SHAPE-ID
Shaping interdisciplinary practices in Europe

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SHAPE-ID: Shaping Interdisciplinary Practices in Europe

Deliverable 2.3: Final Report on Understandings of Interdisciplinary and Transdisciplinary Research and Factors of Success and Failure

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Abbreviations

A – Arts
AH – Arts & Humanities
AHSS – Arts, Humanities and Social Sciences
ASJC – All Science Journal Classification
BASE – Bielefeld Academic Search Engine
CLARIN-PL - Common Language Resources and Technology Infrastructure (Poland)
CORDIS – Community Research and Development Information Service
EC – European Commission
GreyLit – Grey Literature dataset
ERC – European Research Council
ETH – Swiss Federal Institute of Technology (partner)
H – Humanities
H2020 – Horizon 2020
IBL PAN – Institute of Literary Research, Polish Academy of Sciences (partner)
ID – interdisciplinarity
IDR – interdisciplinary research
JSTOR – Journal Storage
LitReview – Academic Literature dataset
MD – multidisciplinarity
MDR – multidisciplinary research
MEDLINE – Medical Literature Analysis and Retrieval System Online
OECD – Organisation for Economic Co-operation and Development
OpenAire – European Open Science Infrastructure
OpenGrey – System for Information on Grey Literature in Europe
SCIELO – Scientific Electronic Library Online
SCOPUS – Elsevier's abstract and citation database
SHAPE-ID – Shaping Interdisciplinary Practices in Europe
SSH – Social Sciences & Humanities
SSRN – Social Sciences Research Network
STEAM – Science, Technology, Engineering and Mathematics (STEM) with the Arts (A)
STEM – Science, Technology, Engineering and Mathematics
STEMM – Science, Technology, Engineering, Mathematics and Medicine
TD – transdisciplinarity
td-net – Swiss based Network for Transdisciplinary Research
TDR – transdisciplinary research
WoS – Web of Science
WP – Work package

Groups of disciplines in quantitative analysis
AHSS – all disciplines in Arts, Humanities and Social Sciences
AH – disciplines belonging to Arts and Humanities
SOSC – the narrow Social Sciences disciplinary Group
SSSG – all other disciplines belonging to AHSS, including SOSC, but excluding AH

Executive summary

This report presents findings from a literature review and survey undertaken as part of the SHAPE-ID Horizon 2020 project, which addresses the challenge of improving interdisciplinary research (IDR) and transdisciplinary research (TDR) between Arts, Humanities and Social Sciences (AHSS) and Science, Technology, Engineering, Mathematics, and Medicine (STEMM) disciplines.

The purpose of the research study

We have completed the first phase of the project, which comprised two literature reviews, interviews with policy stakeholders and a survey of researchers engaged in IDR/TDR (Work Package 2). These results will be complemented by insights gathered through a series of six learning case workshops organised across Europe to consult stakeholders on best practices in IDR/TDR (Work Package 3). A framework synthesising the results of these activities will be validated in consultation with the SHAPE-ID Expert Panel (Work Package 4). The project will ultimately deliver a set of recommendations, including a toolkit and associated policy brief (Work Package 5), to guide policy makers, funders, researchers and other stakeholders in achieving successful pathways to inter- and transdisciplinary integration between AHSS and STEMM, as well as within AHSS disciplines.

One of SHAPE-ID's first objectives was to review existing research on IDR/TDR. Through an extensive evidence-scanning exercise drawing on previous work undertaken and complemented by a survey and interviews, the project aimed:

(i) to disentangle the different understandings of interdisciplinarity and transdisciplinarity;

(ii) to identify the factors that hinder or help inter- and transdisciplinary collaboration;

(iii) to clarify which understandings of IDR/TDR and which factors of success and failure are specifically relevant for integrating AHSS in IDR/TDR.

Methods of data gathering and analysis

This final report elaborates on the main findings from the systematic literature reviews and the survey undertaken in WP2. It is accompanied by a Policy Brief highlighting the key findings and implications for policy makers in Europe.

After building a robust sample of literature, the team aligned qualitative and quantitative methods to map understandings and factors for success and failure in IDR/TDR found in the literature. Datasets were created by querying scientific citation databases, supplemented by bibliographies prepared during a preliminary scoping analysis of IDR/TDR literature.

We undertook an extensive and systematic literature review to identify from the academic and grey literatures the different understandings of IDR/TDR and the factors contributing to their success or failure. We qualitatively analysed 101 scientific papers and 102 reports. For the quantitative analyses we used 3910 items from the academic literature, 68,268 items stored in the OpenAire[1] database, 1,912 documents related to Horizon 2020 projects and 75 documents related to Horizon 2020 calls.

We complemented these findings with insights coming from the qualitative survey (41 responses) and follow-up interviews with policy makers and funders (10 interviews). Building also on our preliminary analyses (see Vienni Baptista et al., 2019), we sought a comprehensive approach to addressing the aims of WP2.

Challenges of IDR/TDR and AHSS integration

IDR/TDR and AHSS integration posed several general challenges that are rooted in the nature of the phenomena under investigation. Not only are IDR/TDR and AHSS integration not established as well-structured fields in the academic and grey literatures, but insights on them are scattered across dispersed bodies of literature. Systematising the features of IDR/TDR and AHSS integration in different thematic contexts is an intricate task that has to cover scientific papers, reports and internal documents from funding agencies and research organisations, the latter sometimes more promoting than describing IDR/TDR and AHSS integration.

Besides the heterogeneity and diversity of the fields, further general challenges we identified for AHSS integration in IDR and TDR are:

- the lack of perceived legitimacy of IDR/TDR as scientifically sound modes of knowledge production, requiring us to adapt and mix qualitative and quantitative methods to study IDR/TDR.
- the fragmentation of interdisciplinary and transdisciplinary communities of practice. They have long traditions in Europe but there are major differences between countries, regions and institutions. National and international policy and practice also show substantial differences in their treatment and funding of IDR/TDR.
- the different motivations and purposes for undertaking or calling for IDR/TDR.

[1] OpenAire: https://www.openaire.eu

- a lack of policy learning about how to facilitate IDR/TDR, leading to the frequent repetition of recommendations about how to facilitate IDR/TDR derived from the academic and grey literatures.
- the pervasiveness of the "AHSS" label, which obscures differences between AHSS disciplines in terms of values, contributions to IDR/TDR and insights into societal challenges.
- a lack of perceived legitimacy of AHSS disciplines in relation to STEMM contributions, and the need to defend AHSS's constitutive territory.

These challenges are the background of our analysis of AHSS integration in IDR/TDR. Our suggestions can only have an effect if these general challenges are addressed too. In this study, we approach them in a constructive manner attempting to bridge some of the gaps in knowledge about IDR/TDR and understand the ways in which AHSS researchers can participate on equal terms in such research.

Key Findings

Our findings are presented in the context of the following SHAPE-ID Work Package 2 objectives: (i) to disentangle the different understandings of interdisciplinarity and transdisciplinarity; (ii) to identify the factors that hinder or help inter- and transdisciplinary collaboration; and (iii) to clarify which understanding of IDR/TDR and which factors of success and failure are specifically relevant for integrating AHSS in IDR/TDR.

Disentangling different understandings of inter- and transdisciplinarity

All our analyses highlight the fact that there is currently no dominant definition. Instead, there is a plurality of understandings, which is not taken into account or not made use of by research institutions, policy makers and funders:

- The academic literature shows plurality, heterogeneity and on occasion overlapping definitions. Diverse definitions of inter- and transdisciplinarity coexist within the literature and are reproduced by researchers and practitioners. This means that it is necessary to find connections among existing conceptualisations rather than develop new definitions for ID and TD.
- In the grey literature we find another form of disconnection between definitions as the terms interdisciplinarity and transdisciplinarity are widely used but rarely defined. Due to few links between the academic and grey literature, many authors did not provide a definition of IDR/TDR, but instead used the term "interdisciplinary" as if its meaning was simple and widely agreed upon. This lack of explicit definition is problematic because, in the grey literature, it is

often combined with an implicit model of IDR that sees it solely as a means of solving societal challenges, missions or problems.

- In a similar fashion, the quantitative analysis confirmed that although interdisciplinarity is discussed more often than transdisciplinarity throughout the literature, IDR and TDR seem to be used synonymously, especially in contexts not focused on interdisciplinarity but in common scholarly uses (e.g. in project descriptions). The analysis of definitions in the context of funding schemes and applications show a tendency to use the term IDR as a marker of innovative and timely research.

ID and TD constitute an array of interrelations between disciplines and bodies of knowledge, that includes interrelations between disciplines but also programmatic statements, policy interventions, institutional forms, theoretical statements, instruments, materials and research practices immersed in a process of negotiation (Barry and Born, 2013).

The challenge, therefore, is not to arrive at a single understanding that obscures differences in understandings of IDR/TDR, but to build dialogue between different understandings while recognising their differences. Three discourses summarise the implications of differing definitions and conceptualisations (based on Klein, 2014, 2020). They are useful to clarify different perspectives on IDR/TDR, especially their differing implication for the role of AHSS disciplines:

- the philosophical or transcendence discourse, that aims at unity of knowledge, transcending the narrowness of disciplinary worldviews and practices;
- the problem-solving discourse, that is oriented to instrumental needs, specifically to cope with complex problems;
- the critique or transgression discourse, that interrogates the other two perspectives and emerges out of a fundamental critique of the system of knowledge and education, and also relates to discourses on the democratisation of knowledge.

The problem-solving discourse – also representing a technology-focused understanding of IDR/TDR – is pervasive in the academic and grey literatures analysed. Its instrumental view of IDR/TDR as problem solver makes research using this model very unattractive to non-STEMM researchers, especially those in the Arts and Humanities who see their role as promoting the critique or transgression discourse. In this respect, focusing calls and programmes on the "problem-solving" discourse can result in a lack of AHSS participation in IDR/TDR, building on one "silo" instead of on the whole range of IDR/TDR.

A structure to sort out plural understandings

Based on the systematic literature review, we identified six cross-cutting axes on which understandings of ID and TD differ. For those interested in disentangling different understandings, we suggest going through the following questions :

- ***What:*** What are the definitions of ID and TD and their conceptualisation, including how disciplines are understood and how they relate to ID and TD?
- ***Who:*** Which researchers, funders, policy makers, and other stakeholders, as well as communities and teams develop or contribute to IDR and TDR?
- ***How:*** Which methods and tools are used to achieve IDR and TDR, in particular for integration?
- ***Why:*** What are the motivations and logics behind undertaking or supporting IDR and TDR?
- ***When:*** What time and timing is dedicated to IDR/TDR practices?
- ***Where:*** What are the spaces for IDR and TDR that establish the institutional contexts for individual or collective endeavours?

(i) What factors influence IDR/TDR?

The analysis of the academic literature provided a vast array of factors influencing IDR/TDR some of which were confirmed by the survey and in the grey literature analysis. Table 1 below displays the 25 types of factors we found, assigned to the six cross-cutting axes (detailed above).

Table 1 Factors that influence IDR/TDR success or failure

WHAT?	WHO?	WHY?	HOW?
Academic tribalism	Cognitive	Career path	Dealing with complexity
Assumptions about other disciplines	Mutual ignorance on collaboration	Motivations for IDR/TDR	Evaluation
Division of scientific labour	Qualities of ID/TD researchers	Change	Social
Ontological	Ethical		
Dynamics of power	Interactional	WHEN?	WHERE?
Non-epistemological values	Ideological	Current research policies	
Objectivity – Subjectivity	Communicative	Institutional	
Epistemological	Emotional - affective	Temporalities	Spatial conditions

There was no “most important factor” that can be easily addressed according to the academic literature. Rather there is a system of factors that has to be related to a particular funding or research context in order to identify the relevant ones. This is because:

- factors are related to each other and the weight given to each of them depends on temporal and spatial context and the model of ID/TD underlying the project;
- factors are dynamic: they change during different phases of a project;
- factors are dual: they can have negative or positive effects on research and whether they hinder or help IDR and TDR depends on the specific disciplines participating in the project;
- factors are related to the roles assigned to each discipline and field of knowledge;
- factors are influenced by different potential logics (Barry & Born, 2013; Barry et al., 2008) of IDR and TDR.

The grey literature confirmed the relevance of the factors "current research policies", "career path" and "temporalities", expressed as:

- a lack of appropriate funding and the need for innovative approaches to remedy this e.g. small response-mode grants and more funding to develop collaborations;
- existing academic career structures which were seen as particularly unfavourable for early career researchers; and
- the extended timescale required for IDR/TDR and its impact on the integration of AHSS within the Horizon 2020 research programmes.

(ii) Understandings of ID/TD and factors specifically relevant for integrating AHSS

Our analysis shows that understandings and factors should not be discussed for AHSS in general, but for the different disciplines individually. The labels used to refer collectively to the Arts, Humanities and Social Sciences – "AHSS" and "SSH" – obscure important differences between disciplines that influence the different ways they position themselves in relation to IDR/TDR and to their interactions with other AHSS or STEMM disciplines. The results of the quantitative analysis reveal the following differences:

- Arts and Humanities (AH) researchers experience obstacles to their potential involvement in IDR and TDR. While disciplines from the Social Sciences are clear leaders in the adoption of IDR/TDR, the Arts and Humanities are in third place, coming after Environmental Science. Social Sciences vocabulary also combines more often with IDR/TDR vocabulary, suggesting that disciplines from this group adopt the models of IDR/TDR more frequently than those from the Arts and Humanities.
- At the same time, due to the greater diversity of disciplines they connect with, the Social Sciences are better integrated with non-AHSS disciplines than with the Arts and Humanities. However, analysis of academic papers' abstracts shows that the biggest portion of Arts and

Humanities disciplinary pairings connect with Social Sciences, meaning that there is the potential for Arts and Humanities to interact with more other disciplines.

According to the insights collected in our survey and interviews, the root cause of difficulties regarding AHSS integration is to be found in a lack of understanding by researchers, policy makers and funders, about what the AHSS are and what these disciplines can contribute to solving societal problems (Spaapen et al., 2020). A different attitude is necessary in all these sectors of the research system, so that those who really believe in AHSS and want to stimulate AHSS research integration do not have to fight prejudice before becoming effective. Changes in attitude are necessary both in the personal and in the disciplinary realm, as mutual understanding is crucial in all stages of research.

Recommendations for change

In this report, we claim that IDR and TDR urgently need to be better supported by research institutions, funding and policy. The paradox of interdisciplinarity (as Peter Weingart (2000) named it twenty years ago) – where IDR is often encouraged at policy level but poorly rewarded – still challenges cross-sectoral boundaries and connections. The role of AHSS disciplines in IDR/TDR raises questions about barriers to their integration. Three major implications and nine recommendations for change emerged from our study:

a) *An urgent need to acknowledge plural understandings of ID and TD beyond the problem-solving approach and permit them to shape research and funding environments.*

We see the plural understandings of ID and TD as a resource to be used to improve inter- and trans-disciplinary research policy making and funding. Such wider understanding and acceptance could stimulate researchers from the AHSS, and especially early career researchers, to engage in IDR/TDR: acknowledging that this urgency entails researchers and funders alike recognising that IDR and TDR are conceived for different purposes and conducted in different ways.

Recommendations:

1) To promote the establishment and consolidation of stakeholder communities (among researchers, funders, evaluators, research users and policy makers) that explore the different understandings of IDR and TDR, in particular for a stronger integration of AHSS in research and funding policies and in the co-design of calls.
2) When preparing new calls, to specifically include AHSS scholars when framing the challenges and when defining the underlying understanding of IDR/TDR.

3) In calls, to state the underlying understanding of IDR/TDR by default and to ask applicants to state their own understanding and to explain why the applicant's understanding is considered appropriate to address the call's challenges.

Benefit: Promotion of greater policy learning addressing the current gap in shared understanding between the policy and academic literatures. Inclusion of AHSS from the outset of research agenda setting.

b) A recognition of the diverse factors that influence IDR/TDR and of their context-dependency: factors that hinder IDR/TDR can be transformed into enabling measures, even during the development of a research project.

A promising finding on the diverse factors (Table 1) that can help or hinder IDR/TDR collaboration is the indication from the literature that the same factor may be either a barrier or an opportunity, depending on the circumstances of a project. This means that factors can be changed, transforming them from problematic to enabling during the research process.

Recommendations:

4. To allow time and money to develop mutual understanding between potential partners in IDR/TDR, including funders, evaluators and the different stakeholder communities. Time and money required for developing mutual understanding between project participants can be seen as counterpart to the laboratory costs in STEMM research, as this exchange and learning is a key element of IDR and TDR integration (Bammer, 2008).
5. Given the diverse factors, to support (with specific funding) the creation of toolkits that relate factors to actors (e.g. researchers, funders and policy makers) able to influence them and guide research and policy processes alike.
6. To document and systematise the variety of research processes and practices of AHSS integration in IDR/TDR. This would lower entry barriers and avoid research teams "re-inventing the wheel" each time that an IDR or TDR project is developed. Such systematisation also serves to emphasise the current state of the art of IDR/TDR.

Benefit: Innovative approaches to complex problems can emerge, generating new interactions between disciplines and more integration of AHSS disciplines.

c) A requirement (and a responsibility) to reassess AHSS roles and functions in IDR/TDR so that these disciplines can contribute fully in inter- and transdisciplinary settings.

The root cause of difficulties regarding AHSS integration in IDR/TDR is to be found in a lack of understanding among researchers, evaluators, policy makers and funders, of what "AHSS" is and what these individual disciplines that are aggregated under this acronym can contribute to solving problems

in society. More knowledge leading to mutual understanding and a change in attitude among actors in all these sectors is necessary. This will not only improve collaboration but will also help public officers who champion AHSS research integration do not have to counter prejudices and preconceptions before becoming effective. ASSH integration is a special case of IDR/TDR, since different scientific disciplines as well as non-academic stakeholders are involved in the research process (Graf, 2019).

Recommendations:

7. To facilitate ways for AHSS to contribute to IDR/TDR in the light of policy demands and given the different roles that these disciplines can perform. Mapping different understandings and roles leads to new spaces (epistemological, team-based, institutional, cross-sectoral) where IDR and TDR can be developed. In these spaces, AHSS disciplines can be encouraged to adopt new collaborative functions, rather than be restricted to instrumental tasks. Differences among understandings are not necessarily a hindering factor; they can also be used constructively to develop better IDR/TDR rooted in AHSS knowledge.
8. To embed IDR/TDR knowledge and experience in the education and training of early career researchers in all academic disciplines. This could include inviting stakeholders to discuss societal issues that demand input from researchers.
9. To make knowledge about IDR/TDR more readily available, for example via an extensive EU-funded web portal providing access to practical, theoretical and methodological knowledge, case study examples, toolkits, etc.

Benefit: Development of new methodologies and tools for IDR/TDR. These may be applied in different contexts, avoiding re-invention of the wheel each time.

1 Background, Aims and Objectives

SHAPE-ID: Shaping Interdisciplinary Practices in Europe addresses the challenge of improving inter- and transdisciplinary cooperation between the Arts, Humanities and Social Sciences (AHSS) and other disciplines, primarily Science, Technology, Engineering, Mathematics and Medicine (STEMM).[2] The project aims at establishing a comprehensive knowledge base covering the different understandings of inter- and transdisciplinary research (IDR and TDR), the factors that inhibit or support them and a set of success criteria for integrating AHSS disciplines in IDR/TDR practices that aim to solve key societal challenges.

We have completed the evidence-scanning phase of the project, which comprised a literature review, interviews with policy stakeholders and a survey (Work Package 2, completed in March 2020). A series of six learning case workshops organised by SHAPE-ID partners around different thematic areas is currently underway (Work Package 3). A knowledge framework synthesising the results of these activities will be validated in consultation with the SHAPE-ID Expert Panel (Work Package 4). The project will ultimately deliver a set of recommendations, including a toolkit and associated policy brief (Work Package 5), to guide policy makers, funders, researchers and other stakeholders in achieving successful pathways to inter- and transdisciplinary integration between AHSS and STEMM, as well as within AHSS disciplines.

One of SHAPE-ID's first objectives is to review existing research contributing to the understanding of IDR/TDR. Through an extensive evidence scanning exercise drawing on previous work undertaken, the project aims to identify the factors that support successful or unsuccessful integration of methodologies, techniques, personnel and administrative structures both within AHSS disciplines, and between AHSS and STEMM disciplines and other sciences at a national, European and international level. WP2 pursues the following specific objectives:

- O2.1 To disentangle the different understandings of IDR/TDR;
- O2.2 To identify the factors that hinder or help inter- and transdisciplinary collaboration;
- O2.3 To clarify which understanding of IDR/TDR and which factors of success and failure are specifically relevant for integrating AHSS in IDR/TDR.

[2] We use the term STEMM for convenience hereafter to denote STEM + Medicine. SHAPE-ID adopts a working classification of AHSS disciplines from the Glossary used in the Horizon 2020 programme and a classification of STEM disciplines from EU Skills Panorama (2014). For the purpose of the quantitative analysis, we use the All Science Journal Classification (ASJC).

To achieve these objectives, we undertook an extensive literature review to identify from the academic and grey literatures the different understandings of IDR/TDR and the factors contributing to their success or failure. These results are complemented by a survey of IDR/TDR projects involving AHSS integration and AHSS-STEMM integration and exploratory interviews with policy makers and funders. Corpora of academic literature and grey literature have been analysed using qualitative and quantitative methods.

This report presents the main findings of the completed analysis.

2 Challenges of IDR and TDR: key issues for AHSS integration

Interdisciplinary research (IDR) and transdisciplinary research (TDR) are still associated with the promise that science will be able to solve wicked and multidimensional problems. Both have a long history of twists and turns in different fields of research. Why, then, are they not mainstream yet? In short, they are challenging and they demand long-term cultural change.

With the aim of improving pathways to AHSS involvement in IDR/TDR, we undertook a significant evidence-scanning exercise to explore the state of AHSS integration in IDR/TDR. Systematising the features of IDR/TDR and AHSS integration in different thematic contexts is an intricate task that has to cover scientific papers, reports and internal documents from funding agencies and research organisations, the latter sometimes promoting more than describing IDR/TDR and AHSS integration.

Besides the heterogeneity and diversity of the fields, further general challenges we identified for AHSS integration in IDR and TDR are:

Legitimacy of IDR/TDR as modes of knowledge production: IDR/TDR are not yet mainstream (Lawrence, 2015) and both are questioned by institutions, policy makers and researchers alike. They are rendered invisible in many academic spheres and their outcomes are not always taken into consideration by research institutions, policy makers and funders. This challenge implies that systematising the features that IDR/TDR have in different contexts is an intricate task: scientific papers, reports and internal documents from funding agencies and research organisations, randomly and selectively promote the advantages of IDR/TDR .

Interdisciplinary and transdisciplinary communities: IDR and TDR have long traditions in Europe. Countries have differences in the way they institutionalise ID and TD. Policy and practice also show substantial differences in their treatment and funding of IDR/TDR. This situation means that researchers – senior and early career – often have difficulties finding a community of practice and participating in IDR/TDR associations and networks. Some national cases are worth mentioning: the

Association of Interdisciplinary Studies in the United States[3] and td-net (Network for Transdisciplinary Research, Swiss Academies of Arts and Sciences)[4] in Switzerland have promoted IDR/TDR in many ways, by establishing well-known conferences and publications. More recently, the Global Alliance for Inter- and Transdisciplinary Research and Education (ITD Alliance)[5] is developing activities to link those who share an interest in ID and TD. Nevertheless, the interdisciplinary and transdisciplinary communities are still scattered and divided throughout the globe. IDR and TDR papers are published in different journals, partly due to the lack of specialist publications, and researchers often face substantial obstacles trying to publish their results. Gaps in the literature, widely dispersed findings and scattered literature are key challenges in IDR/TDR. In our study we needed to use specific methods of analysis (see Section 3, below) to overcome this fragmentation.

Purposes and aims of IDR/TDR: Different research communities conduct IDR/TDR with different purposes and aims for their research, which demand specific kinds of support. We have identified three main groups (for a full description see Vienni Baptista et al., 2019) representing different understandings of ID and TD, each with specific implications for AHSS integration, namely:

(i) *Studies of ID and TD:* perspectives that consider either term as an object of study. The main focus of the scholars grouped under this category is to study how IDR and TDR are performed, under which conditions, in which contexts, etc.;

(ii) *Interdisciplinary and transdisciplinary studies:* under this label we include scholars who apply interdisciplinary and transdisciplinary approaches – either methodologically or theoretically;

(iii) *Case studies:* this group includes examples of IDR and TDR performed and institutionalised in specific contexts. The challenge encountered, in this case, is to differentiate these groups and understand their purposes in undertaking IDR/TDR.

Methods to study IDR/TDR: ID and TD constitute different modes of knowledge production. They require different methods to capture their multiple dimensions of collaboration. Several methods and tools have been developed, including mixed methods approaches (complementing quantitative and qualitative methods) or tailored techniques to map collaborations "in the making" , such as "The Diary Room", "the Hubbub Collaboration Questionnaire" (Callard, Fitzgerald and Woods, 2015) or the rich picture (Checkland 2000; td-net, 2020), among many others. The need for specific methods and tools

[3] https://interdisciplinarystudies.org

[4] http://www.transdisciplinarity.ch/en/td-net/Ueber-td-net.html

[5] http://www.itd-alliance.org

to study and to perform IDR/TDR (Klein, 1996, 2005) presents the challenge of reframing our methods to better understand the problem we are investigating. There is a need for further studies of how IDR/TDR are developed and how to approach them:

> It is startling how few studies of interdisciplinarity there actually are, despite the almost daily injunctions for researchers to collaborate with people of other disciplines (…) On the other hand, it represents an opportunity: it means that researchers in interdisciplinary projects have access to data to an important and under-represented topic within the landscape of contemporary knowledge-production (Callard and Fitzgerald, 2015, p. 93).

We also encountered such methodological issues: we had to face the double challenge of building a robust dataset and overcoming the bias that the underrepresentation of AHSS results in scientific databases presents in the academic and grey literatures (Kulczycki et al., 2018). We have confronted the challenge of applying a mix of qualitative (meta-ethnography, content-analysis, Grounded Theory, semi-structured interviews, qualitative survey) and quantitative methods (analysis of subject tags and disciplinary affiliations, concept mining, topic modelling) to our data. In doing this, we are seeking a plural but complete approach to the WP2 aims (see Section 3 for full details on the methodology).

Lack of policy learning about how to facilitate IDR/TDR: The fact that recommendations in the academic and grey literatures have been made repeatedly points to a lack of policy learning about how to facilitate IDR/TDR, resulting from the weak links between academic and policy literature. There are important gaps in the grey literature on AHSS and IDR/TDR between three largely separate literatures on European AHSS, IDR/TDR and AHSS integration within H2020.

AHSS disciplines and how they interact: There are differences between AHSS disciplines that must be taken into consideration in our study. They are not homogenous: they use a wide variety of methods, they have diverse set of values and they pursue different aims and objectives. They also understand ID and TD in differing ways. These conditions influence the potential interfaces that can be built between different AHSS disciplines and between them and STEMM disciplines. In our previous report (Vienni Baptista et al., 2019), we argued that the AHSS/SSH label is unhelpful as the disciplines included are too heterogeneous.

AHSS legitimacy and relationship with STEMM: different authors have studied the need to defend the constitutive territory of the AHSS. The literature discusses attempts to bridge AHSS and STEMM disciplines to overcome the lack of perceived legitimacy of AHSS values. This lack of legitimacy is reproduced when trying to integrate AHSS disciplines in IDR/TDR. This challenge implies that AHSS disciplines are invisible in some realms and their contribution to IDR/TDR differ according to country, context of application and division of academic fields.

These challenges underpin the current state of AHSS integration in IDR/TDR and demand further investigation. In this study, we approach them in a constructive manner, attempting to bridge some of the gaps in knowledge about IDR/TDR and understand the ways in which AHSS researchers can participate on equal terms in such research. This report provides further insights into this problem.

3 Methodology

This section presents the research methods used to develop the systematic literature review, interviews and survey in WP2. The systematic literature review was undertaken using quantitative and qualitative methods. The survey used a qualitative approach. Complementarities of such analyses are drawn where possible.

Data collection and data consolidation of the academic literature and grey literature corpora took place from March to June 2019. Alongside this, data analysis of the academic and grey literature corpora commenced in April 2019. The quantitative analysis has involved network analysis, topic modelling and concept mining of academic and grey literature corpora. The qualitative analysis entailed a systematic literature review, in the form of a meta-ethnography (Noblit & Hare, 1988), and content analysis of selected academic literature and grey literature using Grounded Theory (Corbin & Strauss, 2008) (Figure 1). This phase ended in January 2020. Simultaneously, we developed a qualitative survey among European researchers with experience in IDR/TDR (selected from extensive databases) and interviews with policy makers and funders. This phase ended in February 2020.

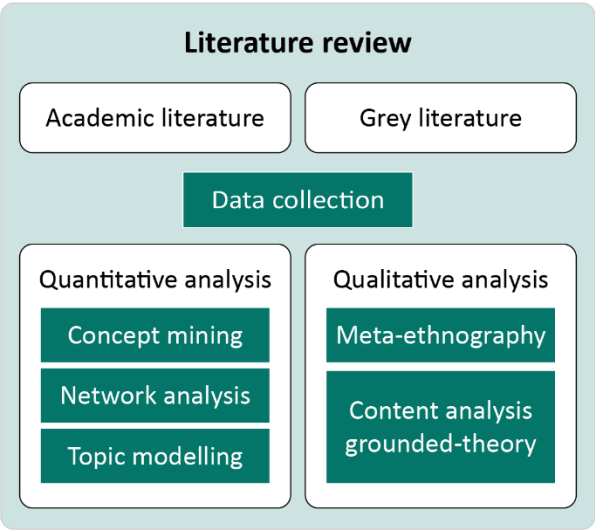

Figure 1 Methods used in WP2 for the literature review

This section is organised as follows. Firstly, we present the data collection process developed to assist in the consolidation of datasets for WP2 (for full details see Vienni Baptista et al., 2019). Next, the

methods used for quantitative analysis are summarised. These were applied to different corpora. The systematic review of the academic and grey literatures and their qualitative analysis are then explained. Finally, we present the qualitative approach used for the survey and the exploratory interviews.

3.1 Data collection and processing

Data collection procedures were aligned with the SHAPE-ID conceptual framework which consisted of the following dimensions concerning multi-/inter-/transdisciplinarity: understandings, factors, challenges, attitudes, institutional dimension, skills and examples. The goal was to gather the data relevant to the following units of analysis: researchers, policy makers, funders and institutions.

Four main sources were used in this process (see Table 2): (i) records from citation databases and digital repositories of scholarly publications (LitReview), (ii) documents relevant to SHAPE-ID's scope stored in the OpenAire repository (OpenAire)[6], (iii) research projects funded within the Horizon 2020 framework programme (H2020Projects), and (iv) Horizon 2020 Work Programmes (H2020Calls).

Table 2 SHAPE-ID corpora

#	Corpus name	Dataset description	Types of data in corpus	All items	Items used	Number of words
1.	LitReview	Academic literature	Publication abstracts, subject tags	5,040	3,910	700,871
2.	OpenAire	Documents mentioning IDR/TDR from OpenAire database	Documents abstracts, subject tags	99,170	68,268	19,673,622
3.	H2020Projects	H2020 projects mentioning IDR/TDR	Project abstracts ("objectives")	1,912	1,912	523,056
4.	H2020Calls	H2020 Work programmes sections (2014-2019)	Full texts	84	75	2,233,865

The following sections describe data collection procedures in greater detail while Section 3.2 of analysis outlines the analytic procedures.

3.1.1 Academic Literature dataset

In the course of the systematic literature review, we queried Web of Science (WoS), Scopus and JSTOR databases for records on IDR and TDR. For WoS we used Core Collection, Current Contents Connect, Data Citation Index, MEDLINE and SCIELO. To compensate for the known bias of WoS and Scopus against AHSS literature (Kulczycki et al., 2018), we also searched the JSTOR database. For WoS and

[6] A list of document types employed by OpenAire is available at: https://develop.openaire.eu/graph-dumps.html

Scopus, complex search strings were created that reflect the main research questions of the literature review (see Figure 11 in Appendix A). The queries in article databases were based on the seven sets of keywords corresponding to our main research questions, relevant to interdisciplinarity, transdisciplinarity, research, policy, integration, understanding, factors and success/failure (see Table 8 in Appendix B). The JSTOR database offers less advanced data-analytical tools, but we decided to include items with ID or TD in the title, to counterbalance the reported biases against AHSS in Scopus and WoS. These three data sources were complemented by bibliographies prepared during the preliminary scoping analysis of IDR/TDR literature.

The resulting dataset consists of 5,040 records, i.e., scholarly publications metadata (author, abstract, title, keywords and tags). Based on a systematic review, a sample of the literature was selected for qualitative analysis. At the same time, the bibliographic metadata was analysed with computationally assisted quantitative methods. Figure 2 presents the overall workflow for the academic literature review data collection phase (Vienni Baptista et al., 2019).

