SHAPE-ID
Shaping interdisciplinary practices in Europe

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SHAPE-ID: Shaping Interdisciplinary Practices in Europe

Deliverable 2.1: Preliminary Report of Literature Review on Understandings of Interdisciplinary and Transdisciplinary Research

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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
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
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

1. Executive summary

This report presents emerging findings from a literature review being 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) disciplines and other scientific disciplines (hereafter we use the term STEMM to refer to Science, Technology, Engineering and Mathematics disciplines plus Medicine). The literature review is an ongoing activity which commenced in March 2019 and will conclude in March 2020. On completion of this work, a final report on findings from the literature review and the SHAPE-ID survey will be published, with an accompanying Policy Brief highlighting the key findings and implications for policy makers in Europe.

The work undertaken to date has focused on building a robust sample of literature, aligning qualitative and quantitative methodologies and beginning to map understandings and factors for success and failure in the literature. Building on this work and our preliminary analysis, subsequent steps will address in more depth the contextual differences and relationships between different understandings, subject areas and factors with a view to building a more comprehensive understanding of the implications of these for AHSS integration in particular.

We emphasise the preliminary and provisional nature of the findings presented in this report, which will be refined in the final report on the literature review.[1]

The literature review is being conducted using qualitative and quantitative analysis undertaken on samples of academic literature and "grey literature". Datasets were created by querying scientific citation databases, complemented by bibliographies prepared during a preliminary scoping analysis of IDR/TDR literature and by ongoing review of available and emerging literature as appropriate.

The preliminary findings of the literature review to date are presented below in the context of the following SHAPE-ID Work Package 2 (WP2) objectives: to disentangle the different understandings of inter- and transdisciplinary research; and to identify the factors that hinder or help inter- and transdisciplinary collaboration. Implications for AHSS integration are also considered.

[1] A longer version of this report has been produced as an internal working document within the SHAPE-ID project and may be requested by contacting Bianca Vienni (bianca.vienni@usys.ethz.ch) or Christian Pohl (christian.pohl@usys.ethz.ch).

Disentangling Understandings of Inter- and Transdisciplinarity

- Interdisciplinarity (ID) and transdisciplinarity (TD) denote a spectrum of experience and the literature reveals a strong tendency to problematise these concepts rather than accepting a single definition or understanding. Both are contested terms, and there are differences between the two.
- The literature reveals heterogeneous understandings of inter- and transdisciplinarity, reflecting a diversity of practice and expectations across disciplines and communities. This contrasts with a frequent assumption in reports and policy briefs that the terms are well understood.
- Some patterns of consensus are evident: the common features of many discussions and definitions in the academic literature are that interdisciplinarity and transdisciplinarity involve inter-dependence, cooperative labour, and mutuality, all oriented towards shared purposes.
- The challenge is not to arrive at a single understanding that collapses differences, but to build dialogue between different understandings while recognising their differences.

What Factors Hinder or Help Inter- or Transdisciplinary Research?

- A provisional list of 25 factors that are considered to help or hinder IDR/TDR has been identified from the academic literature. The first classification of factors is based on the preliminary results from the qualitative content analysis. This allowed a variety of factors to be identified and related to the different understandings of ID/TD:

  - Academic tribalism
  - Assumptions about other disciplines
  - Career Path
  - Change
  - Collaboration
  - Cognitive
  - Communicative
  - Community building / identity
  - Current Policies
  - Dealing with complexity
  - Division of scientific labour
  - Dynamics of power
  - Emotional
  - Epistemological
  - Ethical
  - Evaluation
  - Institutional
  - Interactional
  - Motivations for IDR/TDR
  - Mutual Ignorance on collaboration
  - Non-epistemological values
  - Objectivity / subjectivity
  - Ontological
  - Qualities of inter- and transdisciplinary researchers
  - Social

  The report provides a short definition for each factor and its implications for AHSS integration. The list so far provides indications of the many interconnected issues that can be important when developing IDR/TDR and poses the question of how to support teams trying to overcome one or more of these issues.

- The factors that can influence the success of IDR/TDR are interrelated, context-dependent and dynamic. They depend on such contextual features as the level of understanding of IDR/TDR, the

phase a project is at, the roles assigned to different partners, the logics and motivations underpinning the work and the disciplines and actors involved. Furthermore, different factors may be important to different partners in a collaboration.

- Factors can act positively or negatively depending on the context, and the phase of the project. Factors can potentially be transformed from problematic to enabling during the research process. This is a promising area for further investigation.

Implications for AHSS Integration

- The labels used to refer collectively to the Arts, Humanities and Social Sciences – "AHSS" and "SSH" – obscure important differences between disciplines that bear on the different ways they position themselves in relation to doing inter- or transdisciplinary research and to other disciplines (AHSS and STEMM) that they interact with. The label AHSS (or SSH) needs to be problematised and how each field can contribute to IDR/TDR analysed. Factors that contribute to successful IDR/TDR need to be analysed in a field-dependent fashion to consider means for transforming obstacles into enabling opportunities.

- The potential contribution of AHSS disciplines in IDR/TDR is not fully understood. While policy reports frequently advocate for the contribution AHSS disciplines can make to solving societal challenges, the academic literature suggests that there is often a perception that humanities researchers have little to offer and their contributions are difficult to understand and integrate. There are indications that few in the sciences are aware of what humanities researchers can contribute, and that few in the humanities are aware of it either (B. Robinson et al., 2016).

- The AHSS-STEMM gap remains a significant challenge. The literature analysed so far shows little dialogue between AHSS and STEMM disciplines and few suggestions for bridging the gap, although the problem, gap and need to bridge them are widely acknowledged.

The plurality of understandings of IDR/TDR reflect differences in experience and differing views of the purpose of research and education, the role of disciplines and the role of critique (Klein, 2005). The challenge is to build dialogue between different understandings while acknowledging their differences.

In the next steps of this research, the current analysis will be completed with the connection between different understandings of IDR and TDR and the factors that hinder or help AHSS integration. The emerging findings will inform the development of a series of workshops organised by the SHAPE-ID project and will be synthesised with results from a survey and exploratory interviews for the final report and Policy Brief in March 2020.

2. 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 and Mathematics, and Medicine (STEMM).[2] The project will establish 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 with a view to solving key societal challenges.

SHAPE-ID is currently undertaking the first activities of the evidence-scanning phase of the project, which comprises a literature review and survey (Work Package 2, due for completion in March 2020), a series of learning case workshops held across Europe from December 2019 to May 2020 (Work Package 3), and a knowledge framework synthesising the results of these activities which will be validated in consultation with the SHAPE-ID Expert Panel (Work Package 4, due for completion in September 2020). 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 (Figure 1).

