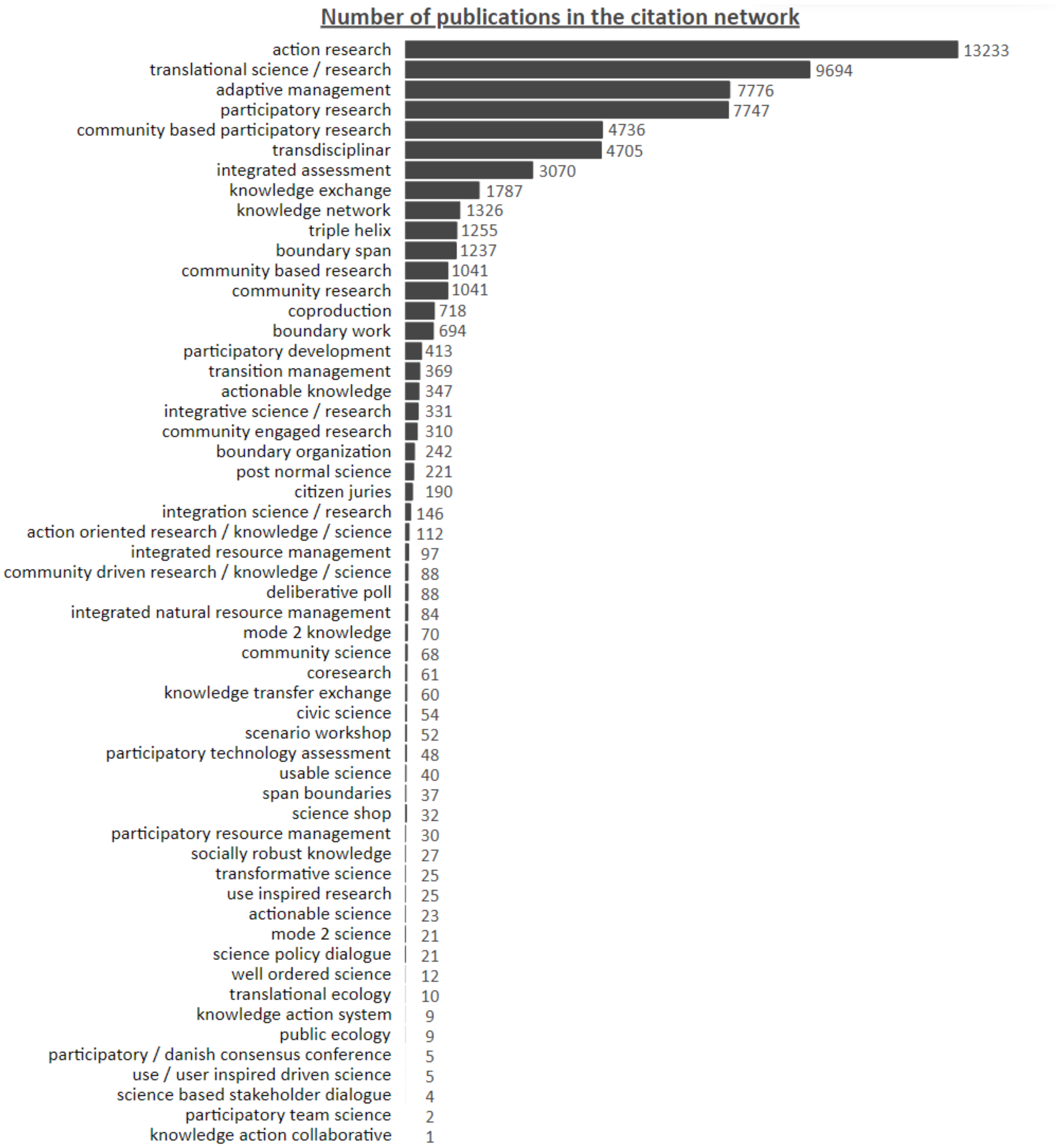

Figure 13 - Number of publications in the direct citation network mentioning each of the 55 transdisciplinary approaches.

4.2.1. Distribution of the transdisciplinary approaches across domains and communities

Most transdisciplinary approaches (52 of the 55) are mentioned in publications of more than one community and domain. While the 11 dominant transdisciplinary approaches are mentioned in publications of at least 10 communities and all five domains, the 44 rare transdisciplinary approaches vary in terms of the number of communities and domains they are mentioned or used. However, the number of publications per approach within the network explains well the variation in the number of communities that mentioned them (Appendix H).

The PCoA of the frequency of the 11 dominant approaches across the 13 largest communities (Figure 14) indicates that certain domains contain communities dominated by similar transdisciplinary approaches. This is the case of the Socio-environmental domain, whose four communities (left, top quadrant) are dominated by adaptive management alone (Ecosystem management and Resilience to environmental and climate change) or together with either integrated assessment (Models and scenarios of energy, emissions, and climate) or transdisciplinarity (Sustainability and policy). It is also the case of the Medicine domain (left, down quadrant), whose two communities are dominated by translational research.

Similarly, the three communities of the Health domain (right, center to down quadrant) are dominated by participatory research and community based participatory research with increasing relevance of the action research approach (from Community and minority health to Participatory inquiry for community development and to Care and nursing). The only community of Teaching and Education domain (right, top quadrant) is dominated by action research and secondarily by participatory approaches. The same is true for the Information system community (also in the right, top quadrant), which differs considerably from the other two communities of the Business and management domain (left, down quadrant), which are dominated by knowledge exchange and knowledge network together with either boundary spanning (Organizational processes) or triple helix (Technology, innovation and development).

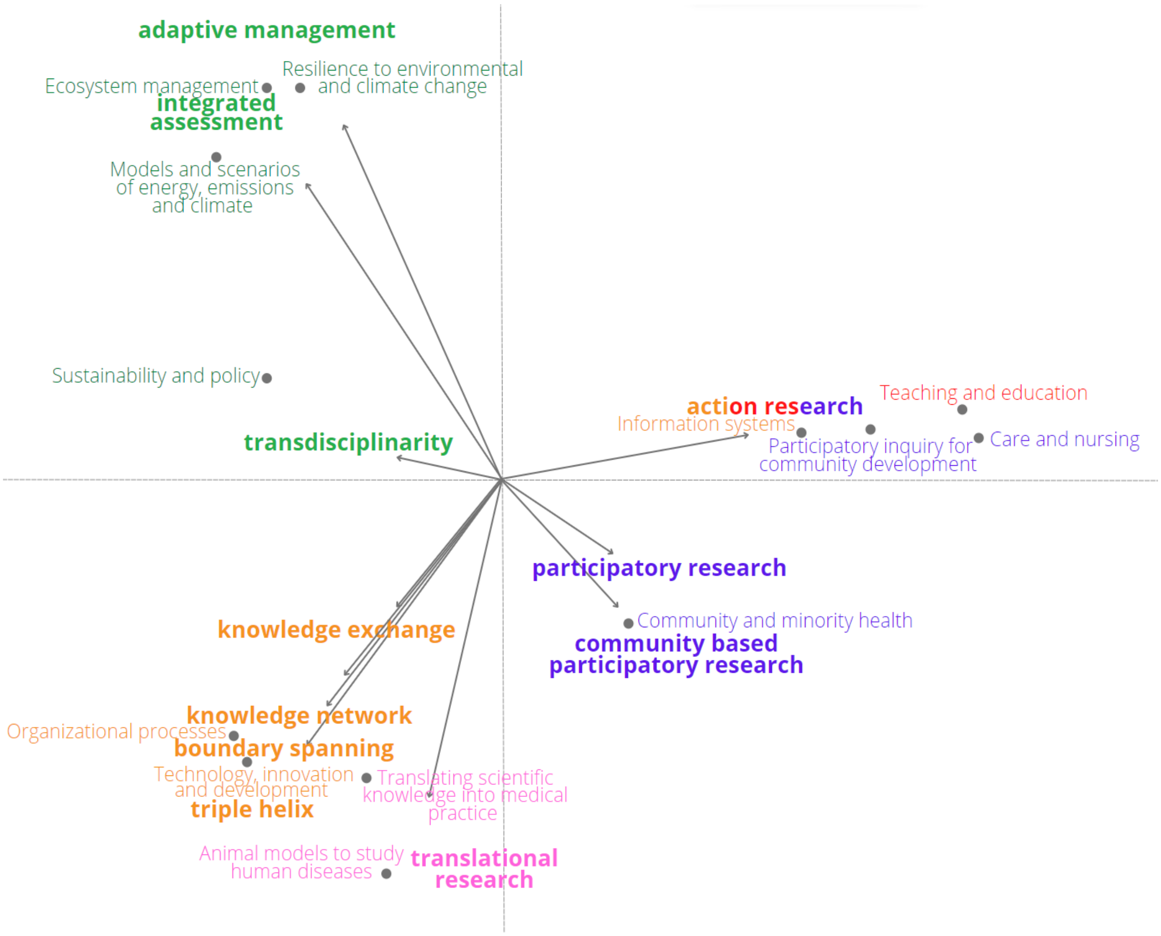

Figure 14 - PCoA biplot of the 13 largest transdisciplinary communities (dots and light letters) in terms of their similarities concerning the 11 transdisciplinary approaches (arrows and bold letters). Colors identify the different domains: green – Socio-environmental, pink – Medicine, blue – Health, orange – Business and management, and red - Teaching and education; action research is colored with three colors because it dominates communities of the domains represented with blue, red and orange.

4.2.2. Qualitative similarities and differences among the 11 dominant approaches

The 11 dominant transdisciplinary approaches represent a variety of propositions on how (through which guiding tenets, general methodological guidelines, and stakeholders) and why (focusing on which entities and processes, and with which central goals) to share, articulate and create knowledge (Table 7).

The focal entities under consideration range from groups of individuals, communities, organizations, and systems to complex problems and global issues (Table 7). While approaches used in the Socio-environmental domain focus on socio-ecological systems as a whole or on complex problems and global issues associated with them, approaches used in other domains focus on subcomponents of socio-ecological systems. Approaches used in the Health domain focus on communities and those used in the Business and management, Teaching and education, and Medicine domains focus either on groups of individuals or on organizations (Figure 15). In turn, the focal processes to be changed vary from management and governance, policy making, providing rights and services or confronting challenges in marginalized communities or social practice in general, to connecting or translating information and knowledge (Table 7).

However, within each of the approaches the combination of the entity under consideration and of the focal process to be changed are closely tied to its central goal, and consequently, to the thematic domain where each transdisciplinary approach is most used (Table 7; Figure 15). In this sense, the three approaches most used within the Socio-environmental domain focus either on the management and governance of socio-ecological systems with the goal of increasing the resilience of these systems (adaptive management), integrating models and data sources to inform policy (integrated assessment), or on a variety of processes concerning complex problems in general to produce socially robust orientations towards sustainable transitions (transdisciplinary). Similarly, the three approaches most used within the Health and the Teaching and education domains focus on either the social practice of groups of individuals to promote transformative social change (action research, also dominant in one community of the Business and management domain) or on the challenges, rights, and services of communities to promote community well-being, equity and empowerment (community-based participatory research and participatory research) (Figure 15). In turn, the other four approaches most used within the Business and management domain concern the collaboration and sharing of information and knowledge either among groups of individuals aiming at the effectiveness of policies and decision making (knowledge exchange), among organizations to bridge the gap between knowledge and action (knowledge network) and to promote evidence-informed decision-making (boundary spanning) or among sectors (specifically academia, industry and government) to foster innovation and economic development (triple helix) (Figure 15). Finally, the approach most used within the Medicine domain centers on translating discovery into practices across groups of producers and users of knowledge to improve human health (translational research) (Figure 15).

The linkages, within each approach, of its entity under consideration, focal process to be changed and central goal lead to guiding tenets that are specific to each approach, but similar across approaches from the same domain (Table 7, Figure 15). For instance, while both adaptive management and integrated assessment (Socio-environmental domain) emphasize the need to accommodate uncertainty and incorporating diverse perspectives concerning complex systems or complex global change, community-based participatory research, and participatory research (Health domain) stress the importance of building on community strength and resources and of values of democracy, equity and self-(community-)determination. Similarly, boundary spanning, knowledge exchange, knowledge network and triple helix (Business and management domain) all highlight the significance of the broader context and emphasize the need for meaningful engagement with different actors (each of which has their distinct expectations, norms, and values) for effective communication and sharing. However, there are guiding tenets that cut across domains because they are associated with key criteria that define transdisciplinary approaches in general, such as valuing diverse knowledge and perspectives (articulated in adaptive management, action research, boundary spanning, triple helix, and translational science).

In contrast, in terms of the general methodological guidelines, while some are characteristic of the approaches within the same domain, many cut across approaches from different domains (Table 7, Figure 15). The general methodological guideline of generating knowledge in a specific context with a particular group of people through a research process jointly planned and developed is restricted to approaches most used in the Health domain (community-based participatory research and participatory research). Similarly, the general methodological guideline of creating specialized organizations (or people) to mediate dialogue and communication among distinct professionals/sectors is restricted to approaches most used in the Business and management domain (boundary spanning and triple helix). However, both adaptive management (from the Socio-environmental domain) and action research (from the Health, Teaching and education, and Business and management domains) center on a general methodological guideline that comprises a continuous and cyclical process encompassing problem identification, action planning, implementation, and outcome evaluation to guide subsequent actions. In the same vein, articulating diverse available perspectives and knowledge either on a problem (integrated assessment and transdisciplinarity) or across phases of a process or groups of people (knowledge exchange, knowledge network, and translational science/research) is a general methodological guideline of approaches that cut across the Socio-environmental, Business and management and Medicine domain.

Aside from researchers, who are present in all approaches as a criterion for the approach to be considered transdisciplinary, distinct stakeholders come into play across approaches (Table 7; Figure 15). The literature mentions generic terms to enumerate various possible actors — such as “end users”, “practitioners”, “non-academic partners” and “other stakeholders”. We standardized the term “other stakeholders” to encompass unspecified actors, which are context-dependent. They may encompass any of the other actors besides researchers and boundary spanners/intermediaries. Managers play a significant role in adaptive management, and boundary spanning. Decision and policy makers take the forefront in integrated assessment, transdisciplinarity, boundary spanning, knowledge exchange, and knowledge network, driving policy and decision-making processes. Politicians and other government representatives also are important in the transdisciplinary context, playing a role in the boundary spanning, and knowledge network and triple helix, respectively. Boundary spanners/intermediaries are also distinguished stakeholders involved in the boundary spanning and knowledge exchange approaches as mediators between distinct groups/organizations with different cultures and languages. Community members emerge as pivotal stakeholders in community-based participatory research and participatory research, shaping the research agenda and co-creating knowledge that is contextually relevant to their needs. Nongovernmental organizations also play a role in community-based participatory research and are likewise involved in knowledge networks and integrated assessment. Finally, other stakeholders - which vary from citizens, patients, doctors, and representatives of industry, business, and other societal sectors to unspecified others - are involved in adaptive management, integrated assessment, transdisciplinarity, participatory research, action research, boundary spanning, knowledge exchange, translational science, and triple helix.

Table 7 – Characteristics of the 11 dominant transdisciplinary approaches considering six aspects: their focal elements (i.e. entities under consideration); focal process to be changed; central goals of the change; principles (i.e. guiding tenets); general methodological guidelines; and main stakeholders involved. The references used for characterizing each approach are those in Appendix G.

Approach | Aspect	Entities under consideration	Focal process to be changed	Central goals of the change	Principles/ guiding tenets	General methodological guidelines	Main stakeholders involved
Adaptive management	socio-ecological systems	management and governance of systems	increasing resilience in complex socio-ecological systems	delivering tangible outcomes while actively accommodating uncertainty, complexity, and unpredictability, and demonstrating a commitment to experiential learning and embracing diverse perspectives	continuous cycle of identifying a problem, planning, and implementing actions to address the problem, and then evaluating the outcomes to inform further actions	managers, researchers, and other stakeholders of socio-ecological systems
Integrated assessment	complex global change issues	policy making	supporting and improving policies	accommodating uncertainties, complexities, and value diversities of global environmental risks	analyzing and reviewing existing knowledge, assembling, and summarizing pieces of information, and organizing and interpreting them to help evaluate possible actions or think about a problem	researchers, citizens, decision makers, NGOs and representatives of business and other societal sectors
Transdisciplinarity	complex real-world problems	varied	socially robust orientations towards sustainable transitions	importance of context and flexibility, of capacity building among all participants, of consensus building about what the main problems are (including their genesis and transformation) and of strategies for mitigating emerging conflicts	facilitated (mediated) process of mutual learning that links interdisciplinary knowledge (scientific, theoretic, and abstract epistemics) and multi-stakeholder discourses (experiential knowledge from outside academia)	researchers, legitimate decision makers, and a broad range of stakeholders
Community based participatory research	communities	that concerns rights and services in marginalized communities	promoting community well-being and equity	building on existing community strengths and resources, and facilitating partnerships that are equitable, collaborative, empowering, and address social inequalities	engage community members as active partners in all stages of the research, including generating research ideas, reviewing protocols, interpreting results, and disseminating findings, in a way their specific needs and concerns are addressed	community members, NGOs representatives, researchers
Participatory research	communities	that concerns challenges faced by (and relevant to) communities	empowering communities and promoting social change	commitment to values of democracy, equity, working with the environment as a habitat for people and other organisms, and the value of self- and community-determination	sequential reflection and action, carried out with and by local people (rather than on them), in which local knowledge and perspectives form the base for research and planning	community members, researchers, and other stakeholders

Table 7 – Continued.

