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Article

Embracing heterogeneity: Why plural understandings strengthen interdisciplinarity and transdisciplinarity

Bianca Vienni-Baptista[1,*], Isabel Fletcher[2], Catherine Lyall[2] and Christian Pohl[3]

[1]Transdisciplinarity Lab, Department of Environmental Systems Science, Swiss Federal Institute of Technology, Universitätstrasse 16—CHN K76.2, Zürich 8092, Switzerland, [2]Science Technology and Innovation Studies, School of Social and Political Science, University of Edinburgh, Old Surgeon's Hall, High School Yards, Edinburgh EH1 1LZ, UK and [3]Transdisciplinarity Lab, Department of Environmental Systems Science, Swiss Federal Institute of Technology, Universitätstrasse 16—CHN K78, Zürich 8092, Switzerland

*Corresponding author. E-mail: bianca.vienni@usys.ethz.ch

Abstract

Interdisciplinarity and transdisciplinarity are seen as promising ways to address societies' grand challenges and so have become important topics in academic and policy discourses, particularly as part of discussions about mission-oriented knowledge production and research funding processes. However, there is an important disconnect between the way these terms are defined and used in the academic literature and the way they are defined and used in the policy literature. Academic writing on interdisciplinarity and transdisciplinarity offers plural understandings of both terms, whereas policy documents argue for concrete and simplified definitions. In this paper, we analyse the implications of these differences for research and funding. On the basis of an extensive literature review, we argue that the heterogeneity of understandings in interdisciplinarity and transdisciplinarity constitutes an asset. We advocate for the plurality of understandings to be used constructively in order to strengthen and promote effective research and research funding.

Key words: transdisciplinary research; interdisciplinary research; science policy; academic literature; policy literature.

1. Introduction

'Interdisciplinarity' (ID) and 'transdisciplinarity' (TD)[1] have become important topics in academic and policy discourses, particularly as part of discussions about mission-oriented knowledge production and associated research funding processes (Huutoniemi et al. 2010). Recent reports and policy briefs demonstrate an increasing demand from the policy sector for greater integration of interdisciplinary research (IDR) and transdisciplinary research (TDR) into research calls and funding programmes, so that they can be used to address societies' grand challenges (Graf 2019; Stamm 2019).

Even though policymakers and funding organisations increasingly promote interdisciplinary and transdisciplinary collaborations, knowledge about the nature and practice of ID/TD is currently dispersed across many communities and referred to selectively in different contexts. In this article, we argue that neither the academic nor the policy literatures develop cohesive understandings about the nature of these research practices or even agree upon how to define ID and TD. We will show that there is little overlap between the academic and policy literatures on the practice of ID and TD, leading to an endless process of 'reinventing the wheel' where key problems in conducting IDR and TDR are repeatedly rehearsed in policy documents, while the solutions to such problems provided by the academic literature are ignored. Moreover, we make the case that disconnections between the academic and the policy literatures have a wider significance for institutions and individuals. Disagreements about definitions mean that the fundamental qualities of IDR/TDR are often misunderstood, weakening processes of institutionalisation.

Other authors have already highlighted the gap that exists between the academic and the policy discourses, labelling it the 'paradox of interdisciplinarity' (Weingart 2000). We extend this argument to TD, proposing a parallel 'paradox of transdisciplinarity'. Weingart argues that the top-down focus on 'challenge-based' research in the policy literature is accompanied by the continuing use of disciplinary systems of governance for evaluating and funding research (Woelert and Millar 2013). IDR and TDR are, therefore, trapped in a mismatch between discourses encouraging the use of ID/TD on the one hand and relatively inflexible monodisciplinary research funding and evaluation practices on the other (Weingart 2000; Woelert and Millar 2013). We argue that better connecting the academic and policy discourses of ID and TD will benefit both, by producing more nuanced definitions of ID/TD that have the potential to improve research practice and respond to current calls from the EU for evidence-based development of support for IDR/TDR.

In this paper, we ask the following questions: (1) How do the academic and policy literatures define and characterise ID/TD? and (2) What are the implications for research and funding of the different understandings of IDR/TDR in the academic and policy literatures? Unlike other authors who assume that there should only be one agreed upon definition of ID and TD (Aboelela et al. 2007; von Wehrden et al. 2017),

we start from the premise that plural definitions of these terms reflect the many ways in which ID and TD are practised and understood. Therefore, we argue that the heterogeneity of understandings in ID/TD constitutes an asset in research and policy and definitely not a deficit.

Here, heterogeneity refers to the plurality of practices and discourses expressed in different context-dependent configurations of ID/TD (following Rabinow and Stavrianakis 2016). We use this term because 'heterogeneity implies a collective entity that interactively integrates different entities, whereas diversity implies divergence, not integration. Consequently, striving for diversity alone may increase social injustice and reduce epistemic outcomes of academic institutions and governance structures (Shavit et al. 2016: 3). As a concept, heterogeneity encompasses the variability in conceptualisations of ID/TD, acting as a collective term that allows for differences and nuances. Such differences arise from different understandings of the nature and conditions of IDR/TDR. In our study, we do not propose that such differences are diluted but rather we want to make them visible by using the term heterogeneity. We pay attention to plurality between understandings of ID/TD, arguing that differences between definitions actually strengthen research practices, and help to advance IDR/TDR in science, policy, and research funding.

With this analytical perspective, we contribute to a growing body of critical studies of ID/TD (Barry and Born 2013; Marres and De Rijcke 2020; Lyall 2019), seeking to advance the potential of ID and TD by creating space for more nuanced discussions about the nature of ID and TD in research policy and improving the support for IDR/TDR in research funding.

The paper is organised as follows: in the next section, we detail the systematic literature reviews and qualitative content analyses of the selected literature that form the basis of our study. Then, we present the findings and describe how ID/TD are interpreted differently in academic and policy literature. We discuss the implications of these differences for the scientific and policy discourses. Finally, we draw conclusions that also open lines for future research.

2. Framework and method of the literature review

Describing how ID and TD are defined is challenging due to the nature of these phenomena. Not only are ID/TD not established as well-structured fields in the academic and policy literatures, but insights on them are also scattered across several bodies of literature. Comparing different definitions and accounts of ID and TD across a range of thematic contexts is an intricate task that requires analysing scientific papers, reports, and internal documents from funding agencies and research organisations, some of which aim to promote rather than understand IDR/TDR (Vienni Baptista et al. 2020a).

As part of the EU project 'Shaping interdisciplinary practices in Europe' (SHAPE-ID),[2] we conducted a systematic literature review (Jahan et al. 2016) that aimed to disentangle the different understandings of ID/TD. We compiled academic and policy literatures on ID/TD and critically examined these sources in order to (1) map different approaches to the same topic across these two corpora and (2) bring together different theoretical perspectives (Burgers et al. 2019). Academic literature consists of peer-reviewed journal articles, book chapters, and books on ID/TD. The category of material that we label here as 'policy literature' consists of non-peer-reviewed documents contributing to debates in research policy.[3] Such documents include evaluation and monitoring reports, event reports, funding calls, guidance and recommendations, position statements, press releases, and surveys of a research field or specific activities within it. In both these literatures concepts of ID/TD overlap significantly with normative accounts of how to conduct IDR/TDR.

The first step of the systematic literature review was determining the specific research questions to be answered. These were as follows: (1) How do the academic and policy literatures define and characterise ID/TD? and (2) What are the implications for research and funding of these different understandings of IDR/TDR? Next, we defined the inclusion and exclusion criteria for the academic and the policy literatures queries (Table 1).

In what follows, we present separately the steps we took to study the academic and the policy literatures, detailing how we connected them throughout the process.

2.1 Academic literature review

2.1.1 Data collection

For the academic literature query, we compiled academic published research on ID/TD using the criteria detailed in Table 1. The next step consisted of defining seven sets of keywords (Table 2) and combining them into complex search strings with Boolean operators. These were used to search Web of Science (WOS), Scopus, and JSTOR from 1990 until 2021 (Wciślik et al. 2020). The resulting data set consisted of 5,060 records (containing author, abstract, title, keywords, and tags). After removal of duplicates, a selection was done based on titles and abstracts. From those 942 records, two researchers performed parallel independent assessments of the titles and abstracts, and a total of 112 records from the academic literature were selected for the content analysis (Vienni Baptista et al. 2020a).

We also employed expansive search techniques, which involved forward and backward citation tracking of all included publications (i.e. checking if there were any further relevant texts that either cited or were cited by included publications); citation alerts were included up to April 2021.