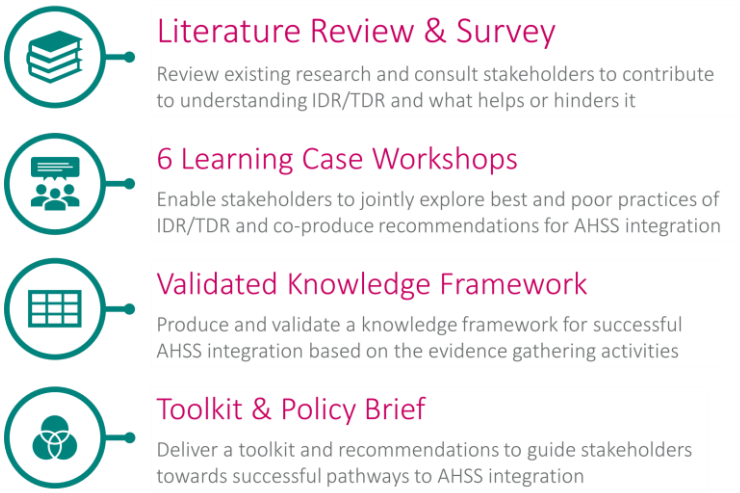

Figure 1 SHAPE-ID Objectives

[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). Both classifications are described in Appendix A below. For the purpose of the quantitative analysis, we use the All Science Journal Classification (ASJC).

One of SHAPE-ID's first objectives is to review existing research contributing to the understanding of IDR/TDR. The project aims to identify, through an extensive evidence scanning exercise drawing on previous work undertaken, 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.

To achieve these objectives, WP2 is currently undertaking an extensive literature review using scientific citation databases such as Scopus, Web of Science (WoS) and JSTOR, to identify the academic literature on understandings of IDR/TDR and on factors contributing to their success or failure. These results will be complemented by an extensive survey of IDR/TDR projects involving AHSS integration and AHSS+STEMM integration. This work is currently in progress. Corpora of academic literature and grey literature have been created and are in the process of being analysed using qualitative and quantitative methods. A first aim of the analysis is to relate different understandings of IDR/TDR and the function IDR/TDR play in different fields. A second aim is to sort the factors of success and failure in a comprehensive but manageable number of clusters.

To date the analysis has focused on Objectives 2.1 and 2.2, disentangling understandings of IDR/TDR and identifying the factors that help or hinder IDR/TDR. Objective 2.3, connecting these specifically to the challenge of AHSS integration, will be addressed in future research steps.

3. Methodology

This section presents the design and research methods used to develop the literature review in WP2. The academic literature review (LitReview) was undertaken in parallel with the grey literature review (GreyLit), and both corpora were analysed using quantitative and qualitative methods.

The work to date has been developed over several iterative phases. From March 2019 onwards, work focused on query formation for data collection and aligning methodologies for the qualitative and quantitative analyses to address the SHAPE-ID research questions and objectives. This required several months of adjustments due to the features of the literature on IDR, TDR and AHSS. As previous studies

have pointed out, inter- and transdisciplinary literature is scattered and not compiled in a fixed set of journals (Aboelela et al., 2007; Wagner et al., 2011; among others). The team encountered a double challenge, to build a robust dataset and to overcome the bias that the underrepresentation of AHSS results in scientific databases presents in the academic literature and grey literature (Kulczycki et al., 2018).

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 entails 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). The analysis is ongoing.

This section is organised as follows. Firstly, we present the data collection process developed to assist in the consolidation of datasets for WP2. Next, the methods used for quantitative analysis are summarised and the systematic review of academic literature and its qualitative analysis are explained. Finally, we present the qualitative approach applied to the grey literature sample. The methods applied were selected taking into consideration the question and the aims of WP2. According to previous studies (Rafols & Meyer, 2010; Wagner et al., 2011; among others) a combination of qualitative and quantitative methods are needed to better understand how inter- and transdisciplinary research are developed. The methods applied aim at providing a complete overview of the problem addressed in WP2 in terms of the robustness of the data collected and of its analysis.

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, 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 (Table 1): (i) records from citation databases and digital repositories of scholarly publications (LitReview), (ii) reports on inter- and transdisciplinarity and various documents relevant to SHAPE-ID's scope stored in the OpenAire repository (GreyLit), (iii) research projects funded in Horizon 2020 framework programmes (H2020Projects), and (iv) Horizon 2020 Work Programmes (H2020Calls).

Table 1 SHAPE-ID corpora

#	Corpus name	Dataset description	Type of data	All items	Items used	Number of words
1.	LitReview	Academic literature	Article abstracts	5040	3910	700871
2.	GreyLit	Reports on IDR/TDR	Full texts	93	93	1412483
3.	H2020Projects	H2020 projects mentioning IDR/TDR	Project abstracts ("objectives")	1912	1912	523056
4.	H2020Calls	H2020 Work programmes parts (2014-2019)	Full texts	84	75	2233865

The following section describes the data collection procedures in greater detail while Section 3.2 outlines the methods of analysis.

3.1.1. Academic Literature dataset

In the course of the systematic literature review, the project team queried 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 bias of WoS and Scopus against AHSS literature (Kulczycki et al., 2018), we also searched the JSTOR database. For WoS and Scopus, complex search strings were created that reflect the main research questions of the literature review (see Appendix B for an overview of the query schema used). 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 Appendix C for a complete list of keywords). The JSTOR database offers less advanced data-analytical tools, but the project team decided to include items that have ID or TD in the title, to counterbalance the reported biases against AHSS in Scopus and WoS (Kulczycki et al., 2018). These three data sources were complemented by bibliographies prepared during the preliminary scoping analysis of IDR/TDR (see Section 3.2.2). Figure 2 presents the overall workflow performed for the academic literature review data collection phase.

The resulting dataset consists of 5040 records i.e. scholarly publications metadata (author, abstract, title, keywords, tags). Based on a systematic review, a sample of the literature has been selected for qualitative analysis.[3] At the same time, the bibliographic metadata is being analysed with computationally assisted quantitative methods.

[3] See Appendix D for the inclusion and exclusion criteria used for selecting the sample of academic literature and for qualitative analysis.

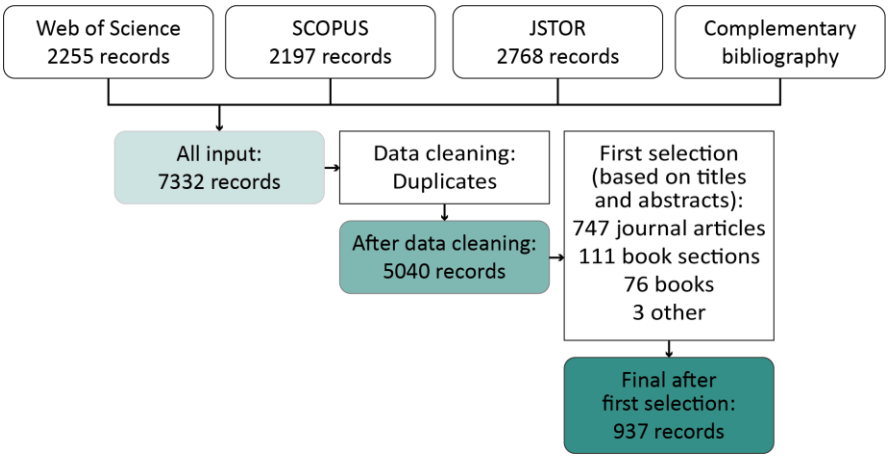

Figure 2 The complete academic literature review data-collection workflow

3.1.2. Grey Literature dataset

For the purposes of this study, grey literature is defined as "any information that is not produced by commercial publishers. It includes research reports, working papers, conference proceedings, theses, preprints, white papers, and reports produced by government departments, academics, business and industry" (Leeds, 2019).