Approach | Aspect	Entities under consideration	Focal process to be changed	Central goals of the change	Principles/ guiding tenets	General methodological guidelines	Main stakeholders involved
Action research	groups of individuals	social practice	promoting transformative change and improvement of social action	practical outcomes and social action, rather than just theoretical knowledge, engaging with uncertainty, complexity, and messiness, and being willing to learn from experience and engage with diverse perspectives	a spiral of steps consisting of planning, action, and fact-finding about the result of the action. This process involves a continuous cycle of identifying a problem, planning, and implementing actions to address the problem, and then evaluating the outcomes to inform further actions	researchers and other stakeholders
Boundary spanning	organizations	exchange between organizations	improving evidence-informed decision-making concerning "wicked problems" or complex social challenges	considering the broader context of actors, perspectives, values, contested evidence, decision-making history, and power dynamics in shaping a productive knowledge exchange process	set of activities that engage actors on both sides of a boundary, involving trajectories of boundary work overtime, from defining boundaries to establishing ownership and use of generated boundary objects conducted by boundary spanners (organizations or individuals)	researchers, citizens, boundary spanners, politicians, managers and decision makers
Knowledge exchange	groups of individuals	generating and sharing knowledge	improving policy and decision making	communication and exchange	encompasses all facets of knowledge production, sharing, storage, mobilization, translation, and use	intermediaries, researchers, decision and policy makers and other stakeholders
Knowledge network	organizations	disseminating information and knowledge across sectors of society involved in technological and policy innovations	bridging the gap between knowledge and action	membership, effective communication and interaction between knowledge producers and knowledge users	developing, disseminating, and applying knowledge, with a focus on enhancing communication and interaction, as well as establishing effective feedback mechanisms	policy makers, researchers, government agencies, and nongovernmental organizations representatives

Table 7 – Continued.

Approach | Aspect	Entities under consideration	Focal process to be changed	Central goals of the change	Principles/ guiding tenets	General methodological guidelines	Main stakeholders involved
Triple helix	organizations	collaboration between academia, industry, and government	fostering innovation and economic development	dialogue, identification and understanding of the different expectations, norms, and values of each sector and innovation in a knowledge-based economy	fostering an innovation ecosystem, through various hybrid organizations, such as technology transfer offices, venture capital firms, incubators, accelerators, and science parks that connects the basic research in universities, the production of commercial goods in industries and the regulation of markets in governments	researchers, industry, and government representatives
Translational science / research	groups of individuals	translating scientific discoveries into clinical settings or public health interventions	improving human health and well-being	bidirectional and cyclical nature of the research process, the integration of diverse disciplines and perspectives, and the focus on addressing health disparities	the generation of evidence through basic science discoveries, testing and application in developmental stages, dissemination of findings, and implementation of research results in clinical practice, public health programs, and community settings	researchers, and other stakeholders, including patients and doctors

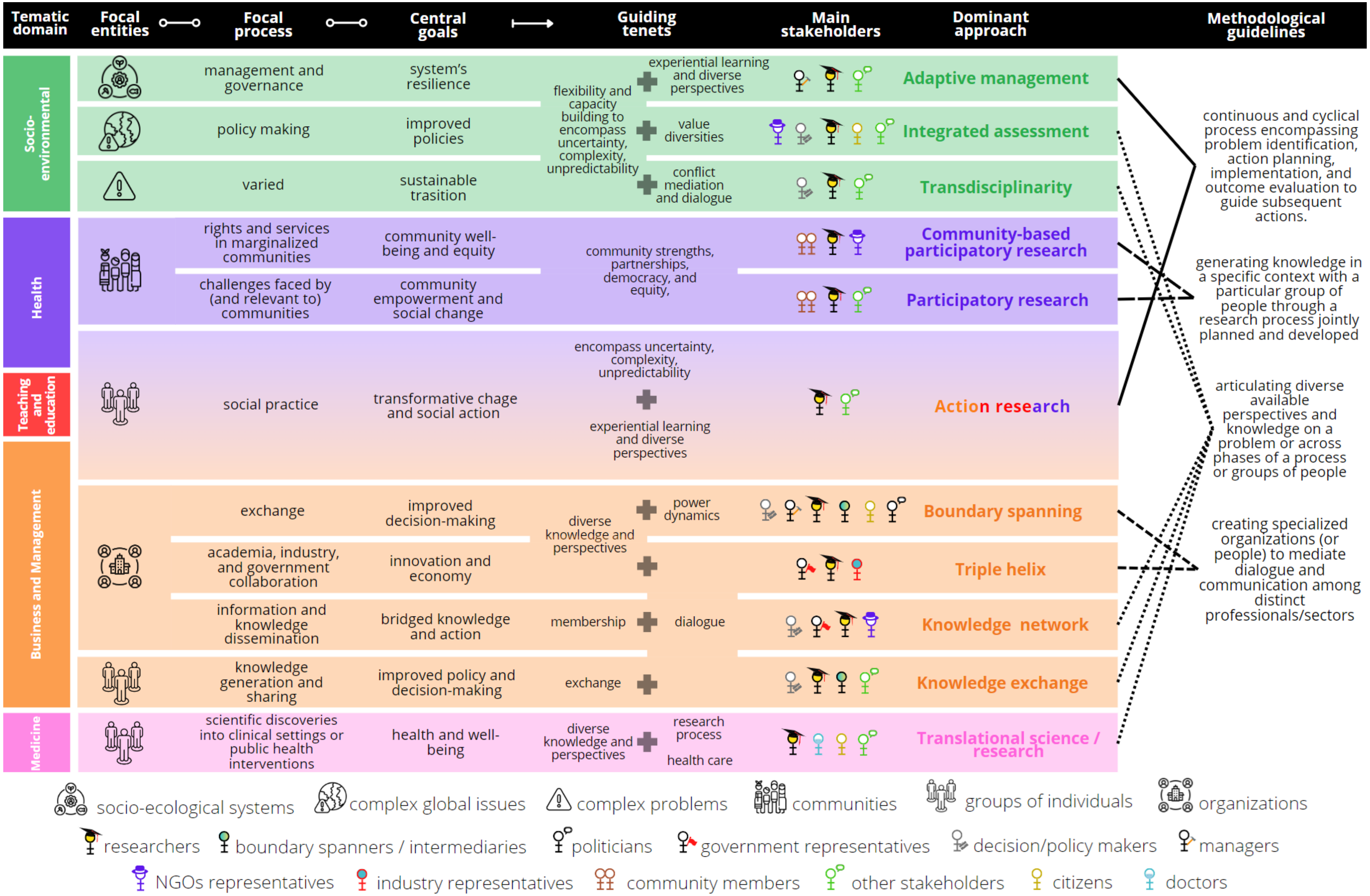

Figure 15 - Schematic connections in terms of entities under consideration, focal processes, central goals, guiding tenets, main stakeholders and methodological guidelines among the 11 dominant transdisciplinary approaches within and across thematic domains.

5. DISCUSSION

In the context of the complex interrelated problems we face today – climate emergence, injustice and inequality, and threat to local and indigenous ways of life and cultures (Latour & Weibel, 2005; Shiva, 2005; Galeano, 2010), traditional, discipline-oriented science has limitations to support transformative change, given its compartmentalization and detachment from societal pressures (Lubchenco, 1998; Sarewitz, 2004; McNie, 2007; Dilling & Lemos, 2011; Bertuol-Garcia et al., 2018). This situation underscores the significance of incorporating and implementing transdisciplinary approaches that are grounded on collaborative partnerships, guided by problem-solving, and aimed at transformation (Collingridge & Reeve, 1986; Rocha et al., 2020). Such approaches have indeed had their potential acknowledged (Jahn et al., 2012; Nature, 2018) and have proliferated across many scientific fields (McNie, 2007). In this study, we aimed to organize and compare the multitude of both transdisciplinary approaches and scientific communities utilizing them to highlight the diversity of options available, their strengths and complementarity, aiding in the informed selection and improved practice of transdisciplinary.

5.1. Scientific communities using transdisciplinary approaches organize around five thematic domains

In face of the recognition and dissemination of transdisciplinary approaches, several reviews have been conducted on transdisciplinarity (sometimes using instead the term coproduction), either documenting different approaches and techniques (Rowe & Frewer, 2005; McNie, 2007), proposing common ground and discourse (Jahn et al., 2012), detailing different types or modes (Chambers et al., 2022), as well as identifying meanings (Bandola-Gill et al., 2023) and principles (Norström et al., 2020). Some reviews are restricted to a specific scientific field or topic (e.g., Brandt et al., 2013; Norström et al., 2020), while others cover a broader scope (e.g., McNie, 2007). In a complementary effort to these endeavors - through a meticulous mapping of transdisciplinary approaches and communities across a citation network spanning all fields of the scientific literature - our review enables the recognition of the linkages between the main transdisciplinary scientific communities and approaches through the identification of their thematic domains and main characteristics and features. Despite the inherent difficulties and limitations in determining a priori which terms to incorporate into our search and review, our effort identified over 50 transdisciplinary approaches and nearly 2,500 communities. It underscores how the diversity of transdisciplinary approaches is distributed and shared across scientific communities, showing that - despite this multitude of approaches and communities - a significant portion of the scientific production focusing on transdisciplinarity is concentrated within 13 communities and 11 approaches.

Our findings indicate that these dominant transdisciplinary communities and approaches are associated with five interdisciplinary thematic domains applied to various facets of modern societal issues, namely the Socio-environmental, Health, Business and management, Teaching and education, and Medicine domains. This supports preview studies that also suggest that these are indeed the most transdisciplinary topics (Bohensky & Maru, 2011; Brandt et al., 2013; Reyes-García & Benyei, 2019; Ludwig et al., 2023). Each of these five thematic domains represent a specific combination of scientific fields or areas, especially among the arts and humanities; the social sciences, economics, econometrics and finance, and psychology; the environmental science, agricultural and biological sciences, and earth and planetary sciences; the medical and health sciences, biochemistry, genetics and molecular biology, pharmacology, toxicology and pharmaceutics, nursing, and neuroscience; the business, management and accounting, computer science, engineering and decision sciences. Although they encompass diverse scientific areas, it is noteworthy that some fields, particularly those associated with exact sciences, such as chemistry, physics and astronomy, and mathematics, are underrepresented in transdisciplinary endeavors. This scenario implies an opportunity to include researchers from these fields in transdisciplinary processes, in which they could make valuable contributions.

In terms of the countries where authors are affiliated, those in the global North, which typically dominate scientific literature overall (Blicharsk et al., 2017; Koller, 2019), are also those that predominate within the transdisciplinary communities we identified, namely the United States, United Kingdom, Canada, Australia, Germany and the Netherlands. However, the relevance of countries in the global South for the transdisciplinary literature, especially South Africa and Brazil, is significant, and might be even greater, considering that the database we used (i.e. Scopus) does not comprehensively capture academic production in languages other than English. Reviewing and synthetizing the contributions of the Global South to transdisciplinary endeavors – overcoming the barriers imposed by the language - is of foremost importance, given the region biocultural diversity (Parra-Vázquez et al., 2020; Mardero et al., 2023) and the complex and drastic problems they face.

Interestingly, our analyses reveal that the communities within each of the five transdisciplinary domains - even though they share a theme and use the same set of transdisciplinary approaches - are not necessarily communicating through citations. Only the communities focusing on the Socio-environmental domain are particularly connected to each other through citations. This underscores that what links communities focusing on themes of the same domain is, in most cases, the shared use of the same transdisciplinary approaches rather than citations. It also highlights that many communities are using references from different thematic domains. It is possible that these connections between communities from different domains reflect the history of the origin and spread of transdisciplinary approaches across scientific disciplines and fields – a topic worth exploring in future studies.

5.2. A framework for comparing, choosing and articulating transdisciplinary approaches

Given that the multitude of available transdisciplinary approaches are spread across a vast literature from distinct fields, it is challenging to access their characteristics in a comparative way. Beyond describing the scientific communities and domains that use transdisciplinary approaches, our review also qualitatively characterized the 11 approaches dominating the literature. While reviews comparing approaches have been previously published (e.g. Knapp et al., 2019; Scholz, 2020), as far as we are aware none of them compare as many approaches as ours, nor do they do so by departing from well-defined dimensions and considering the thematic domains where they are mainly used, aiding the identification of strengths and complementarities among them.

By doing so, our study contributes to the recognition that the most commonly used transdisciplinary approaches exhibit specificities that make them more suitable for addressing certain contemporary societal problems, such as socio-environmental (e.g. climate emergence), health (e.g. well-being in marginalized communities), education (e.g. education reform and curriculum development), business and management (e.g. coordination and connection across organizations and sectors), and medical (e.g. developing clinical innovations) issues. Our analysis indicates a close association between the entities under consideration, focal process to be changed, and central goals of each approach, making groups of them more suited to address problems in specific thematic domains. For instance, in the Socio-environmental domain, the studied entities often include socio-ecological systems or problems, and the focal processes concern governance and policies, whereas in the Health domain, the entities are marginalized communities, and the focal processes, promoting community well-being and equity. Consequently, communities that share themes also share transdisciplinary approaches designed and suited for these entities and processes. Among the 11 identified dominant transdisciplinary approaches, action research is the only one that is frequently used in more than one domain, namely Health, Education and teaching, and Business and management. This may be associated with the fact that action research is the oldest among the 11 dominant approaches, proposed in 1946, and has inspired other approaches (Martin & Sherington, 1997).

As such, our findings suggest that different contemporary societal problems are addressed with approaches that differ in which guiding tenets they emphasize given the distinct obstacles associated with addressing particular entities-processes-goals. Thus, although some guiding principles transverse approaches used in distinct thematic domains, as they reflect intrinsic aspects of transdisciplinary, such as valuing diverse knowledge and perspectives, some tenets are peculiar to approaches with certain domains. In particular, uncertainty and complexity are mostly emphasized in the Socio-environmental domain dealing with whole socio-ecological systems or their problems, whereas democracy, equity and self-determination represent the main concern in the Health domain focusing on marginalized communities.

Hence, recognizing these linkages – approaches developed to focus on particular entities and processes to attain certain goals through specific guiding tenets – allows more clarity for users to select transdisciplinary approaches that best fit the specific context of a particular situation or problem. However, the association between transdisciplinary approaches and distinct domains may be in part a consequence of the origin and history of use of the approaches within particular scientific fields. As such, our comparative analysis also provides a framework to find support in other transdisciplinary approaches, communities, and literature to deal with challenges faced by groups using a particular approach that do not account for, or emphasize, those challenges.

Despite the specificities of entities-processes-goals-tenets inherent to approaches most used to address different contemporary issues from distinct domains, our comparative analysis reveals only four types of general methodological guidelines among the 11 dominant transdisciplinary approaches, some of which are shared across thematic domains. While these basic types are sometimes confined to groups of approaches within a domain (research together— Health domain; and creating bridging organizations — Business and management domain), at times they are shared across domains (action-reflection-action cycle and articulating available knowledge). Once again this illustrates the potential to learn from other traditions and eventually combine methodologies.

An example of how combining approaches can advance the practice of transdisciplinary can be found in some criticism that have been articulated to this practice within the Socio-environmental domain. The complexity of socio-environmental problems, while justifying an emphasis on uncertainties and scientific data, may, without due consideration, neglect other crucial forms of knowledge and values (Turnhout et al., 2020; Gerlak et al., 2023) – such as from managers and members of affected communities, resulting in potentially less transformative processes. These projects could then benefit from the inclusion of such stakeholders in the way participatory research, action research, and community-based participatory research propose. This entails involving such actors throughout the entire process, sharing leadership and decision-making responsibilities — differently from what

Gerlak et al. (2023) observe to be the norm in the majority of processes to coproduce knowledge for environmental decision-making. Moreover, besides including these actors, it is essential to recognize – and deal with - power asymmetries within these transdisciplinary groups. In a review of coproduction in socio-environmental domain, Turnhout et al. (2020) show that this literature overlooks power and risk asymmetries, especially those created and maintained by viewing scientific knowledge and expertise as the most (or only) valid, hindering contestation and pluralism. To address this criticism, groups using approaches from the Socio-environmental domain could use and emphasize the guiding tenets of participatory research and community-based participatory research that concern democracy, equity and self-determination, as well as building on existing strengths and resources, and facilitating partnerships that are equitable, collaborative, empowering, and address social inequalities. Taking these principles as guiding tenets, may help recognizing and addressing power and risk inequities within the group, and hence establishing ways to create space for contestation and pluralism and to recognize and articulate different authorities and expertise.