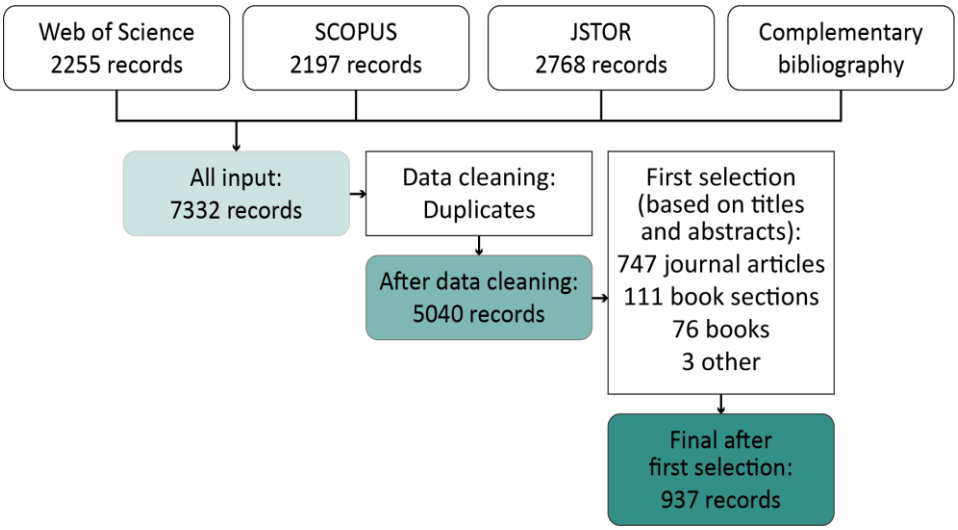

Figure 2 The complete academic literature review data-collection workflow

3.1.2 OpenAire Literature dataset

In order to access a variety of documents about IDR/TDR research and overcome the possible biases of commercial databases of journal articles, SHAPE-ID established cooperation with the OpenAire e-infrastructure. Given the fact that OpenAire did not support contextual search at the moment of data collection, we could not use the string developed for the literature search. Instead, with the kind support of the OpenAire team, we searched for keywords with all possible suffixes: interdisciplinar* OR

transdisciplinar*, matched against title, abstract, subjects, for documents published between 1990 and 2019.

The search yielded 99,170 bibliographic records which were delivered by the OpenAire team in xml format. Appendix C shows the breakdown of OpenAire document types.[7] Articles are most significant as they make up almost half of the sample. Theses (Bachelor's, Master's and doctoral) collectively make up 17% of the sample. Quite interestingly, other research products (ORP), i.e., objects hard to classify like events, lectures and models, make up 11% of the sample. Books, book chapters and reports amount to 5% of the sample.

3.1.3 H2020 Projects data

The metadata of projects funded under the Horizon 2020 framework programme is collected in the Cordis database. We used periodic data dumps, stored in the European Commission's open data portal[8]. We used the data dump from May 2019, which contained information on about 23,144 projects. These were narrowed down to 1,912 project which featured the search terms interdisciplinar* or transdicsiplinar* in the title or abstract ("objective").

3.1.4 H2020 Work Programmes

To gain more insight into the way the European Commission approaches IDR/TDR, the team downloaded a set of biannual work programmes (2014-2015; 2016-2017; 2018-2019) from the Funding and Tenders Portal[9] using WinHTTrack Website copier. The resulting set consisted of 84 PDF documents, available as sections of biannual work programmes.

3.2 Methods of analysis

This section presents the procedures used for the four strands of analysis: (i) quantitative analysis; (ii) qualitative analysis of academic literature; (iii) qualitative analysis of grey literature; and (iv) qualitative survey and exploratory interviews.

[7] A list of document types employed by OpenAire is available at: https://develop.openaire.eu/graph-dumps.html

[8]The data dump contains such fields as id, acronym, status, programme, topics, framework Programme, title, startDate, endDate, projectUrl, objective, totalCost, ecMaxContribution, call, fundingScheme, coordinator, coordinatorCountry, participants, participantCountries, subjects.
https://data.europa.eu/euodp/en/data/dataset/cordisH2020projects

[9]https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/how-to-participate/reference-documents;programCode=H2020

3.2.1 Quantitative analysis

Data analysis focused on two kinds of operations intended to give more high-level insights into the SHAPE-ID datasets. Firstly, **metadata classification** was employed to understand the relationships between documents. The analysis aimed at identifying relationships between disciplines and key topics pertaining to discussions of IDR/TDR using both abstracts and subject tags associated with documents. The following studies were performed: analysis of disciplinary affiliations (LitReview and OpenAire samples), network analysis of disciplinary relationships and analysis of LitReview subject tags. Secondly, the material was subjected to **concept mining** to map understandings of IDR/TDR through linguistic analysis of those concepts in abstracts (describing the meaning associated with our key terms). The following studies were performed to that effect: contextual search in collected corpora (detecting the contexts of IDR/TDR most pertinent to the SHAPE-ID datasets), followed by the analysis of selected excerpts and topic modelling of abstracts to detect key issues and concepts for IDR/TDR in our corpora.

The methods we applied were:

a) Analysis of disciplinary affiliations: The aim of this study was to trace which disciplines co-occur most often in the context of IDR/TDR. We decided to work with two datasets – Literature Review Bibliography (LitRev) and OpenAire database (OpenAire) – because they are complementary and allow for the triangulation of results. By using those datasets as proxies we provide an overview of collaborations which feature IDR/TDR issues. The fact that we arrived at similar results having performed the analysis separately for these complementary, yet independent datasets, reinforces the robustness of the findings.

   The method features quantitative analysis of disciplinary affiliations of journals represented in the LitRev and OpenAire database, based on a matrix, which matches scientific disciplines attributed to the journals present in the dataset, weighted by the number of articles from our sample, which were published in these journals (see Table 9 in Appendix C). We take disciplinary affiliations of journals as a proxy of disciplinary characteristics of the journal articles in the LitRev dataset, mindful of the fact that a particular article might deviate from the disciplinary affiliation of the journal in which it was published.

   In the ASJC schema, the AHSS "supergroup" is labeled "Social Sciences", and consists of the following groups of disciplines: Arts and Humanities, Social Sciences (the group), Psychology, Decision Sciences, Economics, Econometrics and Finance, and Business, Management and Accounting. We will refer to this supergroup as AHSS. However, we will discuss the Arts and

Humanities group, referred to as AH, separately from the remaining AHSS disciplinary groups, which we will discuss together as "Social Sciences supergroup" (SSSG)[10].

b) Analysis of Literature Review subject tags: The subject tags were freely assigned by authors of the articles in the LitReview sample, hence they contained important information about the conceptual scope of the paper. Since not all articles in our sample had subject tags, this analysis features 2163 articles from the Literature Review sample, which were assigned such tags. 25,522 tag occurrences were transformed into a co-occurrence network consisting of 9,525 nodes (individual tags) and 132,114 edges (connections between them).

c) Contextual analysis of SHAPE-ID corpora and creation of excerpts: In order to gain a better understanding of which issues relevant to the SHAPE-ID literature review are covered in our corpora, we analysed the corpora using keywords pertinent to the main contexts of IDR/TDR (see Table 10 in Appendix C for a detailed version of the keywords sets). The analysis of all SHAPE-ID corpora was conducted with the AntConc tool (Anthony 2019), using a combination of two main search terms (interdisciplin* & transdisciplin*, with the asterisk allowing for all possible suffixes) with the list of context words for each of the SHAPE-ID keywords within a span of 5 or 2 words[11].

d) Topic modelling: Topic modelling is an analytic method allowing for finding co-occurring cohorts of words that presumably reveal (latent) semantic relations and could be interpreted as the most recurrent concepts appearing in a given corpus (Blei, 2012). Previous research on similar material (scholarly journals) proved the interpretive potential of this method to assess the conceptual clusters in large-scale corpora. For instance, Goldstone and Underwood used topic modelling to describe the evolution of American literary scholarship on the example of articles from major academic journals (Underwood & Goldstone, 2012) and seven major literary journals (Goldstone & Underwood, 2014).

[10] In the LitRev dataset, based on a subset of 3,955 journal articles that had an ISSN number, we generated a list of 2,202 journal titles in which these articles appeared (henceforth LitRev sample). To each journal title we attributed a weight factor based on how many articles featured in the given journal, and at least one discipline from the ASJC schema. The disciplinary affiliations of OpenAire records had to be inferred from the subject tags, assigned by authors or providers. We prepared a list of keywords for ASJC disciplines which should appear alone (e.g. Anthropology) or in pairs (e.g. Cultural Studies) and ran a tailored R script to find the matches. We managed to find disciplinary matches for almost half of the records (47,982 out of 99,170), and counted 124,903 disciplinary hits in total, which gives 2.6 disciplines per record on average.

[11] Additionally, excerpts of analysed texts amounting to 500 characters before and after the searched keyword were generated for further analyses. Set 1 contains excerpts on Success/Failure and Factors from LitReview, GreyLit and OpenAire corpora (3-word span). Set 2 contains definitions, i.e. understandings of IDR/TDR in H2020Calls and H2020 projects datasets.

Topic modelling was applied to analyse the distribution of topics related to SHAPE-ID research questions (understandings of IDR, policy and integration) within the corpora as a whole, and in correspondence with the disciplinary trends of the topics. The analysis was performed on two textual corpora. The Literature Review corpus (LitRev) consisted of 3910 items, while the Grey Literature Review corpus (GreyLit) had 541 items. For each corpus a set of 50 topics, each counting 40 words, was generated (Vienni Baptista et al., 2019).

The analyses presented in the following sections were performed with TopicML, a web-based analytical tool developed by the Polish node of the Common Language Resources and Technology Infrastructure (CLARIN-PL). Table 11 and Table 12 in Appendix D (with additional commentary) present the full list of topics for each of the datasets with disciplinary and IDR/TDR trends ascribed to them.

3.2.2 Qualitative analysis of Academic Literature

The qualitative analysis of the academic literature was carried out based on the corpus selected from a systematic review (Jahan, Naveed, Zeshan, & Tahir, 2016). We developed a meta-ethnography review to analyse the commonalities, differences and connections across the literature. This is a seven-phase methodology (France et al., 2014; Noblit & Hare, 1988) that "aims to produce novel interpretations and involves systematically comparing primary studies to identify and develop new overarching concepts, theories, and models" (France et al., 2019, p. 448). This proves to be a useful method because it allows us to better understand the differences between concepts and definitions.

The seven phases of a meta-ethnography are (following Noblit and Hare, 1988):

- Phase 1 – Getting started: This phase and the subsequent review focus on the research question and three objectives pursued by WP2.
- Phase 2 – Deciding what is relevant to the initial interest: Study selection comprised identifying and selecting study accounts to synthesise (Noblit & Hare, 1988). In our case, this phase was developed in two consecutive steps: (1) building the main corpus or dataset, and (2) literature selection. As a first step (1) of the research process, consortium partners were asked to complete a short questionnaire to register the main literature they consider important on the topic. This subset of primary studies totaled 23 publications. These were coded and analysed to extract a set of keywords used for queries (see Table 8 in Appendix B). The workflow followed is detailed in Figure 1 above. From those 937 records, two researchers performed parallel independent assessments of the titles and abstracts in a second loop. After this, a total of 122

records were selected for the meta-ethnography systematic review and 101 were fully processed using qualitative content analysis[12].

- Phase 3 – Reading the studies: This step comprises the repeated reading of studies and noting of metaphors (France et al., 2014; Noblit & Hare, 1988). We developed a qualitative content analysis for systematically describing the meaning of data collected (Mayring, 2000; Schreier, 2014). Data from the selected references were coded in NVivo 12®. Grounded Theory (Corbin & Strauss, 1998, 2008) was the main method guiding the analysis and was complemented by the use of categorial thinking (Freeman, 2017). Triangulation (Flick, 2014) between the methods allowed quality assessment and constant verification of the progress of the coding phase.
- Phase 4 – Determining how the studies are related: A list of key phrases, ideas and concepts and their relations used in each account was developed (Noblit & Hare, 1988). In order to arrive at an initial assumption about how the studies relate to each other, we built several tables and figures that compare the academic literature.
- Phase 5 – Translating the studies into one another: The metaphors and concepts in each publication and their interactions were compared and translated within and across the literature (Noblit & Hare, 1988).
- Phase 6 – Synthesising translations: This phase focuses on bridging the translations obtained in Phase 5. These translations are compared with one another to see common types (Noblit & Hare, 1988). Results from this phase are elaborated in Section 0.
- Phase 7 – Expressing the synthesis: Section 4.1 synthesises the main findings from the academic literature review.

3.2.3 Qualitative analysis of Grey Literature

For the qualitative component of the grey literature review, document curation – searching for and cataloguing appropriate sources – has been an important and time-consuming element of the literature search. It was developed separately from the data collection described in Section 3.1.

Our search protocol therefore had three phases, which entailed first sourcing documents; then screening and assessing their suitability for inclusion; and finally conducting a content analysis. As

[12] We also employed expansive search techniques which involved gathering relevant publications known to the project team; 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); and citation alerts. Any new relevant published or in-press publications identified through these methods were included up to January 2020.

publications sourced from the grey literature tend not to include the equivalent of an academic abstract or keywords, this third phase required detailed searching of full documents in most cases.

Locating relevant documents was carried out in four stages following a recognised template (Fuller and Lenton, 2018). We used various permutations of the keywords “interdisciplinary”, “multidisciplinary”, “transdisciplinary, “arts” and “humanities”, to perform a series of searches in different databases. We started with general search engines and academic databases (e.g. Scopus, Web of Science and Open Grey) and, when this did not give us relevant new documents, switched to searching the websites of organisations listed in the SHAPE-ID Stakeholder Database (D6.3) and checking bibliographies or citations in key documents.

Searches of the websites of stakeholder organisations produced the most comprehensive results. Sources located using this search are mostly discrete documents, rather than online sources such as website pages or blogs. 187 documents were provisionally identified as relevant and of 102 were analysed in NVivo 12® (see below). Four basic criteria are widely accepted in assessing the quality of documents, (Scott, 1990): authenticity, credibility, representativeness and meaning. Unlike some grey literature material, it is relatively straightforward to establish that these sources satisfy the first two criteria. Their representativeness and meaning are discussed in Section 0 (below) which describes the results of our analysis.

Such texts have been created for a range of different purposes, including as public contributions to debates about European research policy (particularly in the run up to new funding schemes); as summaries of the implications of academic research into IDR/TDR; as surveys of particular academic fields; or to monitor major research programmes such as Horizon 2020. Broadly, this sample is composed of three distinct and only partially overlapping bodies of literature: reports and guidance based in the academic literature on IDR/TDR; surveys of and commentary on Arts and Humanities research both in Europe and globally; and evaluations of the integration of AHSS research within Horizon 2020 research programmes.

Because of this very limited overlap, many of the texts address the role of AHSS in IDR/TDR indirectly or very generally, as part of these broader discussions. This makes the coding of such documents a complex process requiring a significant amount of interpretative labour. Due to this, an abbreviated version of the codebook used to analyse the academic literature (Vienni Baptista et al., 2019) has been used to code the grey literature sources.

The key tasks of locating documents and assessing their suitability were largely completed by November 2019, with a further 28 items added to the dataset in January 2020.

3.2.4 Gaps in the literature on AHSS and IDR/TDR

The coded sources were categorised according to the geographic level of the publishing organisation (global, European or national), a basic typology of these organisations (funding agency; learned/professional organisation; research organisation)[13], type of document[14] (the most common were position statements, guidance documents and research-based reports) and whether the primary focus was on AHSS, IDR/TDR or Integration (Table 3).

This breakdown demonstrates the important contribution to this literature made by learned/professional bodies, especially (unsurprisingly) at the European level. These organisations produce the most position statements, many of which focus on the integration of AHSS disciplines in Horizon 2020 programmes. Research organisations, especially at the national level, more often produce reports and guidance based on the academic literature about IDR/TDR. This is also not surprising but such a pattern does start to explain the existence of the three separate literatures referred to above: analyses of the field(s) of AHSS, summaries and discussions of academic research about IDR/TDR, and evaluations of the integration of AHSS in Horizon 2020. These literatures are separate because there are two significant gaps in publications on AHSS and IDR. The first of these is between the literature on IDR/TDR and the literature on the integration of AHSS. The integration literature does not often refer to academic research on IDR/TDR and often contains an implicit assumption that such integration equates to interdisciplinarity. Secondly, until recently, literature on IDR/TDR has rarely discussed AHSS – a 2014 LERU report is the only exception in this sample – but instead has focused heavily on interdisciplinary research within STEMM or between STEMM subjects and the Social Sciences.

[13] Funding agencies include the EC, the Global Research Council, the Research Councils UK, the Irish Research Council and Wellcome. Learned/ professional organisations included the Academy of Finland, Academia Europaea, Alliance of All European Learned Academies (ALLEA), European Alliance for the Social Sciences and the Humanities (EASSH), the GUNi Network, League of European Research Universities (LERU), the Russell Group, Science Europe and The Guild. Research organisations included the AAU, the Academy of Finland, the INTREPID project, the University of Edinburgh, Trinity College Dublin and td-net.

[14] These categories overlap to some extent, but we have categorised documents based on what their primary purpose appears to be. Evaluation and research-based reports are similar in form but have institutional roles. Similarly, many of the guidance documents refer to some research but they are written in order to provide advice to researchers, research organisations and funding agencies. Positions statements are often labelled as such but we have also included in this category a collection of case studies by LERU as it is arguing for the inclusion of the creative arts in universities. Finally, we have labelled accounts of a particular set of projects or area (e.g. the digital humanities) case studies, and those of a field (e.g. European AHSS) or type of research (IDR/TDR) as a surveys.

Table 3 Classification of grey literature sources

GEOGRAPHIC LEVEL/TYPE OF ORGANISATION	TYPE OF DOCUMENT	NO. of DOCUMENTS	CENTRAL TOPIC (AHSS or IDR/TDR or INTEGRATION)[15]
Global			
Funding agency	Position statement	1	IDR/TDR
	Research-based report	1	IDR/TDR
	Survey	1	IDR/TDR
Learned/professional organisation	Call for contributions	1	AHSS
	Position Statement	1	Integration
	Research-based report	2	IDR/TDR
	Survey	1	AHSS
Total		**8**	
European			
Funding agency (EC including EURAB, FET and i4g)	Case study/studies	1	Integration
	Evaluation report	5	AHSS (1) Integration (4)
	Guidance	3	Integration (2) IDR/TDR (1)
	Position statement	1	Integration
	Research call	1	AHSS
	Research-based report	1	IDR/TDR
	Strategy document	1	IDR/TDR
Learned/professional organisation	Case study/studies	4	AHSS (1) AHSS + IDR/TDR(1) IDR /TDR (2)
	Event summary	1	IDR/TDR
	Position statement	22	IDR/TDR
	Research-based report	1	AHSS (4) IDR/TDR (4) Integration (14)
	Survey	2	IDR/TDR AHSS
Research organisation	Evaluation	1	IDR/TDR
	Event summary	2	IDR/TDR (1) Integration (1)
	Guidance	2	IDR/TDR (1) Integration (1)
	Research-based report	8	AHSS (2) AHSS + IDR (1) IDR (5)
Total		**56**	
National			
Funding agency	Case study/studies	3	AHSS (1) IDR/TDR (2)
	Evaluation	1	AHSS
	Event Summary	1	IDR
	Guidance	2	AHSS (1) IDR/TDR (2)
	Position statement	1	IAHSS + IDR
	Research-based report	1	DR/TDR
	Strategy Document	1	IDR
	Survey	3	AHSS (1) IDR/TDR (2)
Learned/professional organisation	Position statement	3	IDR/TDR (2) Integration (1)
	Research-based report	4	IDR/TDR
Research organisation	Case study/studies	1	AHSS
	Event summary	1	AHSS
	Guidance	13	IDR/TDR
	Research report	3	IDR/TDR (2) Integration (1)
Total		**38**	

[15] We did not define these terms but categorised the documents based on the terminology the authors used.

3.2.5 Survey design and exploratory interviews[16]

In our survey with researchers working on inter- and transdisciplinary projects, we addressed two main questions: (i) When developing a European inter- or transdisciplinary project, what are the main difficulties people encounter in realising a good research team that is balanced in terms of the various interests and goals of the different participants, and (ii) Which factors of success and failure do researchers integrating AHSS in larger projects consider relevant for their daily practice of IDR/TDR?

Data were gathered using a qualitative survey among European researchers and through interviews with policy makers. We aimed with these activities to enhance the knowledge about inter- and transdisciplinary collaboration (for full details see Spaapen et al., 2020). A semi-structured questionnaire, mainly qualitative, was sent out to 268 researchers working on projects identified from the Cordis database and a number of other sources. The responses were analysed with Nvivo 12®.

Exploratory interviews with 10 policy stakeholders were conducted using a guideline that follows the three phases of the policy process, ex ante, ex durante and ex post project implementation (for full details see Spaapen et al., 2020). We focused on the AHSS, but also on the growing collaboration between these and STEMM disciplines.

4 Findings

This section presents the main findings emerging from the quantitative and qualitative analyses of the systematic literature review and the qualitative survey and interviews. To highlight how these findings contribute to addressing the objectives of Work Package 2 (O.1, O.2 and O.3), we organise this section according to our objectives:

(iv) Section 4.1 addresses O.1, i.e.: to disentangle the different understandings of interdisciplinarity (ID) and transdisciplinarity (TD);

(v) Section 4.2 addresses O.2, i.e.: to identify the factors that hinder or help inter- and transdisciplinary collaboration;

(vi) Section 4.3 addresses O.3, i.e.: to clarify which understandings of IDR/TDR and which factors of success and failure are specifically relevant for integrating AHSS in IDR/TDR.

4.1 Understandings of Interdisciplinarity and Transdisciplinarity

This section focuses on definitions of interdisciplinarity and transdisciplinarity and the different ways these terms are understood. It builds on the preliminary findings presented in a report in October 2019

[16] The methodology and full details on the survey case selection is described in Spaapen et al. (2020).

(Vienni Baptista et al., 2019). We first present an introduction to the topic from the academic literature review (4.1.1). Next, we analyse how those definitions of ID and TD are considered in the grey literature, taking into consideration three levels: national, European and international (Section 4.1.2). A quantitative analysis of different bodies of literature (academic literature and grey literature) is presented in Section 4.1.3.

4.1.1 Disentangling Understandings of ID and TD in the Academic Literature

To analyse the different understandings of ID and TD that help to better understand the gap in AHSS integration, we identify three main topics in the academic literature review: (i) definitions most used in the academic literature, (ii) discourses of ID and TD; and (iii) modes and logics of ID and TD (see Vienni Baptista et al., 2019). These provide a set of cross-cutting axes, detailed in Section 4.1.1.2. This set is useful for finding commonalities and differences among plural understandings. It also allows us to develop our hypothesis that differences among understandings are not a hindering factor, but can constructively be used to improve AHSS integration into IDR/TDR. In the words of Julie Thompson Klein, one of the key scholars of ID/TD: "(…) diversity is not a detriment, rather a reflection of heterogeneity" (Klein, 2020).

Below we summarise our findings according to these three dimensions, which serves as an introduction to the topic (for a complete overview see Vienni Baptista et al., 2019).

4.1.1.1 Definitions most used in the Academic Literature

When facing the challenge of defining ID and TD, several authors (Barry & Born, 2013; Klein, 2017; Lury, 2018; Lyall, 2019) conclude that these concepts represent contested discourses. The definitions that do exist reveal an interwoven set of references containing different levels of understanding of what ID and TD constitute (Vienni Baptista et al., 2019). Efforts to categorise and conceptualise the processes and outcomes of collaborative research depend fundamentally on the distinctions ranging from unidisciplinary to transdisciplinary scientific collaboration (Stokols et al., 2003).

In the case of ID, Julie Thompson Klein is the author most quoted in efforts to define the term. In the case of TD, the German and Swiss communities have built a fuller discussion of the topic (Vienni Baptista et al., 2019).

In 1990, Julie Thompson Klein provided an overview of the interwoven perspective needed to address ID and TD.

> Interdisciplinarity has been variously defined in this century: 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. Cutting across all these theories is one recurring idea. Interdisciplinarity is a means of solving problems and answering questions that cannot be satisfactorily addressed using single methods or approaches. Whether the context is a short-range instrumentality or a long- range reconceptualisation of epistemology, the concept represents an important attempt to define and establish common ground (Klein, 1990, p. 196).

One definition appears across different communities as the authoritative description of the concept and the practice of ID:

> Interdisciplinary research is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline (National Academy of Sciences, 2005, p. 2).

ID constitutes an array of interrelations between disciplines that includes programmatic statements, policy interventions, institutional forms, theoretical statements, instruments, materials and research practices immersed in a process of negotiation (Barry and Born, 2013). ID is different from multidisciplinarity. In multidisciplinary research, disciplines remain separate and are juxtaposed, but retain their original identity (Klein, 1996).

Taxonomies and further classifications addressing the different connotations of ID are an important topic and are present in the literature of different countries. Klein (2010, 2017) and Lyall, Bruce, Tait & Meagher (2011) are just two examples of this. While Klein offers a flexible taxonomy in which categories can be linked with and complemented by each other, Lyall et al. (2011) identify two different types of ID: academically oriented and problem focused.

Another example is provided by Fitzgerald, Brunner, Koellinger, and Navarro (2013). The authors propose a simple but strong distinction based on what constitutes “good” ID. They advocate truly interdependent collaboration – whether contributions are conceptual, technical or methodological – based on broadly equal or symmetrical relations between researchers from (in their example) the Life Sciences and Social Science disciplines. “Bad” or “ugly” collaboration, on the contrary, may involve imbalanced contributions or relations in the partnership, and lack of real mutual engagement or understanding of each other’s epistemological standards and assumptions.

For its part, transdisciplinarity is understood as a reflexive, integrative, method-driven scientific principle in many of the publications we analysed. Authors focus on how to solve societal problems by integrating knowledge from various scientific and social bodies of knowledge (Hirsch Hadorn et al., 2008; S. Hoffmann, Pohl, & Hering, 2017; Lang et al., 2012; among others). It is important to acknowledge that it also has a theoretical connotation that members of td-net (Swiss Academies of

Science) have extended to include problem orientation and inclusion of stakeholders (Hirsch Hadorn et al., 2008; Pohl & Hirsch Hadorn, 2007). To cite an authoritative definition:

> Transdisciplinary research, therefore, aims at identifying, structuring, analysing and handling issues in problem fields with the aspiration: (a) to grasp the relevant complexity of a problem, (b) to take into account the diversity of live-world and scientific perceptions of problems, (c) to link abstract and case-specific knowledge, and (d) to develop knowledge and practices that promote what is perceived to be the common good (Hirsch Hadorn et al., 2008, p. 4).

Against this background, this plurality of definitions may be understood as expressing the diverse aims or purposes that researchers pursue when practicing inter- and transdisciplinary research, and, therefore, when defining it (td-net, 2019).

4.1.1.1 How can different understandings of ID and TD be organised?

The heterogeneity of understandings thus influences the kind of IDR and TDR being developed. As terms, ID and TD denote a spectrum of experience (Lyall, 2019) and are defined heterogeneously (Mäki, 2016). As a result, the literature reveals a tendency to problematise them (Barry & Born, 2013), rather than thinking of the terms as historically given.

As a means to synthesise the plurality of understandings of interdisciplinarity, Thompson Klein (1990, 1996, 2005, 2020) suggests three discourses that summarise the implications of differing definitions and conceptualisations. Discourses are distilled from historical trends that have shaped the main tendencies in theoretical and methodological approaches to ID/TD (Klein, personal communication, 2019). Taking these discourses into consideration contributes to understanding the ways in which AHSS discourses can be integrated into IDR/TDR.

The three discourses are:

- The philosophical discourse: Scholars adopting this perspective discuss epistemological issues on how interdisciplinary knowledge is constructed and the nature of reality (Klein, 2020). This perspective searches for the unity in science in which a concept, theory or object cannot be explained by summing up their parts or properties. The idea of unity has also been linked with the concept of holism in biology, physics and social theory (Klein, 2020).
- The problem-solving discourse: ID, in this case, is oriented to instrumental needs, specifically to cope with complex problems. Interdisciplinary problem solving has a long history. It can be traced to the National Academy of Science report (2005), which provides an authoritative definition (see previous section). According to Klein (2020) during the 1980s and early 1990s the discourse of problem solving became entwined with the concept of transdisciplinarity in

environmental research in German-speaking countries with non-academic stakeholders as main participants in TDR.

- The critique discourse: This discourse interrogates the principle of unity, instrumental problem solving, disciplinarity, and interdisciplinarity. This discourse implies "(a) critique of the state of the disciplines being restructured and, either implicitly or explicitly, the prevailing structure of knowledge" (Klein, 1996, p. 11).

The discourse on transdisciplinarity has become manifold and widespread as well. Two further contributions to the analysis of TD conceptualisation, elaborated by Thompson Klein (2004) and P. Osborne (2015), classify these discourses according to their main features. In an earlier reflection on discourses of transdisciplinarity, Thompson Klein (2014) identified three major streams that converge and overlap:

- The transcendence discourse: aiming at unity of knowledge, 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.

Related to the first stream, Nicolescu (2000) sees TD as new universality of thought and education informed by the worldview of complexity in science, fostering an open-minded rationality, subjectivity, and ethics. This understanding builds on the definition developed in 1972 at the OECD Seminar (OECD, 1972). Nicolescu (2000) proposes that TD transcends entrenched categories to formulate problems in new ways that are transnational and trans-epistemic. Collaborators may accept an epistemological perspective unique to the effort, in the process redrawing boundaries between disciplinary knowledges (Eigenbrode et al., 2007; Miller et al., 2008). This definition is widely used in the literature related to AHSS studies.

Furthermore, due to the complexity, ambiguity, and uncertainty (Hoffmann, Pohl, & Hering, 2017) of the problems ID and TD approach, definitions cannot be unique and should adapt to different contexts (Vienni Baptista et al., 2019). Spaapen, Dijstelbloem, and Wamelink (2007) advise that research is too complex to be put into boxes that ignore the particularities of context (Klein, 2005).

The question that arises from this classification is whether AHSS disciplines relate themselves to each of these discourses or propose specific understandings of IDR/TDR? We have confirmed that discourses related to transgression and critique are present in most AHSS literature. Authors also acknowledge

that the problem-solving discourse does not invite AHSS disciplines to participate in IDR/TDR (Aldama, 2006).

This means that not all inter- and transdisciplinary practices are the same but rather different relations between disciplines in a collaboration can be understood as taking one of several forms (Barry, Born & Weszkalnys, 2008):

- In a 'subordination-service' relationship, one or more disciplines occupy a subordinate or service role conceived as making up for an absence or lack in others;
- In an 'integrative-synthesis' relation disciplines are integrated in a more symmetrical manner;
- In an 'agonistic-antagonistic' relationship there is a commitment to more radical shifts in knowledge practices occurring through collaboration.

The different roles research partners may play is often underpinned by assumptions about the purpose of the collaboration. For instance, Barry, Born and Weszkalnys (2008) identify three logics that are embodied in interdisciplinary practices – the logics of accountability, innovation and ontology:

- The logic of **accountability** is best represented by efforts to introduce forms of knowledge that can be seen to provide ethical or societal oversight in science and technology projects;
- The logic of **innovation** understands the purpose of interdisciplinarity as better understanding societal needs to enable industry to address them;
- The logic of **ontology** represents more thoroughgoing efforts to transform the practice of research and training, inside and outside the academy, leading to the generation of novel problems, objects and relations of research, as well as interdisciplinary subjectivities.

The academic literature also highlights that IDR/TDR practices can create opportunities for disciplines to evolve, with challenging intellectual debates emerging at the boundaries of existing disciplines and in the gaps between them, potentially reconfiguring and transforming disciplines (Lyall, 2019). This transformative potential has strong implications for researcher careers (Fletcher & Lyall, 2019; Lyall, 2019).

4.1.1.2 A structure to sort out plural understandings

Based on the systematic literature review, we identified six cross-cutting axes on which understandings of ID and TD differ. For those interested in disentangling different understandings, we suggest going through the following questions:

- ***What?*** What are the definitions of ID and TD and their conceptualisation, including how disciplines are understood and how they relate to ID and TD?
- ***Who?*** Which researchers, funders, policy makers, and other stakeholders, as well as communities and teams develop or contribute to IDR and TDR?.
- ***How?*** Which methods and tools are used to achieve IDR and TDR, in particular for integration?
- ***Why?*** What are the motivations and logics behind undertaking or supporting IDR and TDR?
- ***When?*** What time and timing is dedicated to IDR/TDR practices?
- ***Where?*** What are the spaces for IDR and TDR that establish the institutional contexts for individual or collective endeavours?

This classification aims to incorporate the diversity of concerns bound up with understanding and practicing IDR/TDR and shed light on our aim of disentangling different understandings of IDR/TDR. The heterogeneity of understandings influences the kind of IDR and TDR being developed combined with the analysis of these practices and emphasises the need for contextual understandings.

Key Findings

How can we navigate across different understandings of ID/TD? How do these understandings influence AHSS integration? Plural understandings of ID/TD can be sorted out taking into consideration:

1. Discourses of ID/TD

For TD, there are three discourses (Klein, 2014): (i) transcendence, (ii) transgression, and (iii) problem-solving.

For ID, the three discourses are (Klein, 2020): (i) critique, (ii) philosophical, and (iii) problem-solving.

2. Phases of a project/programme

Projects/Programmes can be divided into different phases in which different actions are performed: (i) preparatory phase, (ii) core phase; and (iii) follow-up phase[17]. These phases can be further sub-divided depending on the scheme.