2.1.2 Data analysis

We performed a qualitative content analysis to systematically describe the meaning of the data collected (Schreier 2014) using NVivo 12®. This was done by assigning successive parts of the material to the categories of a coding frame. Nodes or coding categories were based on the principles of grounded theory (Corbin and Strauss 1998) complemented by categorial thinking (Freeman 2017). Grounded theory allows for openly exploring and analysing inductive data and leads to developing a theory grounded in data (Charmaz and Mitchell 2001). Induction starts with the study of a range of individual cases and extrapolates patterns from them to form a conceptual category (Charmaz 2014:188). Categorial thinking was used to create criteria to identify and organise the nodes or data units and determine their relationships to the research questions (Freeman 2017). In further iterations, these nodes were also used in the policy literature review to create a shared analytical scheme (see section 2.2).

Table 1. Inclusion and exclusion criteria for academic and policy literatures.

	Academic literature	Policy literature
Scope	Key terms derived from the research questions	
Topic coverage	All papers had to contain: interdisciplinary or transdisciplinary	
Exclusion criteria	• Publications that exclusively relate to teaching and/or education • Publications where the title or abstract is not in English • Papers that analyse the interdisciplinary trajectory of a person or researcher • Publications that included the above terms with no further definition or discussion of how to conduct such research • Publications that exclusively refer to STEMM[9] subjects with no mention of the arts, humanities, or social sciences	
Inclusion criteria	All documents must meet at least one of these criteria: • Outline concepts/definitions and/or understandings of ID/TD research (interdisciplinary, multidisciplinary, transformative, participatory, collaborative, applied) • Explore factors that hinder/enable successful inter- and transdisciplinary research (conditions, principles) • Describe challenges of inter- and transdisciplinary research • Present integration processes and examples of good practices or reflect on how to perform this integration • Analyse and/or evaluate research projects empirically (quantitatively and/or qualitatively) and/or derive recommendations for designing or conducting inter- and transdisciplinary research	All documents must meet at least one of these criteria: • Outline concepts/definitions and/or understandings of ID/TD research (interdisciplinary, multidisciplinary, transformative, participatory, collaborative, applied) • Describe challenges of inter- and transdisciplinary research • Present integration processes and examples of good practices or reflect on how to perform this integration • Analyse and/or evaluate research projects empirically (quantitatively and/or qualitatively) and/or derive recommendations for designing or conducting inter- and transdisciplinary research
Geographic barriers	No geographic barriers Balance between countries represented in the analysed corpus was pursued	Publications from European (e.g. ALLEA, EC, or LERU) and global (e.g. OECD and GRC) organisations
Language	English	English
Period of time	1990–2021	1990–2021
Source	Scopus, WOS, and JSTOR	Scopus, WOS, Open Grey, SSRN, Bielefeld Academic Search Engine (BASE), and research organisations' websites

Table 2. Sets of keywords for the academic and policy literatures review.

Set A	Set B	Set C	Set D	Set E	Set F	Set G
Interdisciplinarity/transdisciplinarity	Research	Policy	Integration	Understanding	Factors/indicators	Success/failure
interdisciplinar*, transdisciplinar*	research* scien* knowledge collaborat* process* cooperat* partici* pat* practi* team* approach	polic* politic* guide* instrument* recommend* fund* govern*	integrat* interact* interplay boundar*	understanding* definition* concept*	factor* condition* challenge* barrier* principle* indicat* marker* criteria measur* evaluat* assess* metric*	success* quality effect* impact* benefit* unsuccess* fail* barrier obstacle difficult*

2.2 Policy literature review

2.2.1 Data collection

For the policy literature review, document curation—searching for and cataloguing appropriate sources—was an important and time-consuming element of the literature search. Our search protocol therefore had two phases, which entailed first sourcing documents and then screening and assessing their suitability for inclusion. As publications sourced from the policy literature tend not to include the equivalent of an academic abstract or keywords, this second phase required detailed searching of full documents in most cases.

Locating relevant documents was carried out using a range of strategies and following a recognised template (Fuller and Lenton 2018): (1) conducting search engines searches, (2) conducting database searches (manually searching the websites of relevant organisations), and (3) consulting experts within the SHAPE-ID team. We used the first set of keywords in Table 2 to perform a series of searches in different databases including academic databases such as WOS, Scopus, and Open Grey. We then switched to searching the websites of relevant organisations and checking bibliographies or citations in key documents. Finally, we consulted project members to identify any missing texts. Sources located using this search were mostly discrete documents. One hundred eighty-seven documents were provisionally identified as relevant, and 103 were retained for content analysis. Documents were included in the final sample if they provided some kind of definition of

one or more forms of collaborative research (cross-, inter-, multi-, or transdisciplinarity) or discussed the role that Arts, Humanities, and Social Sciences (AHSS) might play in such research.

The search strategy for the policy literature was designed in parallel with, and to mirror, the strategy for the academic literature (see section 2.1.1) and made use of a comparable set of inclusion criteria (Table 1) and the same search terms (Table 2). However, no geographical limit was applied to the academic search, whereas the policy literature search focused largely on documents published by organisations based in Europe (with a few from influential global organisations also included). Our reasoning for this difference was that English-language research is, in some senses, global, whereas research policy is more geographically limited—the roles played by national funders (often governments) and the EU means that we can meaningfully talk about European research policy.

2.2.2 Data analysis

One hundred three documents were analysed using NVivo 12®. An abbreviated version of the codebook used to analyse the academic literature (Table 2) was used to code the policy literature documents. Policy literature texts have been created for a range of different purposes including: (1) as public contributions to debates about European research policy (particularly in the run up to new funding schemes), (2) as summaries of the implications of academic research into IDR/TDR, (3) as surveys of particular academic fields, or (4) to monitor major research programmes such as Horizon 2020 (Vienni Baptista et al. 2020a). Despite the use of a simplified codebook, coding this set of documents was a complex process that required a significant amount of interpretative labour.

The coded sources were categorised according to: (1) the geographic level of the publishing organisation (global, European, or national), (2) a basic typology of these organisations (funding agency, learned/professional organisation, and research organisation), and (3) type of document (the most common were position statements, guidance documents, and research-based reports). As well as national bodies, funding agencies included the European Commission (EC), the Global Research Council, and the Wellcome Trust. Learned and professional organisations included the Alliance of All European Learned Academies (ALLEA), European Alliance for the Social Sciences and the Humanities (EASSH), the League of European Research Universities (LERU), and Science Europe. Research organisations included the Academy of Finland, and the Network for Transdisciplinary Research (td-net, Swiss Academies of Arts and Sciences). We categorised documents based on what their primary purpose appeared to be. For example, many of the guidance documents refer to some research, but they were written to provide advice to researchers, research organisations, and funding agencies. Position statements are often labelled as such, but we have also included in this category a collection of case studies by LERU as the authors use them to argue for the inclusion of the creative arts in universities.

3. Findings

This section presents our findings on how the academic and the policy literatures each understands definitions of ID/TD.

3.1 The academic discourse on inter- and interdisciplinarity

In the academic literature, ID and TD denote a spectrum of experience (Lyall 2019) and are usually defined as contested terms (Barry and Born 2013; Hessels and van Lente 2008; Klein 2014; Lury 2018; Lyall 2019). ID and TD can both be understood as an object of study, a governmental demand, or a reflexive orientation (Barry and Born 2013). Each represents an array of interrelations between disciplines and further bodies of knowledge such as programmatic statements, policy interventions, institutional forms, theoretical statements, research instruments, materials, and practices all immersed in processes of negotiation (Barry and Born 2013).

The most widely used schema for defining collaborative research (i.e. multidisciplinary, interdisciplinary, and transdisciplinary) derives from a typology presented at the first international conference in 1970 (Organisation for Economic Co-operation and Development (OECD), 1972).[4] Since then, ID has been defined more fully

> as a methodology, a concept, a process, a way of thinking, a philosophy, and a reflexive ideology. It has been linked with attempts to expose the dangers of fragmentation, to re-establish old connections, to explore emerging relationships, and to create new subjects adequate to handle our practical and conceptual needs (Klein 1990: 196).

This partially overlaps in meaning with the term TD, which is often used in German-speaking countries, the Netherlands, and some Nordic countries (Pohl 2008) to refer to a reflexive, integrative, method-driven scientific principle, aiming at solving societal problems by integrating knowledge from various scientific and social perspectives (see, as just one example, Hirsch Hadorn et al. 2008). However, the term TD is rarely used in the UK, where the understanding of ID can sometimes imply the inclusion of non-academic stakeholders (Lyall et al. 2015).

Heterogeneity is recognised as a relevant feature of the definition of ID (Lyall 2019; Mäki 2016; Nersessian 2019) and TD (Pohl 2010). The academic discourse on ID and TD reveals divergence, nuance, and contextual specificity (Klein 2005), with differences evident across disciplines, regions, and scholarly communities (td-net 2020; Vienni Baptista et al. 2020a). ID and TD do not comprise universal consensual conceptions, as the definition used in each case depends on the knowledge community that applies it (von Wehrden et al. 2017), and it expresses the diverse aims or purposes that researchers pursue (Lyall 2019; td-net 2020).