Similarly, projects employing community-based approaches could enrich their perspectives by considering that the focal communities are part of larger, complex socio-ecological systems – the entities considered in approaches of the Socio-environmental domain. This would facilitate a systemic view that emphasizes interdependencies, interactions, and feedback loops (Folke et al., 2016), broadening the understanding of the root causes of problems and identifying paths and alternatives for solutions. It would also enable the consideration of properties potentially relevant for addressing issues in communities, such as resilience, the definition of which is linked to a system's capacity to adapt and self-organize (Folke, 2016). Self-organizing communities withstand challenges due to its resilience (Walker & Salt, 2012).

Indeed, exchanges among transdisciplinary approaches are in part already occurring as in the case of the role of knowledge brokers/boundary spanners. These specialized actors can help facilitating communication, adapting knowledge to political realities, and mediating conflicts of interest. The concept, originally stemming from boundary spanning, has now been embraced and incorporated by various transdisciplinary approaches, such as integrated assessments (Cash & Moser, 2000), knowledge exchange (Cvitanovic et al., 2015) and triple helix (Rosenlund et al., 2017).

Hence, while there are certainly no silver bullets (i.e., transdisciplinary approaches that are universally superior or suitable for any context), we propose that our comparative framework allows for the identification of strengths and complementarities among them. Recognizing the main entities, processes, goals, tenets and methodological guidelines across transdisciplinary approaches facilitates identifying potential articulation between them that may contribute to transdisciplinary practice of different scientific communities focusing on distinct themes. In fact, it is worth noting that, although the transdisciplinary communities we identified are dominated by certain approaches, they do actually use a wide variety of approaches (though less frequently so). This may indicate that different ideas and approaches have already spread across diverse scientific communities and thematic domains. As we indicated above, strengthening this communication by articulating different aspects from distinct transdisciplinary approaches may help those engaging in transdisciplinarity to deal with criticisms associated with the approach they use and improve their practice.

6. CONCLUSION

Our study departs from the limitations of traditional, disciplinary-oriented science to emphasize, organize and compare the diversity of transdisciplinary approaches available in the literature, highlighting the interconnectedness between them and distinct thematic domains and societal issues. It supports identifying approaches that better suit specific contexts and situations, and facilitates articulating them to improve transdisciplinary practices in addressing complex societal issues by considering there is no one-fits-all solution.

- Limitation of traditional science: In the face of the current complex environmental, social-cultural, economic, and political challenges, traditional science is deemed insufficient to support societal transformations due to its disciplinary constraints and detachment from societal concerns. This underscores the relevance of transdisciplinary approaches grounded in collaborative practices, aimed at problem-solving and societal transformation.
- Diversity of transdisciplinary approaches: Through a meticulous mapping of transdisciplinary approaches across the scientific literature, the review identifies 55 transdisciplinary approaches and nearly 2,500 scientific communities using them. Yet, a significant portion of the scientific transdisciplinary production is concentrated within 13 communities and 11 dominant approaches.
- Global participation in transdisciplinary endeavors: Despite a prevalence of authors from countries in the global North, some countries in the global South actively participate in transdisciplinary endeavors.
- Interconnectedness to thematic domains: Dominant transdisciplinary communities are associated with five interdisciplinary thematic domains: Socio-environmental, Health, Business and management, Teaching and education, and Medicine. These groups of communities sharing themes and focusing on the same broad type of societal issues, are linked by shared transdisciplinary approaches rather than by citation.

- Comparing transdisciplinary dominant approaches: The within-approach linkages between entities under consideration, focal processes to be changed, central goals, and main tenets create a specific affinity between the characteristics of transdisciplinary approaches and particular types of societal issues and thematic domains. Yet, the four identified types of general methodological guidelines are shared across transdisciplinary approaches and domains.
- No one-fits-all solution: Acknowledging that there are no universally superior transdisciplinary approaches, the comparative framework we propose allows for the identification of strengths and complementarities among transdisciplinary approaches, and lays the ground for articulating different approaches to improve transdisciplinary practice.

7. REFERENCES

Albaek, E. (1995). Between knowledge and power: Utilization of social science in public policy making. Policy Sciences, 28(1), 79-100.

Amara, N., Ouimet, M., & Landry, R. (2004). New evidence on instrumental, conceptual, and symbolic utilization of university research in government agencies. Science communication, 26(1), 75-106.

Ansell, C., & Gash, A. (2008). Collaborative governance in theory and practice. Journal of public administration research and theory, 18(4), 543-571.

Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4), 959-975.

Aronowitz, S., & Giroux, H. A. (2000). The corporate university and the politics of education. In The educational forum (Vol. 64, No. 4, pp. 332-339). Taylor & Francis Group.

Ashforth, B. E., Kreiner, G. E., & Fugate, M. (2000). All in a day's work: Boundaries and micro role transitions. Academy of Management review, 25(3), 472-491.

Bandola-Gill, J., Arthur, M., & Leng, R. I. (2023). What is co-production? Conceptualising and understanding co-production of knowledge and policy across different theoretical perspectives. Evidence & Policy, 19(2), 275-298.

Bax, S. (2003). CALL—past, present and future. System, 31(1), 13-28.

Bellg, A. J., Borrelli, B., Resnick, B., Hecht, J., Minicucci, D. S., Ory, M., ... & Czajkowski, S. (2004). Enhancing treatment fidelity in health behavior change studies: best practices and recommendations from the NIH Behavior Change Consortium. Health psychology, 23(5), 443.

Berardi, G. (2002). Commentary on the challenge to change: Participatory research and professional realities. Society & Natural Resources, 15(9), 847-852.

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. Ecological applications, 10(5), 1251-1262.

Berkes, F. (2009). Evolution of co-management: role of knowledge generation, bridging organizations and social learning. Journal of environmental management, 90(5), 1692-1702.

Bertuol-Garcia, D., Morsello, C., N. El-Hani, C., & Pardini, R. (2018). A conceptual framework for understanding the perspectives on the causes of the science–practice gap in ecology and conservation. Biological Reviews, 93(2), 1032-1055.

Blicharska, M., Smithers, R. J., Kuchler, M., Agrawal, G. K., Gutiérrez, J. M., Hassanali, A., ... & Mikusiński, G. (2017). Steps to overcome the North–South divide in research relevant to climate change policy and practice. Nature Climate Change, 7(1), 21-27.

Bohensky, E. L., & Maru, Y. (2011). Indigenous knowledge, science, and resilience: What have we learned from a decade of international literature on "integration"?. Ecology and Society, 16(4).

Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landscape and urban planning, 97(3), 147-155.

Brandt, P., Ernst, A., Gralla, F., Luederitz, C., Lang, D. J., Newig, J., ... & Von Wehrden, H. (2013). A review of transdisciplinary research in sustainability science. Ecological economics, 92, 1-15.

Bullough Jr, R. V., & Pinnegar, S. (2001). Guidelines for quality in autobiographical forms of self-study research. Educational researcher, 30(3), 13-21.

Burns, D. (2007). Systemic action research: A strategy for whole system change. Policy.

Busch, L. (2017). Knowledge for sale: The neoliberal takeover of higher education. MIT Press.

Cahill, C. (2007). The personal is political: Developing new subjectivities through participatory action research. Gender, place and culture, 14(3), 267-292.

Carter-Edwards, L., Hurd, T. C., Rumala, B. B., & Wallerstein, N. (2013). A logic model for community engagement within the Clinical and Translational Science Awards consortium: can we measure what we model?. Academic Medicine, 88(10), 1430-1436.

Carter, N. M., & Silva, C. (2011). The myth of the ideal worker: Does doing all the right things really get women ahead? Catalyst.

Cash, D. W., & Moser, S. C. (2000). Linking global and local scales: designing dynamic assessment and management processes. Global environmental change, 10(2), 109-120.

Castleden, H., & Garvin, T. (2008). Modifying Photovoice for community-based participatory Indigenous research. Social science & medicine, 66(6), 1393-1405.

Chambers, R. (1994). The origins and practice of participatory rural appraisal. World development, 22(7), 953-969.

Chambers, J. M., Wyborn, C., Klenk, N. L., Ryan, M., Serban, A., Bennett, N. J., ... & Rondeau, R. (2022). Co-productive agility and four collaborative pathways to sustainability transformations. Global Environmental Change, 72, 102422.

Chevalier, J. M., & Buckles, D. J. (2013). Participatory action research: Theory and methods for engaged inquiry. Routledge.

Choi, B. C., & Pak, A. W. (2006). Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness. Clinical and investigative medicine, 29(6), 351.

Clemensen, J., Larsen, S. B., Kyng, M., & Kirkevold, M. (2007). Participatory design in health sciences: using cooperative experimental methods in developing health services and computer technology. Qualitative health research, 17(1), 122-130.

Coghlan, D. (2011). Action research: Exploring perspectives on a philosophy of practical knowing. Academy of Management Annals, 5(1), 53-87.

Collingridge, D., & Reeve, C. (1986) Science Speaks to Power: The Role of Experts in Policy Making. New York: St. Martin's Press.

Contandriopoulos, D., Lemire, M., Denis, J. L., & Tremblay, É. (2010). Knowledge exchange processes in organizations and policy arenas: a narrative systematic review of the literature. The Milbank Quarterly, 88(4), 444-483.

Coughlan, P., & Coghlan, D. (2002). Action research for operations management. International journal of operations & production management, 22(2), 220-240.

Collins, C. J., & Smith, K. G. (2006). Knowledge exchange and combination: The role of human resource practices in the performance of high-technology firms. Academy of management journal, 49(3), 544-560.

Collins, M., Knutti, R., Arblaster, J., Dufresne, J. L., Fichefet, T., Friedlingstein, P., ... & Wehner, M. (2013). Long-term climate change: projections, commitments and irreversibility.

Creswell, J. W., Hanson, W. E., Clark Plano, V. L., & Morales, A. (2007). Qualitative research designs: Selection and implementation. The counseling psychologist, 35(2), 236-264.

Cvitanovic, C., Hobday, A. J., van Kerkhoff, L., Wilson, S. K., Dobbs, K., & Marshall, N. A. (2015). Improving knowledge exchange among scientists and decision-makers to facilitate the adaptive governance of marine resources: a review of knowledge and research needs. Ocean & Coastal Management, 112, 25-35.

Darling-Hammond, L., & Snyder, J. (2000). Authentic assessment of teaching in context. Teaching and teacher education, 16(5-6), 523-545.

Davis, L. F., & Ramírez-Andreotta, M. D. (2021). Participatory research for environmental justice: a critical interpretive synthesis. Environmental health perspectives, 129(2), 026001.

Davison, K. K., & Lawson, C. T. (2006). Do attributes in the physical environment influence children's physical activity? A review of the literature. International journal of behavioral nutrition and physical activity, 3(1), 1-17.

Diele-Viegas, L. M., de Almeida, T. S., Amati-Martins, I., Bacon, C. D., Cassia-Silva, C., Collevatti, R. G., Murer, B. M. & Virginio, F. (2022). Community voices: sowing, germinating, flourishing as strategies to support inclusion in STEM. Nature Communications, 13(1), 3219.

Dilling, L., & Lemos, M. C. (2011). Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. Global environmental change, 21(2), 680-689.

Eden, C., & Huxham, C. (1996). Action research for management research. British Journal of management, 7(1), 75-86.

EDP - Elsevier Developer Portal. (2023). Retrieved from: https://dev.elsevier.com/support.html.

Eisinger, A., & Senturia, K. (2001). Doing community-driven research: a description of Seattle Partners for Healthy Communities. Journal of Urban Health, 78, 519-534.

Engle, N. L. (2011). Adaptive capacity and its assessment. Global environmental change, 21(2), 647-656.

Eriksson, N., Romar, J. E., & Dyson, B. (2017). The Action Research story of a student–teacher: Change is not easy and it takes time, effort, and critical reflection. IJAR–International Journal of Action Research, 13(1), 11-12.

Escobar, A. (1995). Encountering development: the making and unmaking of the third world. Princeton Studies in Culture/Power/History. Princeton University Press. Princeton. New Jersey.

Etzkowitz, H. (2003). Innovation in innovation: The triple helix of university-industry-government relations. Social science information, 42(3), 293-337.

Etzkowitz, H. (2008) The Triple Helix: University-Industry-Government Innovation in Action. Routledge, London and New York, 15. https://doi.org/10.4324/9780203929605

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. Research policy, 29(2), 109-123.

Etzkowitz, H., Webster, A., Gebhardt, C., & Terra, B. R. C. (2000). The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm. Research policy, 29(2), 313-330.

Fals-Borda, O., & Rahman, M. A. M. A. (1991). Action and knowledge: Breaking the monopoly with participatory action-research. (No Title).

Ferrer-Balas, D., Lozano, R., Huisingh, D., Buckland, H., Ysern, P., & Zilahy, G. (2010). Going beyond the rhetoric: system-wide changes in universities for sustainable societies. Journal of Cleaner Production, 18(7), 607-610.

Fiordelisi, M. F., Cavaliere, C., Auletta, L., Basso, L., & Salvatore, M. (2019). Magnetic resonance imaging for translational research in oncology. Journal of clinical medicine, 8(11), 1883.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., & Walker, B. (2002). Resilience and sustainable development: building adaptive capacity in a world of transformations. AMBIO: A journal of the human environment, 31(5), 437-440.

Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L., & Holling, C. S. (2004). Regime shifts, resilience, and biodiversity in ecosystem management. Annu. Rev. Ecol. Evol. Syst., 35, 557-581.

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. Global environmental change, 16(3), 253-267.

Folke, C. (2016). Resilience (Republished). Ecology and Society, 21(4), 44. https://doi.org/10.5751/ES-09088-210444.

Folke, C., Biggs, R., Norström, A. V., Reyers, B., & Rockström, J. (2016). Social-ecological resilience and biosphere-based sustainability science. Ecology and Society, 21(3).

Freire, P. (1971). Pedagogia do oprimido. Rio de Janeiro: Paz e Terra.

Funtowicz, S. O., & Ravetz, J. R. (1993). Science for the post-normal age. Futures, 25(7), 739-755.

Füssel, H. M. (2007). Vulnerability: A generally applicable conceptual framework for climate change research. Global environmental change, 17(2), 155-167.

Galeano, E. (2010). As veias abertas da América Latina. L&PM Editores.

Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. Global environmental change, 16(3), 293-303.

Gardner, T. A., Ferreira, J., Barlow, J., Lees, A. C., Parry, L., Vieira, I. C. G., ... & Zuanon, J. (2013). A social and ecological assessment of tropical land uses at multiple scales: the Sustainable Amazon Network. Philosophical Transactions of the Royal Society B: Biological Sciences, 368(1619), 20120166.

Gephi - The Open Graph Viz Platform. (2023). Retrieved from: https://gephi.org/.

Gerlak, A. K., Guido, Z., Owen, G., McGoffin, M. S. R., Louder, E., Davies, J., ... & Joshi, N. (2023). Stakeholder engagement in the co-production of knowledge for environmental decision-making. World Development, 170, 106336.

Giatti, L. L. (2019). Participatory research in the post-normal age: unsustainability and uncertainties to Rethink Paulo Freire's Pedagogy of the Oppressed. Springer Nature.

Gilliland, C. T., White, J., Gee, B., Kreeftmeijer-Vegter, R., Bietrix, F., Ussi, A. E., & Austin, C. P. (2019). The fundamental characteristics of a translational scientist. ACS Pharmacology & Translational Science, 2(3), 213-216.

Giuliani, E. (2007). The selective nature of knowledge networks in clusters: evidence from the wine industry. Journal of economic geography, 7(2), 139-168.

Gorelick, P. B., Scuteri, A., Black, S. E., DeCarli, C., Greenberg, S. M., Iadecola, C., ... & Seshadri, S. (2011). Vascular contributions to cognitive impairment and dementia: a statement for healthcare professionals from the American Heart Association/American Stroke Association. stroke, 42(9), 2672-2713.

Gower, J. C. (2014). Principal coordinates analysis. Wiley StatsRef: statistics reference online, 1-7.

Graham, I. D., Logan, J., Harrison, M. B., Straus, S. E., Tetroe, J., Caswell, W., & Robinson, N. (2006). Lost in knowledge translation: time for a map?. Journal of continuing education in the health professions, 26(1), 13-24.

Gray, B. (2008). Enhancing transdisciplinary research through collaborative leadership. American journal of preventive medicine, 35(2), S124-S132.

Green, S. B. (2015). Can animal data translate to innovations necessary for a new era of patient-centred and individualised healthcare? Bias in preclinical animal research. BMC medical ethics, 16, 1-14.