3. Types of understandings of ID/TD

ID and TD can be considered as (Barry and Born, 2013; Callard and Fitzgerald, 2015): (i) object of study; (ii) reflexive orientation; (iii) method; and (iv) governmental demand.

4. Cross-cutting categories

The following questions can better position a project according to the aims and purposes it pursues:

What?: Definitions of ID and TD and their conceptualisation, including how disciplines are understood and how they relate to ID and TD.

Who?: Subjects that develop or contribute to IDR and TDR, whether as researchers, funders, policy makers, and other stakeholders, as well as communities and teams.

How?: Methods and tools used to achieve IDR and TDR, focusing on the problem of integration.

Why?: Motivations and logics behind doing or supporting IDR and TDR.

When?: Time and timing as central topics to better understand IDR/TDR practices.

Where?: Spaces for IDR and TDR that establish the institutional contexts for individual or collective endeavours.

[17] Stauffacher, Flüeler, Krütli and Scholz (2008).

4.1.2 Understandings of Inter- and Transdisciplinarity in the Grey Literature

This section outlines our main findings relevant to disentangling understandings of inter- and transdisciplinarity, namely that few authors in the grey literature define either term adequately and that this results from the weak links that exist between the academic and grey literature on IDR/TDR.

4.1.2.1 The terms IDR and TDR are widely used but rarely defined

Our analysis identified important differences between the grey literature and academic literature. In contrast to long-running discussions within the academic literature about how to define IDR/TDR, analysis of the grey literature showed little effort to explain what is meant by inter- or transdisciplinarity. Out of a sample of 102 documents, only 33 (less than a third) provided any kind of definition of what the authors understood by the term "interdisciplinary". These definitions ranged from the very straightforward – "Interdisciplinary research may be identified as research where two or more disciplines work together to produce a common body of work" (GRC; 2016a, p.4) to a sophisticated taxonomy distinguishing between empirical, methodological and theoretical interdisciplinary and multidisciplinary research (Academy of Finland, 2005).

When an external definition of interdisciplinarity was provided, the most common source was the 2005 US National Academy of Sciences report *Facilitating Interdisciplinary Research* . The same is true for the academic literature (see Section 4.1.1). This is a concise and comprehensive definition, but its citation may also reflect the global prestige of American academia.

A small number of authors (e.g. AAU, 2005; British Academy, 2016) provided family resemblance definitions[18] of interdisciplinarity in order to capture the different activities covered by this label. Others described how:

> Interdisciplinary research can be (…) sub-divided into: research which aims to further the expertise and competence of academic disciplines themselves, e.g. through developments in methodology which enable new issues to be addressed or new disciplines or sub-disciplines to be formed; and research which is problem focused and addresses issues of social, technical and/or policy relevance with less emphasis on discipline related academic outcomes (STIS; 2007, p.1).

However, several authors (EURAB, 2004; IHS, 2019) went even further and refused to provide definitions at all, arguing, for example, that "the generic term 'interdisciplinary research' in reality covers a very broad range of activities which, at this stage, defy easy classification" (ACOLA; 2012, p.1).

[18] Family resemblance definitions highlight a series of overlapping similarities within a group rather than one feature that they all share.

Despite this scarcity of definitions, a distinction between IDR and TDR remains present within the grey literature. Ten of the sources in our sample, almost all research reports, provide a definition of transdisciplinary research in which it is understood as different from interdisciplinary research, usually on the basis of the involvement of stakeholders (e.g. ALLEA, 2013; CEU, 2013; INTREPID, 2017c; LERU, 2016; LERU, 2017; Technopolis, 2016). However, once again, a number of authors argued that it was not possible to distinguish clearly between IDR and TDR, largely because the meaning of both terms varies in different contexts.

Inter- and transdisciplinarity are increasingly relevant concepts and practices within academia (INTREPID, 2017). While various definitions exist, a clear distinction between inter- and transdisciplinarity remains difficult in some contexts (INTREPID, 2017, p.4) in the grey literature. There is at present no widely accepted definition of ID and TD. The terms are used with different meanings depending on thematic and cultural contexts (td_net, 2011, p. 3).

As other research has already concluded (INTREPID, 2016, 2017b), clarity about the meaning of the terms inter- and transdisciplinarity is necessary, in order, for example, to accurately assess IDR/TDR funding applications and evaluate the products of such research. We conclude that such definitions should be provided whenever possible in the grey literature on IDR/TDR.

4.1.2.2 Links between grey and academic literature on IDR/TDR are weak

Most of the documents that did define IDR/TDR were research reports or guidance based on research: only two position papers (LERU, 2016; NET4SOCIETY, 2013) did so. Julie Thomson Klein was the most consistently cited author and many of her texts are cited, whereas for other authors, including Andrew Barry and his co-authors, Ann Bruce and her co-authors or Felicity Callard and Des Fitzgerald, only one key work is usually cited (Barry, Born, & Weszkalnys, 2008; Bruce, Lyall, Tait, & Williams, 2004; Callard & Fitzgerald, 2015). More than a third of the documents in this sample (43 documents) contain no reference at all to the academic literature on IDR. This is an important omission in discussions about a form of research and research policy that are the subject of growing (if widely dispersed) academic literature.

Weak links between the academic and grey literature are presumably one reason why many authors in the sample did not provide a definition of IDR/TDR and used the term “interdisciplinary” as if its meaning was simple and widely agreed upon. This lack of precise definition is problematic for two reasons. Firstly, because the definition of IDR/TDR is actually contested and there are many different definitions currently circulating (Lury, 2018; Lyall, 2019; Vienni Baptista et al., 2019), and secondly because, in the grey literature, it is often combined with an implicit model of IDR that sees it solely as a means of solving societal challenges, missions or problems. Nearly two thirds of the grey literature

documents (72) made some reference to IDR/TDR in this role. This technology-focused understanding of IDR – rooted in innovations such as the Moon Landings (OECD, 1972) – is still pervasive in the grey literature, and its instrumentality makes research framed using this model potentially unattractive to non-STEMM researchers, and especially those in the Arts and Humanities.

Also evident were examples of the same advice being put forward repeatedly. Coupled with the British Academy's (2013, p. 4) comments about SSH integration being "entirely new" (which is clearly false given the FP5 attempts at interdisciplinary integration (e.g. Bruce et al., 2004)), this reinforces our finding about the gap between the academic and grey literature and the resultant lack of policy learning. It also points to the important role of "intermediaries" who can facilitate transmission of academic work to the EC, represented within this dataset particularly by the INTREPID reports.

4.1.3 How are IDR/TDR defined in different corpora? An overview of datasets

In this section, data analysis focused on two kinds of operations intended to provide more high-level insights into the SHAPE-ID research questions. Below, we detail the main findings of the quantitative methods applied to four main datasets corpora: (i) academic literature (LitReview); (ii) OpenAire; (iii) H2020 projects; and (iv) H2020 calls.

How are IDR/TDR defined in different corpora?

Interdisciplinarity is discussed more often than transdisciplinarity in all corpora. Moreover, IDR and TDR seem to be used synonymously, especially in contexts not focused on interdisciplinarity per se (meta discussions), but in common scholarly uses (e.g. in project descriptions). That given, understandings of ID and TD seem to be intertwined and not always clearly separated from each other. The analysis of definitions in the context of funding schemes and applications show a tendency to use the term interdisciplinary as a signifier of innovative, timely research.

The quantitative analysis of the frequency of the concepts of ID and TD in keyword contexts shows how the significance of the discourse on ID and TD is distributed depending on the context of the keywords and the type of text. Table 13 in Appendix E contains the frequencies of context occurrences in four corpora. Altogether we found 55,891 occurrences of SHAPE-ID keyword contexts: research (38,999), factors (4,489), understandings (5,354), success/failure (2,782), policy (1,501) and integration (2,766).

Figure 3 and Figure 4 below provide a visualisation of these numbers, showing how the contexts are distributed in the corpus, with regards to both ID and TD. All frequencies are normalised, i.e. presented as the number of occurrences per 100,000 words to allow for comparison between datasets of different

length. Figure 3 shows that interdisciplinarity is discussed far more often than transdisciplinarity, which may indicate that both concepts may be often treated synonymously by authors.

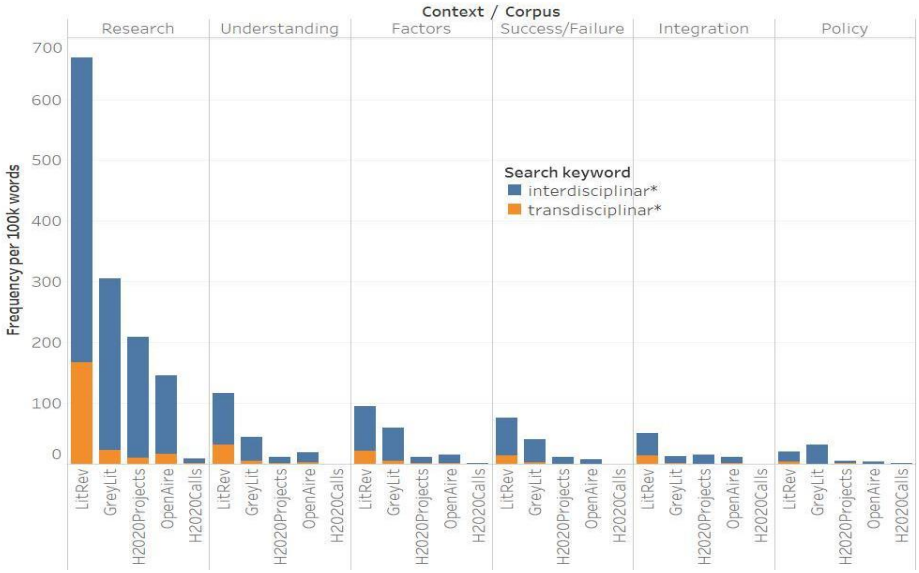

Figure 3 SHAPE-ID context keywords normalised frequency by corpus

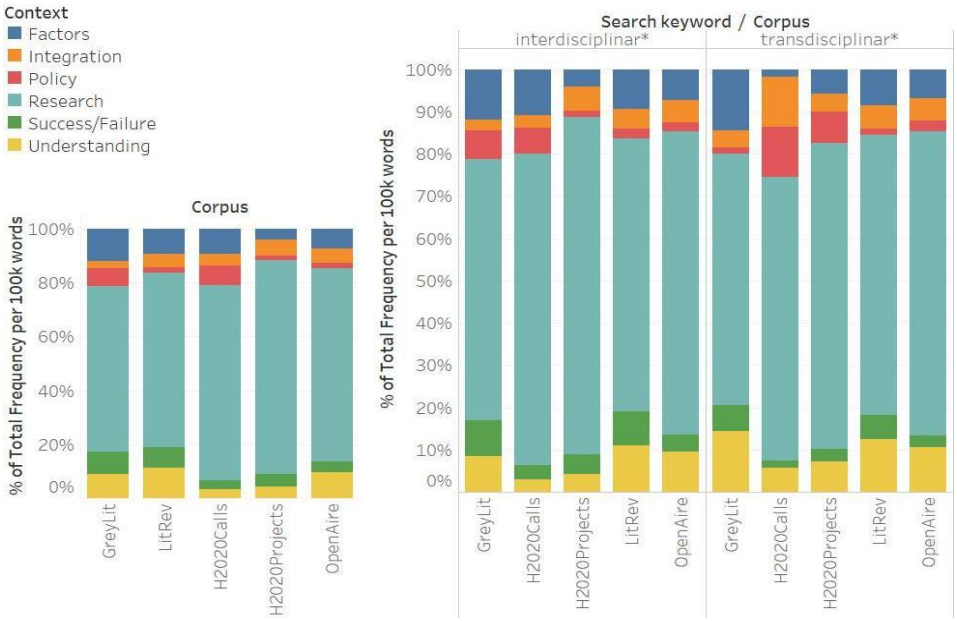

Figure 4 Percentage distribution of SHAPE-ID keyword normalised frequencies in corpora

The two graphs in Figure 4 show the percentage distribution of SHAPE-ID context keywords across all corpora. The graph on the right represents separate results for ID and for TD, while the graph on the

left shows combined frequencies. This quantitative analysis of the frequency of the concepts of ID and TD in keyword contexts shows how the significance of the discourse on ID and TD is distributed depending on the context of the keywords, but also the type of text.

Our results show that interdisciplinarity is discussed much more often than transdisciplinarity (see Figure 3) which may indicate that the former term is used to describe all kinds of collaborations between disciplines.

The LitReview corpus, collected through explicit targeting of the search keywords, as well as the hand-picked Grey Literature corpus (GreyLit) (see Section 4.1.2 for further details), are the richest in terms of the project's keywords. The H2020 project abstracts do not contain many references to IDR/TDR issues: a mere 8% of projects (1,912 out of 23,155) mention those concepts (ID/TD) explicitly. While the context of research was understandably the most prominent in all samples, we may note that issue of factors of IDR/TDR is mentioned more often in LitReview and GreyLit corpora. The latter gives more attention to the policy issues, as do H2020Calls (especially with regards to TDR). Integration seems to be mentioned more often in the context of transdisciplinarity, in particular in the H2020Calls and GreyLit datasets.

In order to recreate the understanding of IDR/TDR we analysed how these terms were used and defined across SHAPE-ID corpora using a simple semantic approach. This method entailed creating a conceptual context of these keywords by pooling together the words that co-occur with them. The analysis of LitReview definitions produced findings aligned with those stemming from the qualitative review, hence we focused on H2020 projects and calls to uncover how IDR/TDR issues are framed in the context of research funding. Altogether 71 excerpts were analysed and combined into a cumulative definition, consisting of all context terms. This definition was subsequently analysed.

The analysis shows that in the analysed abstracts from "H2020 Project" IDR appears only in a positive context. It is perceived as a key value and a new quality, as both a direction and a trend in development of scientific research. The main matters connected to it that were mentioned are: (i) decreasing the boundaries between disciplines; and (ii) connecting experts, approaches and scientific methods. Moreover, expectations of IDR which were voiced concern new methodological solutions, but also creating a new generation of researchers. This way of writing about IDR in short abstracts (which were the object of analysis) can be understood as indicative of IDR being seen as an element of scientific research projects which is increasingly indispensable and often given great importance. Hence this type of understanding could be also viewed as postulative, i.e. bringing such qualities to the project that are crucial for its success.

4.1.3.1 Major contexts of IDR/TDR in the Academic Literature

We used network analysis to produce a collection of the 100 most important tags, according to their weighted degree. Our findings from the quantitative analyses confirm that the issues pertinent to SHAPE-ID are amongst the most frequently discussed in this sample, namely, IDR/TDR (8 keywords, e.g. interdisciplinary approach, transdisciplinarity) and critical contextual concepts attached to them (innovation, integration, obstacles, policy, communication, evaluation, research). Some keywords reflect a genre (e.g. case report, clinical article), or methodology (e.g. controlled study, questionnaire, procedures).

We may distinguish three main fields for discussions of IDR/TDR: health studies (e.g. health care quality, public health, health service), environmental research (e.g. climate change, ecology, biodiversity, environment) and keywords associated with humans (human, humans, male, female), which seem to be central to the network. On one hand, it may mark the connection with the other two areas (e.g. human subjects of experiments), but it also marks that a direct interest in humans (as reflected by the article subject tag) is an important context for IDR/TDR discussions (see Figure 12 and Figure 13 in Appendices F and G). These results, especially with regards to environmental studies seem to be consistent with findings from the disciplinary affiliations analysis, where we found close connection between this discipline and AHSS.

4.1.3.2 In which contexts do IDR/TDR discussions occur?

The analysis of topic models and keyword groups shows different contexts in which interdisciplinarity appears in the LitReview and GreyLit corpora. Topics we analyse are groups of words that frequently co-occur in analysed abstracts. In our previous report (see Vienni Baptista et al., 2019), we compared the grey literature and academic literature datasets for topics where IDR/TDR terms were identified (see Figure 13 and Figure 14 in Appendix G).

In the LitReview corpus ID co-occurs with such words as development, strategy, future, discipline, challenge, experience and important (see Table 11 in Appendix D). In the GreyLit corpus, which generally represents a more policy-oriented discourse, ID appears together with the terms researchers, academic, work, collaboration, problem, important, group, discipline, time and individual (see Table 12 in Appendix D) What is interesting is the linking of IDR with importance in both cases. The LitReview corpus also seems to associate IDR with the language of growth (meaning strategy, development, future).

Another immediately visible difference between the two corpora is that in the GreyLit corpus topics that contain a significant presence of IDR/TDR-related vocabulary are semantically not discipline-specific (these are the topics coded as “multidisciplinary”). But even for non-IDR/TDR topics, a

disciplinary trend could be identified only for 14 topics in the GreyLit corpus, as opposed to 23 in the LitReview corpus (see Table 11 and Table 12 in Appendix D).

In the LitReview corpus the distribution of topics between IDR/TDR and disciplinary trends is on the whole more equal for topics with a significant presence of vocabulary pointing to IDR/TDR in general. For the five topics with vocabulary related to understandings of IDR/TDR, two co-occur with Social Science vocabulary, one with AHSS vocabulary and one with non-AHSS vocabulary. However, IDR/TDR vocabulary does not combine with Arts and Humanities vocabulary in any of the topics (see Table 11 and Table 12 in Appendix D).

Disciplinary trends observed in the LitReview and GreyLit corpora suggest that vocabulary specific to the Arts and Humanities is underrepresented in the topics of both corpora, while Social Sciences vocabulary is pertinent to the LitReview. Health Sciences and Environmental Science are the two non-AHSS disciplines which overlap in both corpora and most often combine with IDR-related vocabulary. Health Sciences are present in more topics but only Environmental Science vocabulary co-occurs with Social Science vocabulary in the context of IDR/TDR. Trends confirm the disciplinary non-specificity of the GreyLit corpus: regardless of whether IDR-relevant or not, fewer disciplines are represented and in fewer topics. The LitRev corpus is more specific in terms of disciplinary trends: there are more disciplines represented and in a greater number of topics.

Academic literature vs. Grey Literature

According to our results, compared to scholarly publications (LitReview), grey literature (GreyLit) discussing IDR/TDR operates at a greater level of generality and is more policy oriented. IDR/TDR is more rarely discussed in the context of Arts and Humanities than in the context of Social Sciences and non-AHSS disciplines.[19]

When ranked according to centrality (i.e. the significant presence of a topic within the corpus) the previous observations suggest that IDR/TDR is more rarely discussed in the grey literature, and more often discussed in the scholarly literature, and further confirm the non-disciplinary character of discussions of IDR/TDR in the grey literature.

[19] This can also mean that topic modelling does not work well with Arts and Humanities vocabulary, which is more prone to use natural language expressions, shared with other disciplines, and has less specific-technical vocabulary of its own, and that makes it harder for the algorithm to detect its presence.

4.2 Factors that Hinder or Help Inter- and Transdisciplinary Research

This section focuses on the second objective of WP2, namely, to identify the factors that hinder or help interdisciplinary and transdisciplinary collaboration. The term "factor" defines a condition that actively contributes to the production of a situation, namely an agent (Vienni Baptista et al., 2019). As our study shows, the term factor is associated with condition, challenge, principle, incentive, and guide (based on S. Hoffmann, 2019). We use it as an umbrella term that helps us to identify and systematise the conditions under which IDR/TDR are performed. Our findings are based on the systematic literature review of academic (Section 4.2.1) and grey (Section 4.2.2) literatures.

4.2.1 What factors and conditions influence inter- and transdisciplinary research?

According to the academic literature review, factors for IDR/TDR encompass three dimensions (Boix Mansilla et al., 2016): cognitive, emotional, and interactional. These dimensions operate in conjunction with institutional conditions. While distinct, in practice these dimensions are deeply entangled, structuring each other (Boix Mansilla et al., 2016).

Factors can be dynamic, synergetic, static, or simultaneously defined by the context, paralleling the plurality in definitions of IDR/TDR. The academic literature presents a plethora of factors that influence IDR/TDR. We identified 25 factors in the academic literature (Vienni Baptista et al., 2019). The list provides a comprehensive and rich picture of the conditions that need to be taken into account when developing inter- or transdisciplinary research (see Table 4 below).

The factors that influence the success of IDR/TDR are interrelated, context-dependent and dynamic. They depend on such features as the types of understanding of ID/TD, the phase of a project, the roles assigned to fields of knowledge, the logics and motivations underpinning the work and the disciplines and actors involved (Vienni Baptista et al., 2019). Furthermore, different factors may be important to different partners in a collaboration (Bozeman, Gaughan, Youtie, Slade & Rimes, 2016).

We find from our systematic literature review that factors can act positively or negatively depending on the context of the project or programme. Factors can also potentially be transformed from problematic to enabling conditions during the research process. To prove this, we have analysed each factor according to their negative and positive implications to show how the academic literature interprets each of them. Table 14 in Appendix H provides a complete list of factors and their implications for AHSS integration in IDR/TDR.

Academic tribalism, the notion that academics in the same discipline are "united by customs, tradition, and adherence to a largely common worldview" (Robinson et al., 2016, p.3), serves as a useful example. Viewed positively, it implies understanding the preoccupations of each member of a team when

developing concrete solutions to a specific problem (Castán Broto et al., 2009, p. 13). When it becomes a barrier to IDR/TDR, it can manifest as conformity of thinking (Robinson et al., 2009) and team members questioning the validity of certain disciplines.

The following features of factors are relevant:

- Factors are related to each other and the weight given to each of them depends on the temporal and spatial contexts and the understanding of ID/TD underlying the project;
- Factors are dynamic: they change depending on the phase of a project;
- Factors are dual, meaning that they have negative or positive effects on research depending on the disciplines and fields of knowledge that are involved in the research process: whether they hinder or help IDR and TDR (or constitute vectors for success or failure) is also associated with the type of disciplines that participate in the research project (see Table 14 in Appendix H for examples of the implications that certain factors have for AHSS disciplines);
- Factors are related to roles assigned (Balmer, 2013; Balmer et al., 2015) to each discipline and field of knowledge;
- Factors are influenced by logics (Barry & Born, 2013; Barry et al., 2008) of IDR and TDR;
- Factors are on occasion not perceived as such by many AHSS researchers because they "live" (Felt, 2009) research in a different way than STEMM researchers. "Factors and motivations that may be extremely important to one partner in a collaboration may be much less important to another" (Bozeman, Gaughan, Youtie, Slade, & Rimes, 2016, p. 227).

A pressing issue in the academic literaure is a lack of discussion on what is considered success and failure in IDR/TDR. Failure is almost hidden from the discourses of ID and TD, because the problematic and conflictual issues of science are usually not studied (some exceptions are Barry and Born (2013); Callard and Fitzgerald (2015); Fam and O`Rourke, 2020). A discussion of what interdisciplinary "success" or "failure" might look like in these situations is not straightforward and warrants context-specific reflections (Fletcher & Lyall, 2019) such as those collected in our survey (Spaapen et al., 2020).

There are other disconnections in the academic literature where interactions and contradictions among factors are discussed. MacMynowski (2007, p. 3) considers:

> evaluations of interdisciplinary research in journals targeted at biophysical scientists include virtually no citations from the social science literature on disciplinarity and interdisciplinarity; even of one of the most widely cited books on the history, theory, and practice of interdisciplinarity is absent (i.e., Klein (1990)). Likewise, in the social science literature, there are virtually no citations from the biophysical literature. The two discussions are running in parallel with stunningly little crossover.

Disciplines are still treated uncritically as monolithic constructs (Klein, 2005), resulting in a mismatch between factors associated with IDR/TDR and those inherent to specific disciplinary cultures.

As a means to overcome the fragmentation and disconnection present in the academic literature on IDR/TDR, we aggregate the factors that we have identified in our study. In section 4.1.2, we propose a set of dimensions to help to disentangle the different understandings of ID and TD, namely: what, who, how, why, when and where. Using these dimensions as a basis of our analysis, we combine them with the list of factors (Table 4; for a complete list of factors and descriptions see Table 14 in Appendix H).

Table 4 Clusters of factors that influence IDR/TDR[20]

CLUSTER	FACTORS	KEYWORDS	DESCRIPTION
WHAT?	**Academic tribalism**	- customs - tradition - worldviews	• The notion that academics in the same discipline are "united by customs, tradition, and adherence to a largely common worldview" (B. Robinson et al., 2016, p. 3).
	Assumptions about other disciplines (Lélé & Norgaard, 2005).	- validity of different types of knowledge - ways of perceiving science	• "(…) some knowledges have to interject and insist on their own usefulness; others have the privilege of taking their universal utility for granted" (Fitzgerald, Littlefield, Knudsen, Tonks, & Dietz, 2014, p. 13).
	Division of scientific labour	- organisation of research groups - social conventions	• The division of scientific labour often "requires scientists to reproduce well-known conventions already embedded within their discipline" (Castán Broto, Gislason, & Ehlers, 2009, p. 924).
	Dynamics of power	- disciplinary politics of power - politics of prestige - many kinds – institutional, epistemic, managerial – 'disciplinary imperialism'	• This factor implies disciplinary politics of power and prestige (Fitzgerald et al., 2013). • There "(…) are many kinds of power – institutional, epistemic, managerial – that we can and do wield in interdisciplinary settings" (Callard & Fitzgerald, 2015 p. 107). • "The abstractions of power and knowledge play out in very real research outcomes, depending on the goals and relative influence of the individuals or groups involved, what interdisciplinary research projects are undertaken, which disciplines are involved, how conflicts are resolved, and the acceptance of the research by the rest of the scientific community are due, in part, to the differentially perceived power of the research and researchers" (MacMynowski, 2007, p. 6).
	Epistemological	- nature and validity of knowledge - disciplinary cultures - ways of knowing - purposes of knowledge	• "The literature on interdisciplinarity commonly regards differences between disciplines as a great obstacle to effective interdisciplinary team collaboration (...) These epistemic differences are an integral part of disciplinary culture" (B. Robinson et al., 2016, p.4). • "Each discipline has a conception of what constitutes knowledge, as well as what are reliable avenues for producing valid knowledge claims. Even how such knowledge can be appropriately applied can vary across disciplines" (Tuana, 2013, p. 1959). • Differences between the epistemological and ontological realms are materialized in spatially, affectively, and through an unequal dynamics of epistemological power (Callard & Fitzgerald, 2015).

[20] Factors are organised according to their relevance for AHSS integration into IDR/TDR

	Ontological	- nature of knowledge and research - habits - beliefs	• "It's about the choreography – the 'deftly balanced coming together of things that are generally considered parts of different ontological orders' (Klein, 2005, p. 8) – through which those things are induced to relate to one another, as well as the habits and modes of comportment that, sometimes, prevent those people and things from getting too close" (Callard & Fitzgerald, 2015, p. 80). • Ontology implies problematisation of things that must be taken up, thought about, and engaged (Rabinow & Bennett, 2012).
	Non-epistemological values	- styles of research - qualities of researchers	• "(…) values are embedded in all types of inquiry and at all stages: in the choice of questions, theoretical positions, variables, style of research and judgments (Lélé & Norgaard, 2005, p. 966).
	Objectivity – subjectivity	- object of study - subject of study	• Approaches to objectivity and subjectivity are quite varied within the social and biophysical sciences, with perceptual and power related differences between areas of inquiry (MacMynowski, 2007).

WHO?	**Cognitive**	- knowledge production processes
		- academic norms
		- intellectual values
			• This factor implies:
			  • "Cognitive emotions associated with ideas and experiences in knowledge production" (Boix Mansilla, Lamont, & Sato, 2016, p. 598).
			  • "Cognitive emotions or passionate thoughts are often rooted in internalised academic norms and intellectual values such as love of truth, concern for accuracy, and disdain for error or lie" (Boix Mansilla et al., 2016, p. 598).
			• Both sets have proved to be an inevitable challenge for ID (Lowe, Phillipson, & Wilkinson, 2013).

	Mutual ignorance on collaboration	- interaction - stereotypes - collaboration - assumptions about other disciplines	• Few in the sciences are aware of what a humanities researcher can contribute, and further, few in the humanities are aware of it either. "Following Snow, we submit that the lack of interdisciplinary interaction involving scientists and humanities researchers is less about hostility and more about mutual ignorance. As Snow put it, 'They have a curious distorted image of each other" (M. J. F. Robinson, Robinson, Berridge, & Whybrow, 2014, p. 4).
	Qualities of inter- and transdisciplinary researchers	- skills - competencies - capabilities - communication - collaborative research - experiential learning	• Embodied dispositions and shared cultures—a 'habitus' (Bourdieu, 1977, p. 9) that shapes our actions as interdisciplinarians (van Rijnsoever & Hessels, 2011). • Two broad categories: operational and innate characteristics. • Some characteristics, such as communication and pattern-recognition skills, are operational in nature, whereas others, such as creativity and curiosity, require experiential learning and/or are innate characteristics of an individual (Guimarães, Pohl, Bina, & Varanda, 2019, p. 12). • "(…) multipotentialities thrive on learning, exploring, and mastering new skills, and they are described as being excellent at bringing disparate ideas together in creative ways. They are associated with innovation and problem solving"(Guimarães, Pohl, Bina, & Varanda, 2019, p. 12).
	Ethical	- ethics in research - values - ontology	• The ethical and affective nuance of collaboration in practice (Callard & Fitzgerald, 2015).
	Interactional	- collective action - teams and groups - social-interactive qualities	• The group's growing competency for deliberation and learning from each other, and the development of meaningful social relations with group members. It includes: " (…) a climate of conviviality (…), the social-interactive qualities of participants (…), such as sociability and communicative styles, and effective leadership (…)" (Boix Mansilla et al., 2016, p. 594). • The creation of new knowledge is dependent on the interpersonal and 'spontaneous interactions' of researchers that are not always facilitated by traditional departments (Boix Mansilla et al., 2016; Rhoten, 2004). • "Sociability and communicative styles are also essential dimensions of interaction" (Boix Mansilla et al., 2016, p. 594). • The capacity building challenge (Lowe et al., 2013).

	Communicative	- languages - interaction	• "Different disciplines use different 'languages' and the same word may mean different things in different disciplines, resulting in a great deal of frustration until this is clarified" (Bruce, Lyall, Tait, & Williams, 2004, p. 467).
	Emotional	- role of emotions beyond individual cognition - affective	• "(…) how emotions shape cognitive innovation and social dynamics in interdisciplinary work remains underexplored" (Boix Mansilla et al., 2016, p. 579). • Emotional counterpart of cognition (Boix Mansilla et al., 2016). • Role of emotions beyond individual cognition (Boix Mansilla et al., 2016). • "Emotions are also a powerful source of cognitive and interpersonal bonds" (Boix Mansilla et al., 2016, p. 592).They can tell us a great deal about points of epistemological, ontological and political blockage within any interdisciplinary configuration (Boix Mansilla et al., 2016). • Emotion can be influential in carving out the perimeters of an interdisciplinary space and to determine who is inside and outside of it (Callard & Fitzgerald, 2015). • Political and ontological differences can be experienced affectively (and vice versa) (Callard & Fitzgerald, 2015). • The "eruption of unexpected – and superficially unimportant – moments of affect can be diagnostic of important lines of conjunction and contestation within interdisciplinary spaces" (Callard & Fitzgerald, 2015, p. 127). • Acknowledgement of " (…) affective bewilderment while in interdisciplinary spaces is easily misconstrued as either a deliberate or unwitting removal from the terrain of the political" (Callard & Fitzgerald, 2015, p. 127).
WHY?	**Career Path**	- academic status - trajectories - transfer of cultures, methods, techniques, fantasies, and habits	• Interdisciplinarity takes many forms and this can influence the types of career paths that academic researchers experience (Lyall, 2019).
	Motivations for IDR/TDR	- intrinsic - extrinsic	• ID is certainly a key term to transform the relations between research, economy and society, and the promotion of interdisciplinarity has come to be central to the government of research (Barry & Born, 2013). • Extrinsic motivations include possible rewards or anticipated benefits. Intrinsic motivations focus on the desire to engage with issues in the non-academic world that do not seem to lend themselves to easy solutions using traditional approaches (van Rijnsoever & Hessels, 2011). • Access to expertise, access to instruments, "(…) cross fertilisation across disciplines, improving access to funds, obtaining prestige or visibility, learning tacit knowledge about a technique, pooling knowledge for tackling large and complex problems, enhancing productivity, educating a student, increasing specialization of science, and fun and pleasure" (van Rijnsoever & Hessels, 2011, p. 464).
	Change	- transformation - relations with other actors and disciplines	• Resistance to changes in researchers' practices, particularly those that bear most directly on relations with industry, publics and of course on the design and development of novel artefacts (Balmer, 2013, p. 3). • "(…) the closer one gets to the grit of trying to change these practices, the more obstinate, tacit and invisible become the frameworks, understandings, assumptions and processes that resist such work" (Balmer, 2013, p. 2).