Due to the complexity, ambiguity, and uncertainty of the problems that ID/TD approach (Hoffmann et al. 2017), some authors argue that definitions cannot be universal and should adapt to different contexts (Jahn et al. 2012; Spaapen et al. 2007). In further studies (e.g. Madsen 2018), ambiguities in conceptualisations show that the difference between opposite positions can be reconciled when referring to integration but also that disagreements remain in the literature as some positions are antagonistic and mutually exclusive.

Notwithstanding this divergence of definitions, ID and TD are seen to share some common features: interdependence, co-operative labour, and mutuality among participants, combined with an orientation towards a shared intellectual purpose, are seen as present in most interdisciplinary and

transdisciplinary settings (Fitzgerald et al. 2014; Rabinow and Bennett 2012).

As a means of dealing with this complexity, academics have begun to problematise the definitions of ID and TD. Klein's (1990) was the first milestone, followed in the last two decades, by a growing number of scholars studying the development of ID/TD in different contexts (e.g. Barry et al. 2008; Barry and Born 2013; Callard and Fitzgerald 2015; Felt et al. 2016; Hoffmann et al. 2013; Lengwiler 2006; Lindvig and Hillersdal 2019; Lyall 2019; Marres and De Rijcke 2020; among others). Klein's (1990, 2005) historical perspective on ID/TD allowed her to identify the following three discourses of ID:

- The philosophical discourse: discusses epistemological issues on how interdisciplinary knowledge is constructed and the nature of reality, searching for unity in science.
- The problem-solving discourse: oriented to instrumental needs, specifically developed to cope with complex problems. During the 1980s and early 1990s, this discourse became entwined with the concept of transdisciplinarity in environmental research in German-speaking countries.
- The critique discourse: implying '[the] critique of the state of the disciplines being restructured and, either implicitly or explicitly, the prevailing structure of knowledge' (Klein 1996: 11).

Further contributions to the analysis of TD conceptualisation, elaborated by Klein (2014) and Osborne (2015), classify the following three transdisciplinary discourses that converge with those elaborated for ID:

- The transcendence discourse: aiming at the unity of knowledge and transcending the narrowness of disciplinary worldviews and practices.
- The problem-solving discourse: aiming to transform concrete situations and approach complex problems.
- The transgression discourse: emerging out of a fundamental critique of the system of knowledge and education and relating to discourses on democratisation of knowledge.

In a similar fashion, Pohl (2010) analysed three types of definitions of TD as the combination of four characteristic features of the term, namely: (1) relation to socially relevant issues, (2) transcendence and integration of disciplinary paradigms, (3) participatory research, and (4) the search for a unity of knowledge. He argues that feature (1) represents research that transcends and integrates disciplinary paradigms in order to address socially relevant issues. For some authors, it also implies a new mode of governing science (Maasen and Lieven 2006) or means of bridging science and policy (Pohl 2008). Nicolescu (2000), for instance, represents concept (4) arguing that TD is a new universality of thought and education informed by the worldview of complexity in science, fostering an open-minded rationality, subjectivity, and ethics to formulate problems in ways that are transnational and trans-epistemic.

When confronted with the tension between plural understandings of ID/TD and the demand for a single universal definition, the academic discourse presents a range of arguments in order to address this tension. One method is to reduce heterogeneity. For example, Aboelela et al. (2007: 331) argue that a precise definition of IDR is necessary to guide successful research design and funding decisions. Following a similar overarching aim, Pregernig (2006) develops a meta-level analysis of definitions of TD. Although Aboelela et al. (2007) find relevant paradigmatic differences among the literature, they ultimately elaborate a definition of ID that does not provide any new elements to those offered in previous studies. Under their perspective, ID is:

> (…) based upon a conceptual model that links or integrates theoretical frameworks from those disciplines, uses study design and methodology that is not limited to any one field, and requires the use of perspectives and skills of the involved disciplines throughout multiple phases of the research process (Aboelela et al. 2007: 341).

In another attempt to simplify diversity, von Wehrden et al. (2017) seek to build a common understanding of ID and TD, outlining the characterising features included in existing definitions. Their analysis identifies a set of building blocks for IDR/TDR, including: (1) creation of collective glossaries, (2) definition of boundary objects, (3) use of combined problem- and solution-oriented approaches, (4) inclusion of a facilitator of IDR/TDR within the team, and (5) accompanying research to promote reflexivity. From our perspective, the identification of these building blocks does not amount to a new classification of ID/TD. Rather, it shows the common conditions that need to be in place to carry out these types of research effectively.

A different approach aims to accommodate heterogeneity. Frickel et al. (2016) classify the academic interdisciplinary literature into three categories dealing with: (1) ecologies of interdisciplinary knowledge, (2) phases of interdisciplinary creation, and (3) efforts to find and bridge the gap between disciplines. These authors aim at better understanding what researchers do and what they study when they embark upon IDR.

Finally, in a refined version of this approach, Huutoniemi et al. (2010) propose a conceptual framework to fulfil the need for a robust and nuanced approach of ID. They contend that no general interdisciplinary indicator useful for science–policy purposes has been yet accepted. As others have argued, nuances and differences are relevant as '(…) differing definitions, assessment tools, evaluation processes, and measures all shed light on different aspects of IDR' (Wagner et al. 2010: 14).

While definitions differ, ID and TD refer to dynamic epistemic and social processes, which imply levels of integration that can also change over time in a research project (Hoffmann et al. 2017; Woelert and Millar 2013). ID and TD '(…) often flourish most where they are not actively encouraged through measures and incentives, but where sufficient room is given for the pursuit of more open-ended, risky and collaborative research endeavours' (Woelert and Millar 2013: 765). In such endeavours, new definitions are built as part of practice (Lengwiler 2006: 424). IDR constitutes a field of multiple 'styles of practices' each with its own potentials and problems that depend upon the organisational and epistemic conditions of the specific research field (Lengwiler 2006; Nersessian 2019).

From the analysed academic literature, we can conclude that most definitions of ID/TD focus on defining the

features of knowledge produced by applying an inter- or transdisciplinary approach and how disciplines interact in such contexts (e.g. Aboelela et al. 2007; Barry et al. 2008; Klein 1996). Most of these definitions of ID/TD consider integration as crucial to successful inter- and transdisciplinary processes (e.g. Pohl et al. 2021).

Most of the definitions studied also identified the specific participants involved in these knowledge production processes. However, the type of participant and their roles vary according to the understanding of IDR or TDR. For instance, authors analysing TDR processes have produced much more sophisticated classifications of societal actors and their roles than scholars interested in IDR (e.g. Duncan et al. 2020; Mielke et al. 2016). These definitions are the result of ongoing processes of negotiation between disciplines, participants, and institutions. Such contextual differences between research fields, institutions, and countries greatly influence the potential for successful IDR/TDR, showing that heterogeneity should and must be taken into consideration to fully understand the impact these different contexts might have.

3.2 The policy discourse on inter- and transdisciplinarity

In what follows, we draw insights on how the policy discourse defines ID and TD. Although some authors have discussed the need for new policy agendas and plans (Krull 2004; Palma Conceição et al. 2020), the policy literature in Europe offers few links to the academic discourse. We also found little effort in much of the policy literature to explain or define what is meant by ID or TD.[5] Out of a sample of 103 documents analysed in our study, only thirty-three provided any kind of definition of the term 'interdisciplinary', the rest assuming that its meaning is clear and widely agreed upon. In terms of definitions, the National Academy of Sciences report (2005) is the most commonly quoted definition of ID. When quoting scholarly work on ID/TD, Julie Thompson Klein is the most consistently cited author (Vienni Baptista et al. 2020a). Other authors (e.g. Barry et al. 2008; Bruce et al. 2004; Callard and Fitzgerald 2015) are cited but usually for only a single publication.

When definitions were provided, they were—compared with the academic discourse—un-nuanced or over-simplified, for example, 'Interdisciplinary research may be identified as research where two or more disciplines work together to produce a common body of work' (GRC 2016: 4). For its part, Net4Society (2013: 1) defines ID as '(…) hard to practice as it is to pronounce. And, *like most buzz words*, it often lacks clear definition and usage' (our emphasis). The authors characterise ID as looking '(…) at same phenomena from different viewpoints but tries to integrate the explanations thus producing connected stories' (Net4Society 2013: 2).

Moreover, several authors in the policy literature (e.g. EURAB 2004; IHS 2019) refuse to provide definitions by arguing, for example, that 'diverse definitions of inter- and transdisciplinarity coexist within scientific literature and in the mind of researchers and practitioners' (INTREPID 2017: 4). Despite this scarcity of definitions, the distinction between IDR and TDR often remains present, usually on the basis of the involvement of stakeholders (e.g. ALLEA 2013; Mayer et al. 2013; LERU 2014, 2016; OECD 2020; Technopolis 2016). For Net4Society (2013: 2), TD 'draws together theories and approaches to form a shared conceptual and analytical framework - a new discipline thus resolving in an integrated story'.