Guyatt, G. H. (2000). Users' Guide to the Medical Literature. XXV. Evidence-Based Medicine: Principles for applying the users' guides to patient care. JAMA, 284, 1290-1296.

Gunderson, L. H. (2000). Ecological resilience—in theory and application. Annual review of ecology and systematics, 31(1), 425-439.

Guston, D. H. (2001). Boundary organizations in environmental policy and science: an introduction. Science, technology, & human values, 26(4), 399-408.

György, B., Szabó, T. G., Pásztói, M., Pál, Z., Misják, P., Aradi, B., ... & Buzás, E. I. (2011). Membrane vesicles, current state-of-the-art: emerging role of extracellular vesicles. Cellular and molecular life sciences, 68, 2667-2688.

Hall, B. L., & Tandon, R. (2017). Decolonization of knowledge, epistemicide, participatory research and higher education. Res. All, 1, pp. 6-19, 10.18546/RFA.01.1.02

Hansen, M. T. (2002). Knowledge networks: Explaining effective knowledge sharing in multiunit companies. Organization science, 13(3), 232-248.

Harris, P. A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., & Conde, J. G. (2009). Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. Journal of biomedical informatics, 42(2), 377-381.

Harris, P. A., Taylor, R., Minor, B. L., Elliott, V., Fernandez, M., O'Neal, L., ... & Duda, S. N. (2019). The REDCap consortium: building an international community of software platform partners. Journal of biomedical informatics, 95, 103208.

Hekkert, M. P., Suurs, R. A., Negro, S. O., Kuhlmann, S., & Smits, R. E. (2007). Functions of innovation systems: A new approach for analysing technological change. Technological forecasting and social change, 74(4), 413-432.

Hergenrather, K. C., Rhodes, S. D., Cowan, C. A., Bardhoshi, G., & Pula, S. (2009). Photovoice as community-based participatory research: A qualitative review. American journal of health behavior, 33(6), 686-698.

Hessels, L. K., & Van Lente, H. (2008). Re-thinking new knowledge production: A literature review and a research agenda. Research policy, 37(4), 740-760.

Hitt, M. A., Beamish, P. W., Jackson, S. E., & Mathieu, J. E. (2007). Building theoretical and empirical bridges across levels: Multilevel research in management. Academy of Management journal, 50(6), 1385-1399.

Holter, I. M., & Schwartz-Barcott, D. (1993). Action research: what is it? How has it been used and how can it be used in nursing?. Journal of advanced nursing, 18(2), 298-304.

Horowitz, C. R., Robinson, M., & Seifer, S. (2009). Community-based participatory research from the margin to the mainstream: are researchers prepared?. Circulation, 119(19), 2633-2642.

Hulme, P. E. (2014). Bridging the knowing-doing gap: know-who, know-what, know-why, know-how and know-when. J. Appl. Ecol., 51, pp. 1131-1136, 10.1111/1365-2664.12321.

Hyland, K. (2007). Genre pedagogy: Language, literacy and L2 writing instruction. Journal of second language writing, 16(3), 148-164.

Israel, B. A., Schulz, A. J., Parker, E. A., & Becker, A. B. (1998). Review of community-based research: assessing partnership approaches to improve public health. Annual review of public health, 19(1), 173-202.

Israel, B. A., Schulz, A. J., Parker, E. A., & Becker, A. B. (2001). Community-based participatory research: policy recommendations for promoting a partnership approach in health research. Education for health, 14(2), 182-197.

Jacquez, F., Vaughn, L. M., & Wagner, E. (2013). Youth as partners, participants or passive recipients: A review of children and adolescents in community-based participatory research (CBPR). American journal of community psychology, 51, 176-189.

Jahn, T., Bergmann, M., & Keil, F. (2012). Transdisciplinarity: Between mainstreaming and marginalization. Ecological economics, 79, 1-10.

Jakeman, A. J., Letcher, R. A., & Norton, J. P. (2006). Ten iterative steps in development and evaluation of environmental models. Environmental Modelling & Software, 21(5), 602-614.

Kellogg, K. C., Orlikowski, W. J., & Yates, J. (2006). Life in the trading zone: Structuring coordination across boundaries in postbureaucratic organizations. Organization science, 17(1), 22-44.

Kelly, R. A., Jakeman, A. J., Barreteau, O., Borsuk, M. E., ElSawah, S., Hamilton, S. H., ... & Voinov, A. A. (2013). Selecting among five common modelling approaches for integrated environmental assessment and management. Environmental modelling & software, 47, 159-181.

Kemmis, S., McTaggart, R., & Retallick, J. (2004). The Action Research Planner (revised). Aga Khan University. Institute for Educational Development, Karachi.

Kitcher, P. (2003). In Mendel's mirror: Philosophical reflections on biology. Oxford University Press.

Klavans, R.; & Boyack, K. W. (2016). Which type of citation analysis generates the most accurate taxonomy of scientific and technical knowledge? Journal of the Association for Information Science and Technology, 68(4), 984–998.

Kloprogge, P., & Sluijs, J. P. V. D. (2006). The inclusion of stakeholder knowledge and perspectives in integrated assessment of climate change. Climatic Change, 75(3), 359-389.

Knapp, C. N., Reid, R. S., Fernández-Giménez, M. E., Klein, J. A., & Galvin, K. A. (2019). Placing transdisciplinarity in context: A review of approaches to connect scholars, society and action. Sustainability, 11(18), 4899.

Koller, S. H. (2019). Internationalization and knowledge visibility of psychological science. Annals of Medicine, 51(sup1), 23-23.

Kremen, C. (2005). Managing ecosystem services: what do we need to know about their ecology?. Ecology letters, 8(5), 468-479.

Kremen, C., Williams, N. M., Aizen, M. A., Gemmill-Herren, B., LeBuhn, G., Minckley, R., ... & Ricketts, T. H. (2007). Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. Ecology letters, 10(4), 299-314.

Krenak, A. (2019). Ideias para adiar o fim do mundo (Nova edição). Editora Companhia das Letras.

Kurtz, C. F., & Snowden, D. J. (2003). The new dynamics of strategy: Sense-making in a complex and complicated world. IBM systems journal, 42(3), 462-483.

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., ... & Thomas, C. J. (2012). Transdisciplinary research in sustainability science: practice, principles, and challenges. Sustainability science, 7, 25-43.

Laniak, G. F., Olchin, G., Goodall, J., Voinov, A., Hill, M., Glynn, P., ... & Hughes, A. (2013). Integrated environmental modeling: a vision and roadmap for the future. Environmental modelling & software, 39, 3-23.

Latour, B., & Weibel, P. (2005). Making things public: Atmospheres of democracy.

Lee, K. N. (2001). Appraising adaptive management. In Biological diversity (pp. 3-26). CRC Press.

Leifer, R., & Delbecq, A. (1978). Organizational/environmental interchange: A model of boundary spanning activity. Academy of Management Review, 3(1), 40-50.

Leung, M. W., Yen, I. H., & Minkler, M. (2004). Community based participatory research: a promising approach for increasing epidemiology's relevance in the 21st century. International journal of epidemiology, 33(3), 499-506.

Levina, N., & Vaast, E. (2005). The emergence of boundary spanning competence in practice: Implications for implementation and use of information systems. MIS quarterly, 335-363.

Levin, D. Z., & Cross, R. (2004). The strength of weak ties you can trust: The mediating role of trust in effective knowledge transfer. Management science, 50(11), 1477-1490.

Lewin, K. (1946). Action Research and Minority Problems. Journal of Social Issues 2(4): 34–46.

Lewin, K. (1947). Frontiers in group dynamics: II. Channels of group life; social planning and action research. Human relations, 1(2), 143-153.

Leydesdorff, L., & Etzkowitz, H. (1996). Emergence of a Triple Helix of university—industry—government relations. Science and public policy, 23(5), 279-286.

Libby, P., Ridker, P. M., & Hansson, G. K. (2011). Progress and challenges in translating the biology of atherosclerosis. Nature, 473(7347), 317-325.

Lingard, L., Albert, M., & Levinson, W. (2008). Grounded theory, mixed methods, and action research. Bmj, 337.

Lubchenco, J. (1998). Entering the century of the environment: a new social contract for science. Science, 279(5350), 491-497.

Ludwig, D., El-Hani, C., Gatti, F., Kendig, C., Kramm, M., Neco, L., Delgado, A. N., Poliseli, L., Renck, V., Ressiore, A., Galindo, L. R., Rickard, T. L., De La Rosa, G., Turska, J. J., Vergara-Silva, F. & Wilson, R. (2023). Transdisciplinary Philosophy of Science: Meeting the Challenge of Indigenous Expertise.

Mamlok-Naaman, R., & Eilks, I. (2012). Different types of action research to promote chemistry teachers' professional development—a joined theoretical reflection on two cases from Israel and Germany. International Journal of Science and Mathematics Education, 10, 581-610.

Mardero, S., Schmook, B., Calmé, S., White, R. M., Chang, J. C. J., Casanova, G., & Castelar, J. (2023). Traditional knowledge for climate change adaptation in Mesoamerica: A systematic review. Social Sciences & Humanities Open, 7(1), 100473.

Martin, A., & Sherington, J. (1997). Participatory research methods—implementation, effectiveness and institutional context. Agricultural systems, 55(2), 195-216.

Max-Neef, M. A. (2005). Foundations of transdisciplinarity. Ecological economics, 53(1), 5-16.

McGlade, C., & Ekins, P. (2015). The geographical distribution of fossil fuels unused when limiting global warming to 2 C. Nature, 517(7533), 187-190.

McGonigle, P., & Ruggeri, B. (2014). Animal models of human disease: challenges in enabling translation. Biochemical pharmacology, 87(1), 162-171.

McNie, E. C. (2007). Reconciling the Supply of Scientific Information with User Demands: An Analysis of the Problem and Review of the Literature. Environmental Science & Policy 10(1): 17–38.

Meinshausen, M., Smith, S. J., Calvin, K., Daniel, J. S., Kainuma, M. L., Lamarque, J. F., ... & van Vuuren, D. P. (2011). The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. Climatic change, 109, 213-241.

Mendenhall, T. J., Doherty, W. J., Berge, J. M., Fauth, J. M., & Tremblay, G. C. (2013). Community-Based Participatory Research: Advancing Integrated Behavioral Health Care Through Novel Partnerships. Integrated behavioral health in primary care: Evaluating the evidence, identifying the essentials, 99-130.

Metcalf, H., Russell, D. & Hill, C. (2018). Broadening the science of broadening participation in STEM through critical mixed methodologies and intersectionality frameworks. Am. Behav. Scientist 62, 580–599.

Meyer, J. (2000). Using qualitative methods in health related action research. Bmj, 320(7228), 178-181.

Mies, M., & Shiva, V. (1998). La praxis del ecofeminismo: biotecnología, consumo y reproducción (Vol. 128). Icaria Editorial.

Millar, C. I., Stephenson, N. L., & Stephens, S. L. (2007). Climate change and forests of the future: managing in the face of uncertainty. Ecological applications, 17(8), 2145-2151.

Mohan, G., & Stokke, K. (2000). Participatory development and empowerment: the dangers of localism. Third world quarterly, 21(2), 247-268.

Morgan, K. (2004). The exaggerated death of geography: learning, proximity and territorial innovation systems. Journal of economic geography, 4(1), 3-21.

Morgan, M. G., & Dowlatabadi, H. (1996). Learning from integrated assessment of climate change. Climatic change, 34(3-4), 337-368.

Mullane, K., Winquist, R. J., & Williams, M. (2014). Translational paradigms in pharmacology and drug discovery. Biochemical Pharmacology, 87(1), 189-210.

Murer, B. M., Machado, A. R., & Pivello, V. R. Guia para planos de manejo de parques naturais municipais brasileiros. Goiania - GO: Editora Espaço Acadêmico, 2018.

Myers, M. D. (1997). Critical ethnography in information systems. In Information Systems and Qualitative Research: Proceedings of the IFIP TC8 WG 8.2 International Conference on Information Systems and Qualitative Research, 31st May–3rd June 1997, Philadelphia, Pennsylvania, USA (pp. 276-300). Boston, MA: Springer US.

Nature. (2018). Power to the people. Nature, 562, p. 7

Neff, M. W. (2020). How academic science gave its soul to the publishing industry. Issues in science and technology, 36(2), 35-43.

Nelson, D. R., Adger, W. N., & Brown, K. (2007). Adaptation to environmental change: contributions of a resilience framework. Annu. Rev. Environ. Resour., 32, 395-419.

Ness, B., Urbel-Piirsalu, E., Anderberg, S., & Olsson, L. (2007). Categorising tools for sustainability assessment. Ecological economics, 60(3), 498-508.

Nilsen, P. (2015). Making sense of implementation theories, models, and frameworks. Implementation Science 3.0, 53-79.

Noffke, S. E. (1997). Chapter 6: Professional, personal, and political dimensions of action research. Review of research in education, 22(1), 305-343.

Norström, A. V., Cvitanovic, C., Löf, M. F., West, S., Wyborn, C., Balvanera, P., ... & Österblom, H. (2020). Principles for knowledge co-production in sustainability research. Nature sustainability, 3(3), 182-190.

Nutley, S. M., Walter, I., & Davies, H. T. (2007). Improving research use in practice contexts. In Using evidence (pp. 195-230). Policy Press.

Olsson, P., Folke, C., & Berkes, F. (2004). Adaptive comanagement for building resilience in social–ecological systems. Environmental management, 34, 75-90.

Olsson, P., Gunderson, L. H., Carpenter, S. R., Ryan, P., Lebel, L., Folke, C., & Holling, C. S. (2006). Shooting the rapids: navigating transitions to adaptive governance of social-ecological systems. Ecology and society, 11(1).

Owen-Smith, J., & Powell, W. W. (2004). Knowledge networks as channels and conduits: The effects of spillovers in the Boston biotechnology community. Organization science, 15(1), 5-21.

Pace, R., Pluye, P., Bartlett, G., Macaulay, A. C., Salsberg, J., Jagosh, J., & Seller, R. (2012). Testing the reliability and efficiency of the pilot Mixed Methods Appraisal Tool (MMAT) for systematic mixed studies review. International journal of nursing studies, 49(1), 47-53.

Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. Global environmental change, 19(3), 354-365.

Pain, R. (2004). Social geography: participatory research. Progress in human geography, 28(5), 652-663.

Parra Vázquez, M. R., Arce Ibarra, M., Bello Baltazar, E., & Gomes de Araujo, L. (2020). Local Socio-Environmental Systems as a Transdisciplinary Conceptual Framework. Socio-Environmental Regimes and Local Visions: Transdisciplinary Experiences in Latin America, 3-24.

Pardini, R., Bertuol-Garcia, D., Araújo, B. D., Mesquita, J. P., Murer, B. M., do Carmo Pônzio, M., ... & Prado, P. I. (2021). COVID-19 pandemic as a learning path for grounding conservation policies in science. Perspectives in Ecology and Conservation, 19(2), 109-114.

Parkin, P. (2009). Managing change in healthcare: Using action research. Managing Change in Healthcare, 1-248.

Pham, J., & Pelletier, D. (2015). Action-oriented population nutrition research: high demand but limited supply. Global Health: Science and Practice, 3(2), 287-299.

Pine, G. J. (2009). Teacher action research: Building knowledge democracies. Sage.

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. Journal of educational Psychology, 95(4), 667.

Pullin, A. S., & Knight, T. M. (2001). Effectiveness in conservation practice: pointers from medicine and public health. Conservation biology, 15(1), 50-54.

Quijano, A. (2000). Colonialidad del poder, eurocentrismo y América Latina (Vol. 13). Buenos Aires: clacso.

Redfern, W. S., Carlsson, L., Davis, A. S., Lynch, W. G., MacKenzie, I. L., Palethorpe, S., ... & Hammond, T. G. (2003). Relationships between preclinical cardiac electrophysiology, clinical QT interval prolongation and torsade de pointes for a broad range of drugs: evidence for a provisional safety margin in drug development. Cardiovascular research, 58(1), 32-45.

Reidsma, P., Ewert, F., Lansink, A. O., & Leemans, R. (2010). Adaptation to climate change and climate variability in European agriculture: the importance of farm level responses. European journal of agronomy, 32(1), 91-102.

Reyers, B., Roux, D. J., Cowling, R. M., Ginsburg, A. E., Nel, J. L., & FARRELL, P. O. (2010). Conservation planning as a transdisciplinary process. Conservation biology, 24(4), 957-965.

Reyes-García, V., & Benyei, P. (2019). Indigenous knowledge for conservation. Nature Sustainability, 2(8), 657-658.

Riahi, K., Rao, S., Krey, V., Cho, C., Chirkov, V., Fischer, G., ... & Rafaj, P. (2011). A scenario of comparatively high greenhouse gas emissions. Climatic change, 109, 33-57.

Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. Policy sciences, 4(2), 155-169.

Roberts, N. (2000). Wicked problems and network approaches to resolution. International public management review, 1(1), 1-19.

Rocha, P. L. B. D., Pardini, R., Viana, B. F., & El-Hani, C. N. (2020). Fostering inter-and transdisciplinarity in discipline-oriented universities to improve sustainability science and practice. Sustainability Science, 15, 717-728.

Rosenfield, P. L. (1992). The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. Social science & medicine, 35(11), 1343-1357.

Rosenkopf, L., & Nerkar, A. (2001). Beyond local search: boundary-spanning, exploration, and impact in the optical disk industry. Strategic management journal, 22(4), 287-306.

Rosenlund, J., Rosell, E., & Hogland, W. (2017). Overcoming the triple helix boundaries in an environmental research collaboration. Science and Public Policy, 44(2), 153-162.

Ross, J., Stevenson, F., Lau, R., & Murray, E. (2016). Factors that influence the implementation of e-health: a systematic review of systematic reviews (an update). Implementation science, 11(1), 1-12.

Rotmans, J., Kemp, R., & Van Asselt, M. (2001). More evolution than revolution: transition management in public policy. foresight, 3(1), 15-31.

Rowe, G., & Frewer L. J. (2005). A Typology of Public Engagement Mechanisms. Science, Technology, & Human Values 30(2): 251–90.

Saban, A. (2021). Curriculum development through action research: A model proposal for practitioners. Pegem Egitim ve Ogretim Dergisi, 11 (1).

Sackett, D. L., Rosenberg, W. M., Gray, J. M., Haynes, R. B., & Richardson, W. S. (1996). Evidence based medicine: what it is and what it isn't. Bmj, 312(7023), 71-72.

Sallis, J. F. (2006). An ecological approach to creating active living communitied. Annu Rev Public Health, 27, 297-322.

Sarewitz, D. (2004). How science makes environmental controversies worse. Environ. Sci. Policy, 7, pp. 385-403, 10.1016/j.envsci.2004.06.001

Sarewitz, D. (2015). Science can’t solve it. Nature, 522, pp. 413-414, 10.1038/522413a

Sarewitz, D., & Pielke Jr, R. A. (2007). The neglected heart of science policy: reconciling supply of and demand for science. environmental science & policy, 10(1), 5-16.

Scholz, R. W., & Binder C. R. (2011). Environmental Literacy in Science and Society: From Knowledge to Decisions. Cambridge; New York: Cambridge University Press.

Scholz, R. W., & Steiner G. (2015). The real type and ideal type of transdisciplinary processes: Part I-theoretical foundations. Sustainability Science 10(Nr.4): 527–44.

Scholz, R. W. (2020). Transdisciplinarity: science for and with society in light of the university’s roles and functions. Sustainability science, 15, 1033-1049.

Shinn, T. (2002). The triple helix and new production of knowledge: prepackaged thinking on science and technology. Social studies of science, 32(4), 599-614.

Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., ... & Bonney, R. (2012). Public participation in scientific research: a framework for deliberate design. Ecology and society, 17(2).

Shiva, V. (2005). Earth democracy: Justice, sustainability and peace. Zed Books.

Shiva, V. (2016). Staying alive: Women, ecology, and development. North Atlantic Books.

Shultz, L. D., Ishikawa, F., & Greiner, D. L. (2007). Humanized mice in translational biomedical research. Nature Reviews Immunology, 7(2), 118-130.

Singh, V. K., Singh, P., Karmakar, M., Leta, J., & Mayr, P. (2021). The journal coverage of Web of Science, Scopus and Dimensions: A comparative analysis. Scientometrics, 126, 5113-5142.

Smith, A., Stirling, A., & Berkhout, F. (2005). The governance of sustainable socio-technical transitions. Research policy, 34(10), 1491-1510.

Schneider, S. H. (1997). Integrated assessment modeling of global climate change: Transparent rational tool for policy making or opaque screen hiding value-laden assumptions?. Environmental Modeling & Assessment, 2, 229-249.

Seok, J., Warren, H. S., Cuenca, A. G., Mindrinos, M. N., Baker, H. V., Xu, W., ... & Wong, W. H. (2013). Genomic responses in mouse models poorly mimic human inflammatory diseases. Proceedings of the National Academy of Sciences, 110(9), 3507-3512.

Somekh, B., & Zeichner, K. (2009). Action research for educational reform: Remodelling action research theories and practices in local contexts. Educational action research, 17(1), 5-21.

Spruijt, P.; Knol, A. B.; Vasileiadou, E.; Devilee, J.; Lebret, E.; & Petersen, A. C. (2014). Roles of scientists as policy advisers on complex issues: a literature review. Environmental Science & Policy, 40, 16-25.

Straub, D. W., & Welke, R. J. (1998). Coping with systems risk: Security planning models for management decision making. MIS quarterly, 441-469.

Stokols, D., Harvey, R., Gress, J., Fuqua, J., & Phillips, K. (2005). In vivo studies of transdisciplinary scientific collaboration: Lessons learned and implications for active living research. American journal of preventive medicine, 28(2), 202-213.

Stokols, D., Misra, S., Moser, R. P., Hall, K. L., & Taylor, B. K. (2008). The ecology of team science: understanding contextual influences on transdisciplinary collaboration. American journal of preventive medicine, 35(2), S96-S115.

Teixeira, A. S. (1988). Educação e universidade. Rio de Janeiro: Editora UFRJ.

Tress, B., Tress, G., & Fry, G. (2005). Defining concepts and the process of knowledge production in integrative research. From landscape research to landscape planning: Aspects of integration, education and application, 12, 13-26.

Tripp, D. (2005). Action Research: a methodological introduction. Research and Education, 31(3), 443-466.

Turnhout, E., Metze, T., Wyborn, C., Klenk, N., & Louder, E. (2020). The politics of co-production: participation, power, and transformation. Current Opinion in Environmental Sustainability, 42, 15-21.

Van der Worp, H. B., Howells, D. W., Sena, E. S., Porritt, M. J., Rewell, S., O'Collins, V., & Macleod, M. R. (2010). Can animal models of disease reliably inform human studies?. PLoS medicine, 7(3), e1000245.

van Driel, J. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. In Science Teachers' Knowledge Development (pp. 38-72). Brill.

van Gemert-Pijnen, J. E., Nijland, N., van Limburg, M., Ossebaard, H. C., Kelders, S. M., Eysenbach, G., & Seydel, E. R. (2011). A holistic framework to improve the uptake and impact of eHealth technologies. Journal of medical Internet research, 13(4), e1672.

Van Vuuren, D. P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., ... & Rose, S. K. (2011). The representative concentration pathways: an overview. Climatic change, 109, 5-31.

Vermeulen, S. J., Campbell, B. M., & Ingram, J. S. (2012). Climate change and food systems. Annual review of environment and resources, 37, 195-222.

Vincenot, C. E. (2018). How new concepts become universal scientific approaches: insights from citation network analysis of agent-based complex systems science. Proceedings of the Royal Society B: Biological Sciences, 285 (1874), 20172360.

Visser, M. S., van Eck, N. J. & Waltman, L. (2020). Large-scale comparison of bibliographic data sources: Web of Science, Scopus, Dimensions, Crossref, and Microsoft Academic. Retrieved from https://arxiv.org/abs/2005.10732.

Walker, B., & Salt, D. (2012). Resilience thinking: sustaining ecosystems and people in a changing world. Island press.

Wallerstein, N., & Duran, B. (2010). Community-based participatory research contributions to intervention research: the intersection of science and practice to improve health equity. American journal of public health, 100(S1), S40-S46.

Wang, C. C. (1999). Photovoice: A participatory action research strategy applied to women's health. Journal of women's health, 8(2), 185-192.

Wasko, M. M., & Faraj, S. (2000). It is what one does: why people participate and help others in electronic communities of practice. The journal of strategic information systems, 9(2-3), 155-173.

Whitehead, D., Taket, A., & Smith, P. (2003). Action research in health promotion. Health Education Journal, 62(1), 5-22.

Whyte, W. F. (1989). Advancing scientific knowledge through participatory action research. In Sociological forum (Vol. 4, pp. 367-385). Kluwer Academic Publishers-Plenum Publishers.

Wiesel, E. (1999). The perils of indifference. Speech given at the White House on Apr, 12.

Williamson, G. R., Bellman, L., & Webster, J. (2012). Action research in nursing and healthcare. Action Research in Nursing and Healthcare, 51-65.

Woolf, S. H. (2008). The meaning of translational research and why it matters. Jama, 299(2), 211-213.

Xia, Y. (2020). Correlation and association analyses in microbiome study integrating multiomics in health and disease. Progress in molecular biology and translational science, 171, 309-491.

Xu, L., & Kajikawa, Y. (2018). An integrated framework for resilience research: a systematic review based on citation network analysis. Sustainability Science, 13, 235-254.

Yamada, K. M., & Cukierman, E. (2007). Modeling tissue morphogenesis and cancer in 3D. Cell, 130(4), 601-610.

Yang, K., & Meho, L. I. (2006). Citation analysis: a comparison of Google Scholar, Scopus, and Web of Science. Proceedings of the American Society for Information Science and Technology, 43(1), 1–15.

Yang, Z., Algesheimer, R., & Tessone, C. J. (2016). A comparative analysis of community detection algorithms on artificial networks. Scientific reports, 6(1), 1-18.

Yström, A., Agogué, M., & Rampa, R. (2021). Preparing an Organization for Sustainability Transitions—The Making of Boundary Spanners through Design Training. Sustainability, 13(14), 8073.

Zietsma, C., & Lawrence, T. B. (2010). Institutional work in the transformation of an organizational field: The interplay of boundary work and practice work. Administrative science quarterly, 55(2), 189-221.

Zhu, K., & Kraemer, K. L. (2005). Post-adoption variations in usage and value of e-business by organizations: cross-country evidence from the retail industry. Information systems research, 16(1), 61-84.

APPENDIX A - Identifying the terms used to name potential transdisciplinary approaches and searching for published definitions to check if they fulfill the criteria to be considered transdisciplinary

We identified the established terms naming transdisciplinary-related approaches from our knowledge, scientific literature reviews, glossaries, and an active search on publication databases. Specifically, we followed the steps:

a) searching in scientific reviews related to transdisciplinarity - the consulted reviews were McNie (2007), Knapp et al. (2019), Scholz & Steiner (2015) and Scholz (2017), Jahn et al. (2012), and Rowe & Fewer (2005);
b) conducting a search in Scopus with the term "transdisciplinary" but excluding the terms naming transdisciplinary approaches we already had. The search was:
(TITLE-ABS-KEY(transdisciplinar* AND NOT ("actionable science" OR "action research" OR "adaptive management" OR "boundary management" OR "boundary organizations" OR "boundary spanning" OR "citizen juries" OR "citizen science" OR "civic science" OR "co-research" OR "collaborative decision making" OR "community participatory research" OR "community research" OR "community science" OR "community-based initiatives" OR "community-based natural resource management" OR "community-based research" OR "consensus conferences" OR "consultative panels" OR "deliberative polling" OR "feminist research methods" OR "integrated resource management" OR "knowledge-action collaboratives" OR "knowledge-action system" OR "mode 2 knowledge" OR "mode 2 science" OR "participatory development" OR "participatory planning processes" OR "participatory research" OR "participatory resource management" OR "post-normal science" OR "public ecology" OR "scenario workshops" OR "science shops" OR "socially robust, transparent and participative approach" OR "span the boundaries" OR "team science" OR "transformative science" OR "transition management" OR "translational science" OR "triple-helix" OR "usable science" OR "use-inspired research" OR "well ordered science")))
c) identifying transdisciplinary-related approaches in publications we consulted to obtain the definitions of each approach (see below).

Then, we searched for published definitions of each approach to check if they fulfill the criteria we created to consider an approach transdisciplinary (see main text). The definitions of each approach were obtained from different sources:

a) the definition presented in the publication used to identify the terms used to name transdisciplinary approaches (see above), as most of the terms came from reviews in which the approach is defined and compared to others. However, sometimes the approach is cited but not defined in these publications;

b) the definition presented in a reference cited in the publication used to identify the terms used to name transdisciplinary approaches (see above). Yet, sometimes these publications do not define nor cite any references of the approach;

c) the definition presented in the glossary of the book from Scholz & Binder (2011), an important reference of transdisciplinary, when available;

d) the definition presented in English Wikipedia, when available, as it is a relevant public source and sometimes one of the few that brings a precise definition of the approaches;

e) the definition found in publications from the search of the term in Scopus or in Google - this was done only if definitions found in previous steps were not enough to identify if the approach matches the three criteria defining a transdisciplinary approach.

REFERENCES

Jahn, T., Bergmann, M., & Keil, F. (2012). Transdisciplinarity: Between mainstreaming and marginalization. Ecological economics, 79, 1-10.

McNie, E. C. (2007). Reconciling the Supply of Scientific Information with User Demands: An Analysis of the Problem and Review of the Literature. Environmental Science & Policy 10(1): 17–38.

Knapp, C. N., Reid, R. S., Fernández-Giménez, M. E., Klein, J. A., & Galvin, K. A. (2019). Placing transdisciplinarity in context: A review of approaches to connect scholars, society and action. Sustainability, 11(18), 4899.

Rowe, G., & Frewer, L. J. (2005). A Typology of Public Engagement Mechanisms. Science, Technology, & Human Values 30(2): 251–90.

Scholz, R. W., & Binder C. R. (2011). Environmental Literacy in Science and Society: From Knowledge to Decisions. Cambridge; New York: Cambridge University Press.

Scholz, R. W., & Steiner G. (2015). The real type and ideal type of transdisciplinary processes: Part I-theoretical foundations. Sustainability Science 10(Nr.4): 527–44.

Scholz, R. (2017). The Normative Dimension in Transdisciplinarity, Transition Management, and Transformation Sciences: New Roles of Science and Universities in Sustainable Transitioning. Sustainability 9(6): 991.

APPENDIX B - Terms used to name transdisciplinary approaches

List of approaches considered transdisciplinary (definitions fulfill our three criteria)

1. action oriented research / action oriented knowledge
2. action research
3. actionable knowledge
4. actionable science
5. adaptive management
6. boundary organizations
7. boundary spanning
8. boundary work
9. citizen juries
10. civic science
11. community based participatory research
12. community based research
13. community driven research / community driven knowledge / community driven science
14. community engaged research
15. community research
16. community science
17. coproduction of knowledge
18. coresearch
19. deliberative polling
20. integrated assessments
21. integrated natural resource management
22. integrated resource management
23. integration sciences / integration researches
24. integrative research / integrative sciences
25. knowledge action collaboratives
26. knowledge action system
27. knowledge exchange
28. Knowledge networks
29. knowledge transfer and exchange
30. mode 2 knowledge
31. mode 2 science
32. participatory consensus conferences / danish consensus conferences
33. participatory development
34. participatory research
35. participatory resource management
36. participatory team science
37. participatory technology assessment
38. post-normal science
39. public ecology
40. scenario workshops
41. science based stakeholder dialogues
42. science policy dialogues
43. science shops
44. socially robust knowledge
45. span the boundaries
46. transdisciplinarity
47. transformative science
48. transition management

49. translational ecology
50. translational science / translational research
51. triple-helix
52. usable science
53. use inspired science / user inspired science / use driven science / user driven science
54. use inspired research
55. well ordered science

<u>List of approaches investigated but excluded with a justification for the exclusion</u>

56. boundary management

Boundary management was excluded because the only source that defined it as related to transdisciplinarity is McNie (2007). In every other searched source, the term is related to publications in psychology to mean the management of boundaries within individuals. Besides, we understand McNie (2007) used boundary management as a synonym of 'boundary negotiation', which is associated with “boundary organization”, an approach we included.

57. citizen science

The citizen science approach was excluded because, although sometimes the term refers to a horizontal and influential sharing of knowledge, and focus on real-world problems, these aspects are not at the essence of the approach, which sometimes focus on having citizens collecting data and on getting the public familiarized with science. In this sense, criteria B and C may or may not be - and, therefore, not always are - fulfilled.

58. collaborative decision making

Collaborative decision making was excluded because it may or may not - and, therefore, not always - fulfills criterion B. Although it can be applied in the context of risk and to build logistics in the context of disasters or in the context of policies, economic actions, and assessments of alternatives for sustainable development, it can be used in any context. Besides, the approach does not fulfill criterion C clearly, as scientists not necessarily are involved (thus, even if iterative influential sharing may occur between participants, it is not clear that these include scientists or scientific knowledge).

59. community based initiatives

Community based initiatives (CBI) approach was excluded as it may or may not fulfill criterion C, as scientists or scientific knowledge is not mentioned as required in the process (Igalla et al., 2019).

60. community of practice

Community of practice was excluded because it may or may not - and, therefore, not always - fulfills criterion C, as scientists (scientific knowledge) are not necessarily included.