HOW?	**Collaboration**	- common ground
		- cooperation
		- engagement
		- trading zone
		- boundaries
			• Types of collaboration specific to AHSS:
			  • Boundary crossing or collaboration across domains
			  • Collaborative reflexivity
			  • Collective experimentation
			  • Complexity-led collaboration or solving complex problems
			  • Data-led collaboration
			  • Question-led collaboration
			  • Discussions of unshared goals

			• Modes of intervention (co-authoring, co-experimenting, co-organising) • Taking risks • Undisciplined practices (Fitzgerald, Brunner, Koellinger, & Navarro, 2013).
	Dealing with complexity	- ordering of the world - worldviews - collaboration of different disciplines	• "In order to reduce complexity, in the sense of sorting out the desirable and undesirable effects of its increase, the social system is challenged to re-align its cognitive and practical ordering of the world. In doing so, meaning, the world-reading emanating from the social system, must be taken into account" (Nowotny, 2005, p. 5).
	Evaluation	- assessment - research performance - expertise - success / failure	• Evaluation is defined as a collaborative and discursive learning process (Klein, 2008). • Evaluation is a process that is deeply emotional and interactional (Boix Mansilla et al., 2016). "It is culturally embedded and influenced by the 'social identity' of panelists—that is, their self-concept and how others define them" (Boix Mansilla et al., 2016, p. 578). • "Interdisciplinary and transdisciplinary research performance and evaluation are both generative processes of harvesting, capitalising, and leveraging multiple expertise. Individual standards must be calibrated, and tensions among different disciplinary, professional, and interdisciplinary approaches carefully managed in balancing acts that require negotiation and compromise" (Klein, 2008, p. 116).
	Social	- science and society relations	• Interdisciplinary research is a social practice (Castán Broto et al., 2009). "(…) the way in which society interacts with and organizes academia influences the production of interdisciplinary research (…) Forces at work in a larger society outside academia shape the perception of importance gained by a certain discipline, or by a particular kind of interdisciplinary crossing (…) This generates differences in the attention paid to (and resources commanded by) different disciplines, consequently conditions behavioural patterns" (Lélé & Norgaard, 2005, p. 966).
WHEN? WHERE?	**Community building**	- identity - collective understanding	• "The existing body of knowledge (on ID and TD) is disjointed and dispersed across a wide array of journals and other publications, which renders it less accessible to newcomers and means that, as a research community, we do not have an easily comprehensible 'canon' that would enable us to accumulate shared learning about interdisciplinary careers" (Lyall, 2019).
	Current Policies	- principle or guidelines - formal norms to regulate or facilitate interdisciplinary research - knowledge organisation	• "Policy is understood in an abstract sense as a principle or guideline for action in a specific everyday-world context" (Pohl, 2008, p. 46). "Is transdisciplinary research a suitable way to bridge science and policy?" (Pohl, 2008, p. 52).
	Institutional	- organisational structures - legitimacy of ID/TD - incentives & disincentives for IDR/TDR - academic priorities - capacity building - career paths	• "Institutions enabled and nurtured collaborations, setting parameters for success. Their investments varied in amount and duration (…). They differed in how they put research teams together and the type of control they exercised on the networks. They also varied the conditions they set for teams" (Boix Mansilla et al., 2016, p. 581). • IDR depends "(…) on disciplinary institutions at three levels: 1. organisational (university, research organisations, funding bodies), 2. research community (research colleagues, and project team members) and 3. individual practices" (Castán Broto et al., 2009, p. 14). • The institutions and practices of science are not uniform across disciplines. One consequence is that the claim about the growth of interdisciplinarity must be heavily qualified by considerations of heterogeneity (Mäki, 2016). • "Society also influences the institutional arrangements within academia that create incentives or disincentives for interdisciplinary knowledge production" (Lélé & Norgaard, 2005, p. 986). • "It was also clear that that the needs and priorities of interdisciplinary research had to be considered at various levels from that of the individual researcher to the institutions sponsoring and overseeing the research" (Lowe et al., 2013, p. 217).

This list of factors constitutes a system that has specific implications for AHSS. In the survey we conducted among European researchers experienced in IDR/TDR, we asked respondents to choose the factors that help or hinder IDR/TDR from a list derived from this table (see Spaapen et al., 2020). Some respondents mentioned that they could benefit from more knowledge about IDR/TDR approaches, for example by hiring an expert on this. Institutional factors were mentioned that impede IDR/TDR, such as lack of specific funding, lack of time to invest in the development of IDR/TDR collaboration, and not enough education and training on IDR/TDR. Some researchers stated that it is hard to change the current allocation and reward system because in academia IDR/TDR are still seen as "dangerous for both young researchers and specialist professors" (SHAPE-ID Survey_4, AHSS/STEMM).

Lack of (knowledge about) evaluation methods for IDR/TDR is a serious problem. Part of the problem is the varied outputs of IDR/TDR, the assessment of which has to be synthesised when using different methods. One of the survey respondents explained this as follows:

> In our project there is not one single form of outcome, but many: dissemination by briefings and small scale/open public events with a variety of audiences, publications, web-documentaries, web-site. So there was not one streamlined evaluation, but rather an evaluation of individual events where the IDR/TDR dimension could be appreciated in terms of coordinated and communicable/well communicated research results. Cross-referencing results from different fields was part of the ongoing process of sharing an overarching discussion about integration and disintegration factors (SHAPE-ID Survey_38).

Another pointed out that IDR/TDR evaluation takes more time and effort than a regular disciplinary evaluation:

> This is one of the most difficult problems to address for developing IDR/TDR in academic sphere! In my past experiences, the monitoring of the projects were made through a double evaluation: inside the disciplines and in interdisciplinarity. For instance, some results were submitted to a disciplinary journal, when other results, more interdisciplinary, were proposed to thematic and interdisciplinary journals. Because of the poor contribution of these last journal for the valuation in some disciplines, this double evaluation is necessary, although it is time consuming! (SHAPE-ID Survey_24).

4.2.2 Factors that hinder or help IDR/TDR according to Grey Literature

We analysed the grey literature for what we considered to be the eight key factors that might influence the outcome of IDR/TDR: academic tribalism; academic career structures; cognitive factors; encouragement to undertake IDR/TDR versus the reality; ethical factors; research funding; interactional factors; and the timeframe of research. This selection was based on the most relevant factors identified in the academic literature review. We looked for factors that might help as well as hinder IDR/TDR, but,

in this sample, discussions largely focused on the conditions that hindered the successful conduct of IDR/TDR. The following sections focus on the three factors most often identified in this sample. In order of importance, these were research funding, academic career structures and the length of time required to conduct good quality IDR/TDR.

4.2.2.1 Research Funding

Insufficient funding was considered a problem across all three literatures.[21] Literature analysing the state of the Arts and Humanities in Europe outlines the need for increased and stable funding (AAU, 2005), for individuals (British Academy, 2013, p.2) and for AHSS research infrastructures[22] (ALLEA-RatSWD, 2014; ALLEA, 2015; LERU, 2012, pp.18-19). Those evaluating the integration of AHSS in Horizon 2020 programmes describe decreasing amounts of funding being allocated to AHSS research (which here is labelled as SSH):

> Only 5% of the 2015 budget available for the two major pillars of H2020 (the Societal Challenges and LEIT) go[es] to SSH partners. This is lower than the already disappointing 6% recorded in 2014. If we consider that on average (…) SSH partners coordinate about 20% of the projects under the SSH-flagged projects, this indicates that in spite of SSH researchers doing their best efforts to take part in the programme, the funding allocation remains extremely low overall (EASSH, 2017, pp.1-2).

Authors writing about IDR/TDR also argue that it is underfunded: "Existing efforts by funding organisations still fall short of providing adequate support for interdisciplinary and multidisciplinary work" (British Academy, 2016, p.17, see also INTREPID, 2017b).

One group of authors also describe how low levels of funding make it more difficult for AHSS researchers to collaborate with STEM colleagues:

> A different kind of funding barrier [is] related to the ability of the humanities and social sciences to contribute to joint projects with the science, technology, engineering and mathematics sector. Some of those consulted argued that the former receive much less funding, limiting their ability to make innovative and independent contributions and to 'resist the undertow' that the science sector generates (ACOLA, 2012, p. 22).

[21] The sample is composed of three distinct and only partially overlapping bodies of literature: reports and guidance based in the academic literature on IDR/TDR; surveys of and commentary on Arts and Humanities research both in Europe and globally; and evaluations of the integration of AHSS research within Horizon 2020 research programmes.

[22] AHSS research infrastructures include digital resources such as DARIAH (Digital Research Infrastructure for the Arts and Humanities) and CLARIN (Common Language Resources and Technology Infrastructure), but also "physical and social spaces to foster the development of interdisciplinary networks and facilitate working across disciplines" (GRC, 2016: 6).

Such arguments lead to calls for "greater balance in terms of the amount of funding that is allocated to each area and the share of leadership roles" within IDR/TDR collaborations, especially those involving AHSS and STEM researchers (INTREPID, 2017b, p. 20).

Several authors also highlight the need for innovative approaches to funding including: smaller response-mode grants (British Academy, 2016); funding for collaborative processes such as meetings and training (National Academy of Sciences, 2005); funding of preparatory phases/pilot projects (CEU, 2013; i4g, 2014); simplified processes and two-stage applications (i4g, 2014); and funding for research facilitators (INTREPID, 2017c). The wider roles that funding agencies can play are discussed further in Section 4.3.4 below, where we report on how recommendations for change are presented in the grey literature.

4.2.2.2 Academic career structures

Only in the literature on IDR/TDR were academic career structures seen as a problem, but within that literature concern about the effects of rigid, discipline-based structures of recruitment, evaluation and promotion was pervasive:

> The emergence of good interdisciplinary work is currently impaired by the structure of incentives in academe: top academic journals remain disciplinary journals, which tend to motivate researchers to remain within a disciplinary framework, while interdisciplinary work or publications do not generate rewards within professional hierarchies (EC, 2009, p.34).

> [I]ndividual researchers also express concern about maintaining disciplinary identity and successful career paths. They note practical difficulties in finding appropriate publishers and journals; getting submissions reviewed by peers experienced in interdisciplinarity (and able to discern its particular merits); and issues around career progression in relation to institutional and national evaluations of performance (Institute of Advanced Study, 2015, p.12).

> Careers rooted solely in IDR are perceived to be risky (particularly for early career researchers) and as less appreciated by HEIs, thus discouraging researchers from conducting IDR. Peers may view IDR as less rigorous, and interdisciplinary career paths may be less traditional, which may create challenges for IDR researchers trying to build a long-term career. Recruitment and promotion criteria were perceived as more easily evidenced through monodisciplinary research, resulting in a perception that promotion and tenure policies in HEIs discourage IDR (Technopolis, 2016, p.9).

These problems were seen as particularly acute for early stage researchers (Trinity College Dublin, 2016, p.20), who are advised to "identify institutions and mentors favourable to IDR" (National Academy of Sciences, 2005, p. 67). Authors recommend that academic institutions should remove

barriers to IDR/TDR by developing more flexible recruitment and career progression practices that, for example allow for hiring across department and college boundaries, as well cost-sharing policies that support IDR/TDR by allowing for shared grants, PhD students and joint appointment (National Academy of Sciences, 2005; see also INTREPID, 2017b).

4.2.2.3 The length of time required to undertake high quality IDR/TDR

The length of time required to undertake high quality IDR/TDR was another important topic within the literature on IDR/TDR (British Academy, 2016; LERU, 2016; STIS, 2008), but it was also a concern for those analysing the integration of AHSS within Horizon 2020 research programmes.

> Most European science investment today is for short projects, which are expected to undertake world-class research and achieve immediate direct impacts on stakeholders. Such a short cycle allows too little time to develop the original and "disruptive" insights that will have deep future impact. The short cycle is particularly deficient in regards to research in evolving and dynamic social systems that integrate contributions from across scientific disciplines. In a three-year project, researchers are often only beginning to learn how to work across disciplinary boundaries just when the project is expected to produce results and impacts (EASSH-EA, 2016, p.2).

Many state that due to its greater complexity IDR/TDR requires longer timescales and therefore higher levels of funding than mono-disciplinary research:

> Appropriate resources and sufficient timeframes should be allocated to ensure that teams have the capacity to organise effectively and to address the challenges of working across disciplinary boundaries, including any necessary training to overcome differences in language and conceptual foundations, recognising that some interdisciplinarity practices are more demanding than others (GRC, 2016b, p.2).

> The answer is more time and funds, not less: ID research requires more time, and more funding. Just completing an integrative literature review will add a significant additional step in a research process. This is all the more relevant when ID is extended to include transdisciplinary practices (INTREPID, 2017a, p.10).

Unlike the problem of academic career structure, this is an issue that funding agencies can address quite readily by taking up the suggestions provided in the academic literature for better approaches to the funding of IDR/TDR, including longer lead-in times between the announcement of calls and the deadline (Trinity College Dublin, 2016, p.5, see also INTREPID, 2017b) and extended funding for existing consortia that operate successfully across diverse institutions and countries (EASSH-LERU, 2019).

4.3 Understandings of IDR/TDR and factors specifically relevant for integrating AHSS in IDR/TDR

This section focuses on how different understandings and factors affecting IDR/TDR influence AHSS disciplines' integration in such research practices. We aim to address Objective 3 of WP2: to clarify which understandings of IDR/TDR and which factors of success and failure are specifically relevant for integrating AHSS in IDR/TDR. We achieve this aim by analysing the specific conditions that influence AHSS engagement in IDR/TDR and by providing a rich picture of the implications that these conditions have for AHSS disciplines.

One of the original aims of our literature review was to relate different understandings of IDR to different thematic fields and the function IDR plays in these fields. It has not been possible to relate understandings, research fields and functions of IDR/TDR in this manner due to the multiple and overlapping meanings of IDR/TDR – there are no consensus definitions even within particular research fields – and the broad and non-specific ways in these terms are used across a range of literatures.

In this section:

- In Section 4.3.1, we first present the findings from the quantitative analysis of disciplinary affiliations of documents discussing IDR/TDR issues from the LitReview and OpenAire datasets. This allows us to provide an overview of how AHSS disciplines behave in the context of IDR/TDR and which connections they are able to establish within or beyond AHSS disciplines. The relevant and innovative contribution of this study is the description of how AHSS disciplines relate to each other and how this influences their integration in IDR/TDR.
- Next, we present insights from the qualitative analysis of the academic literature, focusing on the roles performed by AHSS disciplines and the spaces where these disciplines interact with STEMM disciplines (Section 4.3.2).
- Insights from European researchers practising IDR/TDR, based on the results of our survey, are detailed in Section 4.3.3.
- Section 4.3.4 presents a set of recommendations for change extracted from the grey literature that systematise the different dimensions at play when AHSS integration is taken into consideration in the policy literature.

4.3.1 How do AHSS disciplines relate to each other? Individual disciplines in IDR/TDR

In order to discuss relationships between disciplines invested in IDR/TDR, we analysed disciplinary affiliations of LitReview and OpenAire records. We gradually increase granularity, starting with the

macrolevel of the AHSS supergroup of disciplines, and then moving toward the analysis of connections between disciplinary groups (SOSC and AH)[23], and finally between individual disciplines.

How do AHSS disciplines relate to each other?

Key Findings

- While in both the LitReview and OpenAire samples disciplinary pairings within AHSS prevail over parings between AHSS and non-AHSS disciplines, that self-referentiality works differently for AH and SSSG. The summary weight of internal pairings is significantly higher in SSSG than in AH (and in this sense SSSG is more self-referential), but at the same time SSSG is better integrated with non-AHSS disciplines than AH, both in terms of summary weight and in the greater diversity of disciplines it connects with (and in this sense, less self-referential). In terms of summary weight, the biggest portion of AH disciplinary pairings connect with SSSG.
- The significant presence of AHSS disciplinary affiliations in the LitReview and OpenAire samples, accounting for over 50% of all weighted results, suggests that AHSS has a strong presence in the discourse on IDR/TDR in these samples.
- AHSS disciplines have an important role among "bridging disciplines", i.e. helping to foster connections with various other disciplines. The most important bridging disciplines are: General Medicine, Education, General Arts and Humanities, General Social Sciences.
- In terms of non-AHSS connections, both Social Sciences and AH tend to connect mostly with Engineering, Computer Sciences, Medicine and Environmental Science.

4.3.1.1 Sorting out the AHSS supergroup in the Academic Literature and OpenAire datasets

In the LitReview sample almost 90% of journals have between one and three ASJC discipline attributions: 809 monodisciplinary journals (i.e. journals with a single attribution) make up 37%, 769 bi-disciplinary publications comprise 35% and 366 tri-disciplinary journals comprise 17% of the list. This was not the case with OpenAire, where 23% (11,210) of records had more than three disciplines, and tri- and bi-disciplinary records accounted for 12% (5,725) and 22% (10,711) of all records respectively. Almost half of the records (42%, 20,337) were monodisciplinary.

[23] **Groups of disciplines in the quantitative analysis: AHSS** – all disciplines in the Arts, Humanities and Social Sciences; **AH** – disciplines belonging to Arts and Humanities; **SOSC** – the narrow Social Sciences disciplinary ,group; **SSSG** – all other disciplines belonging to AHSS, including SOSC, but excluding AH.

IDR/TDR discourse in the literature review and OpenAire datasets

The strong presence of monodisciplinary journals and records suggests that IDR/TDR is understood more often as a general feature or quality of a single discipline, and less often used to define particular instances of collaboration between different disciplines.

AHSS Disciplinary affiliations in Journals

The summary weight of disciplinary affiliations belonging to the AHSS supergroup (i.e. the sum of all journals with AHSS disciplines attributed, weighted by the number of articles that appeared in each of the journals) makes up 51.7 % of the LitReview sample and 52.2% of the OpenAire sample (when both samples are compared the OpenAire numbers are always in square brackets).

In the non-AHSS spectrum **Physical Sciences** occupy 25.6 [21.9] %, **Health Sciences** 14.2 [14.75] %, **Life Sciences** 7.7 [10.47] %, and records labeled as multidisciplinary 0.9 [0.6] %.

The strong representation of AHSS as well as overall similarity in disciplinary proportions between the samples indicates that AHSS disciplines adopt the discourse on IDR/TDR more frequently than non-AHSS disciplines, and implicitly, that openness to IDR/TDR integration is greater among AHSS disciplines generally. That observation is reinforced by the fact that keywords in the search queries for both samples did not demonstrate such a high prevalence of AHSS disciplines, and that for the LitReview sample, two data sources, WoS and Scopus, tend to underrepresent AHSS.

On the level of ASJC disciplinary groups,[24] in both samples the same disciplines were prominent in exactly the same order. Social Sciences lead with 29.5% in LitReview and 35.45% in OpenAire, followed by Environmental Science 14.6 [11.4]%, Arts and Humanities 12.2 [11] % and Medicine 11 [5.8] %.[25] All other disciplinary groups fall below the 5% threshold. Disciplinary groups with the highest weight in this bracket are: Business, Management and Accounting; Agricultural and Biological Sciences; Engineering, and Computer Science. Discourse on IDR/TDR is rarest in Veterinary, Dentistry, Chemical Engineering, Physics and Astronomy, and Chemistry.

[24] In the ASJC schema the AHSS supergroup is labeled "Social Sciences", and consists of the following groups of disciplines: Arts and Humanities, Social Sciences (the group), Psychology, Decision Sciences, Economics, Econometrics and Finance, and Business, Management and Accounting. We will refer to this supergroup as AHSS. However, we will discuss the Arts and Humanities group, referred to as AH, separately from the remaining AHSS disciplinary groups, which we will discuss together as "Social Sciences supergroup" (SSSG).

[25] When comparing the distributions in both samples the LitReview numbers are presented first, followed by OpenAire results in square brackets.

From the perspective of disciplines, the first striking feature in both samples is that out of 308 disciplines ranked according to weight, the first 7 of all disciplines make up one quarter of the entire summary weight. Half the summary weight is generated by 23 disciplines and three quarters by 58 disciplines. That clearly shows that the distribution of IDR/TDR discourse among disciplines is rather uneven.

Among the 10 most frequently occurring disciplines in the LitReview sample, the first three come from the Social Sciences group: Education (6.25%), Sociology and Political Science (4.7%), and Geography, Planning and Development (3.3%). These are followed by General Medicine (3.2%), and two disciplines from the Environmental Science group: Management, Monitoring, Policy and Law (2.8%), and Ecology (2.8%). Next we find General Social Sciences (2.6%), Nature and Landscape Conservation (Environmental Science), Literature and Literary Theory, and History (Arts and Humanities) – each of the last four accounting for 2% of the total score.

The most frequently occurring disciplines in the OpenAire sample are similar, and also oriented towards the Social Sciences, with Education (9.14%), General Social Sciences (5.60%), and Development (3.69%) in the lead, followed closely by General Arts and Humanities (3.47%), Logic (2.72%), History (2.7%), Psychiatry and Mental health (2.39%), Communication (2.04%), Sociology and Political Science (1.98%), and General Environmental Science (1.85%). The results need to be qualified in the case of Education. Whereas IDR/TDR research is in the main focus of the SHAPE-ID project, in the case of Education IDR/TDR will most often refer to the methodology of teaching in a given discipline. Otherwise this short list represents the disciplines where IDR/TDR discourse is the strongest in the light of our method.

Among the Top 50 disciplines, 29 disciplines in the LitReview sample and 26 in the OpenAire sample come from AHSS: Social Sciences (14 [15]), Arts and Humanities (8 [7]), Business, Management and Accounting (4 [0]), Economics, Econometrics and Finance (2 [2]), Psychology (1 [1]) and Decision Sciences (0 [1]). 12 [11] disciplines come from Physical Sciences: Environmental Science (9 [3]), Computer Science (2 [2]), Engineering (1 [1]), Earth and Planetary Sciences (0 [2]), Mathematics (0 [1]), Engineering (0 [1]), Energy (0 [1]), Physics and Astronomy (0 [1]). Health Sciences are represented by 5 [6] disciplines from Medicine (4 [3]) and Nursing (1 [3]) groups. Finally, 3 [6] disciplines from Agricultural and Biological Sciences (2 [2]), and Biochemistry, Genetics and Molecular Biology (1 [4]) represent Life Sciences. The OpenAire sample also featured the multidisciplinary category among the top 50 disciplines.

Overall, the two most important observations from this analysis are:

- that the significant presence of IDR/TDR discourse in monodisciplinary journals suggests that the understanding of IDR/TDR is often general rather than specific, i.e. it is often deployed as an internal feature of a discipline (when a discipline promotes interdisciplinary dialogue to achieve better results, etc.) rather than serving to actually bridge two or more specific disciplines;
- that disciplines from the AHSS, Environmental Science and Medicine drive the discourse on IDR/TDR far more than other disciplinary groups.

4.3.1.2 Connections between disciplinary groups

Looking at the distribution of disciplinary pairings in our samples, the first thing we examine are the relationships on the level of disciplinary groups and supergroups, summarised in Table 5.

Table 5 Interdisciplinary connections in the LitReview and OpenAire sample

Pairings refer to connections between two disciplines, weight means the number of occurrences of this pairing, so the sum of weights is the summary score of all connections, while average weight describes how many occurrences an individual paring in the given group has on average.

	LitReview Sample			OpenAire Sample		
	Pairings	Weights	Average weight	Pairings	Weights	Average weight
AHSS total	1053	12,305	11.7	7,134	116,477	16.3
Intra_AHSS	507	6,769	13.3	1,289	56,917	44.2
SSSG	805	9,046	11.2	5,853	100,922	17.2
Intra-SSSG	338	4,008	11.9	780	30,318	38.9
AH	248	3,259	13.1	1,719	35,989	20.9
Intra-AH	47	791	16.8	71	6,165	86.8
AH-nonAHSS	74	394	6.1	1,200	9,268	7.7
AH-MDR	5	104	20.8	10	122	12.2
AH-SSSG	122	1,970	16.2	438	20,434	46.7
SSSG-nonAHSS	337	2,972	8.8	4,598	49,752	10.8
SSSG-MDR	8	96	12	37	418	11.3
Total	**1,994**	**16,549**	**8.3**	**16,593**	**217,820**	**13.1**

The LitReview sample generated 1,994 pairings with a total weight of 16,549, and an average weight of 8.3. More than half of all pairings (almost 53%) and almost three quarters of all weight (74.3%) involve AHSS disciplines. SSSG is responsible for the bulk of that outcome, with 40.4% of pairings and 54.7% of all weight, while AH scores 12.4% and 19.7% respectively. Out of 16,593 total inter- and transdisciplinary pairings in the OpenAire sample with a total weight of 217,820 (13.1 per pairing on average) almost half (43%) involve AHSS disciplines (AH 10.4%; SSSG 35.3%), which participate in almost two thirds (61.8%) of the overall weight (AH 16.5%; SSSG 46.3%).

Proportionally to the overall weight of each group, the internal distribution of pairings within the AH and SSSG groups is fairly comparable in both samples, confirming their overall validity and complementarity, with the caveat that pairings with non-AHSS disciplines carry more overall weight in the OpenAire sample.

In the LitReview sample, internal pairings account for 24.3 % of the AH group's overall weight (17.1% in case of OpenAire) and 44.3 % of the overall weight in the SSSG Group (30% respectively). AH-SSSG pairings represent 60.4 % [56.8%]) of AH group's weight, but only 21.8 % [20.2%] of the SSSG group's weight. Connections with non-AHSS disciplines correspond to 12.1% [25.8%] in case of the AH group, and 32.9% [49.3%] in case of the SSSG group. Figure 5 visually represents the above results in the form of sankey diagrams, generated separately for AH (left) and SSSG (right) in LitRev (top) and OpenAire (bottom) samples. Blocks with numbers represent the summary weight of each disciplinary group, and ribbons are proportional to the summary weight of pairings that connect the blocks. Looped ribbons represent self-referential pairings.

The data suggests the greater self-referentiality of SSSG disciplines (IDR/TDR understood as collaboration within the SSSG spectrum) and their comparatively better integration with non-AHSS disciplines, compared to AH disciplines, which are better integrated with SSSG disciplines either than internally or with non-AHSS.

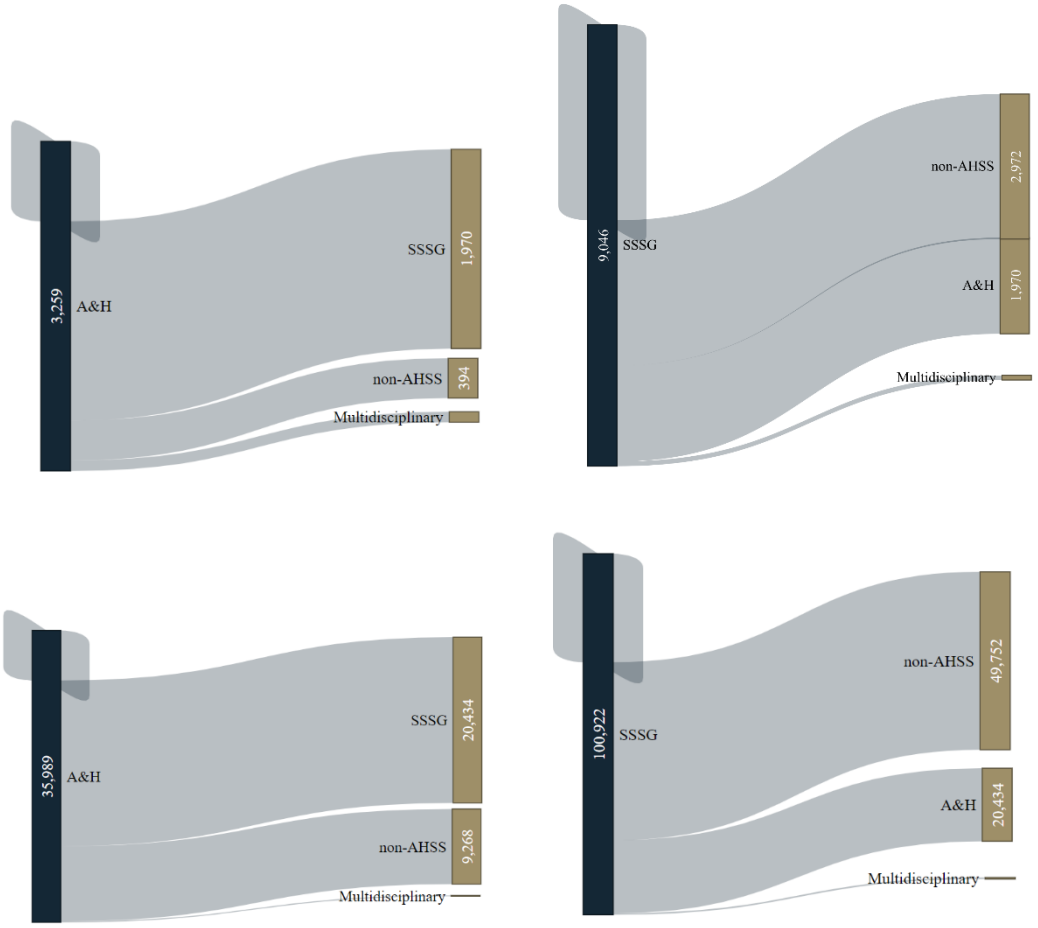

Figure 5 Sankey diagrams of connections between disciplinary supergroups, generated separately for AH (left) and SSSG (right) in LitRev (top) and OpenAire (bottom) samples [26]

The other major difference between SSSG and AH is that SSSG is more diverse in its relationship with other disciplinary groups. In the case of the Arts and Humanities group, the relationship with AHSS disciplines covers 85.5 [73.9] % of all interdisciplinary connections. The non-AHSS disciplinary groups AH connects with most are Engineering (3.1 [1] %), Computer Sciences (3.1 [2.7] %), Medicine (1.9 [3.15] %) and Environmental Sciences (1.1 [6.02] %), as well as the Multidisciplinary group (3 [0.3] %). In the OpenAire sample stronger connections are also visible with Agricultural and Biological Sciences (3.1%), Mathematics (2.77%), Earth and Planetary Sciences (2.45%), and Biochemistry, Genetics and Molecular Biology (1.17%).

[26] Diagrams were generated using http://sankey-diagram-generator.acquireprocure.com

Key Findings

This analysis highlights the self-referential character of the IDR/TDR discourse in AHSS. On the level of journal affiliations, in both samples pairings within the AHSS spectrum account for the majority share in terms of pairings and overall weight. There are however important differences between AH and SSSG in that regard.

SSSG is more self-referential in the sense that the weight of its internal pairings is twice as significant as for AH. SSSG disciplines are better integrated with non-AHSS disciplines than AH, both in terms of overall weight, and in terms of the diversity of non-AHSS disciplines SSSG engages with (in both samples, but more obviously in OpenAire). In the AH group, on the other hand, pairings with SSSG account for most of the overall weight, and in particular exceed the weight of internal pairings. In this sense, within the AHSS spectrum, the AH group results show more of a dialogue within disciplines. On the other hand, it is comparatively less integrated with the non-AHSS spectrum.

4.3.1.3 Disciplinary pairings of AH and SOSC in the LitReview sample

We examined how the above observations translate into direct pairings between disciplines. In Arts and Humanities, there were a total of 248 disciplinary pairings. 47 pairings relate internally to AH disciplines, including 11 mono-disciplinary pairings (i.e. results from journals with a single disciplinary attribution). 122 pairings connect AH with SSSG, and 79 with non-AHSS disciplines. When ranked according to weight, it takes the first 10 pairings (4% of all pairings) to generate over a quarter of the summary weight (25.8 %), with the top 29 results (11.7 % respectively) making up half of the summary weight (50.2 %), and the top 70 (28.2% of all pairings) accounting for three quarters of summary weight (75.2 %).

The AH disciplines best represented are Language and Linguistics (3 pairings, 11.5 % of all weights), History (8/11.2% respectively), and Literature and Literary Theory (5/9%), followed by General Arts and Humanities (5/6/4%), Music (3/3%), Philosophy (2/ 2.9%), Visual Arts and Performing Arts (2/2.7 %), and single pairings of Archaeology (1.8%), History and Philosophy of Science (1.6%), Religious Studies (1.8%).

It is worth noting that Language and Linguistics performs best not only in terms of overall summary weight, but also by virtue of a smaller number of pairings with bigger weights, which makes these pairings more robust. On the other hand, while for History all pairings clearly have a research character, Language and Linguistics pairs with Literature and Literary Theory, Education, and Linguistics and Language in the SSSG group. In the latter case it is debatable whether the understanding of IDR/TDR

has a research character (in most of the cases Education combines with a discipline in journals dedicated to teaching in that discipline), and the third case might be understood as a crypto-mono-disciplinary group consisting of the same disciplinary category appearing in two different disciplinary groups. Archaeology is another discipline that appears in both the AH and SSSG groups, and thus creates crypto-mono-disciplinary pairings. This is a feature of the ASJC classification that, as explained above, is also pertinent to Archaeology. Finally, Visual Arts and Performing Arts is the only discipline pairing with non-AHSS discipline Computer Science Applications.

The Social Sciences supergroup have generated 805 pairings: 338 pairings are produced between disciplines from that supergroup, including 31 mono-disciplinary pairings. Social Sciences disciplines are connected with non-AHSS disciplines in 345 cases, and with AH disciplines in 122 cases, as we saw above. It takes 20 pairings (2.5 % of all pairings) to make a quarter of the entire score, with the first 76 pairings (9.4% respectively) accounting for slightly over half of the total score (50.5%), and exactly 75% of the total score is generated by the first 211 pairings (26.2%). When compared with AH, despite the difference in the number of pairings, the distribution of pairings per score is fairly similar in both cases, even though for the SSSG the top quarter has fewer pairings with greater weight (Figure 6). As in the entire dataset, in the AHSS spectrum there are pairings which clearly drive the discourse on IDR/TDR.