Keywords used to consolidate the academic literature dataset were also applied to the search of grey literature databases such as OpenGrey, SSRN and Bielefeld Academic Search Engine (BASE) databases. Simultaneously, we developed a list of relevant organisations that have been contributing to research policy on IDR/TDR and the integration of AHSS. Together with the first draft of the SHAPE-ID Stakeholder Contact Database (D6.3), we used both datasets to expand the search for suitable documents, initially by analysing titles and summaries followed by the same keyword searches applied to the academic literature.[4]

The resulting Grey Literature corpus consists of 93 documents and 1,412,483 words (approximately 15,000 words per document). Details on the document curation and qualitative analysis are provided in Section 3.2.3 below.

[4] See Appendix E for the inclusion and exclusion criteria used for selecting the sample of grey literature for qualitative analysis.

3.1.3. H2020 Projects data

The metadata of projects conducted under Horizon 2020 is collected in the CORDIS database. The SHAPE-ID project has accessed the periodic data dumps[5] from this database that are stored in the EU open data portal[6]. The data dump contains fields such as id, acronym, status, programme, topics, framework Programme, title, start/Date, end/Date, project/Url, objective, total/Cost, ecMax/Contribution, call, funding/Scheme, coordinator, coordinator/Country, participants, participant/Countries, subjects. We used the data dump from May 2019, which contained information about 23,144 projects. These were searched for interdisciplinar* or transdisciplinar*, matched against title or abstract ("objective").

This procedure allowed for the creation of a subset of 1,912 projects which contained these keywords. Using this dataset, we created a corpus of abstracts (H2020Projects) containing 1,912 documents and 273,569 words (273 words per document on average).[7]

3.1.4. H2020 Calls

To allow more insights into the way the European Commission tackles the issues of IDR/TDR, the team downloaded a set of biannual work programmes (2014-2015; 2016-2017; 2018-2019) from the Funding & Tenders Portal[8] using the WinHTTrack Website copier. Given that ERC Work Programmes were repetitive and thus could distort the results, they were excluded from the dataset. The files were converted into text format (.txt). The resulting corpus of H2020 Calls consists of 84 documents and 2,233,865 words (approximately 30,000 words per document on average). Quantitative analysis of this dataset will be conducted later in the project.

3.2. Methods of analysis

This section presents details of the procedures used for the three strands of analysis: (i) a quantitative analysis, (ii) qualitative analysis of academic literature and (iii) qualitative analysis of grey literature.

3.2.1. Quantitative analysis

For the quantitative analysis, topic modelling and network analysis were applied together with concept mining and generic statistical approaches. We used these various quantitative approaches on both

[5] We use the term "dump" in two interrelated senses: (i) as the process of acquisition of a digital dataset; and (ii) as a synonym of "dataset".
[6] https://data.europa.eu/euodp/en/data/dataset/cordisH2020projects
[7] This dataset was evaluated qualitatively to select use-cases for the SHAPE-ID survey, which is due to be completed by February 2020. Quantitative analysis of the dataset will be conducted later in the project.
[8] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/how-to-participate/reference-documents;programCode=H2020

academic literature and grey literature datasets. Data analysis focused on two kinds of operations intended to provide more high-level insights into the SHAPE-ID datasets:

- **Documents content and metadata classification:** The goal is to understand the relationships between documents using topic modelling and network analysis of article metadata (subject tags and disciplinary affiliations). The analysis aimed to identify key topics pertaining to discussions of IDR/TDR using both abstracts and subject tags associated with the documents.
- **Concept mining:** This aims to map understandings of IDR/TDR and attitudes towards them through linguistic analysis of those concepts in abstracts (describing the meaning associated with our key terms). The contextual search in collected corpora aimed to describe the contexts of usage of the terms inter- and transdisciplinary research (based on SHAPE-ID keywords) that were most pertinent to the datasets.

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). This section details the type of systematic review – in this case a meta-ethnography – developed to study the academic literature. A meta-ethnography review 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; France et al., 2014). Due to the complexity that the dataset presents, we consider this to be an appropriate method that allows us to better understand the differences between concepts and definitions.

The seven phases of a meta-ethnography are briefly described below 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 comprises identifying and selecting study accounts to synthesise (Noblit & Hare, 1988). The process of literature selection was shared and discussed with WP2 partners in an iterative manner. 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 Appendix C for more details). The workflow followed is detailed in Figure 2 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 qualitative content analysis[9].

Phase 3 – Reading the studies: This step comprises the repeated reading of studies and noting of metaphors with close attention to details and what they tell about the area of interest (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 it 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: Noblit and Hare (1988) recommended that reviewers create "a list of key metaphors, phases, ideas and concepts (and their relations) used in each account, and to juxtapose them" in order to make an initial assumption about how the studies relate to each other. For this we have simultaneously applied a reciprocal and refutational translation (Noblit & Hare, 1988).

Phase 5 – Translating the studies into one another: The metaphors and concepts in each publication and their interactions are being compared or translated within and across accounts while trying to retain the structure of relationships between them (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 or if some translations or concepts can encompass those from other studies (Noblit & Hare, 1988).

Phase 7 – Expressing the synthesis: This phase is still in process. So far the data have been coded, repeatedly read by one reviewer and systematically compared to the research question and keywords (Noblit & Hare, 1988). At this point, preliminary findings are regularly discussed with WP2 team, the Principal Investigators and some members of the SHAPE-ID Expert Panel.

[9] 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 June 2019.

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. 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 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 & Lenton, 2018). As mentioned, we used various permutations of the keywords “interdisciplinary”, “multidisciplinary”, “transdisciplinary”, “arts” and “humanities”, to perform a series of searches in different databases.

The searches of targeted websites of organisations known to publish research policy documents produced the most comprehensive results. Some academic databases claim to include grey literature but did not produce relevant results. The sources located using this search are discrete documents, rather than online sources such as website pages or blogs. Currently, they can be categorised as press releases, research summaries and practical guidelines; consultation responses and position statements; monitoring and evaluation reports; and conference and workshop proceedings.

Scott (1990) gives four basic criteria for assessing the quality of documents, namely 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 will be further analysed after the contents have been coded.

Such texts have been created for a range of different purposes – to monitor major research programmes or assess the state of a specific research area – and often address the topic of AHSS and IDR/TDR indirectly or very generally, as part of broader discussions about, for example, the state of Arts and Humanities research in Europe. This makes the coding of such documents a complex process requiring a significant amount of interpretative labour. Because of this, an abbreviated version of the codebook used to analyse the academic literature has been used to code the grey literature documents.