An exception to this pattern is the reports published by LERU (2014) and the Academy of Finland (2005). Having interdisciplinary and transdisciplinary scholars as co-authors (i.e. Julie Thompson Klein and Katri Huutoniemi, among others), these documents provide more sophisticated taxonomies distinguishing between multi-, inter-, and transdisciplinarity and their sub-types. And a few other authors also argue for more nuanced definitions of ID:

> We set out with a 'family resemblance' concept of interdisciplinarity, focusing on ways that it is practised, rather than a strict definition. The kinds of IDR we were considering included:
>
> • Individual researchers learning methods from other areas (…).
>
> • Exploratory collaborations between disciplines to find areas of common interest (…).
>
> • Challenge- or question-focused research that requires the input of a range of disciplines working together (…).
>
> • Emerging disciplines that bring together approaches from separate areas (…).
>
> • Individuals or groups of researchers working in areas seen as inherently interdisciplinary (British Academy 2016: 8, see also Adams et al. 2016: 1).

More recently, the OECD (2020: 24) published a detailed analysis of transdisciplinary projects searching for those nuances, stating the urgent need to address the differences between discourses:

> The definition and theoretical basis for transdisciplinarity remains contested, with different knowledge communities adopting different principles. Whilst this might be considered a purely academic consideration with limited practical relevance, it is problematic in that it divides the research and policy communities and is consequently a barrier to communication, mutual learning, and the consolidation of guidelines and best practices.

Another set of policy documents focuses on how to conduct or evaluate IDR/TDR (e.g. ALLEA 2013). These highlight exemplary interdisciplinary projects, discuss the difficulties in doing such research, and provide practical recommendations to improve it. However, some of these more empirical accounts largely remain embedded in broad disciplinary areas from which they derive a distinctive terminology and set of references. This embedding leads to a series of fragmented and only partially overlapping accounts of IDR and TDR (e.g. Mayer et al. 2013).

Calls promoting IDR/TDR constitute a third type of document within the policy literature. In this literature, EC funding officers see approaches to the heterogeneity of definitions as not sufficient to encourage better IDR/TDR (see Graf 2019).[6] For example, the Horizon 2020 Programme aimed at implementing ID through an integrated

scientific approach (NCP. National Contact Point Brussels 2014) and when addressing how to achieve 'true' ID across all seven challenges, refers to a broad range of collaborative research approaches (i.e. multi-, inter-, cross-, and transdisciplinarity and co-creation and co-design) (Graf 2019).

Some definitions were provided on the Horizon 2020 FAQ section, but this focuses on ID and contained no proper conceptualisation of TD (Graf 2019). For this author, ID implies 'the integration of information, data, techniques, tools, perspectives, concepts or theories from two or more disciplines' (Graf 2019: 33). Horizon 2020 topic texts provided some hints of what TD is, but no official definition has yet been provided by the EC (Graf 2019). However, a guidance document for evaluators published in 2014 states that '(…) transdisciplinarity (…) refers to approaches and methodologies that integrate as necessary (a) theories, concepts, knowledge, data, and techniques from two or more scientific disciplines, and (b) non-academic and non-formalized knowledge' (European Commission 2014: 1).

In the same fashion, the series of the EC monitoring reports (Kania and Bucksch 2020; Kania et al. 2019) analyse how much budget is dedicated to successful inter- and transdisciplinary projects and specifically to humanities and social sciences research within these projects (Stamm 2019). Indicators of ID are not provided in reporting, as its existence is taken for granted and identified as 'best practice' in some funded projects.

According to our analysis, the policy literature focuses on the dimension of 'what is ID/TD?' and approaches the topic in a prescriptive or top-down approach. For example, Horizon 2020 topics clearly indicated how research should be carried out and the expected impacts. But, pre-defined topics and research outcomes are in conflict with ideas of collaboration and co-production that are key to many forms of ID and TD. This lack of openness in the research process is symptomatic of a wider problem of weak links between the academic and policy literatures on IDR/TDR. Knowledge about how best to fund, conduct, and evaluate IDR/TDR developed in the academic literature is consistently ignored in the policy literature. Such 'knowledge gaps' between and within these two corpora exacerbate the problems of contested definitions of ID/TD; lend further weight to the implicit model of IDR/TDR as solely a means of solving societal challenges, missions, or problems; and discourage cumulative learning, among other implications (Vienni Baptista et al. 2020b).

4. Discussion: the implications of different understandings of inter- and transdisciplinary research and funding

This paper addresses two research questions: (1) How do the academic and policy literatures define and characterise ID/TD? and (2) What are the implications of the different understandings of ID/TD in the academic and policy literature for research and funding? Our analysis demonstrates a substantial difference in how the policy and the academic literatures treated these terms:

- In the policy discourse, there is an accepted assumption of a shared understanding of ID and TD that can be unproblematically used in research funding programmes that respond to the increasing demand in Europe for more IDR/TDR addressing key societal challenges (Graf 2019; Net4Society 2013). Nevertheless, in these contexts, the terms ID and TD are often left undefined and used as if their meanings are interchangeable.

- By contrast, the academic discourse presents different definitions of ID and TD. These are plural and coexist in different overlapping contexts, reflecting multiple ways of approaching and dealing with complex problems (td-net 2020). IDR and TDR employ a wide range of procedures and methods to realise interdisciplinary and transdisciplinary knowledge production (Barry and Born 2013; Callard and Fitzgerald 2015; Maasen et al. 2006). These eclectic contexts mean that different definitions are used and developed in practice (Lengwiler 2006).

Absent, multiple, or conflicting definitions of ID/TD closely relate to how we value these forms of research. Many concepts are contested, particularly in the humanities and social sciences, but the gaps and contestations we describe above are important because ID/TD are not just parts of academic theory but challenge the current way in which we manage and conduct research. No single discipline 'owns' the terms ID and TD, so their advancement as modes of research needs to be adequately supported by a plethora of different institutions and funding agencies. Given the increasing amounts of public money that have been directed towards ID/TD at both national and international levels—under the labels of mission-oriented or problem-oriented research—it is vital that we ensure the effectiveness of this funding. This demands a better shared understanding of this model of research practice.

Based on our analysis, we found that the differences between the academic and the policy discourses on ID/TD demonstrate a lack of understanding of the distinctive practices of IDR/TDR, partly reflected in absent or incomplete definitions of these terms. These have (at least) the following three sets of implications for the future development of IDR/TDR:

(i) Researchers try to frame their problems and research questions according to the incomplete models found in the policy discourse.
(ii) As a direct result, ID and TD do not achieve their full potential in the scientific realm as they are poorly understood and badly supported by the policy sector.
(iii) The role that policymakers and funders play further reproduces the ID/TD paradox. Over-simplified definitions give rise to un-nuanced understandings of research processes, meaning that IDR/TDR projects do not have sufficient time to be conducted properly. This can lead to poor integration processes or fake collaborations that only mimic IDR/TDR.
(iv) The way IDR/TDR are valued and how this affects their status within institutions. Universities and research centres still consider IDR/TDR as an 'epiphenomenon' or secondary effect of funding priorities (Lyall 2019). They are weakly institutionalised as longer term funding policies discourage ID/TD by legitimising academic

individualism and shortening timelines for research and learning (Vienni Baptista et al. 2022).

The first set of implications (i) refer to scientists reframing the research problems in IDR/TDR to 'fit in' (Weingart 2000: 38) with the demands of political agendas. What 'fit in' means varies within and between funding agencies, as expectations of IDR/TDR differ depending on perceptions of what ID or TD is, what each can do, and who the researchers are (Bromham et al. 2016; Schneider et al. 2019). Efforts to 'fit in' mean that the flow of knowledge between the scientific and the policy realms 'is not neutral' (Strathern 2004: 554). In some disciplines, a specific way of doing ID is implemented, based not only on scientific demands and needs but also on the policy logics (Strathern 2004). Researchers influenced by funding 'mania for interdisciplinariness' (Dai 2020) feel compelled to develop a putative IDR topic and organise their research collaboratively, sometimes risking their own research integrity (Hessels and Kingstone 2019).

Efforts to 'fit in' also restrict the degree to which ID/TD are effective. This is influenced, in the first place, by the setting up, focus, and agenda of the funding programme (Bruce et al. 2004; Lyall et al. 2013). Through efforts to 'fit in', programmes fund projects that are only multidisciplinary (Lyall et al. 2013; Lyall and Fletcher 2013) or lead to the creation of 'fake collaborations' (Dai 2020). Furthermore, funding methods may also encourage such dubious behaviours (Conroy 2020) by using disciplinary-based evaluation criteria and idiosyncratic definitions combined with a fuzzy understanding of ID/TD. We agree with other authors who argue that the policy and funding systems work against the development of rigorous interdisciplinary work (Bromham et al. 2016; Lindvig and Hillersdal 2019; Lyall and Fletcher 2013; Schneider et al. 2019).