61. community based natural resource management

Community based natural resource management was excluded as the approach may or may not - and, therefore, not always - fulfills criterion C, as scientific knowledge is not mentioned.

62. consensus conferences

Following Scholz & Binder (2011), there are two types of consensus conferences: (a) a primarily or purely academic activity that builds consensus among scientists and transfers this to the public by journal articles or media conferences (more or less following the sender–receiver metaphor); and (b) a transdisciplinary process in which experts discuss “attitudes and recommendations” (ibid., p. 332) related to questions from citizens. Hence, we kept “participatory consensus conference” OR “danish consensus conference” and excluded “consensus conference”.

63. consultative panels

Consultative panels approach was excluded because it doesn’t fulfill criterion C, as it does not mention science or scientists as participants, and focus on consultancy instead of horizontal collaborations.

64. feminist research methods

Feminist research methods do not fulfill criterion C, as scientists or science are not required.

65. knowledge with action

Knowledge with action does not fulfill criterion A. It is related to the desired result instead of the process (or approach) to get to it. Besides, there is no clear concept or definition in many publications using the term.

66. participatory integrated assessment - PIA

As it is contemplated with the term integrated assessment already included, we exclude it.

67. participatory planning processes

Participatory planning processes approach was excluded because it may or may not - and, therefore, not always - fulfills criterion C, as scientists (scientific knowledge) are not necessarily included.

68. rapid assessment process - RAP

Rapid assessment process approach was excluded because although It integrates stakeholder knowledge into the research process, it is not certain the process will indeed be horizontal, influential and iterative. Therefore, criterion C may or may not be - and, therefore, not always is - fulfilled.

69. stakeholder collaboration

Stakeholder collaboration may or may not - and, therefore, not always - fulfills criterion C, as scientists (scientific knowledge) are not necessarily included. Because of that, it was excluded.

70. stakeholder dialogues

Although the stakeholder dialogues approach brings different perspectives together, and enables the stakeholders to jointly seek solutions that are not partial and that do not ignore difficulties, the scientific actor is not explicitly mentioned. Therefore, criterion C may or may not be - and, therefore, not always is - fulfilled.

71. team science

Team science is designed to promote collaborative, and often cross-disciplinary (which includes multi-, inter-, and transdisciplinary) approaches to answering research questions about particular phenomena. In this sense, it may or may not be transdisciplinary. To maintain only the transdisciplinary team science approaches, we used “participatory team science”.

REFERENCES

Igalla, M., Edelenbos, J., & van Meerkerk, I. 2019. What explains the performance of community-based initiatives? Testing the impact of leadership, social capital, organizational capacity, and government support, Public Management Review, DOI:10.1080/14719037.2019.1604796.

McNie, E. C. (2007). Reconciling the Supply of Scientific Information with User Demands: An Analysis of the Problem and Review of the Literature. Environmental Science & Policy 10(1): 17–38.

Scholz, R. W., & Binder C. R. (2011). Environmental Literacy in Science and Society: From Knowledge to Decisions. Cambridge; New York: Cambridge University Press.

APPENDIX C - The Scopus search keywords list:

The search in Scopus Topic Field was conducted as presented in Tables AC 1 and AC 2 in Scopus notation.

Table AC 1 - Scopus notation of the search for 54 of the 55 transdisciplinary approaches.

TITLE-ABS-KEY *("action oriented research" OR "action oriented knowledge" OR "action oriented science" OR* *"action research" OR* *"actionable knowledge" OR* *"actionable science" OR* *"adaptive management" OR* *"boundary organization*" OR* *"boundary span*" OR* *"boundary work*" OR* *"citizen* jur*" OR* *"civic science" OR* *co-research OR coresearch OR* *"community based participatory research" OR* *"community based research" OR* *"community driven research" OR "community driven knowledge" OR "community driven science" OR* *"community engaged research" OR* *"community research" OR* *"community science" OR* *"deliberative poll*" OR "deliberative opinion poll" OR* *"integrated assessment*" OR* *"integrated natural resource management" OR* *"integrated resource management" OR* *"integration science*" OR "integration research*" OR "integration and implementation science*" OR* *"integrative research*" OR "integrative science*" OR* *"knowledge action collaborative*" OR* *"knowledge action system" OR*

"knowledge co-production" OR "co-production of knowledge" OR "knowledge coproduction" OR
"coproduction of knowledge" OR
"knowledge exchange" OR
"knowledge network" OR*
"knowledge transfer and exchange" OR
"mode 2 knowledge" OR
"mode 2 science" OR
"participatory consensus conference" OR "danish consensus conference" OR
"participatory development" OR
"participatory research" OR
"participatory resource management" OR
"participatory team science" OR
"participatory technology assessment" OR
"post normal science" OR
"public ecology" OR
"scenario workshop" OR*
"science based stakeholder dialogue" OR*
"science policy dialogue" OR*
"science shop" OR*
"socially robust knowledge" OR
"span the boundar*" OR*
transdisciplinar OR*
"transformative science" OR
"transition management" OR
"translational ecology" OR
"translational science" OR "translational research" OR
"usable science" OR
"use inspired research" OR "use inspired basic research" OR
"use inspired science" OR "user driven science" OR
"well ordered science")

Because the approach “triple helix” has the same name as a protein structure, publications associated with biochemistry and molecular biology, but not related to transdisciplinarity also returned by searching “triple helix” at Scopus. Thus, the search for the approach was developed separately from the other 54 approaches (Table 2) and resulted in 7,073 publications that were a posteriori screened.

Table AC 2 - Scopus search notation of triple helix approach.

TITLE-ABS-KEY ("triple helix")

The resulting publications were screened by the abstract content. As the essence of the triple helix approach is the interaction of science, industry, and govern (Leydesdorff & Etzkowitz, 1996; Leydesdorff & Meyer, 2003), we kept only the publications that mentioned “government”, “industry” and “university” or their synonyms in the abstract. With this procedure, we retained 6,933 publications for the triple helix approach.

The list of screened publications of the triple helix search were, then, joined to the publications of the search of the other 54 transdisciplinary approaches. The final number of publications related to the 55 transdisciplinary approaches were 130,279 publications.

REFERENCES

Leydesdorff, L., & Etzkowitz, H. (1996). Emergence of a triple helix of university-industry-government relations. Sci Public Policy 23(5):279–286.

Leydesdorff, L., & Meyer, M. (2003). The Triple Helix of university-industry-government relations. Scientometrics, 58, 191-203.

APPENDIX D - R Script to extract bibliographic data from the Scopus API and details on the citation network analysis

The R script we developed to extract information from the list of returned publications through the Scopus API has involved adapting functions (mainly abstract retrieval and convert2df) from the Rscopus R package (https://github.com/muschellij2/rscopus). In order to use this package and access API information, it is necessary to use an API key from https://dev.elsevier.com/sc_apis.html.

The input of our adapted function (Table AD 1) is a list of terms or expressions to be searched at Scopus database. The first output consisted of a list Scopus IDs of the returned publications, from which details - such as authors and their affiliations, title, abstract, keywords, standard references, journal, knowledge area/subject, and year of publication, among others - of each returned publication is extracted in a table format called bibliographic dataframe.

Table AD 1 - Developed R script to extract information through the Scopus API. The example here is the search for the term "transdisciplinarity".

```
library(rscopus)
library(bibliometrix)
library(dplyr)
library(xml2)
library(plyr)

api_key = "****************"
key = set_api_key("****************")
token = "****************"
hdr = inst_token_header(token)

years=1900:2021
 rl=list()
 for(i in years)
 {
  r=scopus_search(paste0('TITLE-ABS-KEY("transdisciplinar*") AND PUBYEAR = ', i), headers = hdr)
  if (r$total_results>0)
  {rl[[which(i==years)]]=r}
  else
   rl[[which(i==years)]]=NULL
 }
```

```
 rl=rl[!sapply(rl,is.null)]
 r=Reduce(function(...)mapply(c, ...), rl)
 sum(r$total_results)
 r

 id.scopus <- sapply(r$entries,"[","dc:identifier")
 id.scopus[sapply(id.scopus,is.null)]=NA
 id.scopus=unlist(id.scopus, use.names = F)
 id.scopus <- id.scopus[!is.na(id.scopus)]

fields = function(x){
   content = httr::content(x$get_statement, as = "text")
   content = jsonlite::fromJSON(content, flatten = TRUE)
   authors = content$`abstracts-retrieval-response`$authors$author

   self =  content$`abstracts-retrieval-response`$coredata
   scopus_id = self$`dc:identifier`
   year = substr(self$`prism:coverDate`, 1, 4)
   title = self$`dc:title`

   abstract = self$`dc:description`
  references = paste(content$`abstracts-retrieval-response`$item$bibrecord$tail$bibliography$reference$`ref-fulltext`,
collapse = "; ")

   ref <-content$`abstracts-retrieval-response`$item$bibrecord$tail$bibliography$reference
   references.scopus_id = paste(ref$`ref-info.refd-itemidlist.itemid.$`, collapse = ";")

   journal = self$`prism:publicationName`
affiliation = (paste(content$`abstracts-retrieval-
response`$item$bibrecord$head$correspondence$affiliation$organization$`$`,
          content$`abstracts-retrieval-response`$item$bibrecord$head$correspondence$affiliation$organization$`$`,
          content$`abstracts-retrieval-response`$item$bibrecord$head$correspondence$affiliation$`address-part`,
          content$`abstracts-retrieval-response`$item$bibrecord$head$correspondence$affiliation$`city-group`,
          content$`abstracts-retrieval-response`$item$bibrecord$head$correspondence$affiliation$country, collapse =
","))

   author_keywords = paste(content$`abstracts-retrieval-response`$authkeywords$`author-keyword`$`$`,collapse = "; ")
   document_type = paste(self$subtypeDescription, collapse = ";")
   note = (paste(self$citedby, collapse = ";"))
   issn =  self$`prism:issn`
   url = self$`prism:url`
```

```
  language = paste(content$`abstracts-retrieval-response`$item$bibrecord$head$`citation-info`$`abstract-language`$`@language`,collapse = ";")

  keywords = paste(content$`abstracts-retrieval-response`$idxterms$mainterm$`$`,collapse = ";")
  abbrev_source_title = paste(content$`abstracts-retrieval-response`$item$bibrecord$head$source$`sourcetitle-abbrev`,collapse = ";")
  art_number = paste(self$`article-number`,collapse = ";")
  coden = paste(content$`abstracts-retrieval-response`$item$bibrecord$head$source$codencode,collapse = ";")

  isbn = paste(self$`prism:isbn`,collapse = ";")
  publisher = paste(content$`abstracts-retrieval-response`$item$bibrecord$head$source$publisher$publishername,collapse = ";")
  source = "scopus"
  funding_text1 =  paste(content$`abstracts-retrieval-response`$item$`xocs:meta`$`xocs:funding-list`$`xocs:funding-text`,collapse = ";")

  authors = paste(content$`abstracts-retrieval-response`$authors$author$`ce:indexed-name`, collapse = ";")

  SR_FULL = paste0(authors,", ", year,", ", journal)
  SR = paste0(authors,", ", year,", ", abbrev_source_title)

  address = (paste(content$`abstracts-retrieval-response`$affiliation$affilname, collapse = ";"))

  volume= self$`prism:volume`
  number=self$`prism:issueIdentifier`
  doi = self$`prism:doi`

  pages = self$`prism:pageRange`
  if (is.null(pages)) {
    if (!is.null(self$`prism:startingPage`) & !is.null(self$`prism:endingPage`)) {
      pages = paste0(self$`prism:startingPage`, "-", self$`prism:endingPage`)
    } else {
      pages = "-"
    }
  }
  make_names = c("prism:publicationName", "prism:doi", "prism:volume",
          "prism:issueIdentifier")
  for (iname in make_names) {
    if (is.null(self[[iname]])) {
      self[[iname]] = ""
    }
```

```
   }

   AU = if(!is.null(authors)){paste(authors)} else{NA}
   DE = if(!is.null(author_keywords)){paste(author_keywords)} else{NA}
   ID = if(!is.null(keywords)){paste(keywords)} else{NA}
   C1 = if(!is.null(affiliation)){paste(affiliation)} else{NA}
   CR = if(!is.null(references)){paste(references)} else{NA}
   r.S_ID = if(!is.null(references.scopus_id)){paste(references.scopus_id)} else{NA}
   JI = if(!is.null(abbrev_source_title)){paste(abbrev_source_title)} else{NA}
   AB = if(!is.null(abstract)){paste(abstract)} else{NA}
   PA = if(!is.null(address)){paste(address)} else{NA}
   AR = if(!is.null(art_number)){paste(art_number)} else{NA}
   coden = if(!is.null(coden)){paste(coden)} else{NA}
   DT = if(!is.null(document_type)){paste(document_type)} else{NA}
   S_ID = if(!is.null(scopus_id)){paste(scopus_id)} else{NA}
   DI = if(!is.null(doi)){paste(doi)} else{NA}
   FU = {NA}
   BN = if(!is.null(isbn)){paste(isbn)} else{NA}
   SN = if(!is.null(issn)){paste(issn)} else{NA}
   SO = if(!is.null(journal)){paste(journal)} else{NA}
   LA = if(!is.null(language)){paste(language)} else{NA}
   TC = if(!is.null(note)){paste(note)} else{NA}
   PN = if(!is.null(number)){paste(number)} else{NA}
   PP = if(!is.null(pages)){paste(pages)} else{NA}
   PU = if(!is.null(publisher)){paste(publisher)} else{NA}
   DB = if(!is.null(source)){paste(source)} else{NA}
   TI = if(!is.null(title)){paste(title)} else{NA}
   url = if(!is.null(url)){paste(url)} else{NA}
   VL = if(!is.null(volume)){paste(volume)} else{NA}
   PY = if(!is.null(year)){paste(year)} else{NA}
   FX = if(!is.null(funding_text1)){paste(funding_text1)} else{NA}
   SR_FULL = if(!is.null(SR_FULL)){paste(SR_FULL)} else{NA}
   SR = if(!is.null(SR)){paste(SR)} else{NA}

   resultado<-
as.data.frame(cbind(AU,DE,ID,C1,CR,r.S_ID,JI,AB,PA,AR,coden,DT,S_ID,DI,FU,BN,SN,SO,LA,TC,PN,PP,PU,DB,TI,url,VL,PY,F
X,SR_FULL,SR))
   return(resultado)
  }

  {
```

```
resultado1<-as.data.frame(matrix(nrow = 1, ncol = 31))
colnames(resultado1)<-
c("AU","DE","ID","C1","CR","r.S_ID","JI","AB","PA","AR","coden","DT","S_ID","DI","FU","BN","SN","SO","LA","TC","PN","
PP","PU","DB","TI","url","VL","PY","FX","SR_FULL","SR")

for(i in id.scopus)
{
 ar=abstract_retrieval(i,identifier = "scopus_id", api_key = api_key, headers = hdr)
 if(ar$get_statement$status_code==200)
 {
  D = fields(ar)
  resultado1<- rbind(resultado1,D)
 }
}

{
 {
  resultado1 <- resultado1[-1, ]
 }
 {
  if ("PY" %in% names(resultado1)){resultado1$PY=as.numeric(resultado1$PY)} else {resultado1$PY <- NA}

  if ("TC" %in% names(resultado1)){
   resultado1$TC=as.numeric(resultado1$TC)
   resultado1$TC[is.na(resultado1$TC)] <- 0
  } else {resultado1$TC <- 0}

  if (!("CR" %in% names(resultado1))){
   resultado1$CR="none"
  } else {
   resultado1$CR <- trim.leading(trimES(gsub("\\[,||\\[||\\]|| \\.\\. || \\. ","",resultado1$CR)))
  }
 }

    if ("C1" %in% names(resultado1)) {
     cat("\nGenerating affiliation field tag AU_UN from C1:  ")

      resultado1 <- metaTagExtraction(resultado1, Field = "AU_UN")
      cat("Done!\n\n")
    } else{
      resultado1$C1 = NA
```

```
        resultado1$AU_UN = NA
      }
  }

  {
   suppressWarnings(resultado1 <- metaTagExtraction(resultado1, Field = "SR"))
   d <- duplicated(resultado1$SR)
   if (sum(d) > 0)
     cat("\nRemoved ", sum(d), "duplicated documents\n")
   resultado1 <- resultado1[!d, ]
   row.names(resultado1) <- resultado1$SR
  }

  class(resultado1) <- c("bibliometrixDB", "data.frame")
}

resultado1
class(resultado1)

resultado1 <- duplicatedMatching(resultado1, Field = "S_ID", exact = TRUE)
}
```

From the bibliographic dataframe, the citation network was developed adapting the histNetwork function of Bibliometrix R package (Aria & Cuccurullo, 2017; https://github.com/massimoaria/bibliometrix/blob/master/R/histNetwork.R). The adaptation consists of substituting the TIpost (field that joins title and year of publications) and CR (citation references) fields - and that are used to create the correlation matrix - by, respectively, Scopus ID of returned publications and of their references.