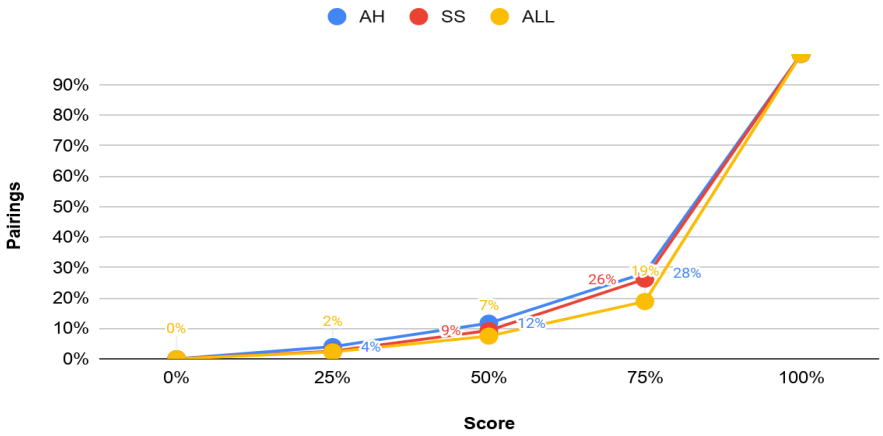

Figure 6 Distribution of pairing weights for AH and SSOC in connection with other disciplines

The SSSG disciplines best represented in the pairings generating half of the entire score are: Education (10 pairings / 12.8% of the entire score), Sociology and Political Science (14/8.6% respectively), Geography, Planning and Development (10/6.5%), General Social Sciences (9/4.9%), Health (social science) (6/2.8%), Development (2/2%), Linguistics and Language (2/1.9%), Cultural Studies (3/1.8%), Library and Information Sciences (3/1.3%), and Economics and Econometrics (2/1.2%). These are followed by: Management Science and Operations Research (2/1.1%), Anthropology (2/0.9%), Archaeology (2/0.9%), Law (2/0.8%), Public Administration (2/0.7%), Management of Technology and Innovation (0.7%), Political Science and International Relations (0.4%), General Psychology (0.4%), Business and International Management (0.3%), General Business, Management and Accounting (0.3%).

As mentioned above, the top result must be qualified by the applied rather than research character of the understanding of IDR/TDR in the case of Education. Sociology and Political Science, and Geography, Planning and Development, are disciplines that connect most to Environmental Sciences, while also including high scores for interdisciplinary pairings, which suggests that IDR/TDR discourse in those disciplines is both part of their internal vocabulary and integrates with non-AHSS science. The versatile category of General Social Sciences also has a high score for mono-disciplinary pairings, but connects mostly to AHSS disciplines, with single pairings with Computer Science Applications and General Environmental Science. The SOSC discipline of Health, surprisingly, has more robust ties to Environmental Studies than to any discipline in Health sciences (only the pairing with Public Health, Environmental and Occupational Health in Medicine is included in the top tier discussed).

In sum, the analysis in this section expands on the observations already made about self-referentiality and relationships between disciplinary groups, by highlighting the uneven weight of pairings (10% of pairings accounting for half of the score) and identifying those AHSS disciplines that account for the strongest pairings in relationship to other disciplines. In particular, the analysis confirms that there is little integration between AH and non-AHSS disciplines, and that Environmental Studies and Medicine are two disciplinary groups with which SSSG is most integrated.

4.3.1.4 Network analysis of disciplinary relationships

In order to go beyond studying bilateral pairings and capture disciplinary relationships in a broader context of multiple, intertwining inter- and transdisciplinary connections, we turned to network analysis using Gephi software. Each interdisciplinary pairing constituted an edge (relationship) between two nodes (disciplines). The weight of the pairing (i.e. number of times this pairing appeared in the sample) was translated into the edge weight. Figure 7 and Figure 8 present the overview of both networks with the labels of particular nodes removed for clarity. The size of the node depends on its degree (i.e. the

number and strength of connections of this node), while its colour signifies the discipline supergroup: pink for Physical Sciences, light green for Health Sciences, blue for AHSS, red for Life Sciences and dark green for Multidisciplinary. In both cases the same visualising algorithm (OpenOrd) was employed, in order to highlight the communities (Figure 7 and Figure 8).

The comparison of both networks highlights the clear differences between both samples. The LitReview sample is sparser than the OpenAire sample (1,994 edges, which is 8 times smaller) and features closer connections between various disciplines. The OpenAire sample, on the other hand, breaks down into a few interdisciplinary clusters: AHSS and Environmental issues in the middle, Health on the right, Ecology on the bottom, Energy and transportation cluster on top, (bio)Chemistry and Immunology on the left, Ecology on the bottom. The only AHSS disciplines that cluster with other supergroups are Conservation, and subdisciplines of Psychology: general, clinical and physiological. Figure 9 and Figure 10 show the 50 most important nodes (i.e. disciplines) in both networks.

Figure 7 Literature Review sample disciplines network

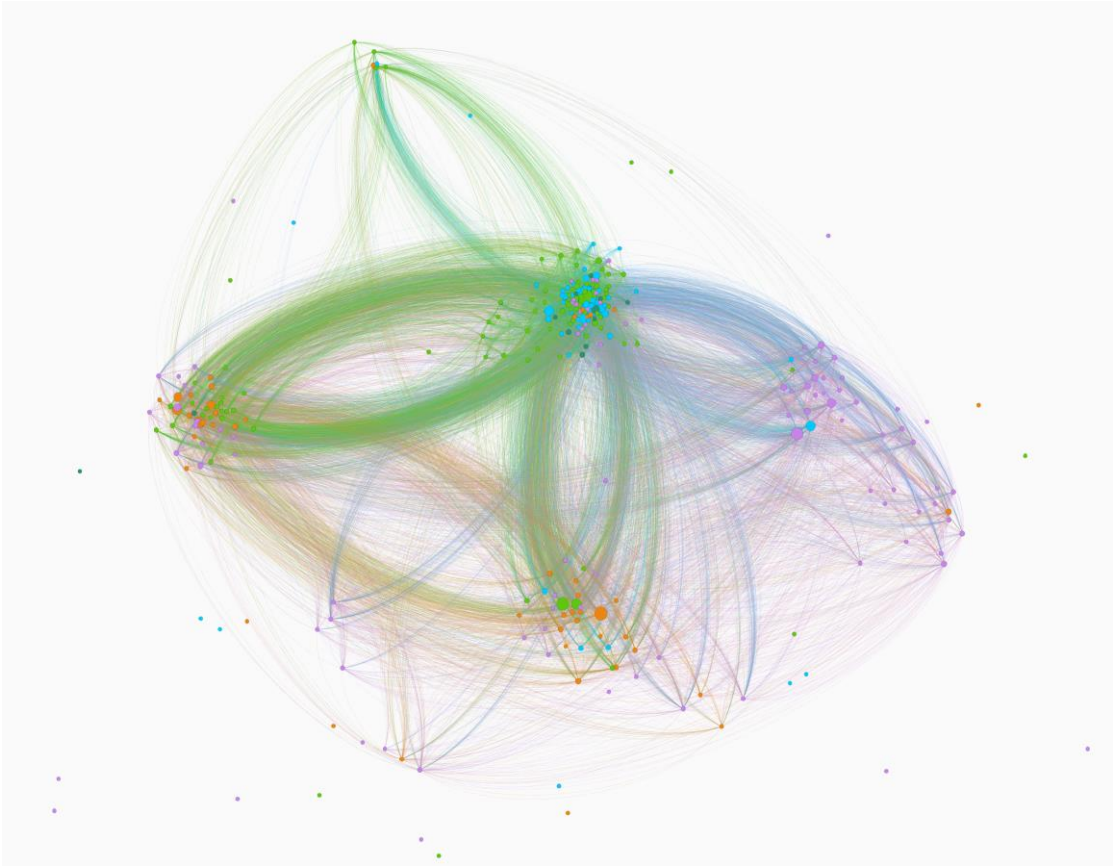

Figure 8 OpenAire sample disciplines network

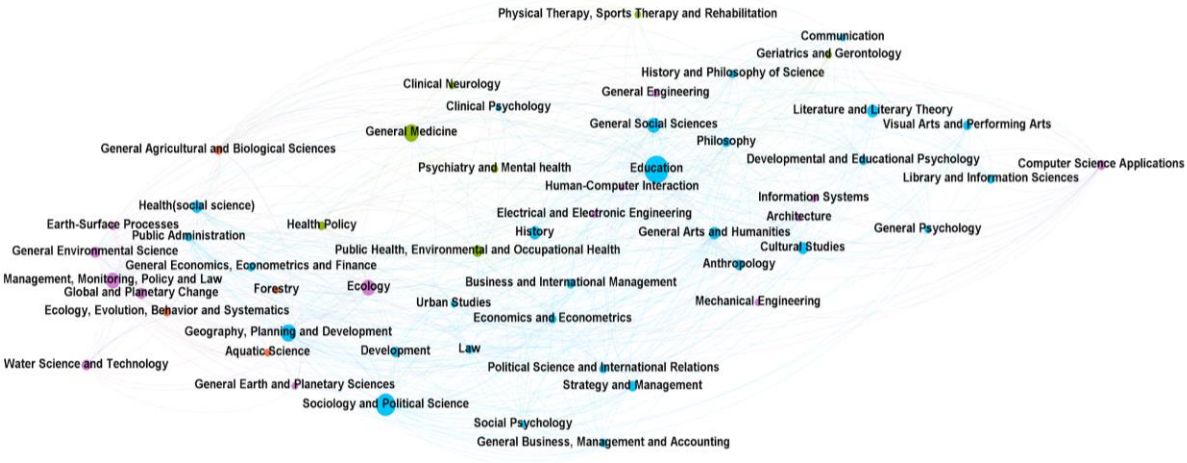

Figure 9 LitReview disciplines network. 54 nodes (16.17 %) with the highest degree are visible. LitReview disciplines network. 54 nodes (16.17 %) with the highest degree are visible.

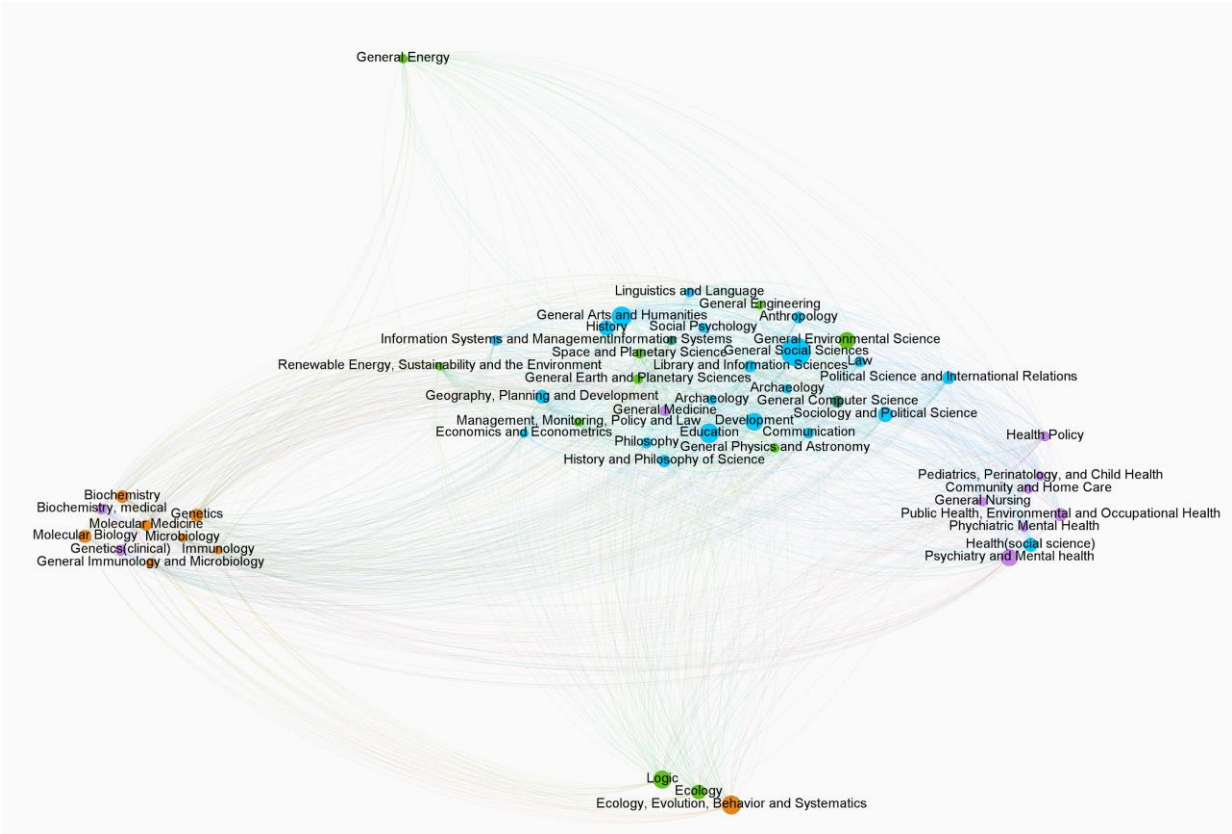

Figure 10 LitReview disciplines network. 51 nodes (15.27%) with the highest degree are visible

The graphs (Figure 9 and Figure 10) are slightly different, especially in terms of clustering among non-AHSS disciplines, which seem to be more separate in the OpenAire sample. However, both show how central the AHSS disciplines are for discussions on interdisciplinarity.

Network analysis has also brought to the fore those nodes that may not have the highest degree (i.e. do not feature the highest number of connections), but that serve as bridges between otherwise poorly connected nodes, i.e. have a high "betweenness centrality" measure. This is especially important for our analysis, which looks for disciplines that may facilitate interdisciplinary dialogue.

The results show the importance of AHSS in fostering interdisciplinary connections by linking disciplines and groups of disciplines which would be otherwise loosely connected.

4.3.2 How can AHSS disciplines be integrated in IDR/TDR? Some examples of spaces and roles

The literature on AHSS integration is scattered and each discipline presents the problem of integration from a different perspective. As already discussed (Vienni Baptista et al., 2019), the label AHSS (or SSH as it is often termed) needs to be problematised and the ways in which individual disciplines can contribute to IDR/TDR analysed in greater detail. The following quote is indicative of the relevance of this type of study:

> However, reflections on our positions within technoscience have often paid little attention to the actual dynamics of these relationships, so that whilst some of the ontological and epistemological challenges of different forms of interdisciplinarity have been mapped (Barry et al., 2008) we have only a few examples of what it is like to work day to-day in these spaces (Balmer et al., 2016, p.4).

The academic literature highlights that AHSS disciplines are usually perceived as having little to contribute and their contributions are mainly difficult to understand and integrate in IDR and TDR (Callard & Fitzgerald, 2015; Fitzgerald et al., 2013; Fitzgerald, Littlefield, et al., 2014; B. Robinson et al., 2016). Following Snow (1964), B. Robinson et al. (2016) submit that the lack of interdisciplinary interaction involving scientists and humanists is less about hostility and more about mutual ignorance. As a means to overcome this obstacle, we analyse in this section the varied ways in which the AHSS interact with other disciplines. Having demonstrated through our quantitative analysis (see preceding section) the importance of AHSS in fostering interdisciplinary connections by linking disciplines and groups of disciplines which would be otherwise loosely connected, we now detail the roles that are assigned to AHSS disciplines in IDR/TDR.

Balmer (2015) characterises collaborative spaces as an emergent mode of social scientific collaboration. Taking his approach as an inspiration, we identify different types of connections and relationships

between AHSS and STEMM disciplines in the academic literature. These relationships influence the roles and functions that each discipline plays in an inter- or transdisciplinary setting.

Some authors, such as Mäki (2016), consider that these connections can develop into new models for the Humanities within interdisciplinary settings. Table 6 summarises the set of connections identified in the academic literature and provides the main features of each one. These are presented in a gradient – from connections that allow for active participation of AHSS disciplines in IDR/TDR to those that imply less interaction with other fields of knowledge.

These relationships provide a setting for better understanding the factors that influence AHSS integration in IDR/TDR (see Section 4.2.1 and Table 14 in Appendix H for a detailed list). To give an example, academic tribalism is identified as one of the factors that usually hinders AHSS integration, due to "silos" that cannot be transformed. If researchers embark on "coupled ethical-epistemological" research (as Tuana (2013) defines it), different disciplines work together on integrating ethical values that help to dissolve those silos.

Table 6 Types of relationships between AHSS and STEMM disciplines

Type of relationship	Variants	Description
Coupled Ethical-Epistemological Research		Integrating ethical and epistemological values in research (Tuana, 2013). Dialogue that allows partners to rethink values and assumptions embedded in research practices (Tuana, 2013).
Epistemological Pluralism		An approach to conducting innovative and collaborative research while acknowledging several valuable ways of knowing (Miller et al., 2008).
Experimental Entanglement	Critique Ebullience Interaction	These connections or "experiments" "(…) take place as much in the relationships that unfold between collaborators, in the interrventions that they choose to make in their respective fields, in the various ways that historical archives might be reopened, as much as they do in regular scientific protocols to produce new data" (Callard and Fitzgerald, 2015, p. 9).
Transformational (specifically for Sustainability challenges)	Building capabilities Critique Deconstruction & emancipation Design & reflect TD processes Evidence & contingency	These are different ways in which SSH can potentially contribute to sustainable development initiatives (according to Erdejan et al. 2019).
Intersecting Knowledge Claims Scenarios	Conflict Cooperation & Identification Tolerant Ambivalence Transformation	These encounters ensue "when different forms of knowledge intersect and span the range from the divisive conflict to radical transformation" (MacMaynowski, 2017, p. 4).

Reconfigurations of AHSS & STEM	"the articulation between contemporary programmatic statements and practices of interdisciplinarity" that allows for "the reconfiguration of the relations between the social and natural sciences" (Barry and Born, 2013, p. 13). It implies the rethinking of boundaries and the consolidation of new poles of study.
Values – Productive Convergence	Values "serve as a ground for collaborative interaction between the humanities and the sciences"(Robinson et al., 2016, p. 2). "Values (…) help underwrite important theoretical principles of knowledge production (…) as well as non-epistemic principles of conduct" (Robinson et al., 2016, p. 2).
Trespassing	"(…) a form of transport or translation; someone with knowledge was basically someone who went somewhere and brought something without transforming it in ways that were detrimental to knowing thigs about it" (Osborne, 2013, p. 88).
Parasitism	According to T. Osborne (2013) this implies borrowing from another discipline in a unilateral manner.
Poaching	"The poacher ventures into another field, takes what he or she understands to be the key insights of that field, and then seeks to return these to his or her own area of research" (Osborne, 2013, p. 87).

To expand on this table, below we present three examples that show the differences found in the types of relationships between AHSS and STEMM disciplines. These relationships are not always predefined in an inter- or transdisciplinary setting, but they can change according to the aims and goals pursued by the project or programme. In the following examples, we show how relationships can be fruitful for AHSS integration (as experimental entanglements) or have a more specific purpose (as parasitism):

- Experimental entanglement: can take the form of (i) critique; (ii) interaction; or (iii) an ebullient relationship leading to long-term collaborative work (Callard and Fitzgerald, 2015). In the last case, the ebullient mode tends to take experimental experiences as a means to create active and prominent connections between natural and social sciences (Callard and Fitzgerald, 2015). These spaces are useful, for example, "to shed new light on the multiple meanings of climate change in diverse cultures, and to create new entry points for policy innovation, the interpretative social sciences, arts and humanities need new spaces for meeting as equals with the positivist sciences" (Brom, 2019, p. 4).
- Coupled Ethical-Epistemological research: these connections are related to value decisions embedded in research models and methods (Tuana, 2013). Making these values transparent and examining how they couple with ethical and epistemological decisions in research is an

under-represented resource in most interdisciplinary projects. This model can add resources and dialogue between knowledge practices by rethinking and recreating ethical assumptions in a research project.

- Parasitism: this type of connection allows "cross-fertilization" among disciplines as T. Osborne (2013) suggests. It is a type of behavior that takes the form of "borrowing", where one discipline takes advantage of another in a unilateral knowledge production process. According to T. Osborne (2013), this type of relationship does not really count as IDR but it is quite normal in many AHSS disciplines as part of their daily work.

The Arts constitute a special case within AHSS and STEMM relationships. Interdisciplinary and transdisciplinary Arts demand a share of attention within the existing literature on ID/TD (Augsburg, 2017). The Arts+Science movement and related programmes are a common area of interaction many authors have analysed (Koek, 2017; Leach, 2011; Piirma & Valk, 2014; Rust, Mottram, & Till, 2007). Interactions have been based on how to bridge this connection, though with uncertainty about their application to the humanities. Furthermore, these programmes range from multidisciplinary to inter- or transdisciplinary (see Koek (2017) and Piirma & Valk (2014); as two examples). Mostly there is a lack of consensus in the literature about what the so-called interdisciplinary arts entail (Augsburg, 2017).

From our analysis, we identified four types of relationships between Arts and STEMM disciplines:

1. Expression versus utility: this relationship highlights the fundamental divide between expression (that takes the form of the copyright) and utility (that is transformed into patents) (Leach, 2011). This divide results in a problematic relationship (utility vs. originality) that is exercised by both artists and scientists. As a result, this is a "conflicting basis for understanding the value of different kinds of knowledge and different kinds of persons" (Leach, 2011, p. 145).
2. Intersubjective reality: in this connection the artist can comment upon a "social reality" that is distinct from but not opposed to a "physical reality" informed by science. In this interface, an intersubjective reality is built as Arts present a subjective interpretation that may be shared (Leach, 2011).
3. Unstated contributions: this constitutes a fruitful setting for Arts integration in IDR/TDR. Utility as a value in itself does not always represent the artistic perspective (Leach, 2011). Going beyond the contradiction between "utility and expression" implies that other ways of adding value to the artwork are possible and they require positioning of the scientific work in a different realm. They move into a "different domain" where new questions are posed to researchers (Rust, Mottram, & Till, 2007).

4. Science, Technology and Art: This connection usually takes Arts, hybridity, research, and opposing worldviews as objects of study (Augsburg, 2017, p. 137). "This stream of literature acknowledges the considerable growth in the art and technology scholarship, with little emphasis on ID/TD. The encounter between arts and science and technology, implies that the artist has to reconcile with opposing worldviews" – those of science and of art (Augsburg, 2017, p. 137).

Different kinds of spaces for interaction help or hinder different roles assigned to AHSS disciplines (Balmer et al., 2015). Roles and spaces, in turn, are defined by factors that hinder or help inter- or transdisciplinary integration and collaborations. Power relations, for instance, can act as a facilitator for disciplinary integration, or on the contrary, define more instrumental roles for lower status disciplines. Table 7 details the roles identified in the academic literature.[27] It summarises an approach to the messiness and complementary functions that researchers perform simultaneously in an academic environment. Performing roles shows that researchers are "chameleonic in their relationships" as they try to maintain connections with STEMM and even between AHSS disciplines (Balmer et al., 2015). The affective and emotional factors are relevant in this respect; they are important in helping researchers to position themselves in certain roles while closing others off. These factors are so powerful that they can shape our ability to move from one role to the other (Balmer et al., 2015).

Roles assigned to AHSS researchers have also opened a discussion in the academic literature related to a "collaborative turn" in humanities and social science scholarship (Fitzgerald et al., 2014; Balmer et al., 2015). This is usually summarised as the need for humanities to contextualise or decontextualise science advice (Brom, 2019). "How can crucial insights of the humanities be made valuable for the society?", asks Brom (2019, p. 2). According to our findings, acknowledging roles assigned to AHSS disciplines is a means to promote a cultural change towards more participatory and varied tasks assigned to them.

[27] This is a synthesis of findings from a range of literatures and so some of these roles overlap.

Table 7 Roles for AHSS disciplines identified in the academic literature

ROLE	Description
Colleague	Main features of this role are collaboration and the willingness to support a collective process of knowledge production. "In some ways, the relationships between engineers and social scientists are not notably different from those that AHSS researchers develop among themselves" (Balmer et al., 2015, p. 18).
Co-producer of knowledge	He/she has the ability to entangle representations of values, science, and research (Callard and Fitzgerald, 2015). In some ways, this role remains an aspiration in collaborative relationships (Balmer et al., 2015) due to the complex tasks and efforts that he/she has to undertake to accomplish it. According to our survey and interviews, many researchers recognise the relevance of this role for AHSS integration in IDR/TDR. "This role can also become problematic when we find ourselves contributing to an element of the project that we remain uncomfortable with" (Balmer et al., 2015, p. 18).
Critic	He/she has a critical perspective on research and science and questions knowledge and its nature. It is related to the critique discourse in ID/TD (Klein, 2020). A critical stance can, oin ocassions, be interpreted as resentment (Rabinow and Benett, 2012) and also as joyless (Balmer et al., 2015).
Educator	This role supports educational processes within a team and it is explicitly pedagogical (Balmer et al., 2015). It also provides a reflexive perspective on research.
Foreteller	This role is usually assigned to AHSS researchers as having the capacity to predict the impact of social research and unknown conflicts. AHSS researchers might emphasise being "interested in the upstream processes and governance of science and innovation. This insistence (…) can lead us to be cast in the role of "foreteller", and (…) can lead to the expectation that our role is to forecast the way (…) in which a particular technology will or should develop, and how it will be apprehended by various publics" (Balmer et al., 2015, p. 10).
Playfulness	He/she provides joy and fun to a team as a means to a more productive research process. This is an innovative role that implies "the work of self-constitution and selfcare as part of the knowledge production" (Balmer, 2013, p. 3). This role is a "lens through which to look for opportunities to change our own practices in hopes of producing more exciting relationships with our colleagues" (Balmer, 2013, p.3).
Reducing complexity	In this case, AHSS researchers apply specific skills to increase clarity and transferability of research outputs and their ability to translate research outputs in a less complex fashion. "A deeper understanding of complexity, (…) as a social phenomenon is required, which can be guided by metaphors (…)" (Nowotny, 2005, p. 29) provided by AHSS researchers, for instance.
Reflexivity Inducer	Researchers with the ability to facilitate research processes who help to disentangle conflicts in a team and induce reflexive processes. One example of how this role can be fruitfully performed by AHSS researchers is provided by Nowotny (2005, p. 29): they "(…) bring to it their knowledge and practice of history, being able to prove into how the past was perceived, understood and lived by former generations and to what effect".
Representative of the Public	This role implies communicative skills and the ability to translate scientific knowledge to the lay audience. According to Balmer et al. (2015, p. 9) "(…) this role often serves as the initial position from which we are forced to negotiate more substantive relations with the synthetic biology world". This means that AHSS researchers are usually asked to deliver "outreach" to obtain more "public acceptability" of research outputs (Balmer et al., 2015, p.9).
The wife	This role embeds a gendered character (Balmer et al., 2015). Together with good advice and support to the team, researchers performing this role end up managing the emotional labour of collaboration (Balmer et al., 2015). "Here we identify three central facets of the wifely role: being dutiful, gossiping, and being trophy" (Balmer et al., p. 11).
Trickster	A character that exhibits a great degree of intellect or secret knowledge, and uses it to play tricks or otherwise disobey normal rules and conventional behaviour in a research setting (Balmer et al., 2015).

Taking these two sets (spaces and roles) into consideration for AHSS integration helps to understand the multiple dimensions that are at stake in IDR/TDR. These relationships or inner dialogues among disciplines might help to bridge the gap between AHSS and STEMM integration in IDR/TDR. Analysing the roles assigned to AHSS disciplines can encourage them to reposition themselves, developing new connections and relationships with STEMM disciplines. These can lead to reconfigurations of the natural sciences, humanities and social sciences, as Barry and Born (2013) argue.

4.3.3 AHSS integration in IDR/TDR: some insights from researchers, funders and policy makers

According to the insights collected in our survey and interviews, the root cause of difficulties regarding AHSS integration is to be found in a lack of understanding by researchers, policy makers and funders, about what the AHSS are and what these disciplines can contribute to solving problems in society.[28] A different attitude is necessary in all these sectors of the research system, so that those who really believe in AHSS and want to stimulate AHSS research integration do not have to fight prejudice before becoming effective. Changes in attitude are necessary both in the personal and in the disciplinary realm, as mutual understanding is crucial in all stages of the research. One survey respondent argues that:

> (…) there has to be mutual respect among all the researchers and an atmosphere where anyone can challenge the rest of the team about how things are understood, and what is planned and undertaken, without anyone taking offence or feeling proprietorial about their discipline (SHAPE-ID Survey_31, AHSS/STEMM).

Still, the main tendency in the academic world is to first look to STEMM disciplines and then perhaps later include AHSS researchers to address some ethical or legal issues. This is still routine for many researchers, policy makers and funders, despite statements that major problems in society need input from AHSS research, even those with what appears to be a primarily STEMM orientation, such as climate change or energy transition.

One funder outlines another factor that may influence the integration of AHSS and STEMM, which is that the initiative to put projects together "usually comes from STEMM researchers. They put [in] the energy to get the funding and then at some point, then at the end they try to get AHSS researchers" (SHAPE-ID Interview_6). In so far this is true, it is at least partly a consequence of the fact that the majority of the funding programmes are primarily STEMM oriented. But it is arguably also a consequence of a lack of experience in the AHSS community in leading IDR/TDR projects.

[28] These insights provide a general summary of the various results obtained from the survey of researchers and interviews with funders and policy makers. For full details of this study please see Spaapen et al. (2020).

The same funder also states that:

> AHSS must take the initiative at the very beginning of the projects. How can we make researchers to make more IDR/TDR? How to encourage them to take the lead? This has to be a task shared by researchers and policy makers together (SHAPE-ID Interview_6).

And funders can do their part in stimulating a stronger role for AHSS in IDR/TDR projects:

> We also sometimes divide the budget for IDR/TDR themes in a way that no one field can go run with the money. And it is very important to have mixed evaluation committees, not only with different disciplines, but also with stakeholders. (SHAPE-ID Interview_3)

To prevent the frustrating situation for IDR/TDR, and in particular for AHSS to continue at all policy levels, a number of things can (and should) be done:

- Allowing time and money to develop mutual understanding between potential partners in IDR/TDR. As one of our policy interviewees said, IDR/TDR collaboration can be enhanced "by creating the time and space to speak to each other and to understand each other. We need to build a common language and a common ground, not only among funders but with the different communities and academic communities" (SHAPE-ID Interview_1). It is important to realise that this does not always have to involve big sums of money; smaller amounts of seed funding are sometimes enough to develop collaborations.
- Structurally embedding IDR/TDR knowledge and experience in the education and training of young researchers in all academic disciplines. This could include inviting stakeholders to discuss issues in society that demand input from researchers.
- Making knowledge about IDR/TDR more easily available, for example through a well-designed website with both knowledge resources and good examples of IDR/TDR in practice.

4.3.4 Implications for AHSS integration in IDR/TDR: Recommendations for change arising from the grey literature

The grey literature documents were particularly analysed for any specific recommendations for actions intended to increase the integration of AHSS disciplines in IDR/TDR.[29] Aspirations for increasing the amount of AHSS research undertaken featured prominently within this dataset, but with a focus on justifying why AHSS should be integrated, rather than concrete suggestions for how this might be achieved. We were able to identify recommendations related to:

- The development of call texts
- Peer review of interdisciplinary proposals
- Enablers for IDR/TDR

While there is recognition that the impetus for greater engagement in IDR/TDR needs to come from the AHSS community (CEU, 2013; i4g, 2014; INTREPID, 2017b), the umbrella term "SSH" is, itself, unhelpful and fails to recognise that "SSH is characterized by a high degree of internal heterogeneity" and a great diversity of methods and theoretical approaches (i4g, 2014, p.3; see also IHS, 2019, p.17). In particular, the label "SSH" leads to a further isolation and invisibility of the Arts (INTREPID, 2017b).

Moreover, it is suggested that it was "more convenient for policy-makers to set up funding in a way that mimicked the established paths of sciences" (IHS, 2019, p. 17) thus forcing the AHSS disciplines to conform to a STEMM model and promoting "an overarching interdisciplinary research process" that favours such criteria as "validity and reproducibility, which are the hallmark of modern science" (LERU, 2016, p. 13). Such an approach risks alienating AHSS researchers by failing to acknowledge that the social sciences and humanities "arguably have a more complex relationship to truth, power, and knowledge than their siblings from the sciences" (IHS, 2019, p. 17). This predominance of a "science model" for IDR/TDR collaboration is perpetuated by language that talks in terms of "integrating social sciences and humanities **with** the natural sciences and engineering [emphasis added]" (AAU et al., 2014) rather than vice versa.

Advice also highlighted the importance of capacity building (see Section 4.3.4.3.1 below), for example emphasising the career implications for those undertaking IDR/TDR and suggesting the need to start interdisciplinary training earlier within university education. It also provided a valuable reminder that the challenges of interdisciplinarity extend to the mindsets and culture of the research community (GRC, 2016a, p.12, citing Callard and Fitzgerald, 2015).

[29] In line with the lack of definitions discussed in Section 5.1, there were no specific recommendations provided for TDR.