Incomplete, unclear, or divergent definitions of ID/TD also influence research practices and hinder the full potential of IDR/TDR. 'The absence of clear definitions and assessment criteria produced a dominant, all-inclusive, but vague, configuration of interdisciplinarity that affected the research outcome' (Lindvig and Hillersdal 2019: 23) and hinders different types of impact that could be achieved (Molas-Gallart et al. 2014). Differences between ideal descriptions of interdisciplinary collaboration and the daily practices of IDR/TDR are affected by policy agendas, funding calls, and evaluation practices, defined by funder management (Fitzgerald et al. 2014; Lindvig and Hillersdal 2019). The disconnection between discourses in science and policy reproduces power imbalances and acts as a hindering factor for IDR/TDR.

The second set of implications of the differences between discourses (ii) is that ID/TD do not achieve their full potential. This is reinforced by the meagre impact that results from inter- or transdisciplinary projects have often achieved (Pregernig 2006). ID and TD have a complex relationship to impact—because different understandings of IDR/TDR can lead to different types of impact (Molas-Gallart et al. 2014). For example, some projects produced specific and implementable solutions to drive impact, whereas, in other cases, knowledge and its dissemination to stakeholders were interpreted as evidence of impact (Molas-Gallart et al. 2014). In such contexts, the promises of ID and TD successfully addressing grand challenges remain unfulfilled, and participation is reduced to a rhetoric that does not fully represent the different processes of integration that are actually being carried out (Hoffmann et al. 2017).

The third set of implications (iii) highlights policymakers and funders' roles in reproducing the paradox of ID/TD. We argue that policy approaches to ID/TD are often highly instrumental. However, we recognise that this is only one—albeit important—aspect of this particular science–policy interface (Hofmänner and Macamo 2021; Pestre 2007). Policy narratives of IDR/TDR also make use of these topics symbolically, utilising them to align authors and institutions with well-established framings of research driving innovation and economic growth. Funding agencies have their own particular perspectives on the world of research. Given the dependence of science on external funding sources, these perspectives are bound to affect the internal cognitive and organisational divisions of science and the relationship between disciplines (Lyall et al. 2013; Rosales 2021), for instance, by funding some disciplines more generously than others.

The fourth set of implications (iv) acknowledges that IDR and TDR require conditions that differ from those needed for disciplinary research (Schneider et al. 2019). IDR and TDR employ a wide range of institutional arrangements, procedures, and methods in order to realise knowledge production processes (Maasen et al. 2006). This usually means that funding bodies apply existing tacit knowledge in the management of IDR/TDR programmes and projects, while finding it difficult to embed this learning into effective systems and structures for interdisciplinary programmes (Lyall et al. 2013). For example, Spaapen et al. (2020) recently showed that unlike European funding programmes, national funding organisations are often still organised along disciplinary lines. This makes it difficult to develop IDR and TDR programmes and expertise, meaning that specific measures will be required to make institutional settings more hospitable to such ways of working.

Lack of policy learning on how to facilitate and support IDR/TDR permeates the academic and policy literatures, therefore further reproducing the paradox. In the funding discourse, ID/TD are often included tokenistically so that '(…) on the level of actual research policy, only very vague and superficial policy directives and associated governance mechanisms have been implemented that actually target and aim to foster IDR and TDR'(Weingart 2000: 26).

Finally, traditional processes of academic knowledge production are strongly underpinned by policies using (mono)-disciplinary classification mechanisms for evaluation (Woelert and Millar 2013). As a consequence, ID and TD stay as superficial additions to research programmes (Lyall 2019). However, simultaneously, they are strategically used as politically useful tools to build a rhetorical interface between science and key social problems (Weingart and Sterh 2000).

Although, in the last decades, significant policy attention has been paid to the funding of IDR/TDR (EASSH. European Alliance for Social Sciences and Humanities 2019; Graf 2019; Stamm 2019), important challenges endure. Funding schemes have shown little consistency of definition or provided no definitions at all of these terms (EASSH. 2019). This problem was identified several years ago and still persists (Bruce et al. 2004), although the recent Horizon Europe programme shows small positive changes (Reiter-Pázmándy 2021).

To sum up, the interface between academic and policy discourses on ID/TD implies that: (1) researchers do not always

speak the language of policymakers (Bammer 2013) and (2) researchers do not always focus on the issues policymakers stress (Bammer 2013) or may not be able to tailor knowledge products to meet the needs of the policy process (Allio et al. 2006; Budtz Pedersen 2014; Jacob and Hellstrom 1996), and (3) researchers may see their results manipulated for partisan benefit, influencing how the research process is framed (Bammer 2008; Bruce et al. 2004; Lindvig and Hillersdal 2019; Lyall et al. 2013). A relationship, in which knowledge production and its output have to be tailored to fit a particular audience, has profound implications for science in terms of the selection of relevant data and methods (Jacob and Hellstrom 1996). It has also affected the ways in which IDR/TDR have been developed (Conroy 2020; Dai 2020; Lindvig and Hillersdal 2019). The matrix of values, institutions, resources, or political realities in which such a relationship forms determines the way in which a problem can be formulated and perceived, and solutions to it are implemented (Jacob and Hellstrom 1996).

This study has three limitations worth noting. First, we conducted this literature review as part of the SHAPE-ID project, which aimed to provide recommendations to improve the integration of AHSS in IDR/TDR, a relatively understudied topic. For this reason, we took the methodological decision to exclude the policy literature that did not mention the role of AHSS in ID and TD.

Second, the results of the SHAPE-ID project were specifically designed to advise the EC and influence the European research funding landscapes, not those in other regions. We excluded North American reports from our policy literature review but did include some more wide-ranging and influential reports—from organisations such as the OECD—that we label 'global', due to their influence on and connection with the academic literature. Finally, our literature searches were conducted in English, due to time constraints in the research process. The literature on ID and TD in other languages and the ways IDR/TDR are understood in academic and policy literatures in other continents are important topics that deserve similar analyses in future research projects.

5. Concluding remarks

We conclude that the academic and the policy discourses of IDR/TDR are disconnected, creating a pervasive tension between them. We outline the implications of the 'intricate networks of encounters and tensions in which science and policy are embedded' (Pestre 2007: 4) and how these influence the development of IDR/TDR. As a means to approach the connection between discourses, we argue that this tension feeds an already known paradox in the science–policy interface (Weingart 2000), whereby the full potential of ID/TD to address real complex problems remains unfulfilled and integration remains largely rhetorical (Pregernig 2006). This tension between the rhetoric about the necessity of ID/TD proliferating in policy documents and the persistence of government policies based on disciplinary perspectives cause that ID and TD are poorly understood and badly supported by the policy and funding sectors.

As our study shows, ID/TD are often used as buzzwords and included in research funding programmes and policies that do not clearly define them (Bruce et al. 2004; Lyall and Fletcher 2013). An increasing number of programmes call for interdisciplinary and transdisciplinary production of knowledge (Stamm 2019), without clear guidelines on how to understand these terms and properly implement projects that use such approaches (Lindvig and Hillersdal 2019; Spaapen et al. 2020).

This lack of nuance in conceptualisations of IDR/TDR in the policy literature hinders informed discussions and incremental knowledge about the benefits of such research and the difficulties in undertaking it. Lack of explicit definition is problematic because it is often combined with an implicit model of IDR/TDR that sees it solely as a means of solving societal challenges, missions, or problems.

According to our findings, the academic literature has elaborated robust and powerful definitions of ID/TD. We advocate the acceptance of this heterogeneity as an important component of IDR/TDR and the development of instruments, for research and funding, which explicitly acknowledge this mosaic of different definitions. The challenge is not to arrive at a single understanding that collapses differences but to build dialogue between different understandings while recognising and retaining their differences (Vienni Baptista et al. 2020a).

We argue that by making strategic use of a wider range of understandings of ID/TD, heterogeneity could become an accepted and productive element of IDR/TDR funding and research policy. We pose an urgent call to apply different strategies to support the fields of IDR/TDR and specifically their theories and methods. Expertise in IDR/TDR also requires special measures to be developed and supported, as Boone et al. (2020) and Duncan et al. (2020) argue. Advances in interdisciplinary and transdisciplinary theories and methods (Bammer et al. 2020) should aim towards better connections between the academic and policy discourses.