Then, the citation network analysis was performed through biblioAnalysis and termExtraction functions of the Bibliometrix package (Aria & Cuccurullo, 2017). The output involved indices of centrality and most used terms in titles, abstracts and keywords of its publications. Finally, network edges and nodes were extracted from the function networkPlot, also from the Bibliometrix package.

REFERENCES

Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4), 959-975.

APPENDIX E - The use of Scopus ID of returned publications and of their references

The Scopus database presents an identification number (ID) for each of the publications registered within it, which we call Scopus ID (Elsevier also calls it Record ID - https://dev.elsevier.com/academic_research_scopus.html). The use of the Scopus ID of the returned publications (from the bibliographic search) and of their references enables the development of an accurate citation network (i.e. a correlation matrix of publications and its references) that is difficult to obtain otherwise given small but common differences in the citation of authors names or similarity in titles across different publications. However, the Scopus API did not have the Scopus IDs of the references of all publications. From the 130,279 publications returned in the search in Scopus, 9,737 (7.5%) did not cite references (no references in the Scopus API) and as such could not be included in the direct citation network. Of the remaining 120,542 publications that cite references, 83,135 (69%) had the Scopus ID of their references, and were used to build the citation network. Among those, 55,744 cite at least one publication used to build the network, and entered as a node in the network.

APPENDIX F - The mixing parameter (μ)

The mixing parameter (μ) is used as an easily measurable indicator of finding the ranges of reliability of different algorithms (Yang et al., 2016). The parameter is calculated through the formula below, in which k_i^{ext} stand for the number of edges connecting node i to others that belong to different communities and k_i^{tot} for the total degree of the node. We used the package igraph in R to calculate μ.

$$\mu = \Sigma_i k_i^{ext} / \Sigma_i k_i^{tot}$$

The Louvain algorithm is suitable for identification of clusters in large and heterogeneous networks with $\mu > 0.5$ (Yang et al., 2016). Our network fits this description with a mixing parameter of $\mu = 0.77$, varying from 0.59 to 0.89 across communities. In this sense, Louvain was chosen as an adequate algorithm to identify clusters in our network.

REFERENCES

Yang, Z., Algesheimer, R., & Tessone, C. J. (2016). A comparative analysis of community detection algorithms on artificial networks. Scientific reports, 6(1), 1-18.

APPENDIX G - Glossary of dominant transdisciplinary approaches

➢ Definition of transdisciplinary approaches

Transdisciplinary approaches are defined here as ways of conducting research, management, planning, or decision making, or of producing knowledge or public discourse, that aim at solving real-world problems by linking science and practice (including also organizations designed for, and specific techniques used in, the process of doing so). The linkage between science and practice is based on the sharing of multiple scientific and non-scientific - including experiential - types of knowledge in an iterative, multi-way and influential manner.

➢ The criteria that need to be fulfilled so that an approach is considered a transdisciplinary approach

A — Being a way of conducting scientific research, management, planning or decision making; a way actors should interact to produce knowledge; or way of producing knowledge or public discourse; a specific technique, organization, type of knowledge, or group of actors who interact to produce knowledge.

B — Aiming at (or being designed for or used in the process of) solving real-world problems by linking scientists or experts (from inside or outside academia) and practitioners (citizens, tradicional communities, decision-makers, or other societal actors interested or involved in practice).

C — Linking scientists or experts (from inside or outside academia) and practitioners (citizens, decision-makers, or other societal actors interested or involved in practice) based on the sharing of multiple scientific and non-scientific - including experiential - types of knowledge in an iterative, multi-way and influential manner.

➢ How each approach is presented here

Brief characterization: We compiled a brief characterization of each approach covering the focal entity under consideration, the focal process to be changed, the central goal of the change, the guiding tenets, main stakeholders, and the general methodological guidelines of each of them.

Key references: We chose a small list of informative publications to further learning about each approach. The key references result from initial effort to map and screen the names of approaches to enter our bibliographic search, as well as the identification of the most cited and central publications in the citation network.

➢ The dominant transdisciplinary approaches

ACTION RESEARCH

Brief characterization: Action research is defined as "*a participatory, democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview which we believe is emerging at this historical moment. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and their communities*" (Reason & Bradbury, 2001). Its goal is transformative change and improvement of social action (Lewin, 1946). Action research involves engaging with uncertainty, complexity, and messiness, and being willing to learn from experience and engage with diverse perspectives (Brydon-Miller et al., 2003) and consists of a spiral of steps consisting of planning, action, and fact-finding about the result of the action (Lewin, 1946). Finally, according to Scholz & Steiner (2015), action research may be seen as a precursor of transdisciplinarity mode 2 (i.e., as defined below).

Key references:

Brydon-Miller, M., Greenwood, D., & Maguire, P. (2003). Why action research?. Action research, 1(1), 9-28.

Cornish, F., Breton, N., Moreno-Tabarez, U., Delgado, J., Rua, M., de-Graft Aikins, A., & Hodgetts, D. (2023). Participatory action research. Nature Reviews Methods Primers, 3(1), 34.

Lewin, K. (1946). Action Research and Minority Problems. Journal of Social Issues 2(4): 34–46.

Reason, P., & Bradbury, H. (Eds.). (2001). Handbook of action research: Participative inquiry and practice. London: Sage Publications

Scholz, R. W., & Steiner G. (2015). The real type and ideal type of transdisciplinary processes: Part I-theoretical foundations. Sustainability Science 10(Nr.4): 527–44.

Stokols, D. (2006). Toward a science of transdisciplinary action research. American journal of community psychology, 38, 63-77.

Tripp, D. (2005). Action Research: a methodological introduction. Research and Education, 31(3), 443-466.

ADAPTIVE MANAGEMENT

Brief characterization: Adaptive management is "*a structured, iterative process of decision-making with respect to complex socioe-cological systems*" (Scholz & Binder, 2011). It involves delivering tangible outcomes while actively accommodating uncertainty, complexity, and unpredictability, and demonstrating a commitment to experiential learning and embracing diverse perspectives (Holling, 1978; Lee, 1993). The challenge in using the adaptive management approach "*lies in finding the correct balance between gaining knowledge to improve management in the future and achieving the best short-term outcome based on current knowledge*" (Allan & Stankey, 2009). "*Learning and adapting, through partnerships of managers, scientists, and other stakeholders who learn together how to create and maintain sustainable resource systems*" (Allan & Stankey, 2009). The adaptive approach is "*an important component of a search for a new meaning for conservation − a meaning that is bioregional in scope, and collaborative in governance, as well as adaptive in managerial perspective*" (Lee, 2001).

Key references:

Allan, C., & Stankey, G. H. (2009). Adaptive environmental management (Vol. 351). New York: Springer.

Berkes, F. (2009). Evolution of co-management: role of knowledge generation, bridging organizations and social learning. Journal of environmental management, 90(5), 1692-1702.

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. Global environmental change, 16(3), 253-267.

Holling, C. S. (1978). Adaptive Environmental Assessment and Management. Wiley, London

Lee, K. N. (2001). Appraising adaptive management. In Biological diversity (pp. 3-26). CRC Press.

Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. Global environmental change, 19(3), 354-365.

Roling, N. G., & Wagemakers, M. A. E. (Eds.). (2000). Facilitating sustainable agriculture: participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press.

Scholz, R. W., & Binder, C. R. (2011). Environmental literacy in science and society: from knowledge to decisions.

BOUNDARY-SPANNING

Brief characterization: Boundary-spanning is defined as "*work to enable exchange between the production and use of knowledge to support evidence-informed decision-making in a specific context*" (Bednarek et al., 2018). The approach takes into account the broader context of actors, perspectives, values, contested evidence, decision-making history, and power dynamics in shaping a productive knowledge exchange process (Bednarek et al., 2018). The concept first emerged in the 1970s to identify organizational specific functions or roles that facilitate knowledge exchange between organizations (Aldrich & Herker, 1977; Leifer & Delbecq, 1978). The significance of constructive knowledge exchange in this sense has been embraced by those seeking to grapple with wicked problems or complex social challenges such as sustainability (Guston, 2001; Harris et al., 2010). In the boundary spanning approach the role of boundary spanners - individuals or organizations that specifically and actively facilitate the process - is essential. Boundary spanners act as honest brokers, whereby they do not advocate for a single cause or predetermined outcome (Bednarek et al., 2018).

Key references:

Aldrich H., & Herker D. (1977) Boundary spanning roles and organization structure. Acad Manag Rev 2:217–230

Bednarek, A. T., Wyborn, C., Cvitanovic, C., Meyer, R., Colvin, R. M., Addison, P. F., ... & Leith, P. (2018). Boundary spanning at the science–policy interface: the practitioners' perspectives. Sustainability science, 13, 1175-1183.

Davis, E. J., Huber-Stearns, H., Cheng, A. S., & Jacobson, M. (2021). Transcending parallel play: boundary spanning for collective action in wildfire management. Fire, 4(3), 41.

Guston, D. H. (2001). Boundary organizations in environmental policy and science: an introduction. Science, technology, & human values, 26(4), 399-408.

Harris, J., Brown, V. A., & Russell, J. (Eds.). (2010). Tackling wicked problems: Through the transdisciplinary imagination. Taylor & Francis.

Leifer R., & Delbecq A. (1978) Organization/environmental interchange: a model of boundary spanning activity. Acad Manag Rev 3:40–50

Levina, N., & Vaast, E. (2005). The emergence of boundary spanning competence in practice: Implications for implementation and use of information systems. MIS quarterly, 335-363.

Williams, P. (2002). The competent boundary spanner. Public administration, 80(1), 103-124.

COMMUNITY BASED PARTICIPATORY RESEARCH

Brief characterization: Community-based participatory research (CBPR) "*implies building relationships with community members and establishing partnerships which actively engage local stakeholders throughout the research process*" (Amauchi et al., 2022). Rhodes et al. (2010) also mentions the requirement of a partnership "*comprised of committed community members, organizational representatives, and academic researchers*". "*This collaborative approach to research equitably involves all partners in the research process and recognizes the unique strengths that each brings*" (Horowitz et al., 2009). CBPR is related to health inequities challenges in marginalized communities through integrated research and practice, emphasizing community engagement with focus on well-being to address disparities and promote equity (Israel et al., 1998). The approach encompasses a multidirectional exchange of information and learning, emphasizing the critical need for openness and trust among partners, as well as possessing the potential to enhance individual and community capacity, fostering sustainability, dissemination, and the development of future steps to address complex challenges (Rhodes et al., 2010). "*CBPR requires relationship building with community members, which can be achieved through increased and shared responsibility and recognition of the vulnerability of both researchers and participants"* (Amauchi et al., 2022). "*CBPR starts from a research topic of importance to the community with the aim of combining knowledge and action for social change to improve community issues and eliminate disparities"* (Minkler & Garcia, 2012).

Key references:

Amauchi, J. F. F., Gauthier, M., Ghezeljeh, A., L. Giatti, L. L., Keats, K., Sholanke, D., ... & Gutberlet, J. (2022). The power of community-based participatory research: ethical and effective ways of researching. Community Development, 53(1), 3-20.

Eisinger, A., & Senturia, K. (2001). Doing community-driven research: a description of Seattle Partners for Healthy Communities. Journal of Urban Health, 78, 519-534.

Horowitz, C. R., Robinson, M., & Seifer, S. (2009). Community-based participatory research from the margin to the mainstream: are researchers prepared?. Circulation, 119(19), 2633-2642.

Israel, B. A., Schulz, A. J., Parker, E. A., & Becker, A. B. (1998). Review of community-based research: assessing partnership approaches to improve public health. Annual review of public health, 19(1), 173-202.

McElfish, P. A., Kohler, P., Smith, C., Warmack, S., Buron, B., Hudson, J., & Rubon-Chutaro, J. (2015). Community-driven research agenda to reduce health disparities. Clinical and Translational Science, 8(6), 690-695.

Minkler M. & Garcia A. P. (2012). Community-Based Participatory Research: A Strategy for Building Healthy Communities and Promoting Health through Policy Change. Available at: <https://www.policylink.org/sites/default/files/CBPR.pdf >.

O'Fallon, L. R., & Dearry, A. (2002). Community-based participatory research as a tool to advance environmental health sciences. Environmental health perspectives, 110(suppl 2), 155-159.

Rhodes, S. D., Malow, R. M., & Jolly, C. (2010). Community-based participatory research: a new and not-so-new approach to HIV/AIDS prevention, care, and treatment. AIDS education and prevention, 22(3), 173-183.

Westfall, J. M., VanVorst, R. F., Main, D. S., & Herbert, C. (2006). Community-based participatory research in practice-based research networks. The Annals of Family Medicine, 4(1), 8-14.

INTEGRATED ASSESSMENTS

Brief characterization: Integrated Assessment (IA) "*is a research community explicitly focusing on research of complex issues and unstructured problems*" (van Asselt et al., 2022). It is defined as an "*iterative participatory process that links knowledge (science) and action (policy) regarding complex global change issues*" (van der Sluijs, 2002). "*Over the past few decades Integrated Assessment (IA) has emerged as an approach to link knowledge and action in a way that is suitable to accommodate uncertainties, complexities and value diversities of global environmental risks. Responding to the complex nature of the climate problem and to the changing role of climate change in the international climate policy process, the scientific community has started to include stakeholder knowledge and perspectives in their assessments*" (Kloprogge & Sluijs, 2006). This process entails gathering, condensing, structuring, interpreting, and potentially harmonizing various elements of preexisting knowledge, then conveying them in a manner that is pertinent and beneficial to a knowledgeable yet non-specialist decision-maker (Parson, 1995). IA "*can be described as the involvement of stakeholders in the formation of research questions, generation of new information and the discussion on results and recommendations through a series of structured, but open dialogues sessions involving stakeholders and scientists. [...] The group of participants consists of scientists from different disciplines who are experts on (aspects of) the central issue and various stakeholders, primarily decisionmakers, NGOs and representatives of business and other societal sectors*" (van Asselt Marjolein & Rijkens-Klomp, 2002).

Key references:

Cash, D. W., & Moser, S. C. (2000). Linking global and local scales: designing dynamic assessment and management processes. Global environmental change, 10(2), 109-120.

Hamilton, S. H., ElSawah, S., Guillaume, J. H., Jakeman, A. J., & Pierce, S. A. (2015). Integrated assessment and modelling: overview and synthesis of salient dimensions. Environmental Modelling & Software, 64, 215-229.

Kloprogge, P., & Sluijs, J. P. V. D. (2006). The inclusion of stakeholder knowledge and perspectives in integrated assessment of climate change. Climatic Change, 75(3), 359-389.

Parson, E. A. (1995). Integrated Assessment and Environmental Policy Making, In Pursuit of Usefulness, Energy Policy, 23(4/5), 463–476

van Asselt Marjolein, B. A., & Rijkens-Klomp, N. (2002). A look in the mirror: reflection on participation in integrated assessment from a methodological perspective. Global environmental change, 12(3), 167-184.

van der Sluijs, J. P. (2002). Responding to global environmental change, pp 250–253. Munn, R. E. (Ed.). Encyclopedia of global environmental change. Chichester: Wiley.

KNOWLEDGE EXCHANGE

Brief characterization: Knowledge exchange (KE) is a broad approach defined as ''*a process of generating, sharing, and/or using knowledge through various methods appropriate to the context, purpose, and participants involved. KE includes concepts such as sharing, generation, coproduction, co-management, and brokerage of knowledge*" (Fazey et al., 2013). It describes the interchange of knowledge between research users and scientific producers (Mitton et al., 2007). The concept encompasses all facets of knowledge production, sharing, storage, mobilization, translation and use (Best & Holmes, 2010). As such, "*when done successfully it is believed that knowledge exchange increases the likelihood that knowledge and evidence will be used in policy and practice decisions, thus increasing the success of those decisions in meeting their objectives"* (Cvitanovic et al., 2015). Knowledge exchange processes involve autonomy and interdependence and interconnectedness among all participants (Contandriopoulos et al., 2010) and "*is relevant to most areas of research, drawing on insights from diverse fields, including adaptive co-management, participation, stakeholder engagement, and community-based conservation. It can be both formal or informal, from co-management and co-production of research, community-based or collaborative management, knowledge brokering, management of knowledge sharing systems in organizations or to support disaster planning, community communication and knowledge transfer, the translation of research for practice, health education programmes or policy-maker forums*" (Fazey et al., 2014).

Key references:

Best, A., & Holmes, B. (2010). Systems thinking, knowledge and action: towards better models and methods. Evidence & Policy, 6(2), 145-159.

Cvitanovic, C., Hobday, A. J., van Kerkhoff, L., Wilson, S. K., Dobbs, K., & Marshall, N. A. (2015). Improving knowledge exchange among scientists and decision-makers to facilitate the adaptive governance of marine resources: a review of knowledge and research needs. Ocean & Coastal Management, 112, 25-35.