The key tasks of locating documents and assessing their suitability is largely complete, although it is an iterative process and so, if identified, further items can be added to the dataset. The content analysis of the documents has begun. Roughly a quarter of the sample has been coded and the remainder will be coded by January 2020.

4. Emerging Findings

This section presents the main preliminary findings emerging from the quantitative and qualitative analyses so far. To highlight how these findings contribute to addressing the objectives of Work Package 2, we organise this section according to our first two objectives: Section 4.1 addresses disentangling understandings of inter- and transdisciplinarity; Section 4.2 addresses identifying factors that help or hinder inter- or transdisciplinary collaboration. Our analysis includes considerations of the implications for AHSS in Section 4.3.

4.1. Disentangling Understandings of Inter- and Transdisciplinarity

– Disentangling Understandings of Inter- and Transdisciplinarity –

The literature reveals heterogeneous understandings of inter- and transdisciplinarity, reflecting a diversity of practices and expectations across disciplines and communities. This contrasts with a frequent assumption evident in policy documents and reports analysed as part of the grey literature review that the terms are well understood. This suggests that a first challenge is to build dialogue between different understandings, recognising their differences and commonalities. A second challenge is to assess how to address these different understandings in calls and funding schemes.

The labels used to refer collectively to the Arts, Humanities and Social Sciences – "AHSS" and "SSH" – obscure important differences between disciplines that bear on the different ways they position themselves in relation to doing inter- or transdisciplinary research and to the other disciplines (AHSS and STEMM) that they interact with.

While some definitions of inter- and transdisciplinarity are widely used, overall understandings vary substantially across the literature (von Wehrden et al., 2019). Differences can be identified between the grey literature and academic literature analysed in our research, with an analysis of policy reports at European level revealing little effort to explain what is meant by inter- or transdisciplinarity. In this context, these terms are often used as though their meanings are commonly agreed, and IDR and TDR are often used interchangeably. By contrast, the academic literature reveals divergence, nuance and contextual specificity, with differences evident across disciplines, regions and scholarly communities. This is important to acknowledge because understandings inform expectations and practice. The variety of understandings of ID/TD is sometimes seen in the academic literature as obscuring informed discussion about the benefits of such research and the challenges in undertaking it.

4.1.1. Defining Inter- and Transdisciplinarity

The academic literature on inter- and transdisciplinarity is marked by considerable heterogeneity. Any attempt to map understandings must first recognise that these concepts represent contested discourses. Nonetheless, the literature reveals patterns of consensus (Klein, 2019), including the US National Academy of Sciences definition of interdisciplinarity from 2005. Along with Klein and Klein and Newell (1997), this is the most frequently quoted in the literature:

> 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).

Julie Thompson Klein's work is the most widely cited academic source for understanding multi- and interdisciplinarity. According to Klein (2010, p. 17), multidisciplinarity was defined, by the OECD, as an approach that juxtaposes disciplines. Juxtaposition fosters wider knowledge, information, and methods. When applying this approach, disciplines remain separate, and retain their original identity. The existing structure of knowledge is not questioned.

Acknowledging the variety of ways in which interdisciplinarity has been defined, Klein highlights the "recurring idea" cutting across the diverse explorations: "Interdisciplinarity is a means of solving problems and answering questions that cannot be satisfactorily addressed using single methods or approaches" (Klein, 1990, p. 196).

While the plurality of terms within these definitions already points to the complexity of ID and TD configurations and practices, the common features of many discussions and definitions in the academic literature are that inter- and transdisciplinarity involve inter-dependence, cooperative labour, and mutuality, all oriented towards shared purposes.

– Heterogeneity and Problematisation –

Interdisciplinarity and transdisciplinarity denote a spectrum of experience (Lyall, 2019) and are defined heterogeneously (Mäki, 2016). The literature reveals a strong tendency to problematise these terms rather than accept a single definition or understanding (Barry & Born, 2013b).

The heterogeneity of understandings of ID is eloquently summed up by Klein:

> 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 reestablish old connections, to explore

> emerging relationships, and to create new subjects adequate to handle our practical and conceptual needs. (Klein, 1990, p. 196)

(Barry & Born, 2013a, p. 4) add to this understanding, highlighting that ID "has come to be at once a governmental demand, a reflexive orientation within the academy, and an object of knowledge".

– Contested Discourses –

"What counts as interdisciplinarity is widely contested. […] Interdisciplinarity itself has a long history, a variety of definitions and shifting relations to the multidisciplinary and transdisciplinary while recent years have seen the rise of anti-disciplines, non-disciplines and post-disciplinary practices as well as a variety of re-disciplinarizing dynamics" (Lury, 2018, p. 1).

So far, we have found that there is no universally accepted understanding of the differences between inter- and transdisciplinarity. Rather, the use of terms, as well as what is meant by them, varies by country/region and academic community. For example, the term transdisciplinarity is often accepted in German-speaking countries, the Netherlands and some Nordic countries (Pohl, 2008), yet the term is rarely used in the United Kingdom, where interdisciplinarity also includes non-academic stakeholders (Lyall, Meagher, & Bruce, 2015).

Transdisciplinarity is also understood in a variety of ways that vary across contexts and countries. Klein (2014) identifies three major streams:

(i) a discourse of "**transcendence**" that aims at unity of knowledge, transcending the narrowness of disciplinary worldviews and practices;

(ii) a discourse of "**transgression**" that emerged out of an even more fundamental critique of the system of knowledge and education, and that relates to discourses on democratisation of knowledge;

(iii) a discourse of "**problem solving**" that aims to transform concrete situations.

Related to the third stream, transdisciplinarity is understood in the literature as a reflexive, integrative, method-driven scientific principle, with an emphasis on solving societal problems by integrating knowledge from various scientific and social bodies of knowledge (Lang et al., 2012).

This pragmatic approach (Pohl, 2008) to TD differs from the perspective of (Nicolescu, 2000), who 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, 1996) 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.

Evidence from our quantitative analysis, in which we used concept mining to explore the presence of keywords related to inter- and transdisciplinarity, understanding, policy, integration, factors, success/failure and research across the SHAPE-ID corpora, needs to be further analysed, but reveals that interdisciplinarity is discussed far more often than transdisciplinarity across all corpora and in combination with all keywords. Preliminary analysis of a corpus of project abstracts from the Horizon 2020 CORDIS dataset, which will be further analysed in future steps, found that only 8% made explicit reference to either inter- or transdisciplinarity, with interdisciplinarity again significantly more common (see Appendix F for a comparison of the presence of these terms across SHAPE-ID corpora).

Against this background, the plurality of definitions and heterogeneity of understandings may be seen as expressing the diverse aims or purposes that researchers pursue when practicing and defining inter- and transdisciplinary research (td-net, 2019). This presents a challenge to policy makers and funders on how to better address and promote these differences in calls and programmes.