Our study implies that no universal definition is valid but instead argues for a co-productive space in which policymakers, funders, and researchers can jointly elaborate on a range of new common understandings of ID/TD, in the process of developing stronger support and assessment approaches. As our findings show, authors in the academic literature emphasise different dimensions in different modes of collaboration, giving rise to novel forms of organising research. It seems reasonable then that different definitions are being built, used, and enacted and that a plural understanding of these new kinds of research is necessary.

To conclude, we suggest three actions for future research to enhance the role of IDR/TDR at the European level. First, new approaches to societal challenges can be developed using IDR/TDR. In this context, it is important to build greater trust among researchers, funders, and policymakers through a long-term, sustained, and participatory dialogue (Spaapen et al. 2020). Knowledge brokers can play a substantial role in bridging these discourses (Duncan et al. 2020).

Second, in funding calls, applicants should be invited to state their underlying understanding of IDR/TDR and to explain why this approach is necessary to undertake the research called for. Such explanation can then be used to underpin appropriate evaluation criteria.

Third, we see a need for additional research to enable the development of tools that help to address this problem and to build stronger bridges between discourses on ID/TD by analysing key definitions and explaining the implications

different conceptualisations have in different settings. The SHAPE-ID team developed some tools and promoted the need for multiple understandings of ID/TD in a range of formats that included developing a toolkit for IDR/TDR,[7] publishing a series of Open Access policy briefs, and conducting webinars and training events for key stakeholder organisations.[8] Although SHAPE-ID funding has finished, these activities continue as part of our commitment to improving IDR/TDR practices. We advocate for the heterogeneity of understandings of ID/TD to be explicitly taken into consideration and constructively used in the future to promote effective IDR/TDR.

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Notes

1. It is customary to begin an article like this with definitions of key terms, like ID and TD; however, this would invalidate our overall argument. Instead, we note that definitions of ID/TD reflect the wider value we put on research as well as influencing ideas about how IDR/TDR should be conducted in particular contexts. The fact that ID/TD and IDR/TDR are often tightly bound up with each other allows us to consider them together in this study.
2. 'Shaping interdisciplinary practices in Europe' received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No. 822705. SHAPE-ID addressed the challenge of improving interdisciplinary and transdisciplinary cooperation between the arts, humanities, and social sciences (AHSS) and other sciences, particularly science, technology, engineering, and mathematics (STEM).
3. This a specialised sub-set of grey literature, often defined as '(…) that which is produced on all levels of government, academics, business and industry in print and electronic formats, but which is not controlled by commercial publishers' (Tyndall 2008: 2).
4. Here we are not making reference to the variety of taxonomies that the academic literature offers on ID and TD. We acknowledge their relevance to the problem we study, but we do not deepen their analyses.
5. It is not unique to policy literature on ID/TD that key terms are not defined, but as we argue below is particularly problematic as this literature reflects the understanding of research used in funding and evaluation processes.
6. Due to the time frame covered by our study, this analysis does not include the EC Horizon Europe, promising in relation to IDR/TDR promotion.
7. See the SHAPE-ID toolkit: https://www.shapeidtoolkit.eu.
8. The series of webinars 'Shaping conversations on interdisciplinary research' is accessible at: https://www.shapeid.eu/webinars/.
9. Engineering Science, technology, medicine, and mathematics.

References

Aboelela, S., Larson, W., Bakken, E., et al. (2007) 'Defining Interdisciplinary Research: Conclusions from a Critical Review of the Literature', *Health Services Research*, 42: 329–46.

Academy of Finland. (2005), *Promoting Interdisciplinary Research: The Case of the Academy of Finland*. <https://helda.helsinki.fi/handle/10138/232267> accessed 13 Jun 2022.

Digital Science. Adams, J., Loach, T., and Szomszor, M. (2016) 'Digital Research Report: Interdisciplinary Research - Methodologies for Identification and Assessment', *Digital Science. Report*.

ALLEA. (2013), *Sustainable Aquatic Food Supply: Guidelines for an Interdisciplinary Research Project*. <https://allea.org/wp-content/uploads/2015/07/2014_01_30_FullReport_Interdisciplinarity.pdf> accessed 21 Oct 2021.

Allio, L., Ballantine, B., and Meads, R. (2006) 'Enhancing the Role of Science in the Decision-making of the European Union', *Regulatory Toxicology and Pharmacology*, 44: 4–13.

Bammer, G. (2008) 'Enhancing Research Collaborations: Three Key Management Challenges', *Research Policy*, 37: 875–87.

——— (2013) *Disciplining Interdisciplinarity, Integration and Implementation Sciences for Researching Complex Real-world Problems*. Canberra: ANU E-Press.

Bammer, G., O'Rourke, M., O'Connell, D., et al. (2020) 'Expertise in Research Integration and Implementation for Tackling Complex Problems: When Is It Needed, Where Can It Be Found and How Can It Be Strengthened?' *Palgrave Communications*, 6: 5.

Barry, A. and Born, G. (2013) *Interdisciplinarity: Reconfigurations of the Social and Natural Sciences*. New York: Routledge.

Barry, A., Born, G., and Weszkalnys, G. (2008) 'Logics of Interdisciplinarity', *Economy and Society*, 37: 20–49.

Boone, C. G., Pickett, S. T. A., Bammer, G., et al. (2020) 'Preparing Interdisciplinary Leadership for a Sustainable Future', *Sustainability Science*, 15: 1723–33.

British Academy. (2016), *Crossing Paths: Interdisciplinary Institutions, Careers, Education and Applications*. London: <https://www.thebritishacademy.ac.uk/sites/default/files/Crossing%20Paths%20%20Full%20Report_2.pdf> accessed 21 Oct 2021.

Bromham, L., Dinnage, R., and Hua, X. (2016) 'Interdisciplinary Research Has Consistently Lower Funding Success', *Nature*, 534: 684–7.

Bruce, A., Lyall, C., Tait, J., et al. (2004) 'Interdisciplinary Integration in Europe: The Case of the Fifth Framework Program', *Futures*, 36: 457–70.

Budtz Pedersen, D. (2014) 'The Political Epistemology of Science-Based Policy-Making', *Social Science and Public Policy*, 51: 547–51.

Burgers, C., Brugman, B. C., and Boeynaems, A. (2019) 'Systematic Literature Reviews: Four Applications for Interdisciplinary Research', *Journal of Pragmatics*, 145: 102–9.

Callard, F. and Fitzgerald, D. (2015) *Rethinking Interdisciplinarity across the Social Sciences and Neurosciences*. London: Palgrave Macmillan UK.

Charmaz, K. (2014) *Constructing Grounded Theory*, 2nd ed. Los Angeles: SAGE.

Charmaz, K. and Mitchell, R. (2001) 'Grounded Theory in Ethnography'. In: Atkinson P., Coffey A., Delamont S., et al. (eds) *Handbook of Ethnography*, pp. 160–74. London: SAGE.

Conroy, G. (2020), *The Push for Interdisciplinary Teams Can Lead to Fake Collaborations. Funding methods encourage dubious behaviors*. <https://www.natureindex.com/news-blog/push-interdisciplinary-teams-science-research-can-lead-fake-collaborations> accessed 21 Oct 2021.

Corbin, J. M. and Strauss, A. L. (1998) *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. Thousand Oaks: Sage.

Dai, L. (2020), *What are Fake Interdisciplinary Collaborations and Why Do They Occur? It's Not Always Intentional*. Nature Index. <https://www.natureindex.com/news-blog/what-are-fake-interdisci