Contandriopoulos, D., Lemire, M., Denis, J.L., & Tremblay, E. (2010). Knowledge exchange processes in organizations and policy arenas: a narrative systematic review of the literature. Milbank Q. 88, 444e483.

Fazey, I., Bunse, L., Msika, J., Pinke, M., Preedy, K., Evely, A. C., & Reed, M. S. (2014). Evaluating knowledge exchange in interdisciplinary and multi-stakeholder research. Global Environmental Change, 25, 204-220.

Fazey, I., Evely, A. C., Reed, M. S., Stringer, L. C., Kruijsen, J., White, P. C., ... & Trevitt, C. (2013). Knowledge exchange: a review and research agenda for environmental management. Environmental Conservation, 40(1), 19-36.

Graham, I. D., Logan, J., Harrison, M. B., Straus, S. E., Tetroe, J., Caswell, W., & Robinson, N. (2006). Lost in knowledge translation: time for a map?. Journal of continuing education in the health professions, 26(1), 13-24.

Mitton, C., Adair, C. E., McKenzie, E., Patten, S. B., & Perry, B. W. (2007). Knowledge transfer and exchange: review and synthesis of the literature. The Milbank Quarterly, 85(4), 729-768.

KNOWLEDGE NETWORKS

Brief characterization: Knowledge networks are defined as vehicles for bridging the gap between knowledge and action (Feldman & Ingram, 2009). The approach involves policy makers, scientists, government agencies, and nongovernmental organizations (Sarewitz & Pielke, 2007; Jacobs et al., 2005) *"linked together in an effort to provide close, ongoing, and nearly continuous communication and information dissemination among multiple sectors of society involved in technological and policy innovations for managing real world impacts"* (Feldman & Ingram, 2009). The outcomes of the knowledge network encompass the generation of new knowledge, sharing and learning, and the adoption of knowledge (Phelps et al., 2012). Knowledge networks involve implementation of strategies to engage decision makers more directly and, and they seek to reinforce members' innovation and communication skills (Creech, 2001).

Key references:

Creech, H., & Willard, T. (2001). Strategic intentions: managing knowledge networks for sustainable development. IISD, Winnipeg, MB, CA.

Feldman, D. L., & Ingram, H. M. (2009). Making science useful to decision makers: climate forecasts, water management, and knowledge networks. Weather, Climate, and Society, 1(1), 9-21.

Hansen, M. T. (2002). Knowledge networks: Explaining effective knowledge sharing in multiunit companies. Organization science, 13(3), 232-248.

Jacobs, G. M. Garfin, & M. Lenart, 2005: More than just talk: Connecting science and decision making. Environment, 47, 6–22

Owen-Smith, J., & Powell, W. W. (2004). Knowledge networks as channels and conduits: The effects of spillovers in the Boston biotechnology community. Organization science, 15(1), 5-21.

Phelps, C., Heidl, R., & Wadhwa, A. (2012). Knowledge, networks, and knowledge networks: A review and research agenda. Journal of management, 38(4), 1115-1166.

Sarewitz, D., & Pielke, R. A. J. (2007). The neglected heart of science policy: reconciling supply of and demand for science. environmental science & policy, 10(1), 5-16.

PARTICIPATORY RESEARCH

Brief characterization: Participatory research is a way of conducting research in which the focus "*is on a process of sequential reflection and action, carried out with and by local people rather than on them*. *Local knowledge and perspectives are not only acknowledged but form the basis for research and planning"* (Cornwall & Jewkes, 1995). The approach focuses on addressing issues and challenges faced by communities, and aims to empower communities and promote social change (Berardi, 2002). "*There is a commitment to certain values of democracy, equity (the notion that we should generate economic opportunities for all), working with the environment as a habitat for people and other organisms, and, lastly the value of self- and community-determination, with people experiencing the changes that they see as important"* (Berardi, 2002).

Key references:

Berardi, G. (2002). Commentary on the challenge to change: Participatory research and professional realities. Society & Natural Resources, 15(9), 847-852.

Cargo, M., & Mercer, S. L. (2008). The value and challenges of participatory research: strengthening its practice. Annu. Rev. Public Health, 29, 325-350.

Cornwall, A., & Jewkes, R. (1995). What is participatory research?. Social science & medicine, 41(12), 1667-1676.4

Martin, A., & Sherington, J. (1997). Participatory research methods—implementation, effectiveness and institutional context. Agricultural systems, 55(2), 195-216.

Scholz, R. W., & Steiner, G. (2015). The real type and ideal type of transdisciplinary processes: part I—theoretical foundations. Sustainability Science, 10, 527-544.

TRANSDISCIPLINARITY

Brief characterization: Transdisciplinarity is conceived "*as a facilitated process of mutual learning between science and society that relates a targeted multidisciplinary or interdisciplinary research process and a multi-stakeholder discourse for developing socially robust orientations about a specific real-world issue (either a problem or a case)*" (Scholz & Steiner, 2015). Transdisciplinarity "*links scientific, theoretic, and abstract epistemics with real-world factors that are based on experiential knowledge from outside academia*" (Scholz & Binder, 2011) and "*leads to a move from science on/about society towards science for/with society*" (Steiner & Posch, 2006). "*Transdisciplinarity processes may serve capacity building among all participants; consensus* *building about what the main problems are, including their genesis and transformation, strategies for mitigating emerging conflicts (i.e., analytic mediation) in a process of sustainable transformation, and as a means for legitimizing policy options (if representatives of all relevant stakeholder groups have been included and properly considered)*" (Scholz & Steiner, 2015).

<u>Key references:</u>

Choi, B. C., & Pak, A. W. (2006). Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness. Clinical and investigative medicine, 29(6), 351.

Klein, J. T. (2008). Evaluation of interdisciplinary and transdisciplinary research: a literature review. American journal of preventive medicine, 35(2), S116-S123.

Martin, A., & Sherington, J. (1997). Participatory research methods—implementation, effectiveness and institutional context. Agricultural systems, 55(2), 195-216.

Rosenfield, P. L. (1992). The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. Social science & medicine, 35(11), 1343-1357.

Scholz, R. W., & Binder, C. R. (2011). Environmental literacy in science and society: from knowledge to decisions.

Scholz, R. W., & Steiner, G. (2015). The real type and ideal type of transdisciplinary processes: part I—theoretical foundations. Sustainability Science, 10, 527-544.

Scholz, R. W. (2017). The normative dimension in transdisciplinarity, transition management, and transformation sciences: New roles of science and universities in sustainable transitioning. Sustainability, 9(6), 991.

Steiner, G., & Posch, A. (2006). Higher education for sustainability by means of transdisciplinary case studies: an innovative approach for solving complex, real-world problems. Journal of Cleaner production, 14(9-11), 877-890.

Stokols, D., Fuqua, J., Gress, J., Harvey, R., Phillips, K., Baezconde-Garbanati, L., ... & Trochim, W. (2003). Evaluating transdisciplinary science. Nicotine & tobacco research, 5(Suppl_1), S21-S39.

TRANSLATIONAL SCIENCE / TRANSLATIONAL RESEARCH

<u>Brief characterization:</u> Translational research (or Translational science) originally applies "*findings from basic science to enhance human health and well-being. The approach adopts a scientific investigation/enquiry into a given problem facing medical/health practices to surmount such problem which will help to raise aggregate health performance*" (Agency for Healthcare Research and Quality 2017). "*The word 'translation' implies a need for the parties involved to make their languages mutually intelligible, and understand each other's cultural views*" (Knapp et al., 2019).

There are two areas of research within translational research: one in which the interface is between basic science and clinical medicine and the end point is the “*production of a promising new treatment that can be used clinically or commercialized”* and other “*refers to translating research into practice; ie, ensuring that new treatments and research knowledge actually reach the patients or populations for whom they are intended and are implemented correctly*” (Woolf, 2008). Today Translational research appears in medicine, ecology and climate science, with all of these disciplines emphasizing the goal of involving end-users in the research process (Knapp et al., 2019). The approach involves bidirectional (between knowledge producers and potential users) and cyclical (ongoing learning) research processes, integration of diverse disciplines and perspectives, and – in the realm of medicine – a focus on addressing health disparities. It involves a deliberate effort to bring basic science discoveries through the stages of intervention development, intervention testing, dissemination of findings, and implementation of research results in clinical practice, public health programs, and community settings (Dankwa-Mullan et al., 2010).

Key references:

Agency for Healthcare Research and Quality (2017). "Translating Research Into Practice". Availabe at: <www.ahrq.gov>. Retrieved March 25, 2021.

Dankwa-Mullan, I., Rhee, K. B., Stoff, D. M., Pohlhaus, J. R., Sy, F. S., Stinson Jr, N., & Ruffin, J. (2010). Moving toward paradigm-shifting research in health disparities through translational, transformational, and transdisciplinary approaches. American journal of public health, 100(S1), S19-S24.

Gilliland, C. T., White, J., Gee, B., Kreeftmeijer-Vegter, R., Bietrix, F., Ussi, A. E., & Austin, C. P. (2019). The fundamental characteristics of a translational scientist. ACS Pharmacology & Translational Science, 2(3), 213-216.

Knapp, C. N., Reid, R. S., Fernández-Giménez, M. E., Klein, J. A., & Galvin, K. A. (2019). Placing transdisciplinarity in context: A review of approaches to connect scholars, society and action. Sustainability, 11(18), 4899.

Rubio, D. M., Schoenbaum, E. E., Lee, L. S., Schteingart, D. E., Marantz, P. R., Anderson, K. E., ... & Esposito, K. (2010). Defining translational research: implications for training. Academic medicine: journal of the Association of American Medical Colleges, 85(3), 470.

Woolf, S. H. (2008). The meaning of translational research and why it matters. Jama, 299(2), 211-213.

TRIPLE-HELIX

Brief characterization: The Triple Helix approach conceptualizes the interaction of the university, industry and government to foster economic and social development (Etzkowitz, & Zhou, 2017; Leydesdorff, 2012; Galvao et al., 2019). *"The triple helix focuses on 'innovation in innovation' and the dynamic to foster an innovation ecosystem, through various hybrid organizations, such as technology transfer offices, venture capital firms, incubators, accelerators, and science parks"* (Etzkowitz & Zhou, 2017). "*The increase of interactions among the institutions has had the effect of generating new structures within each of them, such as centers in universities or strategic alliances among companies. These interactions have also led to the creation of integrating mechanisms among the spheres in the form of networks, for example, of academic, industrial and governmental researchers, and hybrid organizations*" (Leydesdorff & Etzkowitz, 1996). The approach implies dialogue across sectors, with a focus on identifying and understanding the different expectations, norms, and values of each sector, and innovation in a knowledge-based economy (Leydesdorff & Meyer, 2003; Leydesdorff, 2012; Rosenlund et al., 2017). According to Leydesdorff (2012), each stakeholder has a role in triple helix: universities engaging in basic research, industries producing commercial goods, and governments regulating markets.

Key references:

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. Research policy, 29(2), 109-123.

Etzkowitz, H., & Zhou, C. (2017). The triple helix: University–industry–government innovation and entrepreneurship. Routledge.

Galvao, A., Mascarenhas, C., Marques, C., Ferreira, J., & Ratten, V. (2019). Triple helix and its evolution: a systematic literature review. Journal of Science and Technology Policy Management, 10(3), 812-833.

Leydesdorff L., & Etzkowitz H. (1996). Emergence of a triple helix of university-industry-government relations. Sci Public Policy 23(5):279–286

Leydesdorff, L., & Meyer, M. (2003). The Triple Helix of university-industry-government relations. Scientometrics, 58, 191-203.

Leydesdorff, L. (2012). The knowledge-based economy and the triple helix model. arXiv preprint arXiv:1201.4553.

Rosenlund, J., Rosell, E., & Hogland, W. (2017). Overcoming the triple helix boundaries in an environmental research collaboration. Science and Public Policy, 44(2), 153-162.

APPENDIX H – Testing the relationship between the number of publications and the number of communities mentioning them

To test the relationship between the number of publications of each approach and the number of communities using them, we developed a linear model of the number of communities that mention each approach (dependent variable) as a function of the base 10 logarithm of the number of publications from each approach in the network, using normal distribution and identity link function (Figure AH 1). The linear model indicates the number of publications explains well the variation in the number of communities that mention the approaches ($R^2 = 0.81$).

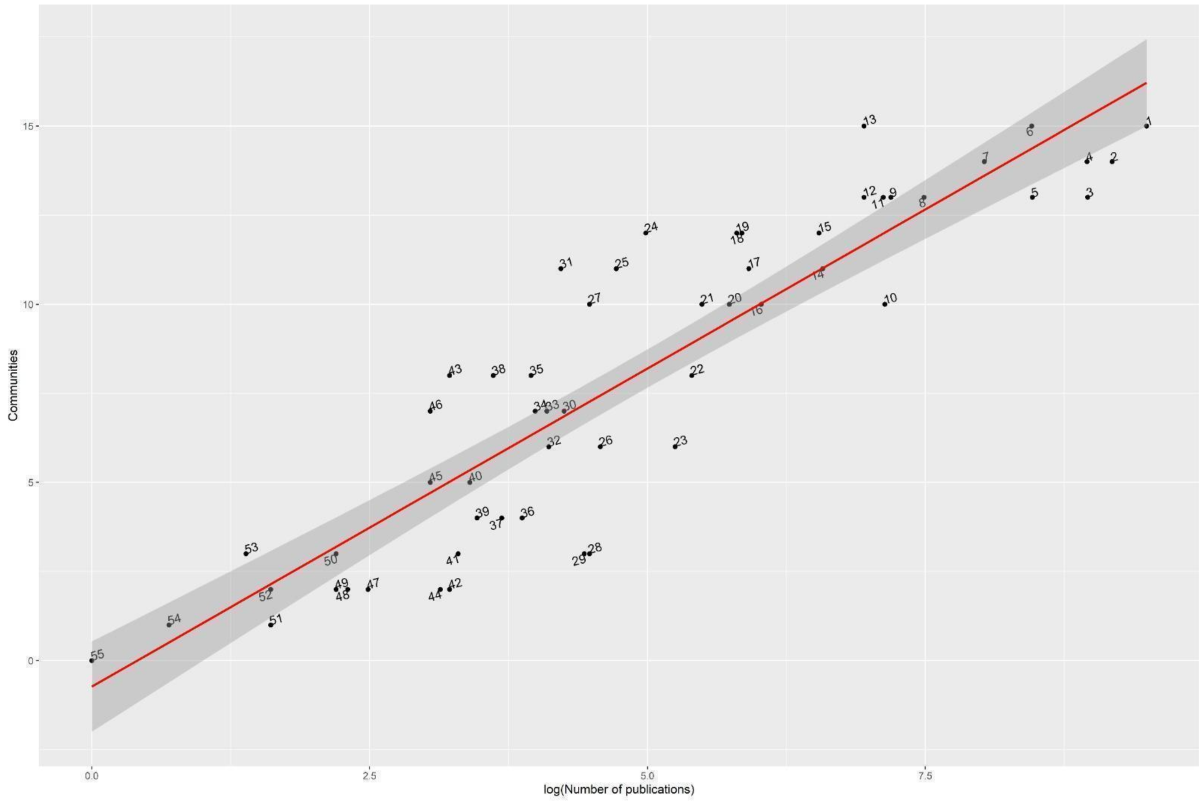

Figure AH 1 - The number of and communities mentioning each transdisciplinary approach as a linear function of logarithm of the number of publications per approach. 1 action research; 2 translational science / research; 3 adaptive management; 4 participatory research; 5 community based participatory research; 6 transdisciplinarity; 7 integrated assessment; 8 knowledge exchange; 9 knowledge network; 10 triple helix; 11 boundary span; 12 community based research; 13 community research; 14 coproduction; 15 boundary work; 16 participatory development; 17 transition management; 18 actionable knowledge; 19 integrative science / research; 20 community engaged research; 21 boundary organization; 22 post normal science; 23 citizen juries; 24 integration science / research; 25 action oriented research / knowledge / science; 26 integrated resource management; 27 community driven research / knowledge / science; 28 deliberative poll; 29 integrated natural resource management; 30 mode 2 knowledge; 31 community science; 32 coresearch; 33 knowledge transfer exchange; 34 civic science; 35 scenario workshop; 36 participatory technology assessment; 37 usable science; 38 span boundaries; 39 science shop; 40 participatory resource management; 41 socially robust knowledge; 42 transformative science; 43 use inspired research; 44 actionable science; 45 mode 2 science; 46 science policy dialogue; 47 well-ordered science; 48 translational ecology; 49 knowledge action system; 50 public ecology; 51 participatory / danish consensus conference; 52 use / user inspired driven science; 53 science based stakeholder dialogue; 54 participatory team science; 55 knowledge action collaboratives.