4.1.2. Approaching the Challenge of Disentangling Understandings of IDR/TDR

To begin to map this heterogeneity, we classify the academic literature into three main categories reflecting different perspectives on IDR and TDR. The aim of this classification is to shed light on the different aims and interests pursued when dealing with IDR and TDR:

- Studies of ID and TD consider either term and its associated practices and discourse as an object of study. Frickel, Ilhan and (Nowotny, 2017) identify three categories within this literature dealing with: (i) ecologies of interdisciplinary knowledge, (ii) phases of interdisciplinary creation; and (iii) efforts to find and bridge the gap between disciplines.

- Interdisciplinary and transdisciplinary studies deal with inter- and transdisciplinary approaches to specific topics or problems, focusing on both theory and methodology. These aim to construct a more comprehensive perspective by drawing on and integrating different disciplinary perspectives to address a topic or problem. We follow the definition of interdisciplinary studies elaborated by Klein and Newell (1997, pp. 393-394): “A process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession… [It] draws on disciplinary

perspectives and integrates their insights through construction of a more comprehensive perspective".

- Case studies discuss specific examples where ID or TD are applied, extracting principles and recommendations from the cases examined.

Across the three categories, we consider it important to examine ID and TD across multiple dimensions, reflecting the complexity of these practices:

- 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 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.

These classifications aim to deal with the diversity of concerns bound up with understanding and practising 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 and the analysis of these practices and the literature strongly emphasises the need for contextual understandings.

Based on these two sets of categories (understandings and dimensions for disentangling ID/TD), we have developed a matrix (Table 2). The matrix offers a means to compare these heterogenous ways of doing IDR and TDR. It can function as a working schema when dealing with conflicting definitions in different inter- and transdisciplinary settings. For this reason, we consider the matrix a useful tool for sorting out plurality rather than seeking one common definition. Our goal is that the tool could be used by researchers and funders alike. Further insights on how this tool can be applied will be developed in the coming months and presented in the final report on this work.

Table 2 Matrix to analyse the different understandings of IDR/TDR

		Understanding		
		Studies of ID/TD	Interdisciplinary studies	Case studies
Cross-cutting issues	What?			
	Who?			
	How?			
	Why?			
	Where?			
	When?			

4.1.3. Motivations and Relationships in IDR/TDR

The range of understandings and assumptions about IDR/TDR in the literature are reflected in practice in the relationships between partners in IDR/TDR and the reasons for doing (or promoting) IDR/TDR. For example, following Barry and Born (2013b), the relations between disciplines in a collaboration can be understood as taking one of several forms:

- 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 (Jasanoff, 2013; Lyall, 2019; Osborne, 2013). This transformative potential can be seen as a threat to existing disciplinary configurations, with implications for researcher careers (Fletcher & Lyall, 2019; Lyall, 2019).

4.1.4. Where are Discussions of IDR/TDR Taking Place?

– Discussions of IDR/TDR –

The AHSS label obscures important differences in the prevalence of smaller groupings and disciplines in discussions of IDR/TDR. The quantitative analysis of our academic literature sample suggests that discussions of IDR/TDR occur more often in journals affiliated with Social Sciences and in journals whose disciplinary affiliation combines Social Sciences with non-AHSS disciplines. Arts and Humanities (AH) are poorly represented among publications publishing on IDR/TDR more frequently.

To explore the relationships between disciplines in our sample, we conducted a network analysis of disciplinary affiliations based on the co-occurrence of disciplines within journals in which papers were published. This contributes to our effort to map understandings of IDR and TDR by providing insight into disciplines particularly invested in understanding IDR and TDR.

Analysing the disciplinary affiliations of the journals in the sample using the All Science Journal Classification (ASJC) codes provides insights into the overall disciplinary areas where discussions of IDR and TDR are most frequently taking place. Preliminary results are based on analysis of a sub-sample of 3244 articles tagged with these codes.

More than two thirds of the articles in our sample were published in journals affiliated with the Arts, Humanities and Social Sciences (AHSS) broadly. However, Arts and Humanities journals collectively account for only 20% of the total sample and Arts journals only 2%. This reveals the extent to which the broad disciplinary grouping “AHSS” obscures differences within that grouping. Further, in the journals that more frequently publish articles on IDR/TDR (i.e. more than 10 articles since 1990), the Arts and Humanities collectively are barely represented. Thus, it appears that explicit discussions of IDR/TDR are far less common in journals affiliated with Arts & Humanities (See Appendix G for more detail).

Because journals can be tagged with multiple ASJC codes we can also map the broad disciplinary connections between articles in our sample. These connections are represented in Figure 3 below (see Appendix H for more detail on the importance of particular disciplinary areas).

This analysis reveals that journals affiliated with Social Sciences have considerably more numerous and more diverse connections with other disciplines than those affiliated with Arts and Humanities, though both feature strongly overall. Environmental Science and Medicine also feature high on the list of disciplines strongly connected to other disciplines through journals with multiple affiliations.

Arts and Humanities and Social Sciences are most strongly affiliated with one another. Beyond this, AH connects most strongly to Engineering and Computer Science, and to a lesser extent to Economics, Econometrics & Finance and to Business, Management & Accounting (see Figure 4), while Social Sciences connect most strongly to these same disciplines but also to Environmental Science and Medicine and to a lesser extent to Psychology and to Earth & Planetary Sciences (see Figure 5). See Appendix I for more detail.