4.3.4.1 Development of call texts

Two key messages regarding the development of funding calls were abundantly clear from the recommendations:

- Appropriate participation of AHSS researchers at the programme design stage (on advisory panels, strategic programming committees, in call and topic-drafting teams) (e.g. CEU, 2013; EASSH, 2018, 2019; IHS, 2019; LERU, 2012; Russell Group, 2018; Trinity College Dublin, 2016).
- Topic texts of future Work Programmes to explicitly call for AHSS contributions and to be framed with AHSS as an integral part of the solution rather than as an "add-on" in a minor supporting role (British Academy, 2016; Russell Group, 2018).

The aim should be to attract proposals in which AHSS are equal partners with those from other disciplines, making explicit that AHSS input into funded projects is welcome and that interdisciplinary proposals in which AHSS-relevant questions are the driving force are eligible and encouraged (FET Advisory Group, 2016). Without specific provisions regarding the scientific framing of the calls, AHSS integration is minimal (EASSH-LERU, 2019) and this is particularly significant for the humanities (EC, 2015, 2017). Others go further, calling for mechanisms to make AHSS participation in certain topics of all Societal Challenges obligatory (CEU, 2013).

Funding calls for innovation and creativity must "move beyond a predominantly technological framing" and encourage more "disruptive" research on the human and social factors in all global challenges (EASSH-EA, 2016, p.2). This requires the facilitation of bottom-up approaches (GRC, 2016) and creative and participatory ways of bringing researchers, citizens and policy officers together to co-create topics and calls (e.g. a hackathon of ideas to discover what challenges to take up) (INTREPID, 2017b).

Finally, the approach of Work Programmes could be abandoned altogether to enable greater creativity and innovation, with one report arguing that the "research community should be given more credit for its ability to define research topics worthy of pursuit" within broadly defined areas (INTREPID, 2017b, p.18).

4.3.4.2 Peer review of interdisciplinary proposals

4.3.4.2.1 Evaluation processes

There is a strong consensus on the need to modify peer review procedures to ensure they are better suited for IDR/TDR purposes (for example CEU, 2013; EURAB, 2004; GRC, 2016a; National Academy of Sciences, 2005) and this is a key area where funders could provide better leadership (ESRC Innogen Centre, 2011). While the recommendations for change, extracted from the grey literature, highlight a lack of competencies and criteria to evaluate IDR/TDR, they also provide a powerful reminder that much

practical advice on this topic exists in the academic literature (e.g. LERU, 2016, p.27 citing Pohl et al., 2011; Lyall et al., 2011; Klein, 2008; Strang & McLeish, 2015).

Synthesis of Recommendations

(based on INTREPID, 2017b)

- Focus on quality not quantity of IDR/TDR research being funded;
- Evaluate how proponents have explained why their research question demands IDR and how this will be operationalised;
- Focus on project feasibility, implementation, relevance;
- Evaluate proposals according to how they plan to achieve objectives: what resources are being planned; what disciplines are included; are these adequate and how will they work together?;
- Panels should look for a truly IDR/TDR approach besides the composition of the consortia and "SSH integration" (interestingly, this is contradicted by advice from the author of the IHS Working Paper (2019, p.12) who suggests that "participation of one (or more) SSH partners would be rewarded through better evaluation scores" but supported by the authors of the i4G policy brief (2014, p.4) who decry the "tick a box" approach when interdisciplinarity within SSH and between SSH and STEM is indicated in a proposal;
- Include "interdisciplinary" and "transdisciplinary" as scientific areas that proponents may choose;
- Impact should include not just short-term tangible effects (new jobs, additional turnover, product improvements...), but also long-term structural effects which are more linked to ID and TD research practice: training, community building, disruptive ideas and social innovation.

Recommendations extracted from our analysis

- Ensure mechanisms for reviewing both (i) the interdisciplinary elements of discipline focused proposals and (ii) fully interdisciplinary proposals (EURAB, 2004);
- Task review committees with an assessment of effective methodologies (ACOLA, 2012);
- Discuss the use and abuse of bibliometrics and impact factors as peer-review criteria (Academia Europea, 2012);
- Extend modifications of the IDR/TRD review process beyond grant application stage to interim and end-of-grant applications (GRC, 2016a; Trinity College Dublin, 2016);
- Acknowledge that IDR/TDR is not necessarily about SSH integration into broadly defined research agendas (INTREPID, 2017b).

4.3.4.2.2 Evaluator selection

If funding is targeting IDR/TDR, then advisory boards, programme committees, evaluation panels and strategy committees should all be IDR-competent and proficient (INTREPID, 2017b) to ensure that proposals are assessed in line with all call requirements (EASSH, 2019).

Given the diversity of the AHSS disciplines, the evaluation stage of proposals does not sufficiently cover the breadth of the AHSS and therefore cannot be evaluated by a single AHSS evaluator (ALLEA, 2019, p.12). To date, these AHSS experts have consisted primarily of economists (IHS, 2019, pp.12-3) and it could be worth exploring whether there should be a minimum number/proportion of AHSS evaluators on each panel (Russell Group, 2018, p.4). Such panels should include experts (including a Chair) in interdisciplinary research (CEU, 2013; EASSH, 2018; FET Advisory Group, 2016). Additionally, discipline-based experts should be chosen on the basis of the breadth of their disciplinary understanding rather than their expertise (no matter how prestigious) in one narrow area (STIS, 2011b).

4.3.4.2.3 Briefing for evaluators

Having recruited suitable evaluators, appropriate training and briefing is paramount. Currently seen as "insufficient" (ALLEA, 2019), the Commission was urged to provide training on IDR/TDR good practice for evaluators, as well as others such as project officers and funding agency staff (possibly via a MOOC or through multi-day participative workshops) (INTREPID, 2017b; Trinity College Dublin, 2016).

Evaluator briefings should draw on existing guidance such as the San Francisco Declaration on Research Assessment and the Leiden Manifesto (ZSI, 2019) and existing international reviews of good practice (for example Luukkonen, 2012; Lyall & King, 2013; td-net, 2011) to shape its own guidance (INTREPID,

2017b), addressing personal biases and the implications this might have for evaluation and advice on the processes to be adopted, including how to deal with disagreements on the value of different disciplinary contributions and what weight to give to disciplinary contributions in relation to overall interdisciplinary quality (STIS, 2011b).

4.3.4.3 Enablers for IDR/TDR

4.3.4.3.1 Capacity building

Recommendations reiterated that universities should do more to build capacity for AHSS engagement with IDR/TDR, from ensuring that researchers are provided with adequate project management support post award (Trinity College Dublin, 2016) to establishing such research as a "core business of the University" (INTREPID, 2017b, p.20). Further recommendations to support this included providing appropriate incentive systems at both national and EU level, through grants, stipends, mobility funds, suitable prizes and brokerage events (Academia Europea, 2012; CEU, 2013; INTREPID, 2017b) and addressing administrative difficulties in sharing funding across institutions (ACOLA, 2012).

Several authors in the grey literature discuss the need for more sharing of knowledge, for example in the form of toolkits and workshops to document and share good practice in IDR/TDR (e.g. ACOLA, 2012).

> If we are to build a system that better supports IDR then all actors in the HE system need to share experiences to avoid reinventing the wheel. Events such as IDR workshops can aid the HE community to share intelligence and foster organisational learning. (Trinity College Dublin, 2016, p.4)

Calls to promote IDR/TDR and AHSS integration by showcasing best practice (e.g. CEU, 2013) involve an important element of knowledge sharing:

> GRC participants should actively work towards contributing to improved awareness of the value and necessity of interdisciplinary research, promoting key success stories and the value of interdisciplinarity, and engaging with policy makers, universities and publishers to work together on better recognition of and opportunities for interdisciplinary research. (GRC, 2016a, p.6)

In order to stimulate better integration, successful interdisciplinary and intersectoral projects should be showcased and rewarded. This could take different forms, such as awarding individual prizes both for projects that have successfully integrated AHSS and STEMM researcher pairings, and for AHSS communities who have "reimagined" their research or roles through collaboration. We should also improve our readiness to learn from fields with experience of interdisciplinary research and teaching, such as Science and Technology Studies, Classics, Archaeology (i4g, 2014, p.4).

4.3.4.3.2 Funding agencies

As well as the innovations suggested above, some authors envisage a wider role for funding agencies in promoting and facilitating IDR/TDR:

> Funders should continue with funding calls that attempt to encourage IDR and should not abandon call structures after a first attempt. It may take a number of call iterations for the research system to fully adapt to the cultural shift that engaging in IDR often requires. (Trinity College Dublin, 2016, p.5)

> Funders can play a truly catalytic role, for instance when problems are just beginning to coalesce, in stimulating interdisciplinary research initiatives. They also play critical roles in building capacity and ensuring long-term sustainability of interdisciplinary research. (STIS, 2011a, p.1)

Member States are asked to provide adequate national support for their AHSS communities, recognising that these disciplines start from a lower knowledge base regarding collaborative research, (CEU, 2013). In the context of the EC's SSH integration monitoring efforts, concern has been noted about the lack of presence of humanities disciplines, such as History, which may provide a long-term perspective (EASSH, 2018), and efforts are encouraged to increase contributions from disciplines that are currently underrepresented (EASSH, 2019).[30]

4.3.4.3.3 Training and education

A key aspect of capacity building was recognised as a need for interdisciplinary training and education, and not simply to focus those efforts on the AHSS disciplines:

> For a true cross-disciplinary research culture to be successful over different methodological, cultural and social contexts, we might have to acknowledge that we are still at an early stage of developing such a culture, where research communities are only beginning to work together and value one another. Thus, we require an even bigger effort within the research community to train scientists in a way that they become aware of the 'bigger picture' in which scientific research is embedded. (ALLEA, 2019, p.15)

In order to strengthen a culture of IDR/TDR such training should:

- link interdisciplinary research and education and provide early educational and training opportunities at all levels (undergraduates, graduate students, and postdoctoral scholars), faculty team-teaching credit, IDR management training including designing and reviewing proposals for funding and evaluating the impact of interdisciplinary research (EURAB, 2004;

[30] Some national funders are already actively working on developing interdisciplinary capacity within and beyond the AHSS community. See, for example, the Irish Research Council's "Statement on 'STEAM' Research", which outlines specific programmes funded to encourage STEAM research and commits to accepting and identifying STEAM proposals under all funding schemes (Irish Research Council, 2017).

GRC, 2016b; INTREPID, 2017b; National Academy of Sciences, 2005; Trinity College Dublin, 2016);

- support SSH **leadership** of large interdisciplinary projects (GRC, 2016; CEU, 2013);
- define new skills for SSH such as **participatory approaches and data science** (CEU, 2013);
- include SSH related training for **policy makers and representatives of the natural sciences and engineering, as well as NGOs, business and industry** (CEU, 2013);
- encourage universities to develop Graduate School structures that can more easily span traditional disciplinary divisions in research training (EURAB, 2004);

and even:

- consider establishing, in conjunction with Member State authorities, **a high level, EU Doctoral Programme** potentially drawing on the NSF IGERT Programme as a model and taking account of recent developments in industry-based and industry-related doctoral training (EURAB, 2004).

5 Discussion and conclusions

Throughout this report, we have argued that IDR and TDR urgently need to be better supported in research institutions, funding and policy. The paradox of interdisciplinarity (as Peter Weingart (2000) termed it twenty years ago) – whereby IDR is often encouraged at the policy level but poorly rewarded – still challenges the establishment of cross-sectoral boundaries and connections. The role of AHSS disciplines in IDR/TDR raises questions about barriers to their integration. Using a range of empirical data, we seek to provide a baseline of information that can be used to overcome these obstacles. From this analysis three major insights (relevant for researchers, funders and policy makers alike) emerged:

i. An urgent need to acknowledge plural understandings of ID and TD and permit them to coexist in research (and funding) environments.
ii. A recognition that the conditions that influence IDR/TDR are context-dependent: factors that hinder IDR/TDR can be transformed into enabling measures, even during the development of a research project.
iii. A demand (and responsibility) to reassess AHSS roles and functions in IDR/TDR so that these disciplines can contribute fully in inter- and transdisciplinary settings.

In what follows, we explore these three insights and draw connections between the different analyses carried out during this phase of the SHAPE-ID project.

i. Acknowledgement and commitment to plural understandings of ID and TD

The academic literature shows no agreement over the definitions of IDR and TDR. Rather, it shows plurality, heterogeneity and overlapping conceptualisations, even contested and contrasting discourses when we take into consideration AHSS perspectives on ID and TD. Solving societal problems is seen as the main purpose of IDR/TDR, but other parallel discussions are taking place which provide alternative and substantial models of collaborative knowledge production processes. For instance, some AHSS communities are aligned to critical and philosophical discourses on ID and TD.

Our study shows that, rather than develop new definitions, it is necessary to find connections between the diverse definitions of ID and TD that currently coexist within the academic literature. The lack of connections between different communities' results in a tendency to adopt a narrow view whereby researchers ignore alternative collaborative pathways; this acts as an obstacle to further integration of AHSS disciplines in IDR and TDR.

The review of the grey literature on AHSS and IDR/TDR has identified a number of issues on this matter. First, there are important gaps in this material, which actually consists of three largely separate literatures on i) the state of European and global AHSS research; ii) how to conduct IDR/TDR; and iii) AHSS integration within H2020 funded research. The terms interdisciplinary and (to a lesser extent) transdisciplinary are widely used across these three literatures, but rarely defined. This lack of definition is symptomatic of a wider problem of weak links between the academic and grey literatures on IDR/TDR. This is a problem that is not restricted to discussions about the role of AHSS in such research but it shows the problem of lack of policy learning more broadly.

In our quantitative analysis, distinct uses of IDR and TDR were difficult to disentangle in the four corpora. Using topic modelling and concept mining, we found that clear-cut distinctions between IDR and TDR were also rarely made. The terms IDR and TDR are usually employed very generally in these datasets to identify general characteristics of a given discipline, rather than collaboration between particular disciplines (especially those across the AHSS-STEMM divide).

Results from the survey show furthermore that contextual differences – between research fields, institutions and countries – influence the potential for successful IDR/TDR. Differences between academic fields with regard to methodologies and output modalities are obvious, but differences also exist between universities (some invest much more time, people and money in supporting IDR/TDR than others), and between countries (some have developed IDR/TDR policies at the national level and some are less advanced in this area) (Spaapen et al., 2020).

Thus, we argue for a plural understanding of ID and TD because this could substantially improve inter- and transdisciplinary research policy making and funding by giving institutions a clearer understanding of the conditions that are needed, in each case, to support IDR and TDR. Such changes could also support early career researchers wanting to focus on IDR/TDR.

Acknowledging this urgency entails that researchers and funders alike recognise that ID and TD are conducted for different purposes and are conceived in different ways, for example, as: (i) objects of study; (ii) methods; and/or (iii) phenomena that vary according to historical and geographical contexts.

Acknowledging this urgency also implies commitments, responsibilities and specific actions from different societal actors and institutions. Actions to be implemented to promote a cultural change towards IDR/TDR can include:

a) Co-production of concepts: To support the coexistence of different definitions that are context-dependent, researchers, funders and policy makers alike can develop co-production processes. Co-producing means simultaneous processes through which understandings of the world are built and related to representations, identities, discourses, and institutions (Jasanoff, 2013). These can be interwoven during the research process or while elaborating funding schemes. Co-production processes foster better integration in IDR/TDR.
b) Systematisation and traceability of a range of processes and practices: To acknowledge that ID and TD imply different phenomena for different societal actors demands that all actors involved in IDR/TDR should develop processes to systematise these varied practices. This would involve creating a "memory" of IDR/TDR common understandings and agreements on what IDR/TDR are, the factors that hinder or help ID/TD development, how to better integrate AHSS and what methods and tools to use.
c) Mapping of understandings: To take into consideration that different modes of ID and TD exist, and these operate according to various logics. Mapping plural understandings, using different tools leads to new spaces (epistemological, team-based, institutional, cross-sectoral) where IDR and TDR can be performed. In these spaces, AHSS disciplines can engage in new collaborative roles and functions.

This set of actions is useful for finding commonalities and differences among plural understandings. It confirms our working hypothesis that differences among understandings are not necessarily a hindering factor; they can also be used constructively to better develop AHSS integration in IDR/TDR.

ii. Factors that affect IDR/TDR can be changed!

Factors that help successful IDR/TDR as well as those that hinder such efforts are concrete realities. If we consider ID and TD as dynamic phenomena with multiple understandings and a heterogeneity of practices, trying to divide a list of factors into positive and negative conditions for research can be tricky.

In the academic literature, we identify 25 factors influencing the outcomes of IDR and TDR. In the Grey Literature, three main factors are mentioned: (i) lack of appropriate funding; (ii) existing academic career structures; and (iii) the extended timescale required to conduct good quality IDR/TDR. Recommendations for improved outcomes for IDR/TDR from the grey literature focus on the greater involvement of AHSS researchers in the development of call texts, improved peer review of interdisciplinary proposals and capacity building within funding agencies and research organisations. These recommendations have all been made previously and the fact that they need to be reiterated once more demonstrates the lack of policy learning about how to facilitate IDR/TDR and the weak links between academic and policy literature highlighted above.

One of the biggest obstacles mentioned by the respondents of our survey when it comes to developing good IDR/TDR projects is career path issues. It is more difficult for inter- and transdisciplinary researchers to publish in high impact journals and it is more difficult for them to get funded. The survey results show that academic cultures and epistemologies are the next most common obstacles. Thirdly, institutional factors constitute a strong barrier to effective IDR/TDR. This confirms the results from our literature review (Spaapen et al., 2020).

A promising finding on the factors that can help or hinder IDR/TDR collaboration is the indication from the literature that the same factor may be a barrier or an opportunity, depending on the circumstances within a project. This means that factors can be changed, transforming them from problematic to enabling during the research process.

iii. A demand (and responsibility) to reassess AHSS roles and functions in IDR/TDR

Both the qualitative and quantitative analyses confirm that AHSS is a problematic label, obscuring the differences between a set of disciplines with very different cultures. The AHSS/SSH label is unhelpful as it obscures major differences in, for example, methods, epistemologies and existing integration in IDR/TDR between disciplines. Moreover, the model of IDR/TDR as providing solutions for complex social problems – sometimes labelled mission-oriented research – can be inhospitable to AHSS researchers due to its instrumental and technocratic approach to research.

Uneven representation of Arts and Humanities and Social Sciences disciplines should be highlighted as well: while the findings confirm considerable level of integration between disciplines from Social

Sciences and Environmental Science, Medicine and Computer Science, they also point out the comparatively lower integration of Arts and Humanities disciplines with non-AHSS disciplines.

Perhaps the biggest challenge for AHSS disciplines is to fight prejudice and misconceptions, among both researchers and policymakers (Spaapen et al., 2020). Our findings show that the subordinate roles and functions assigned to AHSS disciplines discourage their greater involvement with STEMM disciplines in IDR/TDR. The problem has two aspects. On one side, AHSS researchers have a responsibility to show more willingness to collaborate with other disciplines. On the other side, as our interviews confirmed (Spaapen et al., 2020) pro-active funders and policy makers also have a responsibility to change things for the better to support AHSS integration in IDR/TDR.

The academic literature also reveals a plethora of relationships between AHSS and other disciplines in IDR/TDR. Transformative connections (that imply a change in disciplinary domains) and productive convergence (in which researchers integrate different types of knowledges), for instance, go beyond the instrumental function usually attributed to AHSS disciplines.

To conclude, IDR and TDR urgently need to be better supported by research institutions, funding and policy. In this process, AHSS disciplines have a relevant role to play and can contribute to consolidate a cultural change towards IDR/TDR development. This is not a new problem but one that can constructively be solved using a new set of strategies, as the ones that are being implemented in the SHAPE-ID Learning Case Workshop series (under WP3) and toolkit (WP5).

References

AAU. (2005). *Report of the Interdisciplinary Taskforce*. Retrieved from New York: https://www.aau.edu/sites/default/files/AAU-Files/Scholarship/Report-of-Interdisciplinarity-Task-Force-2005.pdf

AAU, AEARU, LERU, G08, RU11, Group, R., & Canada, U. (2014). *Leiden Statement on the role of SSH in the global research landscape* [Press release].

Academia Europea. (2012). *On the situation of the Humanities and Social Sciences in Europe*. Retrieved from London: https://www.ae-info.org/attach/Acad_Main/Publications/Press_release/Role_of_Humanities_and_Social_Sciences/AE_On_the_situation_of_the_Humanities_2012_net.pdf

Academy of Finland. (2005). *Promoting Interdisciplinary Research: The Case of the Academy of Finland* Retrieved from Helsinki: https://helda.helsinki.fi/handle/10138/232267

ACOLA. (2012). *Strengthening Interdisciplinary Research. What it is, what it does, how it does it and how it is supported*. Retrieved from Melbourne, Australia: https://acola.org/wp-content/uploads/2018/08/strengthening-interdisciplinary-research.pdf

Aldama, F. L. (2008). *Why the Humanities Matter: A Commonsense Approach*: University of Texas Press.

ALLEA-RatSWD. (2014). *Facing the Future: European Research Infrastructures for the Humanities and Social Sciences*. Retrieved from Berlin, Germany: https://www.allea.org/wp-content/uploads/2015/09/2014_06_04-FACING_THE_FUTURE.pdf

ALLEA. (2013). *Sustainable Aquatic Food Supply: Guidelines for an interdisciplinary research project* Retrieved from Berlin: https://allea.org/wp-content/uploads/2015/07/2014_01_30_FullReport_Interdisciplinarity.pdf

ALLEA. (2015). *Survey and Analysis of Basic Social Science and Humanities Research at the Science Academies and Related Research Organisations of Europe*. Retrieved from Berlin, Germany: https://allea.org/sassh-project/

ALLEA. (2019a). Delivering Horizon Europe [Press release]. Retrieved from https://allea.org/portfolio-item/delivering-horizon-europe/

ALLEA. (2019b). *Developing a Vision for Framework Programme 9*. Retrieved from Berlin, Germany: https://www.allea.org/wp-content/uploads/2017/07/ALLEA_Statement_FP9.pdf

Anthony, L. (2019). AntConc (Version 3.5.8) [Computer Software]. Tokyo, Japan: Waseda University. Available from https://www.laurenceanthony.net/software

Augsburg, T. (2017). Chapter 10: Interdisciplinary Arts. In R. Frodeman, J. Thompson Klein, & A. Pacheco (Eds.), *The Oxford Handbook of Interdisciplinarity* (pp.): Oxford University Press.

Balmer, A. S. (2013). *Play in Interdisciplinary Collaboration between Natural and Social Scientists*. Paper presented at the 4S/EASST Copenhagen.

Balmer, A. S., Calvert, J., Marris, C., Molyneux-Hodgson, S., Frow, E., Kearnes, M., . . . Martin, P. (2015). Taking roles in interdisciplinary collaborations: Reflections on working in post-ELSI spaces in the UK synthetic biology community. *Science & Technology Studies*.

Bammer, G. (2008). Enhancing research collaborations: Three key management challenges. Research Policy 37(5): 875-887.

Barry, A., & Born, G. (2013). *Interdisciplinarity: Reconfigurations of the social and natural sciences*: Abingdon, Oxon, New York, N.Y : Routledge.

Barry, A., Born, G., & Weszkalnys, G. (2008). Logics of interdisciplinarity. *Economy and Society, 37*(1), 20-49. doi:10.1080/03085140701760841

Blei, D. M. (2012). Probabilistic topic models. *Commun. ACM, 55*(4), 77-84. doi:10.1145/2133806.2133826

Boix Mansilla, V., Lamont, M., & Sato, K. (2016). Shared Cognitive–Emotional–Interactional Platforms: Markers and Conditions for Successful Interdisciplinary Collaborations. *Science, Technology, & Human Values, 41*(4), 571-612. doi:10.1177/0162243915614103

Bozeman, B., Gaughan, M., Youtie, J., Slade, C. P., & Rimes, H. (2016). Research collaboration experiences, good and bad: Dispatches from the front lines. *Science and Public Policy, 43*(2), 226-244. doi:10.1093/scipol/scv035

British Academy. (2013). British Academy response to the consultation on how to shape the role of Social Sciences and Humanities research in Horizon 2020, published by the Lithuanian Presidency of the European Union – June 2013 [Press release]. Retrieved from https://www.thebritishacademy.ac.uk/sites/default/files/BA%20response%20to%20Lithuanian%20Presidency%20consultation%20on%20SSH%20in%20Horizon%202020%20%28June%202013%29-final_0.pdf

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

Bruce, A., Lyall, C., Tait, J., & Williams, R. (2004). Interdisciplinary integration in Europe: the case of the Fifth Framework programme. *Futures, 36*(4), 457-470. doi:https://doi.org/10.1016/j.futures.2003.10.003

Buettel, J. C., Brook, B. W., Cole, A., Dickey, J., & Flies, E. J. (2018). Astro-ecology? Shifting the interdisciplinary collaboration paradigm. *Ecology and Evolution, 8*(19), 9586-9589. doi:10.1002/ece3.4455

Callard, F., & Fitzgerald, D. (2015). *Rethinking interdisciplinarity across the social sciences and neurosciences*: London : Palgrave Macmillan UK.

Callard, F., Fitzgerald, D., & Woods, A. (2015). Interdisciplinary collaboration in action: tracking the signal, tracing the noise. *Palgrave Communications, 1*, 15019. doi:10.1057/palcomms.2015.19

Castán Broto, V., Allen, A., & Rapoport, E. (2012). Interdisciplinary Perspectives on Urban Metabolism. *Journal of Industrial Ecology, 16*(6), 851-861. doi:10.1111/j.1530-9290.2012.00556.x

Castán Broto, V., Gislason, M., & Ehlers, M.-H. (2009). Practising interdisciplinarity in the interplay between disciplines: experiences of established researchers. *Environmental Science & Policy, 12*(7), 922-933. doi:https://doi.org/10.1016/j.envsci.2009.04.005

CEU. (2013). *Horizons for Social Sciences and Humanities Conference Report*. Retrieved from Mykolas Romeris University, Lithuania:

Checkland P 2000. Soft systems methodology: a thirty year retrospective. Systems Research and Behavioral Science, V17, Supplement 1, pp S11–S58.

Corbin, J. M., & Strauss, A. L. (1998). *Basics of qualitative research : techniques and procedures for developing grounded theory* (Second ed. ed.): Thousand Oaks, Calif. [etc.] : Sage Publications.

Corbin, J. M., & Strauss, A. L. (2008). *Basics of Qualitative Research (3rd ed.): Techniques and Procedures for Developing Grounded Theory*. Thousand Oaks, California.

DICE. (2015). *Exploring Interdisciplinarity Summary report of DICE at the James Hutton Institute*. Retrieved from Aberdeen, UK: https://www.researchgate.net/publication/277012530_Exploring_interdisciplinarity_Summary_report_of_DICE_at_the_James_Hutton_Institute

EASSH-EA. (2016). The Future of European Knowledge and the Role of Social Sciences and Humanities Research (Bratislava Declaration) [Press release]. Retrieved from http://www.eassh.eu/PDF/EASSH_Bratislava_final_def.pdf

EASSH-LERU. (2019). European Partnership Statement [Press release]. Retrieved from https://www.frias.uni-freiburg.de/en/news/current-news/joint-statement

EASSH. (2017). Integration of Social Sciences and Humanities in Horizon 2020 2nd Report published by the European Commission. A response from the European Alliance for SSH [Press release]. Retrieved from http://www.eassh.eu/PDF/PP_on_2report_on_SSH_integration_fnl.pdf

EASSH. (2018). Horizon 2020: Struggling with Interdisciplinarity. The 3rd SSH Integration Monitor Report Reveals the Truth about Top Down Interdisciplinarity [Press release]. Retrieved from http://www.eassh.eu/PDF/PP_on_3report_on_SSH_integrationFNL.pdf

EASSH. (2019). Interdisciplinary perspectives for Horizon Europe: Lessons from the 4th SSH Integration Monitor Report [Press release]. Retrieved from http://www.eassh.eu/sites/default/files/fichiers/positionpapers/easshsshintegration4threportfnl.pdf

EC. (2009). *Emerging Trends in Socio-economic Sciences and Humanities in Europe (The METRIS Report)*. Retrieved from BRussels: https://ec.europa.eu/research/social-sciences/pdf/other_pubs/metris-report_en.pdf

EC. (2015). *Integration of Social Sciences and Humanities in Horizon 2020: Participants, Budget and Disciplines* Retrieved from Luxembourg: https://ec.europa.eu/programmes/horizon2020/en/news/integration-social-sciences-and-humanities-horizon-2020-participants-budget-and-disciplines

EC. (2017). *Integration of Social Science and Humanities in Horizon 2020: Participants, Budget and Discipline* Retrieved from Luxembourg: https://op.europa.eu/en/publication-detail/-/publication/acac40f5-e84b-11e6-ad7c-01aa75ed71a1

Eigenbrode, S. D., O'rourke, M., Wulfhorst, J. D., Althoff, D. M., Goldberg, C. S., Merrill, K., . . . Bosque-Pérez, N. A. (2007). Employing Philosophical Dialogue in Collaborative Science. *BioScience, 57*(1), 55-64. doi:10.1641/b570109

ESRC Innogen Centre. (2011). *Key success factors in the quest for interdisciplinary knowledge* Retrieved from Edinburgh: https://core.ac.uk/reader/28965045

EURAB. (2004). Interdisciplinarity in Research. European Union Research Advisory Board.

Fam, D. and M. O'Rourke (Eds.) (2020), *Interdisciplinary and Transdisciplinary 'Failures' as Lessons Learned: A Cautionary*: Springer.

Felt, U. (2009). *Knowing and living in academic research: convergences and heterogeneity in research cultures in the European context*. Prague: Institute of Sociology of the Academy of Sciences of the Czech Republic.

FET Advisory Group. (2016). *The need to integrate the Social Sciences and Humanities with Science and Engineering in Horizon 2020 and beyond*. Retrieved from Luxembourg: https://ec.europa.eu/programmes/horizon2020/en/news/report-need-integrate-social-sciences-and-humanities-science-and-engineering-horizon-2020

Fitzgerald, D., Brunner, E., Koellinger, P., & Navarro, A. (2013). *'The Good, the Bad and the Ugly' – Understanding Collaboration between the Social Sciences and the Life Sciences. Strategic Workshop Report*. Retrieved from Strasbourg: http://www.esf.org/index.php?id=9388

Fitzgerald, D., & Callard, F. (2015). Social Science and Neuroscience beyond Interdisciplinarity: Experimental Entanglements. *Theory, Culture & Society, 32*(1), 3-32. doi:10.1177/0263276414537319

Fitzgerald, D., Jones, N., Choudhury, S., Friedner, M., Levin, N., Lloyd, S., . . . Raikhel, E. (2014). The collaborative turn: Interdisciplinarity across the human sciences.

Fitzgerald, D., Littlefield, M. M., Knudsen, K. J., Tonks, J., & Dietz, M. J. (2014). Ambivalence, equivocation and the politics of experimental knowledge: A transdisciplinary neuroscience encounter. *Social Studies of Science, 44*(5), 701-721. doi:10.1177/0306312714531473

Fletcher, I., & Lyall, C. (2019). Stem Cells and Serendipity: Defying Powerful Forces to Frustrate Feelings of Failure (under review). In D. Fam & M. O'Rourke (Eds.), *Interdisciplinary and Transdisciplinary 'Failures' as Lessons Learned: A Cautionary*: Springer

Flick, U. (2014). *The SAGE handbook of qualitative data analysis*: Los Angeles : SAGE.

France, E. F., Cunningham, M., Ring, N., Uny, I., Duncan, E. A. S., Jepson, R. G., . . . Noyes, J. (2019). Improving reporting of meta-ethnography: the eMERGe reporting guidance. *BMC Medical Research Methodology, 19*(1), 25. doi:10.1186/s12874-018-0600-0

France, E. F., Ring, N., Thomas, R., Noyes, J., Maxwell, M., & Jepson, R. (2014). A methodological systematic review of what's wrong with meta-ethnography reporting. *BMC Medical Research Methodology, 14*(1), 119. doi:10.1186/1471-2288-14-119

Freeman, M. (2017). *Modes of thinking for qualitative data analysis*: New York: New York : Routledge.

Fuller, K., & Lenton, E. (2018). *How to Find & Document Grey Literature Search Plan Template (online resource)*. University of Toronto Libraries, Gerstein Science Information Centre. Toronot, Canada. Retrieved from https://guides.library.utoronto.ca/c.php?g=577919&p=4123572

Graf, J. (2019) Bringing Concepts Together: Interdisciplinarity, Transdisciplinarity, and SSH Integration. fteval Journal for Research and Technology Policy Evaluation (48), 33-36.

GRC. (2016a). *Interdisciplinarity: Survey Report for the Global Research Council 2016 Annual Meeting*. Retrieved from Stockport, UK: https://www.globalresearchcouncil.org/fileadmin/documents/GRC_Publications/Interdisciplinarity_Report_for_GRC_DJS_Research.pdf

GRC. (2016b). Statement of Principles on Interdisciplinarity [Press release]. Retrieved from https://www.globalresearchcouncil.org/fileadmin/documents/GRC_Publications/Statement_of_Principles_on_Interdisciplinarity.pdf

Goldstone, A., & Underwood, T. (2014). Literary Studies Topic Modeling: Metadata and Modeling Outputs. In.

Guimarães, M. H., Pohl, C., Bina, O., & Varanda, M. (2019). Who is doing inter- and transdisciplinary research, and why? An empirical study of motivations, attitudes, skills, and behaviours. *Futures, 112*. doi:10.1016/j.futures.2019.10244

Hirsch Hadorn, G., Hoffman-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., . . . Zemp, E. (2008). *Handbook of transdisciplinary research*: [Berlin] : Springer.