plinary-collaborations-and-why-do-they-occur> accessed 21 Oct 2021.
Duncan, R., Robson-Williams, M., and Edwards, S. (2020) 'A Close Examination of the Role and Needed Expertise of Brokers in Bridging and Building Science Policy Boundaries in Environmental Decision Making', *Palgrave Communications*, 64: 1–12.
EASSH. European Alliance for Social Sciences and Humanities. (2019), *Interdisciplinary Perspectives for Horizon Europe: Lessons from the 4th SSH Integration Monitor Report (April 2019)*. <https://eassh.eu/Position-Papers/easshsshintegration4threportfnl.pdf> accessed 21 Oct 2021.
EURAB. (2004), *Interdisciplinarity in Research* <https://docplayer.net/10594226-Eurab-04-009-final-european-union-research-advisory-board-interdisciplinarity-in-research.html> accessed 21 Oct 2021.
European Commission. (2014), *How Should Trans-disciplinarity Be Addressed and Evaluated in Proposals? Guidance for Evaluators of Horizon 2020 Proposals*. <http://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/pse/h2020-evaluation-faq_en.pdf> accessed 21 Oct 2021.
Felt, U., Igelsböck, J., Schikowitz, A., et al. (2016) 'Transdisciplinary Sustainability Research in Practice. Between Imaginaries of Collective Experimentation and Entrenched Academic Value Orders. Science', *Technology and Human Values*, 41: 732–61.
Fitzgerald, D., Littlefield, M. M., Knudsen, K. J., et al. (2014) 'Ambivalence, Equivocation and the Politics of Experimental Knowledge: A Transdisciplinary Neuroscience Encounter', *Social Studies of Science*, 44: 701–21.
Freeman, M. (2017) *Modes of Thinking for Qualitative Data Analysis*. New York: Routledge.
Frickel, S., Mathieu, A., and Prainsack, B. (2016) 'Introduction. Investigating Interdisciplinarities'. In: Frickel S., Mathieu A., and Prainsack B. (eds) *Investigating Interdisciplinary Collaboration: Theory and Practice across Disciplines*, pp. 5–24. New Jersey: Rutgers University Press.
Fuller, K. and Lenton, E. (2018), *How to Find & Document Grey Literature Search Plan Template*. University of Toronto Libraries, Gerstein Science Information Centre. Toronto, Canada. <https://guides.library.utoronto.ca/c.php?g=577919&p=4123572> accessed 21 Oct 2021.
Graf, J. (2019) 'Bringing Concepts Together: Interdisciplinarity, Transdisciplinarity, and SSH Integration', *Fteval Journal for Research and Technology Policy Evaluation*, 48: 33–6.
Global Research Council (GRC). (2016), *Statement of Principles on Interdisciplinarity*. <https://www.globalresearchcouncil.org/fileadmin/documents/GRC_Publications/Statement_of_Principles_on_Interdisciplinarity.pdf> accessed 21 Oct 2021.
Hessels, L. K. and van Lente, H. (2008) 'Re-thinking New Knowledge Production: A Literature Review and A Research Agenda', *Research Policy*, 37: 740–60.
Hessels, R. and Kingstone, A. (2019), *Fake Collaborations: Interdisciplinary Science Can Undermine Research Integrity*. <https://psyarxiv.com/rqwea/> accessed 21 Oct 2021.
Hirsch Hadorn, G., Hoffman-Riem, H., Biber-Klemm, S., et al. (2008) *Handbook of Transdisciplinary Research*. Berlin: Springer.
Hoffmann, M. H. G., Schmidt, J. C., and Nersessian, N. J. (2013) 'Philosophy of and as Interdisciplinarity', *Synthese*, 190: 1857–975.
Hoffmann, S., Pohl, C., and Hering, J. (2017) 'Exploring Transdisciplinary Integration within a Large Research Program: Empirical Lessons from Four Thematic Synthesis Processes', *Research Policy*, 46: 678–92.
Hofmänner, A. Macamo, E. (2021) The Science Policy Script, Revised. *Minerva*, 59, 331–354.
Huutoniemi, K., Thompson Klein, J., Bruun, H., et al. (2010) 'Analyzing Interdisciplinarity: Typology and Indicators', *Research Policy*, 39: 79–88.
National Contact Point (NCP) Brussels. (2014), EDITORIAL, *The integration of social sciences in H2020 proposals: what do 'horizontal aspects' and 'interdisciplinarity' mean*. <https://ncp.brussels/the-integration-of-social-sciences-in-h2020-proposals-what-do-horizontal-aspects-and-interdisciplinarity-mean> accessed 13 Jun 2022.
IHS. (2019), *SSH-Impact Pathways and SSH-Integration in EU Research Framework Programmes*. <https://www.ssh-impact.eu/wp-content/uploads/2019/06/3_Working-Paper-on-SSH-Impact-Pathways_Final.pdf> accessed 21 Oct 2021.
INTREPID. (2017), *3rd INTREPID Report. Interdisciplinary and Transdisciplinary Research: Finding the Common Ground of Multi-faceted Concepts*. <http://intrepid-cost.ics.ulisboa.pt/wp-content/uploads/2017/05/3rd-INTREPID-Report-ID-TD-WG1-1.pdf> accessed 21 Oct 2021.
Jacob, M. and Hellstrom, T. (1996) 'Reviewing the Science-policy Relationship: The Policy as Theory Alternative (PAST)', *Science & Public Policy*, 25: 218–26.
Jahan, N., Naveed, S., Zeshan, M., et al. (2016) 'How to Conduct A Systematic Review: A Narrative Literature Review', *Cureus*, 8: e864.
Jahn, T., Bergmann, M., and Keil, F. (2012) 'Transdisciplinarity: Between Mainstreaming and Marginalization', *Ecological Economics*, 79: 1–10.
Kania, K. and Bucksch, R. (2020), *Integration of Social Sciences and Humanities in Horizon 2020: Participants, Budgets and Disciplines*. 5th monitoring report on projects funded in 2018 under the Horizon 2020 programme. <https://op.europa.eu/en/publication-detail/-/publication/4f198f8e-4599-11eb-b59f-01aa75ed71a1/language-en> accessed 21 Oct 2021.
Kania, K., Lemaire, C., and Swinnen, L. (2019), *Integration of Social Sciences and Humanities in Horizon 2020. Participants, Budget and Disciplines: 4th Monitoring Report on SSH Flagged Projects Funded in 2017 under the Societal Challenges and Industrial Leadership Priorities*. Directorate-General for Research and Innovation – European Commission. <https://op.europa.eu/en/publication-detail/-/publication/f094a641-30dd-11e9-8d04-01aa75ed71a1/language-en/format-PDF/source-86826299> accessed 21 Oct 2021.
Klein, J. T. (1990) *Interdisciplinarity: History, Theory, and Practice*. Detroit: Wayne State University Press.
——— (1996) *Crossing Boundaries: Knowledge, Disciplinarities, and Interdisciplinarities*. Charlottesville: University Press of Virginia.
——— (2005) *Humanities, Culture, and Interdisciplinarity: The Changing American Academy*. Albany: State University of New York Press.
——— (2014) 'Prospects for Transdisciplinarity', *Futures*, 36: 515–26.
Krull, W. (2004) 'Towards a Research Policy for the New Europe: Changes and Challenges for Public and Private Funders', *Minerva*, 42: 29–39.
Lengwiler, M. (2006) 'Between Charisma and Heuristics: Four Styles of Interdisciplinarity', *Science & Public Policy*, 33: 423–34.
LERU. (2014), *Social Sciences and Humanities: Essential Fields for European Research in Horizon 2020*. <https://www.leru.org/publications/social-sciences-and-humanities-essential-fields-for-european-research-and-in-horizon-2020> accessed 21 Oct 2021.
——— (2016), *Interdisciplinarity and the 21st Century Research-intensive University*. <https://www.leru.org/publications/interdisciplinarity-and-the-21st-century-research-intensive-university> accessed 21 Oct 2021.
Lindvig, K. and Hillersdal, L. (2019) 'Strategically Unclear? Organising Interdisciplinarity in an Excellence Programme of Interdisciplinary Research in Denmark', *Minerva*, 57: 23–46.
Lury, C. (2018) 'Introduction: Activating the Present of Interdisciplinary Methods'. In: Lury C., Fensham R., Heller-Nicholas A., et al. *Routledge Handbook of Interdisciplinary Research Methods*, pp. 1–23. London: Routledge.
Lyall, C. (2019) *Being an Interdisciplinary Academic. How Institutions Shape University Careers*. London: Palgrave Pivot.
Lyall, C., Bruce, A., Marsden, W., et al. (2013) 'The Role of Funding Agencies in Creating Interdisciplinary Knowledge', *Science & Public Policy*, 40: 62–71.