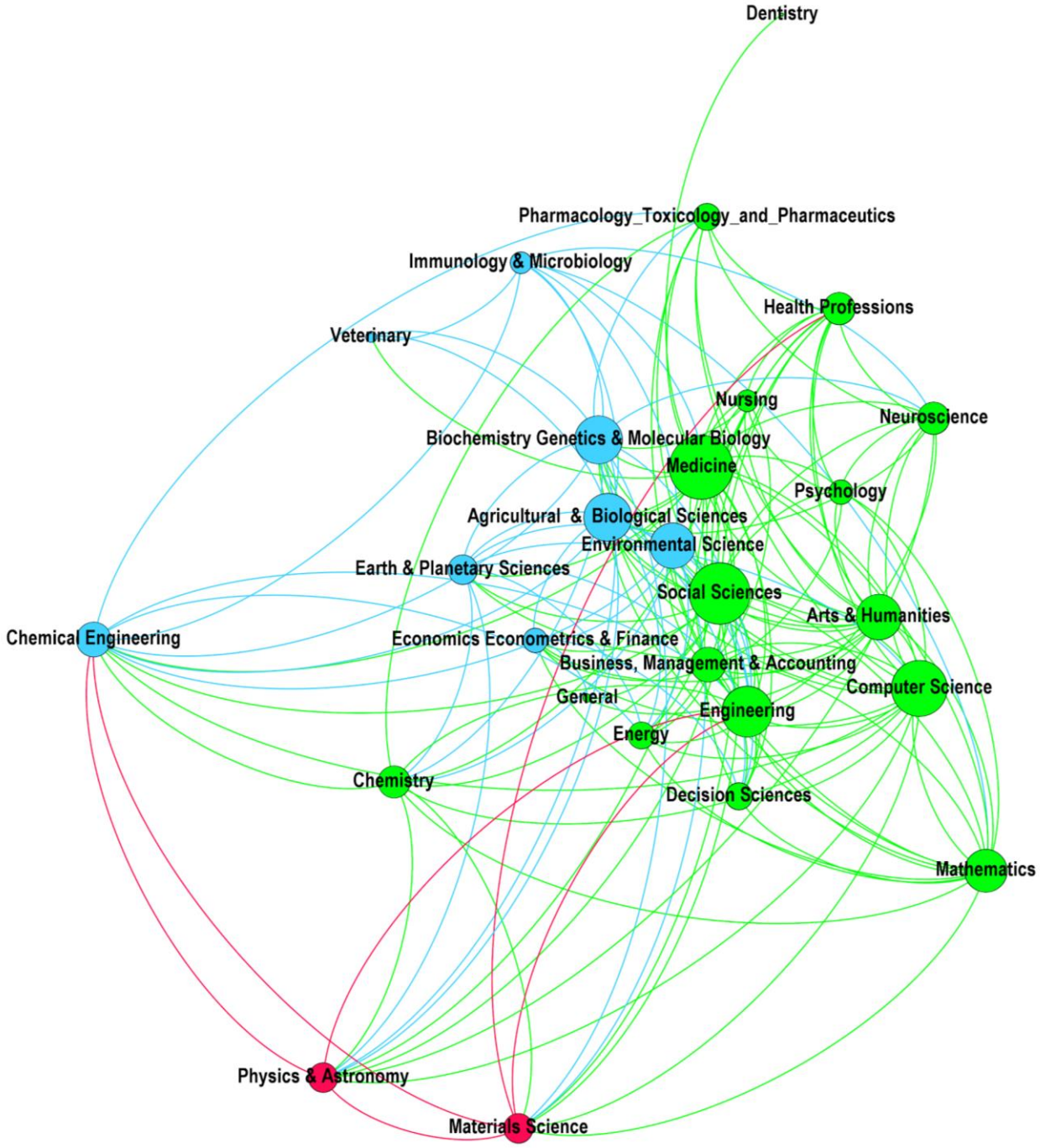

Figure 3 Network of relationships between disciplines in Literature Review sample. Node proximity and colour signal closeness, i.e. they co-occur more frequently. Node size indicates its importance in the sample, i.e. the more connections, the larger a node.

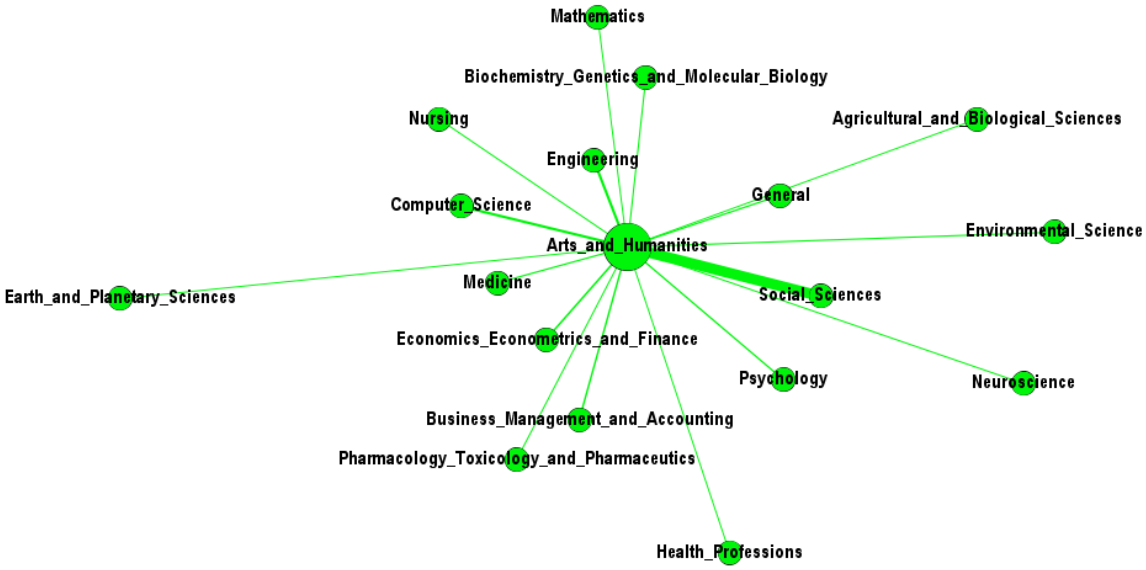

Figure 4 Network of disciplinary connections of Arts & Humanities in Literature Review sample. Node proximity and edge thickness signals closeness, i.e. more frequent co-occurrence.

Figure 5 Network of disciplinary connections of Social Sciences in Literature Review sample. Node proximity and edge thickness signals closeness, i.e. more frequent co-occurrence.

We also looked at the connections between subject tags, i.e. keywords freely assigned to articles by their authors, concentrating on a sub-sample of 2163 articles which featured such keywords. Terms related to IDR/TDR are amongst the most frequent. The analysis also revealed a strong prevalence of terms related to Health Sciences and Environmental Sciences Research, suggesting that these are key areas in which discussions on IDR/TDR are taking place.

To further explore the relationship between our research questions and disciplinary prevalence in the sample, we used topic modelling to analyse both the academic literature review corpus (3910 items) and the grey literature review corpus (93 items). Topic modelling can reveal latent semantic relations by identifying the most commonly recurring concepts in a given corpus (Blei, 2012). Each topic is represented as a cluster of regularly co-occurring words from the corpus. Disciplinary trends were identified in the topics based on the prevalence of associated words (e.g. “health; public; disease; population” indicating Health Sciences disciplines). IDR/TDR trends were identified based on the significant presence of SHAPE-ID keywords IDR/TDR, INTEGRATION, POLICY, UNDERSTANDING. The top 50 topics for each corpus were compared.

In comparing the grey literature and academic literature datasets for topics where IDR/TDR terms were identified, our topic modelling analysis confirmed that the grey literature contains more policy-oriented terms and fewer topics that could be identified with a particular disciplinary grouping, compared to the academic literature (see Figure 6 and Figure 7 respectively, for comparison). This greater level of generality is consistent with the preliminary findings of the qualitative analysis.

Preliminary findings from this analysis also suggest that IDR/TDR are more rarely discussed in the context of Arts and Humanities than Social Sciences and non-AHSS disciplines. This is consistent with our findings from the discipline network analysis.

In the literature review corpus, the most common non-AHSS disciplinary areas represented are Health Sciences and Environmental Sciences, a finding also consistent with our discipline network analysis which suggested a relatively high prevalence of forums representing these disciplinary areas.