Hirsch Hadorn, G., Kueffer, C., Bammer, G., van Kerkhoff, L., & Pohl, C. (2007). Towards a publication culture in transdisciplinary research. *GAIA, 16*(1), 22-26.

Hoffmann, S. (2019, March 3). [personal interview].

Hoffmann, S., Pohl, C., & Hering, J. G. (2017). Methods and procedures of transdisciplinary knowledge integration - empirical insights from four thematic synthesis processes. *Ecology and Society, 22*(1).

i4g. (2014). Laying the Ground for True Interdisciplinarity – Engaging the Social Sciences and Humanities across Horizon 2020 [Press release]. Retrieved from https://ec.europa.eu/research/innovation-union/pdf/expert-groups/i4g-reports/i4g_policy_brief__23_-_engaging_SSH_across_H2020.pdf

IHS. (2019). *SSH-Impact Pathways and SSH-Integration in EU Research Framework Programmes*. Retrieved from Vienna: https://www.ssh-impact.eu/wp-content/uploads/2019/06/3_Working-Paper-on-SSH-Impact-Pathways_Final.pdf

Institute of Advanced Study. (2015). *Evaluating Interdisciplinary Research: a practical guide*. Retrieved from Durham, UK: https://www.dur.ac.uk/resources/ias/publications/StrangandMcLeish.EvaluatingInterdisciplinaryResearch.July2015.pdf

INTREPID. (2016). *Funding Interdisciplinarity*. Retrieved from Barcelona, Spain: http://intrepid-cost.ics.ulisboa.pt/wp-content/uploads/2019/05/DG-RI-STSM-Report-to-Host.pdf

INTREPID. (2017a). *1st INTREPID Policy Brief. Recommendations on Integrating Interdisciplinarity, the Social Sciences and the Humanities and Responsible Research and Innovation in EU Research*. Retrieved from Barcelona, Spain: https://repositorio.ul.pt/handle/10451/29190

INTREPID. (2017b). *2nd INTREPID Report. Interdisciplinarity, the Social Sciences and the Humanities and Responsible Research and Innovation in EU Research*. Retrieved from Barelona, Spain: http://intrepid-cost.ics.ulisboa.pt/wp-content/uploads/2017/05/2ND_REPORT_EU-research-ID-SSH-RRI-Full-REPORT.pdf

INTREPID. (2017c). *3rd INTREPID Report. Interdisciplinary and transdisciplinary research: Finding the common ground of multi-faceted concepts*. Retrieved from Barcelona, Spain: http://intrepid-cost.ics.ulisboa.pt/wp-content/uploads/2017/05/3rd-INTREPID-Report-ID-TD-WG1-1.pdf

Irish Research Council. (2017). Irish Research Council Statement on 'STEAM' Research. Retrieved from http://research.ie/assets/uploads/2017/04/Irish-Research-Council-Statement-on-STEAM-Research.pdf

Irish Research Council. (2018). *Creative Connections Interdisciplinary Research Workshops. Synthesis Report*. Retrieved from Dublin, Ireland: http://research.ie/assets/uploads/2018/10/Irish-Research-Council-Creative-Connections-Synthesis-Report_2.pdf

Jahan, N., Naveed, S., Zeshan, M., & Tahir, M. A. (2016). How to Conduct a Systematic Review: A Narrative Literature Review. *Cureus, 8*(11), e864-e864. doi:10.7759/cureus.864

Jasanoff, S. (2013). Fields and Fallows: A political history of STS. In A. Barry & G. Born (Eds.), *Interdisciplinarity: Reconfigurations of the Social and Natural Sciences* (pp. 99-118). London: Routledge.

Klein, J. T. (1990). *Interdisciplinarity: history, theory, and practice*: Detroit : Wayne State University Press.

Klein, J. T. (1996). *Crossing boundaries: knowledge, disciplinarities, and interdisciplinarities*: Charlottesville, Va. [etc.] : University Press of Virginia.

Klein, J. T. (2004). Prospects for transdisciplinarity. *Futures, 36*(4), 515-526. doi:https://doi.org/10.1016/j.futures.2003.10.007

Klein, J. T. (2005). *Humanities, culture, and interdisciplinarity: the changing American academy*: Albany : State University of New York Press.

Klein, J. T. (2008). Evaluation of Interdisciplinary and Transdisciplinary Research: A Literature Review. *American Journal of Preventive Medicine, 35*(2, Supplement), S116-S123. doi:https://doi.org/10.1016/j.amepre.2008.05.010

Klein, J. T. (2010). *Creating Interdisciplinary Campus Cultures: A Model for Strength and Sustainability*. San Francisco: Jossey Bass and Association of American Colleges and Universities.

Klein, J. T. (2017). A Taxonomy of Interdisciplinarity. In *The Oxford handbook of interdisciplinarity* (Second edition ed., pp. 15-30): Oxford : Oxford University Press.

Klein, J. T. (2019, September 12). [personal interview].

Klein, J. T. (in press) Beyond Interdisciplinarity: Boundary Work, Communication, and Collaboration in the 21st Century, manuscript.

Koek, A. (2017). In/visible: the inside story of the making of Arts at CERN. Interdisciplinary Science Reviews, 42(4), 345-358. doi:10.1080/03080188.2017.1381225

Kulczycki, E., Engels, T. C. E., Pölönen, J., Bruun, K., Dušková, M., Guns, R., . . . Zuccala, A. (2018). Publication patterns in the social sciences and humanities: evidence from eight European countries. *Scientometrics, 116*(1), 463-486. doi:10.1007/s11192-018-2711-0

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*(1), 25-43. doi:10.1007/s11625-011-0149-x

Lau, L., & Pasquini, M. (2004). Meeting grounds: perceiving and defining interdisciplinarity across the arts, social sciences and sciences. *Interdisciplinary Science Reviews, 29*(1), 49-64. doi:10.1179/030801804225012437

Lawrence, R.J. (2015). Interdisciplinary Science: A coming of Age? The New York Academy of Sciences. New York Academy of Sciences Magazine, Spring, 3rd May 2016. http://www.akademien-schweiz.ch/td-net/td-Info/Publications.html?a=0111111. Retrieved in August 2016.

Leach, J. (2011). The self of the scientist, material for the artist: Emergent distinctions in an interdisciplinary collaboration. *Social Analysis, 55*(3), 143-163. doi:10.3167/sa.2011.550308

Lélé, S., & Norgaard, R. B. (2005). Practicing Interdisciplinarity. *BioScience, 55*(11), 967-975. doi:10.1641/0006-3568(2005)055[0967:Pi]2.0.Co;2

LERU. (2012). *Social Sciences and Humanities: Essential Fields for European Research in Horizon 2020*. Retrieved from Leuven, Belgium: http://heranet.info/assets/uploads/2017/11/Social-Sciences-and-humanities-Essential-Fields-for-European-Research-and-in-Horizon-2020.pdf

LERU. (2016). *Interdisciplinarity and the 21st century research-intensive university*. Retrieved from Leuven, Belgium: https://www.leru.org/files/Interdisciplinarity-and-the-21st-Century-Research-Intensive-University-Full-paper.pdf

LERU. (2017). *Beyond the Horizon: LERU's views on the 9th Framework Programme for Research and Innovation*. Retrieved from Leuven, Belgium: https://www.leru.org/files/Publications/Beyond_the_horizon_LERUs_views_on_FP9_final.pdf

Lowe, P., Phillipson, J., & Wilkinson, K. (2013). Why social scientists should engage with natural scientists. *Contemporary Social Science, 8*(3), 207-222. doi:10.1080/21582041.2013.769617

Lury, C. (2018). *The Routledge handbook of interdisciplinary research methods*: London: Routledge.

Lyall, C. (2019). *Being an Interdisciplinary Academic. How institutions shape university careers*: Palgrave Pivot.

Lyall, C., Bruce, A., Tait, J. & Meagher, L. (2011). *Interdisciplinary research journeys : practical strategies for capturing creativity*. London: Bloomsbury Academic.

Lyall, C., & King, E. (2013). *International good practice in the peer review of interdisciplinary research. Report of a scoping study conducted for the RCUK Research Group* Retrieved from Edinburgh: https://www.researchgate.net/publication/303370180_International_good_practice_in_the_peer_review_of_interdisciplinary_research

MacMynowski, D. P. (2007). Pausing at the Brink of Interdisciplinarity: Power and Knowledge at the Meeting of Social and Biophysical Science. *Ecology and Society, 12*(1).

Mäki, U. (2016). Philosophy of interdisciplinarity. What? Why? How? *European Journal for Philosophy of Science, 6*(3), 327-342. doi:10.1007/s13194-016-0162-0

Mayring, P. (2000). Qualitative Content Analysis. *2000, 1*(2). doi:10.17169/fqs-1.2.1089

Miller, T. R., Baird, T. D., Littlefield, C. M., Kofinas, G., Chapin, F. S., & Redman, C. L. (2008). Epistemological Pluralism: Reorganizing Interdisciplinary Research. *Ecology and Society, 13*(2), 46. doi:10.5751/ES-02671-130246

National Academy of Sciences, N. A. o. E., Institute of Medicine. (2005). *Facilitating Interdisciplinary Research*. Washington, DC: The National Academies Press.

NET4SOCIETY. (2013). *Policy Brief: Pulling it together on interdisciplinary research design*. Retrieved from Cologne, Germany https://www.net4society.eu/files/NET4SOCIETY3_320325_D3_1_PolicyBrief_final.pdf

Nicolescu, B. (2000). Transdisciplinarity and Complexity: Levels of Reality as Source of Indeterminacy.

Noblit, G. W., & Hare, R. D. (1988). *Meta-ethnography: synthesizing qualitative studies* (and R. Dwight Hare ed. Vol. Volume 11): Newbury Park, Calif. <etc.>: Newbury Park, Calif. <etc.> : Sage.

Nowotny, H. (2005). The Increase of Complexity and its Reduction. *Theory, Culture & Society, 22*(5), 15-31. doi:10.1177/0263276405057189

OECD. (1972). *Interdisciplinarity: problems of teaching and research*. Retrieved from Paris:

Osborne, P. (2015). Problematizing Disciplinarity, Transdisciplinary Problematics. *Theory, Culture & Society, 32*(5-6), 3-35. doi:10.1177/0263276415592245

Osborne, T. (2013). Inter that Discipline! In A. Barry & G. Born (Eds.), *Interdisciplinarity: Reconfigurations of the Social and Natural Sciences* (pp. 82-98). London: Routledge.

Piirma, P., & Valk, V. (2014). ART & SCIENCE – hybrid art and interdisciplinary research. Retrieved from

Pohl, C. (2008). From science to policy through transdisciplinary research. *Environmental Science & Policy, 11*(1), 46-53. doi:https://doi.org/10.1016/j.envsci.2007.06.001

Pohl, C. (2011). What is progress in transdisciplinary research? *Futures, 43*(6), 618-626. doi:https://doi.org/10.1016/j.futures.2011.03.001

Pohl, C., & Hirsch Hadorn, G. (2007). *Principles for designing transdisciplinary research : proposed by the Swiss Academies of Arts and Sciences*: MΓjnchen : Oekom Verlag.

Quan-Haase, A., Suarez, J. L., & Brown, D. M. (2015). Collaborating, Connecting, and Clustering in the Humanities:A Case Study of Networked Scholarship in an Interdisciplinary, Dispersed Team. *American Behavioral Scientist, 59*(5), 565-581. doi:10.1177/0002764214556806

Rabinow, P., & Bennett, G. (2012). *Designing human practices: an experiment with synthetic biology*: Chicago : The University of Chicago Press.

Robinson, B., Vasko, S. E., Gonnerman, C., Christen, M., O'Rourke, M., & Steel, D. (2016). Human values and the value of humanities in interdisciplinary research. *Cogent Arts & Humanities, 3*(1), 1123080. doi:10.1080/23311983.2015.1123080

Robinson, M. J. F., Robinson, T. E., Berridge, K. C., & Whybrow, P. C. (2014). Incentive Salience in Addiction and Over-Consumption. In S. D. Preston, M. L. Kringlbach, & B. Knutson (Eds.), *The Interdisciplinary Science of Consumption* (pp. 185-198): Mit Press.

Rust, C. (2007). Unstated contributions: How artistic inquiry can inform inter-disciplinary research. *International Journal of Design, 1*(3), 69-76.

Rust, C., Mottram, J., & Till, J. (2007). AHRC research review: Practice-led research in art, design and architecture. Retrieved from

Russell Group. (2018). *Russell Group position paper - Framework Programme 9*. Retrieved from London: https://russellgroup.ac.uk/media/5694/russell-group-position-paper-on-fp9-march-2018.pdf

Schreier, M. (2014). Ways of Doing Qualitative Content Analysis: Disentangling Terms and Terminologies. *2014, 15*(1). doi:10.17169/fqs-15.1.2043

Scott, J. (1990). *A Matter of Record: Using Documentary Sources in Social Research*. Cambridge: Polity Press.

Snow, C. P. (1964). *The two cultures* (14th printing ed.): Cambridge : Cambridge University Press.

Spaapen, J., Dijstelbloem, H., & Wamelink, F. (2007). *Evaluating research in context. A method for comprehensive research assessment (2nd edition)*. The Hague: Consultative Committee of Sector Councils for Research and Development (COS), the Netherlands.

Spaapen, J., Vienni, B., A. Buchner, and C. Pohl (2020) Report on Survey among interdisciplinary and transdisciplinary researchers and post-survey interviews with policy stakeholders, H2020 Project "Shaping interdisciplinary practices in Europe". www.shapeid.eu

STIS. (2008). Short Interdisciplinary Guide 5: Troubleshooting some common interdisciplinary research management challenges. Edinburgh: Science Technology and Innovation Studies, University of Edinburgh.

STIS. (2011a). Short Interdisciplinary Guide 8: A Short Guide for Funders of Interdisciplinary Research. Edinburgh: Science Technology and Innovation Studies, University of Edinburgh.

STIS. (2011b). Short Interdisciplinary Guide 9: A Short Guide to Evaluating Interdisciplinary Research. Edinburgh: Science Technology and Innovation Studies, University of Edinburgh.

td-net. (2011). *Questions to evaluate inter- and transdisciplinary research proposals*. Retrieved from Berne, Switzerland:

td-net. (2020). td-net. Retrieved from http://www.transdisciplinarity.ch/en/td-net/Aktuell/td-net-News.html

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*. Retrieved from Brighton: https://sro.sussex.ac.uk/id/eprint/65332/1/2016HEFCE_Landscape%20review%20of%20UK%20interdisciplinary%20research.pdf

Trinity College Dublin. (2016). *Interdisciplinarity for Impact. Workshop Report*. Retrieved from Dublin, Eire: https://www.tcd.ie/trinitylongroomhub/assets/documents/2018-FinalReport.pdf

Tuana, N. (2013). Embedding philosophers in the practices of science: bringing humanities to the sciences. *Synthese, 190*(11), 1955-1973. doi:10.1007/s11229-012-0171-2

Underwood, T., & Goldstone, A. (2012, December 14). What can topic models of PMLA teach us about the history of literary scholarship? Retrieved 16 December 2012, from The Stone and the Shell website: http://tedunderwood.com/2012/12/14/what-can-topic-models-of-pmla-teach-us-about-the-history-of-literary-scholarship/

van Rijnsoever, F. J., & Hessels, L. K. (2011). Factors associated with disciplinary and interdisciplinary research collaboration. *Research Policy, 40*(3), 463-472. doi:https://doi.org/10.1016/j.respol.2010.11.001

Vienni Baptista, B., Maryl, M., Wciślik, P., Fletcher, I., Buchner, A., Wallace, D. and Pohl, C. (2019) Preliminary Report of Literature Review on Understandings of Interdisciplinary and Transdisciplinary Research, H2020 Project "Shaping interdisciplinary practices in Europe". www.shapeid.eu

Weingart, P. (2000) Interdisciplinarity: The paradoxical discourse. In P. Weingart and N. Sterh (eds.) *Practising interdisciplinarity.*Toronto: University of Toronto Press, pp. 23 - 40.

ZSI. (2019). *Social Sciences and Humanities research matters - Guidelines on how to successfully design, and implement, mission-oriented research programmes.* Retrieved from Vienna, Austria: https://www.ssh-impact.eu/wp-content/uploads/2019/01/guidlines_SSH_FINAL.pdf

Appendix A

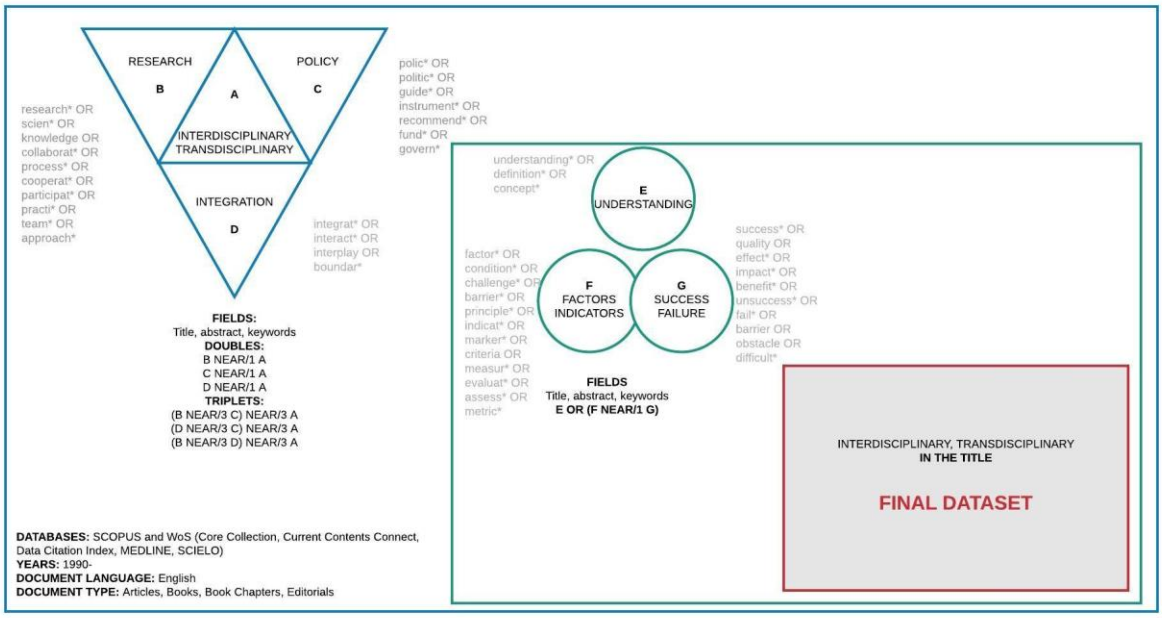

Figure 11 Query workflow for Scopus and WoS. Blue rectangle represents Step 1, green represents Step 2 and red represents step 3. Additional constraints (Step 4) are listed in bottom-left corner.

Appendix B

Table 8 Sets of keywords for the academic literature review

Set A	Set B	Set C	Set D	Set E	Set F	Set G
IDTERDISCIPLINARITY/ TRANSDISCIPLINARITY	RESEARCH	POLICY	INTEGRATION	UNDERSTANDING	FACTORS/ INDICATORS	SUCCESS/ FAILURE
interdisciplinar* transdisciplinar*	research* scien* knowledge collaborat* process* cooperat* participat* practi* team* approach	polic* politic* guide* instrume nt* recomme nd* 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*

Appendix C

Table 9 Schema of data processing from the list of journal titles with weight and attributed ASJC codes (left), to disciplinary matrix (right)

TITLE	Weight	ASJC1	ASJC2	ASJC3		D1	D2	D3	D4
Journal 1	7	D3	D1	D2	**D1**	0	7	10	3
Journal 2	4	D2			**D2**	7	4	7	2
Journal 3	2	D2	D4		**D3**	10	7	0	3
Journal 4	3	D1	D3	D4	**D4**	3	2	3	0

Table 10 SHAPE-ID keyword sets for contextual analysis

SHAPE-ID Keyword groups	Context words (keyword groups indicators)
Understanding	understanding, understandings, definition, definitions, concept, concepts, meaning, as, by, is, mean, means.
Policy	policy, policies, policymaker, policymakers, guide, guides, guidelines, instrument, recommends, recommendation, recommended, recommending, recommend, funds, funding, funded, governance, govern, governs, governing, governed.
Integration	integration, integrated, integrates, integrating, integrate, interaction, interact, interacts, interacting, interacted, interplay, interplays, interplaying, interplayed, boundary, boundaries.
Factors	factor, factors, factoring, factored, condition, conditions, conditioning, conditioned, challenge , challenges, challenged, challenging, barrier, barriers, principles, principle, principled, indicate, indicating, indicates, indicated, indicator, marker, markers, criteria, criterion, measure, measures, measurement, measurements, evaluate, evaluates, evaluated, evaluating, evaluation, assess, assesses, assessed, assessing, assessment, metric, metrics.
Success/Failure	success, successes, successful, succeed, succeeds, succeeded, quality, qualities, effect, effective, impact, impacts, impacted, benefit, benefits, benefited, benefiting, unsuccessful, fail, failed, failing, fails, failure, barrier, barriers, obstacle, obstacles, difficult, difficulties.
Research	research, researcher, researchers, researched, researching, science, scientific, sciences, knowledge, collaborative, collaboration, collaborations, collaborate, collaborates, collaborated, process, processes, cooperate, cooperates, cooperated, cooperating, cooperation, cooperations, participant, participants, participatory, participate, participates, participated, participating, practice, practicing, practiced, practices, team, teams, teamed, approach, approaches, approaching, approached.

Appendix D

Table 11 Annotated 50 topics of the LitReview corpus

TOPIC	CENTRALITY % | No. items		DISCIPLINE TREND	IDR/TDR TREND	SIG_WORDS
0	16%	637	Social Sciences	IDR	university; interdisciplinary; faculty; academic; education; University; student; teaching; program; universities; institution; department; sustainability
1	22%	851	Multidisciplinary	IDR	interdisciplinary; discipline; disciplinary; research; knowledge; boundary; work; multiple; interdisciplinarity
2	14%	565	Engineering		design; energy; engineering; process; product; paper; development; building; system; simulation; technical; efficiency; innovation
3	19%	725	Multidisciplinary	IDR - INTEGRATION	project; research; interdisciplinary; programme; challenge; process; experience
4	19%	748			problem; complex; approach; world; solution; science; real; solving; discipline
5	19%	734	Social Sciences	IDR	study; result; interdisciplinary; participant; survey; method; data; interview; qualitative; level; analysis; response; group; perception
6	15%	601	Environmental Science		environmental; management; ecosystem; conservation; ecological; service; natural; resource; ecology; forest; human; biodiversity
7	19%	739	Social Sciences	IDR	student; interdisciplinary; teacher; teaching; school; curriculum; education; skill; experience; learning
8	17%	653	Health Professions		factor; risk; event; activity; approach; behavior; study; mechanism; safety; physical; related; understanding
9	16%	612	Environmental Science, Social Sciences		system; water; urban; governance; social; approach; city; ecological; resilience; management
10	17%	658	Social Sciences		group; year; study; effect; term; result; control; woman; significant; age
11	15%	594	Health Professions, Nursing, Medicine		health; public; disease; population; Health; animal
12	21%	817	Multidisciplinary	IDR	research; paper; study; interdisciplinary; approach; theoretical; methodology; purpose; framework; practical; literature; methodological; implication; case; concept;

					theory; finding
13	17%	679	Arts and Humanities		cultural; culture; social; people; place; historical; context; life; material; language; approach
14	16%	616	Environmental Science, Agricultural and Biological Sciences, Arts and Humanities		data; soil; analysis; study; water; site; source
15	19%	751			quality; evaluation; review; assessment; method; outcome; study; literature; result; indicator; evidence; criterion; data
16	15%	568	Agricultural and Biological Sciences		food; production; development; system; agricultural; impact; economic; agriculture; product; potential
17	19%	761	Multidisciplinary	TDR	transdisciplinary; research; sustainability; transdisciplinarity; approach; challenge
18	17%	656	Neuroscience, Psychology	IDR/TDR	model; cognitive; concept; function; disability; work; psychological; system; person; brain; models
19	18%	692	Multidisciplinary	IDR - INTEGRATION	collaboration; interdisciplinary; research; communication; collaborative; researchers; discipline; role
20	17%	678	Social Sciences		community; research; policy; practice; development; local; challenge; knowledge
21	19%	751	Multidisciplinary	IDR/TDR - INTEGRATION	research; interdisciplinary; field; knowledge; integration; scientific; discipline; topic; area; researchers; method
22	18%	720			term; individual; definition; aspect; problem; context; relationship; difference; development; interaction; core; paper; specific
23	19%	745	Arts and Humanities		study; history; scholar; american; gender; article
24	16%	632	Health Professions, Nursing, Medicine	IDR	care; health; team; interdisciplinary; clinical; service; patient; nurse; professional; practice; healthcare; medical; provider
25	16%	645	Multidisciplinary	IDR - INTEGRATION	team; member; interdisciplinary; meeting; leadership; teamwork
26	17%	647	Multidisciplinary	IDR - POLICY	interdisciplinarity; research; interdisciplinary; analysis; journal; discipline; field; publication; citation; impact; science; article
27	15%	599	Social Sciences	IDR	program; training; interdisciplinary; graduate; student; experience; skill

28	15%	574	Social Sciences, Business, Management and Accounting		landscape; local; regional; spatial; land; development; tourism; area; global; region; scenario; coastal; change; temporal
29	20%	798	Social Sciences	IDR	theory; discipline; psychology; sociology; social; political; study; approach; economics; book; interdisciplinary
30	15%	595	Medicine, Nursing, Health Professions	IDR	patient; treatment; clinical; cancer; interdisciplinary; medical; therapy
31	20%	774	Social Sciences, Environmental Science	IDR	human; science; life; scientific; society; nature; natural; world; century
32	18%	686	Multidisciplinary	IDR - INTEGRATION	knowledge; transdisciplinary; process; stakeholder; research; project; phase; approach
33	18%	700	Computer Science		information; technology; tool; system; approach; computer; concept; development; data; application
34	16%	613	Environmental Science		change; climate; challenge; global; issue; environmental; impact
35	16%	615	Biochemistry, Genetics and Molecular Biology	IDR - UNDERSTANDING	science; biology; field; interdisciplinary; engineering; understanding; concept; physical; biological; chemistry; chemical; physic
36	18%	706	Social Sciences, Arts and Humanities	IDR - UNDERSTANDING	literature; question; issue; text; interdisciplinary; article; section; discussion; ethical; chapter; sport; method; understanding; analysis; conceptual
37	19%	751	Multidisciplinary	IDR	knowledge; practice; concept; interdisciplinarity; production; process; article; paper; theoretical; scientific; science
38	17%	667	Social Sciences		network; conflict; social; level; analysis; relationship; group; dynamics; factor; cooperation; approach; complex; set
39	8%	296	ARTEFACT	ARTEFACT	de; em; se; la; las; les; le; van; question; social
40	13%	491	Medicine		child; family; early; mental; intervention; therapy; physical; experience; childhood; article; health; understanding; occupational; service
41	17%	658	Arts and Humanities		art; field; practice; author; book; music; concept; idea; media; visual; creative; work; space; paper; discipline
42	18%	685	Social Sciences	IDR - UNDERSTANDING	practice; social; work; professional; interdisciplinary; group; model; interaction; worker; understanding; role
43	15%	573	Social Sciences		international; law; power; legal; state;

					country; South; economic; relation; violence; article; issue; rights; justice; Africa
44	16%	636	Social Sciences	IDR - UNDERSTANDING	education; interdisciplinary; educational; development; article; professional; learning; implementation; higher; approach
45	12%	454	ARTEFACT	ARTEFACT	decision; U+05DC; resource; process; U+05EA; task; internal; specific; special; EA; time; external; making; make; management
46	18%	693			research; science; workshop; funding; National; career; institution; collaboration
47	19%	736	Multidisciplinary	IDR - UNDERSTANDING	study; process; case; analysis; understanding; interdisciplinary; framework; potential; function; movement; result
48	18%	685	Social Sciences, Arts and Humanities		social; science; sciences; scientist; natural; scientific; research; humanity; issue; understanding
49	12%	463	Medicine, Nursing, Health Professions	IDR	patient; pain; care; intervention; interdisciplinary; rehabilitation; study; quality; hospice; result

Table 12 Annotated 50 topics of the GreyLit corpus

TOPIC	CENTRALITY % | No. items		DISCIPLINE TREND	IDR/TDR TREND	SIG_WORDS
0	19%	104	Social Sciences		political; european; social; Europe; form; economic; state; model; governance; EU; issue; process; country
1	25%	135			research; researchers; university; training; student; universities; network; academic; career; opportunity; doctoral; project; researcher
2	9%	46	Social Sciences, Arts and Humanities	IDR - POLICY - INTEGRATION	project; Ssh; partner; topic; SSH; integration; share; discipline; total; country; budget
3	16%	89	Multidisciplinary	IDR/TDR - INTEGRATION - UNDERSTANDING	research; knowledge; problem; interdisciplinarity; transdisciplinary; integration; discipline; question; understanding; inter; practice; approach; process; transdisciplinarity
4	9%	50	Multidisciplinary	IDR/TDR	publication; journal; Idr; article; country; top; UK; citation; number; research; collaboration; Sciences
5	15%	81	Multidisciplinary	IDR	faculty; interdisciplinary; program; department; institution; student; graduate;

					member; center; year
6	23%	126	Arts and Humanities, Social Sciences		social; sciences; humanity; research; world
7	34%	184	Multidisciplinary	IDR/TDR	problem; time; case; discipline; general; group; model; research; interdisciplinarity; activity; type; fact
8	30%	164			research; evaluation; impact; assessment; development; quality; process; measure
9	13%	69	Arts and Humanities, Computer Science		digital; data; access; tool; humanity; standard; open; research; project; publication; infrastructure
10	19%	103	Multidisciplinary	IDR	knowledge; discipline; interdisciplinary; disciplinary; model; research; study; production; interdisciplinarity; science; field; theory
11	16%	89			research; project; policy; activity; area; development; specific; topic; scale; objective; era; role
12	12%	66	Arts and Humanities		art; cultural; student; culture; creative; school; synthesis; scientific; design; international
13	22%	120	Multidisciplinary	IDR	discipline; disciplinary; interdisciplinary; career; structure; project; evidence; academic; problem; work; good
14	32%	171			research; funding; grant
15	17%	94			data; infrastructure; research; access; information; service; survey; administrative
16	14%	75			University; College; School; London; social; de
17	10%	55	Multidisciplinary	IDR - POLICY	project; research; interdisciplinary; proposal; Academy; council; interdisciplinarity
18	11%	59			open; science; universities; LERU; research; policy; institution; access; paper; practice
19	18%	97			collaboration; group; network; work; participant; member; dimension; intellectual; workshop; common; success
20	6%	32	ARTEFACT	ARTEFACT	Academy; Sciences; Institute; Germany; Akademie; Wissenschaften; Studies; der; und
21	20%	108	ARTEFACT	ARTEFACT	University; research; professor; director; National; Research; science; Institute; Sciences; Interdisciplinary; Professor; Dr.
22	25%	137	Multidisciplinary	IDR - POLICY	research; interdisciplinary; discipline;

					interdisciplinarity; disciplinary; academic; universities; challenge
23	20%	107	Social Sciences, Arts and Humanities		research; Humanity; Sciences; Social; Science; social; european; Humanities; European; Research; challenge
24	21%	113			student; university; education; teaching; universities; subject; discipline; knowledge; year; study; higher; system
25	19%	103	Environmental Science, Social Sciences		change; climate; global; policy; societal; impact; social; issue; governance; environmental; research; society
26	5%	28	Multidisciplinary	IDR - POLICY	respondent; funder; IDR; researchers; survey; research; influential; response; area; major; researcher; Idr; minor
27	16%	87	Arts and Humanities, Social Sciences		Ssh; Horizon; SSH; societal; challenge; programme; SSh; report; funding; integration; social
28	14%	75	Health Professions, Nursing, Medicine		health; social; life; mental; care; Health; people; study; medical; child; year; age; family
29	10%	53	Multidisciplinary	IDR - POLICY	IDR; Idr; researchers; research; funding; institution; support; REF; centre; researcher
30	13%	73			innovation; EU; mission; R&I; impact; national; future; investment
31	11%	62			project; research; academy; number; country; staff; survey; european; institution
32	13%	68	Agricultural and Biological Sciences, Energy		food; energy; security; challenge; sustainable; cultural; tion; practice; consumer
33	18%	98	Multidisciplinary	IDR	panel; proposal; review; evaluation; peer; process; assessment; interdisciplinary; expert; application; reviewer; quality
34	19%	101			economic; policy; social; growth; development; area; public; market; system; economy; country; future; major; effect
35	23%	122	Multidisciplinary	IDR/TDR - INTEGRATION	interdisciplinary; research; project; team; Interdisciplinary; interdisciplinarity; challenge
36	23%	122			question; research; ethical; ethic; societal; challenge; development; technology; role; innovation; scientific; debate; problem
37	13%	71	Multidisciplinary	IDR/TDR - INTEGRATION	research; interdisciplinary; discipline; kind; team; problem; user; vignette; project
38	21%	116	Arts and Humanities, Social Sciences		Europe; european; social; research; cultural; society; citizen; development;

					world; global
39	26%	140	Social Sciences		science; social; scientific; research; scientist; result
40	19%	104	Social Sciences		science; system; level; education; structure; society; research; scientific; development; knowledge; type
41	9%	47	Multidisciplinary	IDR/TDR - POLICY	project; evaluation; result; objective; question; program; criterion; proposal; product; transdisciplinary; contribution; management
42	16%	84			innovation; knowledge; public; expert; report; policy; problem; sector; boundary; business; team
43	21%	113	Arts and Humanities, Social Sciences		history; field; study; sciences; social; economics; psychology; sociology; law; science; philosophy; language
44	16%	86			science; society; public; communication; scientific; technology; issue; scientist; knowledge
45	14%	76	Multidisciplinary	IDR - POLICY - INTEGRATION	research; Interdisciplinary; program; IDR; field; Idr; discipline; organization; National; researchers; team
46	16%	84			country; national; report; public; institution; related; policy; decision; debate; activity
47	17%	91	ARTEFACT	ARTEFACT	J.; science; research; M.; R.; S.; A.; D.; c.; Research; L.; Interdisciplinary; T.; W.; Press
48	22%	117			european; Europe; programme; Horizon; innovation; research; European; EU; member; ERC; project; EC
49	11%	58	Medicine		research; trust; programme; medicine; medical; discussion; UK; session; funding; health; number; history; Medical; humanity

Commentary on Table 11 and Table 12

- **Centrality** (column CENTRALITY): expresses the percentage of items within the entire corpus, for which the significance of a given topic was weighted above average. E.g. Topic 2 in the LitRev corpus was significantly present in 14 per cent of items in the corpus (565 items out of 3910 in total).
- **Disciplinary Trend** (column DISCIPLINE TREND): a topic was tagged with ASJC discipline code or codes when words in the topic signaled a disciplinary valency of the topic. The entire set of words was taken into consideration for analysis. E.g. in Topic 43, disciplinary trend towards social sciences was ascertained based on the presence of words such as: international, law, power, legal; state. A topic was labeled as "multidisciplinary" if it did not present a disciplinary trend, and contained words related to IDR/TDR (see below).