Lyall, C. and Fletcher, I. (2013) 'Experiments in Interdisciplinary Capacity-building: The Successes and Challenges of Large-scale Interdisciplinary Investments", *Science & Public Policy*, 40: 1–7.
Lyall, C., Meagher, L., and Bruce, A. (2015) 'A Rose by Any Other Name? Transdisciplinarity in the Context of UK Research Policy', *Futures*, 65: 150–62.
Maasen, S., Lengwiler, M., and Guggenheim, M. (2006) 'Introduction: Practices of Transdisciplinary Research: Close(r) Encounters of Science and Society', *Science & Public Policy*, 33: 394–8.
Maasen, S. and Lieven, O. (2006) 'Transdisciplinarity: A New Mode of Governing Science?' *Science & Public Policy*, 33: 399–410.
Madsen, D. (2018) 'Epistemological or Political? Unpacking Ambiguities in the Field of Interdisciplinarity Studies', *Minerva*, 56: 453–77.
Mäki, U. (2016) 'Philosophy of Interdisciplinarity. What? Why? How?' *European Journal for Philosophy of Science*, 6: 327–42.
Marres, N. and De Rijcke, S. (2020) 'From Indicators to Indicating Interdisciplinarity: A Participatory Mapping Methodology for Research Communities In-the-making', *Quantitative Science Studies*, 1: 1041–55.
Mayer, K., Konig, T., and Nowotny, H. (eds) (2013) Horizons for Social Sciences and Humanities Conference Report. <http://horizons.mruni.eu/> accessed 21 Oct 2021.
Mielke, J., Vermaßen, H., Ellenbeck, S., et al. (2016) 'Stakeholder Involvement in Sustainability science—A Critical View', *Energy Research & Social Science*, 17: 71–81.
Molas-Gallart, J., Tang, P., and Rafols, I. (2014) 'On the Relationship between Interdisciplinarity and Impact: Different Modalities of Interdisciplinarity Lead to Different Types of Impact', pp. 1–23. ArXiv, abs/1412.6684.
National Academy of Sciences, N. A. o. E., Institute of Medicine. (2005) *Facilitating Interdisciplinary Research*. Washington, DC: The National Academies Press.
National Contact Point (NCP) Brussels. (2014) EDITORIAL 28.11.2014 'The integration of social sciences in H2020 proposals: what do "horizontal aspects" and "interdisciplinarity" mean'. <https://ncp.brussels/the-integration-of-social-sciences-in-h2020-proposals-what-do-horizontal-aspects-and-interdisciplinarity-mean> accessed 13 Jun 2022.
Nersessian, N. J. (2019) 'Interdisciplinarities in Action: Cognitive Ethnography of Bioengineering Sciences Research Laboratories', *Perspectives on Science*, 27: 553–81.
Net4Society. (2013), *Policy Brief: Pulling It Together on Interdisciplinary Research Design*. <https://www.net4society.eu/files/NET4SOCIETY3_320325_D3_1_PolicyBrief_final.pdf> accessed 21 Oct 2021.
Nicolescu, B. (2000) *Manifesto of Transdisciplinarity*. Albany: State University of New York Press.
OECD. (1972), *Interdisciplinarity: Problems of Teaching and Research*. <https://files.eric.ed.gov/fulltext/ED061895.pdf> accessed 21 Oct 2021.
——— (2020) Addressing Societal Challenges Using Transdisciplinary Research, OECD Science, Technology and Industry Policy Papers, No. 88. Paris: OECD Publishing.
Osborne, P. (2015) 'Problematizing Disciplinarity, Transdisciplinary Problematics', *Theory, Culture & Society*, 32: 3–35.
Palma Conceição, C., Ávila, P., Coelho, A. R., et al. (2020) 'European Action Plans for Science–Society Relations: Changing Buzzwords, Changing the Agenda', *Minerva*, 58: 1–24.
Pestre, D. (2007) *Science, Society and Politics Knowledge Societies from an Historical Perspective. Report to the Science Economy and Society Directorate European Commission*. Brussels: Directorate European Commission. Accessed 13 Jun 2022.
Pohl, C. (2008) 'From Science to Policy through Transdisciplinary Research', *Environmental Science & Policy*, 11: 46–53.
——— (2010) 'From Transdisciplinarity to Transdisciplinary Research', *Transdisciplinary Journal of Engineering & Science*, 1.
Pohl, C., Thompson Klein, J., Hoffmann, S., et al. (2021) 'Conceptualising Transdisciplinary Integration as a Multidimensional Interactive Process', *Environmental Science & Policy*, 118: 18–26.
Pregernig, M. (2006) 'Transdisciplinarity Viewed from Afar: Science- Policy Assessments as Forums for the Creation of Transdisciplinary Knowledge', *Science & Public Policy*, 33: 445–55.
Rabinow, P. and Bennett, G. (2012) *Designing Human Practices: An Experiment with Synthetic Biology*. Chicago: The University of Chicago Press.
Rabinow, P. and Stavrianakis, A. (2016) 'Movement Space: Putting Anthropological Theory, Concepts, and Cases to the Test', *Hau: Journal of Ethnographic Theory*, 6: 403–43.
Reiter-Pázmándy, M. (2021), *The Next Seven Years of Research on Europe's Society*. What can we expect for and from the Social Sciences and Humanities (SSH) in Horizon Europe? Policy Brief, ERA Portal Austria. <https://era.gv.at/public/documents/4400/20210111_ERA-Policy_Brief_Research_on_Society_in_HEU_final.pdf> accessed 21 Oct 2021.
Rosales, J. S. (2021) 'Interdisciplinary Research, from Modularity to Integration: Humanities on the Horizon 2020 Agenda', *Global Intellectual History*, 6: 34–46.
Schneider, F., Buser, T., Keller, R., et al. (2019) 'Research Funding Programs Aiming for Societal Transformations: Ten Key Stages', *Science & Public Policy*, 46: 463–78.
Schreier, M. (2014) 'Ways of Doing Qualitative Content Analysis: Disentangling Terms and Terminologies', *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*, 15(1).
Shavit, A., Kolumbus, A., and Ellison, A. M. (2016), *Two Roads Diverge in a Wood: Indifference to the Difference between 'Diversity' and 'Heterogeneity' Should Be Resisted on Epistemic and Moral Grounds*. Phil Sci Archive. <http://philsci-archive.pitt.edu/12432/> accessed 21 Oct 2021.
Spaapen, J., Dijstelbloem, H., and Wamelink, F. (2007) *Evaluating Research in Context. A Method for Comprehensive Research Assessment*, 2nd edn. The Hague: Consultative Committee of Sector Councils for Research and Development (COS), The Netherlands.
Spaapen, J., Vienni Baptista, B., Buchner, A., et al. (2020) Report on Survey among Interdisciplinary and Transdisciplinary Researchers and Post-survey Interviews with Policy Stakeholders, H2020 Project "Shaping interdisciplinary practices in Europe".
Stamm, J. (2019) 'Chapter 19: Interdisciplinarity Put to Test: Science Policy Rhetoric Vs Scientific Practice – the Case of Integrating the Social Sciences and Humanities in Horizon 2020'. In: Simon D., Kuhlmann S., Stamm J., et al. (eds) *Handbook of Science and Public Policy*, Vol. 99. pp. 376–99. Cheltenham: Edward Elgar Publishing.
Strathern, M. (2004) 'Laudable Aims and Problematic Consequences, Or: The 'flow' of Knowledge Is Not Neutral', *Economy and Society*, 33: 550–61.
td-net. (2020), *td-net*. <http://www.transdisciplinarity.ch/en/td-net/Aktuell/td-net-News.html> accessed 21 Oct 2021.
Technopolis. (2016), *Landscape Review of Interdisciplinary Research in the UK: Report to HEFCE and RCUK by Technopolis and the Science Policy Research Unit (SPRU), University of Sussex*. <https://sro.sussex.ac.uk/id/eprint/65332/1/2016HEFCE_Landscape%20review%20of%20UK%20interdisciplinary%20research.pdf> accessed 21 Oct 2021.
Tyndall, J. (2008), *How Low Can You Go? Towards a Hierarchy of Grey Literature. Presented at Dreaming 08 – Australian Library and Information Association Biennial Conference*. <https://dspace.flinders.edu.au/xmlui/handle/2328/3326> accessed 21 Oct 2021.
Vienni Baptista, B., Klein, J. T., and Streck, D. (2022) 'Conclusion: A Framework for Institutionalizing Inter- and Trans-disciplinary Research and Teaching in Higher Education'. In: Vienni Baptista B. and Klein J. T. *Institutionalizing Interdisciplinarity and*

Transdisciplinarity. Collaboration across Cultures and Communities, pp. 232–48. London: Routledge.

Vienni Baptista, B., Lyall, C., Ohlmeyer, J., et al. (2020b) Improving Pathways to Interdisciplinary and Transdisciplinary Research for the Arts, Humanities and Social Sciences: First Lessons from the SHAPE-ID Project – Policy Brief.

Vienni Baptista, B., Maryl, M., Wciślik, P., et al. (2020a) Final Report on Understandings of Interdisciplinary and Transdisciplinary Research and Factors of Success or Failure.

von Wehrden, H., Guimarães, M. H., Bina, O., et al. (2017) 'Interdisciplinary and Transdisciplinary Research: Finding the Common Ground of Multi-faceted Concepts', *Sustainability Science*, 14: 875–88.

Wagner, C. S., Roessner, J. D., Bobb, K., et al. (2010) 'Approaches to Understanding and Measuring Interdisciplinary Scientific Research (IDR): A Review of the Literature', *Journal of Informetrics*, 5: 14–26.

Wciślik, P., Maryl, M., Vienni Baptista, B., et al. (2020) SHAPE-ID Literature Review Query Strings for Web of Science and Scopus.

Weingart, P. (2000) 'Interdisciplinarity: The Paradoxical Discourse'. In: Weingart P. and Sterh N. (eds) *Practising interdisciplinarity*, pp. 23–40. Toronto: University of Toronto Press.

Weingart, P. and Sterh, N. (eds) (2000) *Practising interdisciplinarity*. Toronto: University of Toronto Press.

Woelert, P. and Millar, V. (2013) 'The 'Paradox of Interdisciplinarity' in Australian Research Governance', *Higher Education*, 66: 755–67.