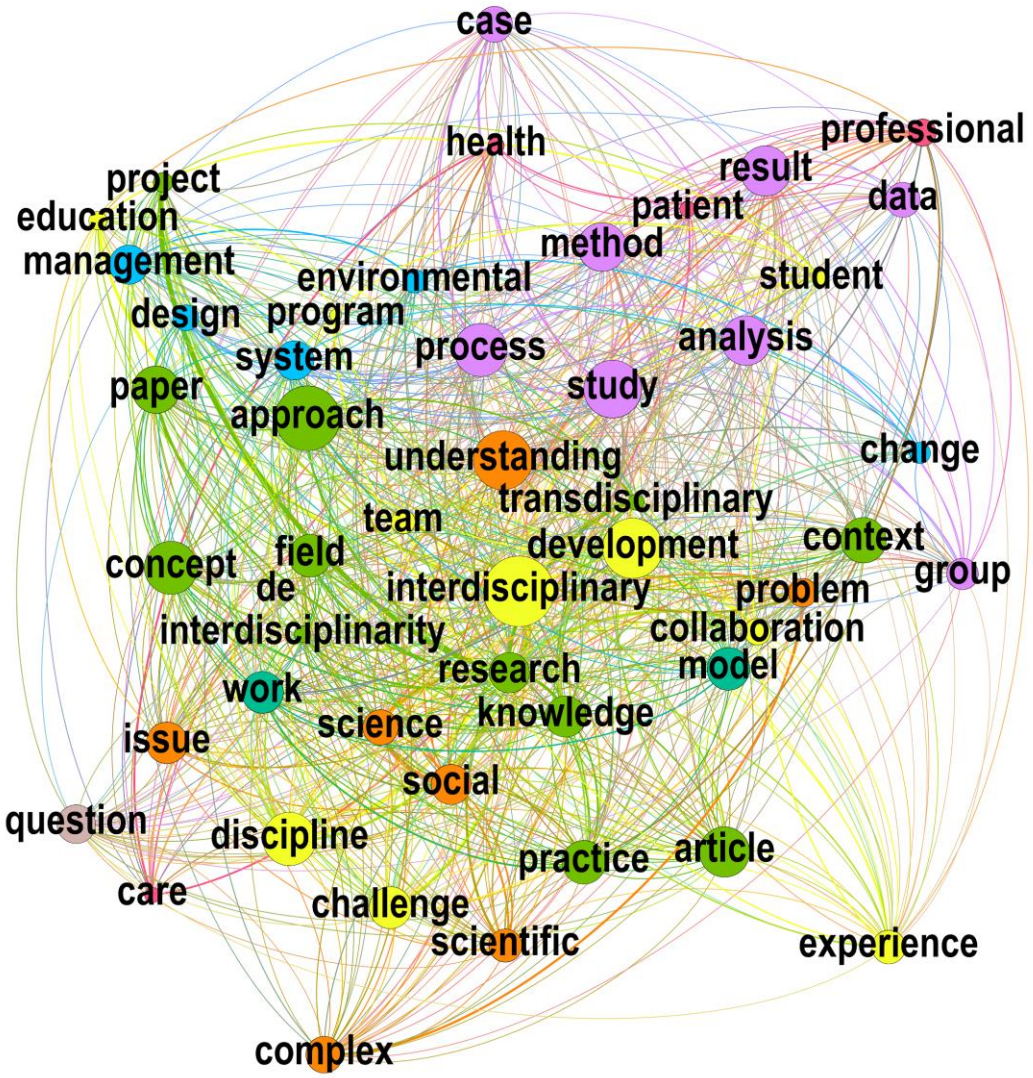

Figure 6 Relationships between 50 most important words in 50 topics of the LitReview corpus (based on weighted degree). It shows mostly the research meta-discourse in discussions of IDR/TDR.

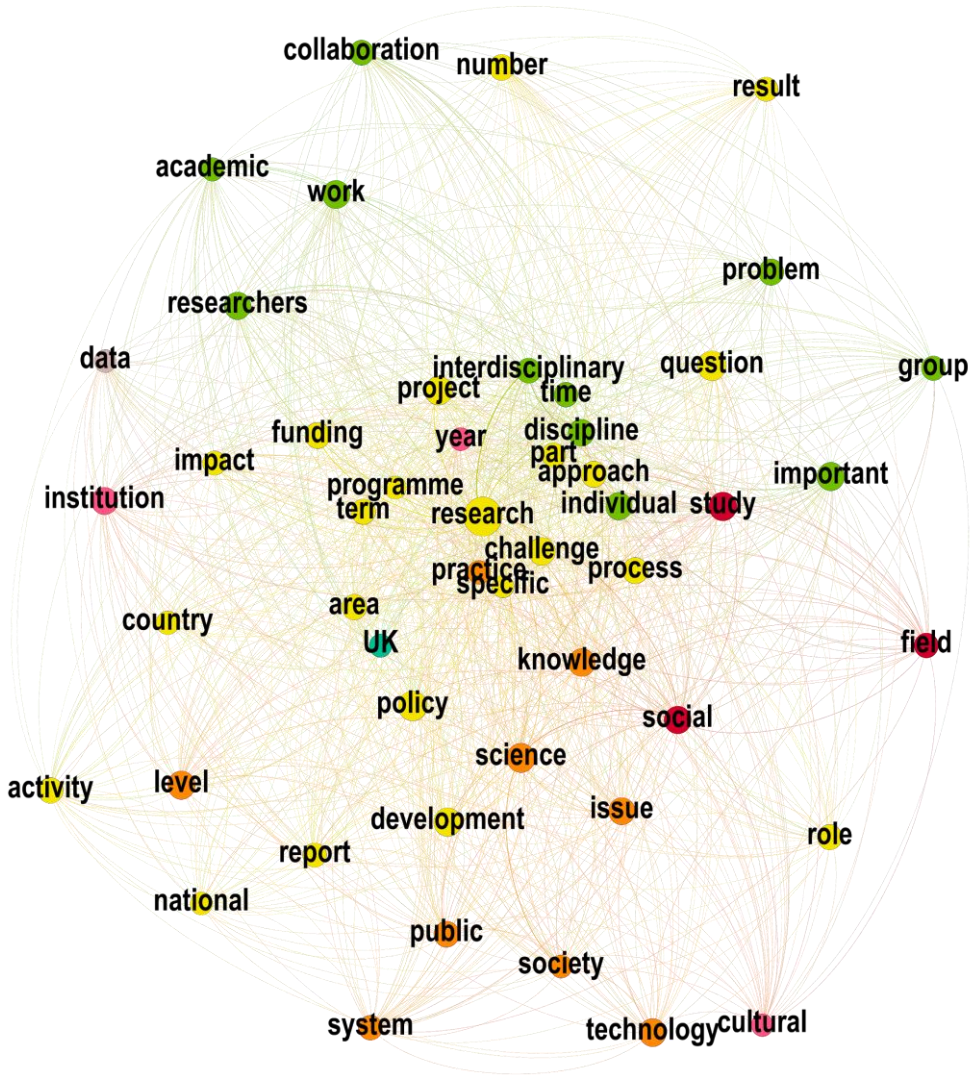

Figure 7 Relationships between 50 most important words in 50 topics of the GreyLit corpus (based on weighted degree). It shows more policy-oriented discourse, in comparison to LitReview keywords presented in Figure 6.