- **IDR/TDR Trend** (column IDR/TDR TREND): topics were tagged with keywords corresponding to SHAPE-ID main categories of analysis: IDR/TDR , POLICY, INTEGRATION, UNDERSTANDING, if words related to these categories were significantly present in a given topic. Two additional criteria were applied: (1) within each topic, only words weighted above average were taken into consideration (see below); (2) only if words related to IDR/TDR were significantly present, other tags were applied. The latter criterion was defined in in order to avoid false positives: only if words related to e.g. UNDERSTANDING do co-occur with words related to IT/TD, we can say with some probability that the topic corresponds to understandings of IT/TD (and not the understandings of other subject matter). For that reason, e.g. topic 46 in the LitRev corpus was not coded in this category, even though in contains words such as "research; science; workshop; funding; National; career; institution; collaboration."
- **Significant words** (SIG_WORDS): a list of the words that were weighted above average within the given topic. Number of words that pass this threshold vary depending on a topic.

Appendix E

Table 13 Frequencies of SHAPE-ID keyword sets in corpora

Corpus	Search keyword	Context	Raw frequency	Normalised frequency per 100k words
LitReview	interdisciplinar*	Understanding	594	84.75
LitReview	transdisciplinar*	Understanding	220	31.39
LitReview	interdisciplinar*	Research	3518	501.95
LitReview	transdisciplinar*	Research	1168	166.65
LitReview	interdisciplinar*	Policy	118	16.84
LitReview	transdisciplinar*	Policy	24	3.42
LitReview	interdisciplinar*	Integration	256	36.53
LitReview	transdisciplinar*	Integration	97	13.84
LitReview	interdisciplinar*	Factors	513	73.19
LitReview	transdisciplinar*	Factors	151	21.54
LitReview	interdisciplinar*	Success/Failure	438	62.49
LitReview	transdisciplinar*	Success/Failure	99	14.13
H2020Projects	interdisciplinar*	Understanding	56	10.71
H2020Projects	transdisciplinar*	Understanding	5	0.96
H2020Projects	interdisciplinar*	Research	1043	199.41
H2020Projects	transdisciplinar*	Research	50	9.56
H2020Projects	interdisciplinar*	Policy	21	4.01
H2020Projects	transdisciplinar*	Policy	5	0.96
H2020Projects	interdisciplinar*	Integration	75	14.34
H2020Projects	transdisciplinar*	Integration	3	0.57
H2020Projects	interdisciplinar*	Factors	53	10.13
H2020Projects	transdisciplinar*	Factors	4	0.76
H2020Projects	interdisciplinar*	Success/Failure	60	11.47
H2020Projects	transdisciplinar*	Success/Failure	2	0.38
GreyLit	interdisciplinar*	Understanding	552	39.08
GreyLit	transdisciplinar*	Understanding	77	5.45
GreyLit	interdisciplinar*	Research	4004	283.47
GreyLit	transdisciplinar*	Research	317	22.44
GreyLit	interdisciplinar*	Policy	438	31.01

GreyLit	transdisciplinar*	Policy	8	0.57
GreyLit	interdisciplinar*	Integration	163	11.54
GreyLit	transdisciplinar*	Integration	22	1.56
GreyLit	interdisciplinar*	Factors	768	54.37
GreyLit	transdisciplinar*	Factors	77	5.45
GreyLit	interdisciplinar*	Success/Failure	537	38.02
GreyLit	transdisciplinar*	Success/Failure	33	2.34
H2020Calls	interdisciplinar*	Understanding	7	0.31
H2020Calls	transdisciplinar*	Understanding	3	0.13
H2020Calls	interdisciplinar*	Research	176	7.88
H2020Calls	transdisciplinar*	Research	34	1.52
H2020Calls	interdisciplinar*	Policy	15	0.67
H2020Calls	transdisciplinar*	Policy	6	0.27
H2020Calls	interdisciplinar*	Integration	7	0.31
H2020Calls	transdisciplinar*	Integration	6	0.27
H2020Calls	interdisciplinar*	Factors	26	1.16
H2020Calls	transdisciplinar*	Factors	1	0.04
H2020Calls	interdisciplinar*	Success/Failure	8	0.36
H2020Calls	transdisciplinar*	Success/Failure	1	0.04
OpenAire	interdisciplinar*	Understanding	3375	17,15
OpenAire	transdisciplinar*	Understanding	465	2,36
OpenAire	interdisciplinar*	Research	25555	129,89
OpenAire	transdisciplinar*	Research	3134	15,93
OpenAire	interdisciplinar*	Policy	757	3,85
OpenAire	transdisciplinar*	Policy	109	0,55
OpenAire	interdisciplinar*	Integration	1907	9,69
OpenAire	transdisciplinar*	Integration	230	1,17
OpenAire	interdisciplinar*	Factors	2593	13,18
OpenAire	transdisciplinar*	Factors	303	1,54
OpenAire	interdisciplinar*	Success/Failure	1491	7,58
OpenAire	transdisciplinar*	Success/Failure	113	0,57

Appendix F

Figure 12 is a network representation of connections between 100 most important tags (according to their weighted degree).

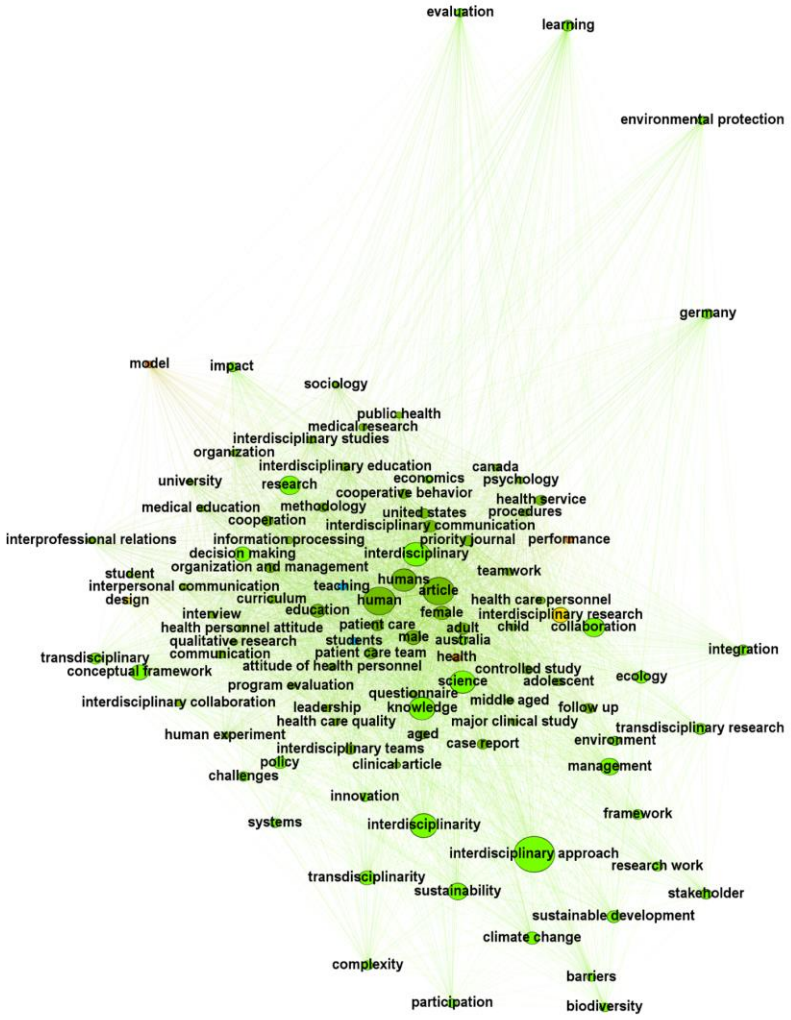

Figure 12 Network of connections between 100 most important tags in Literature Review sample

Appendix G

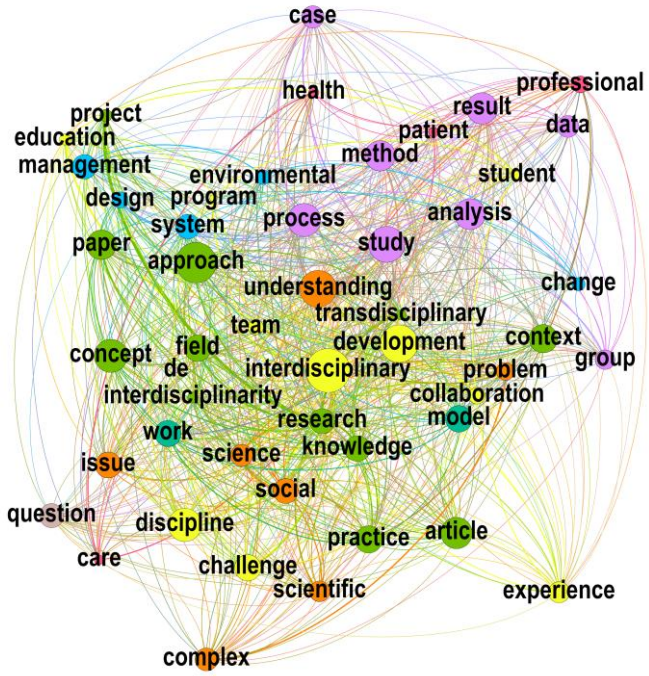

Figure 13 Relationships between 100 most important words in 50 topics of the LitReview corpus (based on weighted degree)

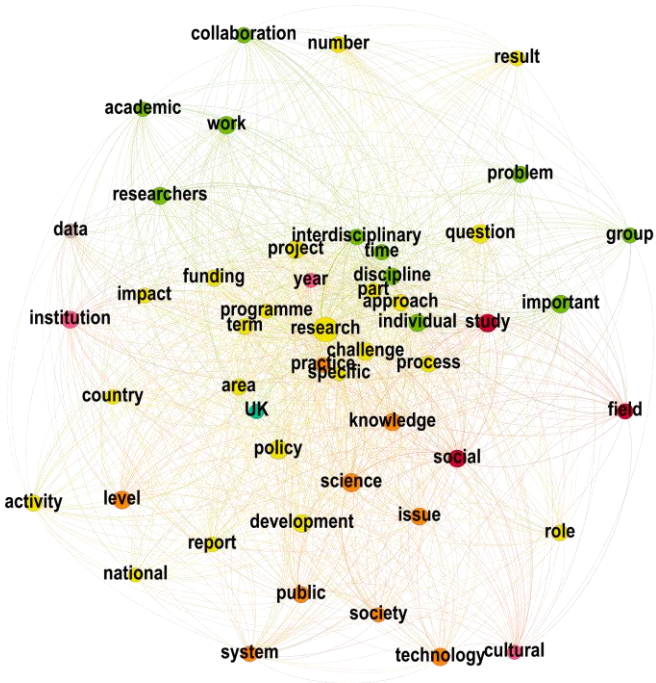

Figure 14 Relationships between 100 most important words in 50 topics of the GreyLit corpus (based on weighted degree)

Appendix H

Table 14 Examples of factors that influence IDR/TDR with their positive and negative implications for AHSS integration

FACTOR	FACILITATES IDR/TDR (POSITIVE)	HINDERS IDR/TDR (NEGATIVE)	EXAMPLES & IMPLICATIONS FOR AHSS
Academic Tribalism	This role implies understanding (Castán Broto et al., 2009, p. 930): • "the preoccupations of each member of a team when developing concrete solutions" (Castán Broto et al., 2009, p. 930), • "the methodological tools available within each discipline, which helped researchers building realistic expectations about what a particular discipline has the capacity to address" (Castán Broto et al., 2009, p. 930). • "the conversations each discipline is having about the subject being studied" (Castán Broto et al., 2009, p. 930). • "the professional costs and benefits for team members of doing interdisciplinary research and using this information to develop deliverables and/or publications that facilitate the career development of all team members" (Castán Broto et al., 2009, p. 930). • -"(…) mastering multiple approaches and methodologies" (Lau & Pasquini, 2013, p. 52).	• "Uniformity of point of view and rejection of interdisciplinarity" (Sternberg, 2014 in Robinson et al., 2016, p.3). • "Negotiating positions within and across rigid research groups to seek employment and secure research" (Lau & Pasquini, 2013, p. 60).	• "Each project member can play the role of the "outsider within" for other members by virtue of their different worldviews so long as differences in worldview are harnessed in a way that illuminates potentially divisive variations in perspective" (Robinson et al., 2016, p.3).
Assumptions about other disciplines	• "The sense of being an outsider is equally valid whether one is moving into the social sciences from the arts or from the sciences" (Lau & Pasquini, 2013, p. 51).	• "Many social science theories and their adherents have tended to ignore or underplay the constraints imposed by natural resources and processes on human actions" (Lelé & Norgaard, 2005, p. 971).	• "Scholars claim that the public task of the humanities is to unmask power structures, not to support them. This self-understanding of the humanities prevents productive collaboration with policy-making from taking place" (Brom, 2019, p. 6).

Career Path	• "New avenues of thought and collaboration" (Lau & Pasquini, 2013, p. 52). • "Linked to a specific ways of perceiving science" (Guimaraes et al., 2019, p. 12). • Being lucky or fortunate in one's career (Lyall, 2019, p. 29).	• "Becoming an interdisciplinary scholar can be uncomfortable and painful process" (Lau & Pasquini, 2013, p. 52). • "Requires much intellectual and personal negotiation" (Lau & Pasquini, 2013, p. 52). • "A hazardous endeavour especially for those at an early stage in their career" (Fitzgerald, 2012, p. 4). • "Risk to individual's career" (Fitzgerald, 2012, p. 5). • "Reap lower career rewards" (Augsburg, 2014 in Guimaraes et al., 2019, p. 5). • "(…) involves the complex and ambivalent transfer of cultures, methods, techniques, fantasies, and habits" (Callard and Fitzgerald, 2015, p. 72).	• Two groups of ID researchers (Lyall, 2019, p. 24): (1) "Problem solvers" focused on the role of interdisciplinarity in solving problems; and (2) "Individual careers" focused on the role of interdisciplinarity in the context of their own careers.
Cognitive	• "Markers of successful interdisciplinary collaboration are: (1) cross-disciplinary exchange that transforms individual research, (2) the project's intellectual generativity beyond its formal purpose and funding period, (3) the development of shared intellectual tools that serve as the common ground for exchange, (4) excellence and relevance of the disciplinary expertise contributing to the collaborative research, and (5) knowledge advancement through integrating different disciplinary perspectives" (Boix Mansilla et al., 2016, p. 590).	• "Assessing others' expertise" (Fitzgerald, 2012, p. 24). • "Variability of standards" (Fitzgerald, 2012, p. 24). • "Lack of common language to discuss core concepts" (Lowe et al., 2013, p. 216). • "Lack of shared research methods or methodologies to apply to the topic" (Lowe et al., 2013, p. 216).	• "The cognate problem of access to data: for example, life scientists may find themselves inadvertent gate-keepers of genetic data" (Fitzgerald, 2012, p. 28). • "Solutions to these challenges, ranging from accompanying colleagues from other disciplines on their field visits through to reading groups where papers from different backgrounds were discussed" (Lowe et al., 2013, p. 217). • Programme-level workshops on interdisciplinary research methods and approaches to data integration (Lowe et al., 2013, p. 218).
Current Policies	• "Consensus within national and international research policy that many striking research advances take place at the boundaries between disciplines, leading in some cases to the emergence of new fields" (Lyall, 2019, p. 2).	• "It appears that policies establishing formal norms to regulate or facilitate interdisciplinary research could be unproductive if they lead to the demise of interplay among disciplines" (Castán Broto et al., 2009, p. 931). • "The researchers are concerned with establishing and maintaining boundaries between the academic and other policy cultures, and consider the academic policy culture to be responsible for reorganizing knowledge" (Pohl, 2008, p. 52).	
Dealing with Complexity	• "Complexity-led collaboration": "recognition of the inherent complexity of some phenomenon,	• "We are engaged in a contradictory process when encountering, analysing and dealing with complexity.	• "The emergent interface that confronts us as social scientists is the co-evolutionary process of

	proceeds on the basis that such complex phenomena can only be adequately understood if analysed from a variety of perspectives" (Fitzgerald, 2012, p. 19). • "Pressure to encourage interdisciplinary research also comes from the need to solve complex socio-scientific problems, where one discipline on its own cannot provide an answer" (Bruce et al., 2004, p. 458). • "The resolution of besetting problems calls for the active engagement of a wide range of sciences" (Lowe et al., 2013, p. 207).	We face opposite tendencies that indicate an inbuilt dynamic, if not a race, between the increase of complexity and its reduction" (Nowotny, 2005, p. 15).	science and society. How has Society come to know, manipulate and control Nature, and how does Society evolve as a consequence of its own approaches to Nature? Such an interface may turn out to be the strategic research site to study how scientific understanding, intervention and societal meaning through social action and the social shaping of science and technology are the two sides of complexity that lead to its continued increase – and its reduction" (Nowotny, 2005, p. 20).
Dynamics of Power	• "There is much to be gained from interdisciplinary collaborators at least becoming more alive to power dynamics, to how they work in their own right, but also to how they structure the emergence of the problem-space as such" (Callard & Fitzgerald, 2015, p. 109).	• "ID as a practice of subjugation our state of subjugation (such as it is) quite clearly has arisen from our having gotten ourselves into some very problematic spaces; that not only is it specious for us to cast ourselves as subjects of power, but that, in lending our support to, and expanding the reach of, scientific disciplines -that we are, in other words, co-producers of the very epistemic power from which we claim to distance ourselves" (Callard & Fitzgerald, 2015, p. 106). • "Attempts failed to substantively address and affect change in the power differential between the natural scientists and the social scientists" (Balmer, 2013, p. 3). • "Interdisciplinary asymmetries of power can produce silences and absences" (Callard & Fitzgerald, 2015, p. 97).	• "The point remains that the progress of the interdisciplinary intellectual effort is fundamentally entwined with the social research process and societal context of doing science. It is at this entwining that knowledge mixes with power"(Mac Mynowski, 2007, p. 18). • "A reason why artists' opinions about the quality and veracity of science are not given equal weight involves the notion of utility" (Leach, 2011, p. 153). • "The value in art was cast in terms of self-expression and culture making, not as potential utility" (Leach, 2011, p. 154).
Emotional - Affective	• "Certain emotional dispositions underlie commitments to rationality, suggesting that academic work is anchored in ''cognitive emotions'' such as ''the joy of verification'' "(Boix Mansilla et al., 2016, p. 577). • "Cognitive consensus is complemented by ''emotional consensus building,'' a process by which group members come to share positive	• "Feeling fuzzy" (Callard & Fitzgerald, 2015, p. 115). • "The orienting ethos of an openness to alterity (the alterity of others' methods, ontologies, and ways of 'doing' research) that tends to frame the normative horizons of interdisciplinary spaces is a terrain conducive to the emergence of the kinds of complex affective states (including bewilderment)" (Callard & Fitzgerald, 2015, p. 115).	• "What might be learnt from the tensions and emotions that run through a particular project? What do they reveal about the broader intellectual and psychological structure in which the project is caught? What can they tell us about how interdisciplinary knowledge is produced?" (Callard & Fitzgerald, 2015, p. 128).

	and negative feelings about different actions and goals" (Boix Mansilla et al., 2016, p. 577). • "To be successful groups must produce specific forms of emotion: flow, 'interpersonal trust, commitment to ideas, and grievances against dominant intellectual trends" (Boix Mansilla et al., 2016, p. 577). • "Joy, passion, and excitement are associated with the experience of and intellectual motivation for work" (Boix Mansilla et al., 2016, p. 593). • "Emotions such as pleasure and a sense of affirmation" (Boix Mansilla et al., 2016, p. 593). • "Effective leadership by individuals who understand the demands (cognitive, emotional, and social) of successful interdisciplinary collaboration" (Boix Mansilla et al., 2016, p. 593). • "Need for emotional regulation in interdisciplinary spaces" (Callard & Fitzgerald, 2015, p. 114).	• "Bodily, psychological, affective – as well as more straightforwardly 'epistemological' – fuzziness and friction are present" (Callard & Fitzgerald, 2015, p. 118). • "We argue that transdisciplinary zones may not only be defined by creoles, pidgins and trades, but also by forms of reserve, reticence and deception. Sometimes people just want to keep things to themselves" (Fitzgerald et al., 2014, p. 712). • "This process of deliberation about one's academic identity and having a suitable "label" was a shared concern" (Lyall, 2019, p. 33). • "(…) but insecurity and identity fatigue were features of interdisciplinary careers (Lyall, 2019, p. 34).	• What kind of collaborative and communicative zone is it, exactly, where researchers assemble concepts they do not fully believe in, and where they pretend to each other that everything is fine? (Fitzgerald et al., 2014, p. 712).
Epistemological	• "A cornerstone of interdisciplinary research is working collaboratively with people trained in other disciplines. The goal of such collaborations was epistemologically grounded because it was felt that such an approach would enhance their understanding of sustainability issues" (Castán Broto et al., 2009, p. 929). • "The typology of knowledge was altered to differentiate among three types of knowledge generally generated by synthesis projects and intended to contribute to sustainability: (1) systems knowledge about the origin of the societal problem, its current state and future trends, (2) target knowledge about the desired goals of future developments, and (3) transformation knowledge about the transition from the current to the target state" (Hoffmann et al., 2017, p. 681).	• "Epistemic barriers include dissimilar and sometimes conflicting styles of thought, methodology, research traditions, techniques, and terminology that can make interdisciplinary teaching, research, or collaboration challenging" (Tuana, 2011, p. 1971). • The divide between the "two cultures" (T. Osborne, 2013). • "When we attempt to bridge the big divide, such hidden value judgments can cause serious problems" (Lelé and Norgaard, 2005, p. 970). • Financial and epistemic power is not distributed equally within the collaboration (Callard & Fitzgerald, 2015, p. 104). • Dynamics of exchange are clearly governed by a larger-scale epistemological politics that renders methodological and conceptual differences between the social, natural and humanistic sciences as a hierarchy of intellectual prestige (Fitzgerald et al., 204).	• "The social sciences have grant awards with titles that are generally more straightforwardly descriptive (rather than discretely hypothetical), and which gesture more commonly not at known unknowns but either at unknown knowns or more interestingly, and more rarely, at unknown unknowns" (Osborne, 2013, p. 77). • "How then might we take the insights regarding the role of epistemologies in the production of knowledge and apply them to the ways in which we organize interdisciplinary research?" (Miller et al., 2008, p. 48). • "Epistemic differences between disciplines constitute not only a significant challenge to the success of interdisciplinary research, but potential avenues to more successful interdisciplinary collaborations" (Tuana, 2011, p. 1971).

	• "Interdisciplinary collaborations provide possibilities for undisciplined practices" (Tuana, 2011, p. 1959).	• "The object of inquiry is often defined by one discipline, thereby entitling their methodological approach and epistemology, imposing a particular set of values—epistemological sovereignty" (Miller et al., 2008, p. 50). • "This siloing can lead to the inability of researchers to shift their disciplinary perspectives, or their general way of looking at or thinking about research space, conditioned by tacit assumptions and commitments instilled or reinforced by their disciplinary experiences" (Robinson et al., 2016, p.3).	
Evaluation	• "(…) seven generic principles provide a coherent framework for thinking about evaluation: (1) variability of goals; (2) variability of criteria and indicators; (3) leveraging of integration; (4) interaction of social and cognitive factors in collaboration; (5) management, leadership, and coaching; (6) iteration in a comprehensive and transparent system; and (7) effectiveness and impact" (Klein, 2008, p. 116).	• "Evaluation by peer review of proposals and publications is one of the most contentious areas in interdisciplinary research" (Bruce et al., 2004, p. 469).	• "Criteria also vary across stages, from ex ante to ex post assessments, and programs and projects differ by knowledge domain, institutional location, goals, and type of integration" (Klein, 2008, p. 117).
Institutional	• "How the historical and institutional conditions within which interdisciplinary initiatives are implanted make a difference. They indicate, as we have remarked, how such initiatives can fail to take root or grow even when research policies and funding are supportive, while also suggesting that initiatives that emerge from the 'bottom up' or that are fomented in the academic margins may be especially fertile, resilient and long lasting – perhaps fuelled by counter-hegemonic energies" (Barry and Born, 2013, p. 13). • "It appears that new interdisciplinary institutions are needed to provide an exclusive space for interdisciplinary research" (Castán Broto et al., 2009, p. 924). • "The future of ITD within academia partly depends on each institution's capacity to find the	• "Many of the constraints operating against interdisciplinary research emanate from academic systems in European universities, which still discriminate against interdisciplinary research" (Bruce et al., 2004, p. 468). • "Tensions emerge between disciplinary and interdisciplinary research, as current disciplinary institutions appear to hinder the practice of interdisciplinarity" (Castán Broto et al., 2009, p. 924). • "lack of clear career trajectories for young researchers in this field, different publication cultures and incentive schemes across disciplines, lack of sufficiently broad IRB approvals" (Fitzgerald, 2012, p. 14). • "Absence of a wide recognition of the importance of ITD in academia" (Guimaraes et al., 2019, p. 14). • "Universities were portrayed as unwilling or unable to address the many administrative issues that impede	• "In the humanities there are very few intermediate institutions where experienced scholars develop systematic interactions with policy and there are very few institutions in which subject-specific humanities research is combined with knowledge intensive interdisciplinary cooperation" (Brom, 2019, p.7).

	proper framing of profiles that are not based on disciplines" (Guimaraes et al., 2019, p. 14).	interdisciplinarians in their daily work. These included: supervision of graduate students who spanned two disciplines or departments leading to uncertainties regarding assessment procedures; the frustration of teaching across different schools; or accessing interdisciplinary studentships administered in other schools" (Lyall, 2019, p. 45).	
Interactional	• "Meaningful personal relations, solid group identity, complementary team roles, socializing outside project meetings, and the development of group working styles and routines" (Boix Mansilla et al., 2016, p. 595). • "Tolerant ambivalence": "Researchers from different disciplines can amicably coexist, even contribute to the same project, but the analytical domains are largely separate. There is maintenance of boundaries, but a largely tolerant, pluralist perspective prevails" (Mac Mynowski, 2007, p. 1). • "Importance of frequent, sustained dialogue" (Lyall, 2019, p. 79). • "Weak ties are characterised as "indispensable to individuals' opportunities and to their integration into communities" in contrast to strong ties, which encourage local cohesion but ultimately lead to fragmentation" (based on Quentin in Lyall, 2019, p. 84). • Cultivation of interdisciplinary subjectivities and skills (Barry and Born, 2013). • "Acceptance that the majority of informal interactions may not lead anywhere" (Lyall & Fletcher, 2019).	• Feelings of ambivalence, critique, reserve and dishonesty (Fitzgerald et al., 2014). • "Lack of communication among researchers who claim to follow different conceptual and methodological paradigms" (Guimaraes et al., 2019, p. 13). • Relationship of negative feelings to experimental outcomes (Fitzgerald et al., 2014).	
Motivations for IDR	• "Enthusiasm, including educational demands for a more rounded pedagogy; the spread of powerful unifying concepts in academic debates; or in response to pressing societal agendas" (Löwe et al., 2013, p. 175).	• "Lack of incentives to engage in interdisciplinary research collaboration" (van Rijnsoever & Hessels, 2011, p. 469). • "Lack of rewards and/or anticipated benefits" (Guimaraes et al., 2019, p. 8).	• "Relative absence of motivation" (Lelé and Noorgard, 2005, p. 969). • "Low motivation for crossing disciplinary boundaries within the natural sciences and social sciences" (Lelé and Noorgard, 2005, p.969).

	• "Joy, passion, and emotion linked with the transdisciplinary inquiry that emerges from a felt need to go beyond some of the limitations of more traditional disciplinary academic approaches and certain established ways of thinking" (Guimaraes et al., 2019, p. 3). • "Epistemological goal: the production of new and broad knowledge of a particular phenomenon" (Klein, 2008, p. 117). • ""the ability to predict" unstudied social and biological phenomena and "tangible success" in explaining something that had not been explained previously" (Klein, 2008, p. 118). • "Desire to improve society and contribute to the advancement of the common good" (Guimaraes et al., 2019, p. 4). • "However, some of the motivations seem intertwined with the characteristics of ITD: the urge to establish links, understand complex issues, and connect and be connected with the real world" (Guimaraes et al., 2019, p. 10).	• "High costs of time, money and management efforts" (van Rijnsoever & Hessels, 2011, p. 469). • "Overemphasized" negative opinions on IDR/TDR (Lyall, 2019, p. 4).	
Non-epistemological values	• "(…) interdisciplinary researchers have a diversity of views about value-neutral inquiry and this diversity is not based on the academic branch to which a researcher belongs" (Robinson et al., 2016, p. 11). • - "Each project member can play the role of the "outsider within" (…) thus, so long as differences in worldview are harnessed in a way that illuminates potentially divisive variations in perspective, the source of the malady can also be the source of its cure" (Robinson et al., 2016, p. 11).	• "(…) difference in values act as the first kind of interdisciplinary barrier (and) is neither directly discernible nor easily separated from the second (difference in theories, models, or worldviews)" (Lelé and Norgaard, 2005, p. 968).	• "Mismatched taxonomies": "Scientists working in a subdiscipline often tend to believe that their particular way of categorizing phenomena (taxonomic system) is the best way of characterizing reality, rather than being open to different ways of representing reality that might be more or less appropriate in different applied contexts" (Lelé and Norgaard, 2005, p. 969).
Objectivity - Subjectivity		• "It is necessary to examine a frequent issue of conflict and misunderstanding between many social and biophysical scientists: how to deal with subjectivity in research" (Mac Mynowski, 2007, p. 18).	• "The debates about subjectivity and role of the researcher, widespread in social inquiry, as well as the differences in resulting conceptual models, have been generally approached by biophysical environmental scientists with more reluctance

		• "Tension over subjectivity and objectivity. Set in contrast to the biophysical or natural sciences, the social sciences are often portrayed as disunified, in constant conflict, or poorly developed in their theoretical foundations" (Mac Mynowski, 2007, p. 18).	than welcoming opportunity" (Mac Mynowski, 2007, p. 15).
Qualities of ID researchers	• "Successful management is linked to developing an active role in conflict resolution within the team, facilitating moderation among the different members' viewpoints and motivations, creating synergies, and encouraging mutual adjustment and compromise among project participants" (Guimaraes et al., 2019, p. 5). • "Group's growing capacity for disciplinary exchange, the construction of a cognitive common ground, emerging group identity, and development of trust" (Boix Mansilla et al., 2016, p. 602). • "Skills and knowledge in more than one discipline" (Bruce et al., 2004, p. 468). • "A clear vision of the project and what it is trying to achieve" (Bruce et al., 2004, p. 468). • "Openness and tolerance about ideas opposed to one's own, acceptance of the unknown, adaptability, and flexibility" (Guimaraes et al., 2019, p. 6). • Trust, cooperation, patience, and openness (Mac Mynowski, 2007).	• "Fear" of doing interdisciplinary research (Castán Broto et al., 2009, p. 928).	• "Understanding these individual characteristics is important, because it is the individual researcher who has to engage in the research collaborations and who has to produce the scientific result that contributes to the solution of the societal problem" (van Rijnsoever & Hessels, 2011, p. 469).