4.2. Factors that Hinder or Help Inter- or Transdisciplinary Research

– What Factors Hinder or Help Inter- or Transdisciplinary Research? –

The academic literature presents a plethora of factors that can influence the success of interdisciplinary research. A preliminary list of 25 categories has been identified and will be refined in our final report.

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

Preliminary findings indicate that it may not make sense to distinguish factors on the basis of "helping" or "hindering". Rather, factors can act positively or negatively depending on the context, particularly the phase of the project. Factors are context-dependent and can potentially be transformed from problematic to enabling during the research process. This is a promising area for further investigation.

The grey literature surveyed so far in the qualitative analysis falls largely into two categories: advocacy for IDR as an essential component of addressing societal challenges, and reports on exemplary projects that include reflections on the challenges of IDR/TDR and recommendations for improvement. From these:

- The most commonly referenced obstacles to successful integration of AHSS disciplines in interdisciplinary research are career structures and research time frames.
- The most commonly mentioned recommendations suggest increased funding for AHSS research, increased involvement of AHSS disciplines in shaping research policy and opportunities for AHSS researchers to lead in the development of projects, including defining the research questions.

The academic literature presents numerous factors that can influence the success of interdisciplinary research, including cognitive, emotional, interactional and institutional conditions. A provisional list of 25 factors that are considered to help or hinder IDR/TDR has been identified from the literature. The first classification of factors that hinder or help AHSS in IDR/TDR, is based on the preliminary results from the qualitative content-analysis. This allowed a variety of factors to be identified and related to the different understandings of ID/TD. Table 3 below provides a short definition for each factor and its implications for AHSS integration. Factors are listed in alphabetical order. The list can so far provide

clues on the many issues that are interrelated when developing inter- or transdisciplinary research and poses the question of how to support teams trying to overcome one or some of these issues.

Table 3 Draft list of factors that hinder or help IDR and TDR according to the academic literature review

FACTORS	DEFINITION
Academic tribalism	• 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).	• "(…) 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).
Career Path	• Interdisciplinarity takes many forms and this can influence the types of career paths that academic researchers experience (Lyall, 2019).
Change	• 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). • "(…) 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).
Cognitive	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).
Collaboration	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).
Communicative	• "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).
Community building / identity	• 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	• "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).
Dealing with complexity	• 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).
Division of scientific labour	• 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	• 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).
Emotional	• "(…) 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).
Epistemological	• 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). • "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). • Epistemological and ontological difference play out spatially, affectively, and through an unequal dynamics of epistemological power (Callard & Fitzgerald, 2015).
Ethical	• The ethical and affective nuance of collaboration in practice (Callard & Fitzgerald, 2015).

Evaluation	• 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).
Institutional	• "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).
Interactional	• 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).
Motivations for IDR/TDR	• 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, 2013b). • 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).

Mutual Ignorance on collaboration	• 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).
Non-epistemological values	• "(…) 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	• 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).
Ontological	• "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). • Problematisation of things (ontology) that must be taken up, thought about, and engaged (ethics and anthropology) (Rabinow & Bennett, 2012).
Qualities of inter- and transdisciplinary researchers	• 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). • 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 et al., 2019).
Social	• 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).

In future steps this draft list of categories will be refined, clustered and areas of interest streamlined. Some relevant existing distinctions to be considered during this future process may include:

- Differentiating what signals interdisciplinary success ("markers") and what facilitates such success ("factors") (Boix Mansilla et al., 2016);
- Clustering factors under three broad areas: institutional barriers, disciplinary barriers and epistemic barriers (Tuana, 2013);

- Organising factors according to: antecedents (including personal factors such as values, goals and experience; the physical environment and bureaucratic structures), processes (including interpersonal, intrapersonal, positive, negative, intentional and unintentional activities); and outcomes (including concepts, interventions, training programs and organisations) (Wagner et al., 2011).

Importantly for SHAPE-ID's objective to develop a toolkit and recommendations on improving AHSS integration in inter- and transdisciplinary research, preliminary findings indicate that it may not make sense to distinguish factors on the basis of "helping" or "hindering". Rather, factors can act positively or negatively depending on the context, particularly the phase of the project. Factors are context-dependent and can potentially be transformed from problematic to enabling during the research process. This is a promising area for further investigation to determine how these transformations can be enabled. Table 4 below presents one example, namely, how academic tribalism can act as a positive or negative factor and its implications for AHSS integration.

Table 4 Example of how a factor, in this case academic tribalism, can act positively or negatively on IDR/TDR depending on the perspective of the literature analysed

ACADEMIC TRIBALISM			
DEFINITION	FACILITATES IDR/TDR (POSITIVE)	HINDERS IDR/TDR (NEGATIVE)	EXAMPLES & IMPLICATIONS FOR AHSS
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).	Understanding the preoccupations of each member of a team when developing concrete solutions (Castán Broto et al., 2009). Understanding "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. 13). Understanding the conversations each discipline is having about the subject being studied (Castán Broto et al., 2009). "Understanding 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. 13). Mastering multiple approaches and methodologies (Lau & Pasquini, 2004).	Uniformity of points of view and rejection of ID (B. Robinson et al., 2016). Debate on the validity of certain disciplines and of IDR (Lau & Pasquini, 2004). Negotiating positions within and across rigid research groups to seek employment and secure research (Lau & Pasquini, 2004).	"Each project member can play the role of the 'outsider within' for other members by virtue of their different worldviews, etc.; thus, so long as differences in worldview are harnessed in a way that illuminates potentially divisive variations in perspective (…)" (B. Robinson et al., 2016).

Reinforcing observations made above, one factor widely considered to be an obstacle to developing inter- and transdisciplinary collaboration is the lack of shared understanding of what is meant by these terms.

Interestingly, the question of failure is little addressed in discourses on ID and TD, because the problematic and conflictual issues of science are seldom studied (some exceptions are Barry and Born (2013b) and Callard and Fitzgerald (2015)). Like success, failure needs to be considered in context, acknowledging that its dimensions and impact will likely vary depending on such factors as career stage, discipline, gender and more (Balmer et al., 2015; Fletcher & Lyall, 2019).

In summary, the factors that can influence the success of IDR/TDR are interrelated, context-dependent and dynamic. They depend on such contextual features as the level of understanding of IDR/TDR, the phase a project is at, the roles assigned to partners, the logics and motivations underpinning the work and the disciplines and actors involved. Furthermore, different factors may be important to different partners in a collaboration (Bozeman et al., 2016).

4.3. Implications for AHSS Integration

– What Understandings and Factors are Relevant for AHSS Integration? –

While policy reports frequently advocate for the contribution AHSS disciplines and IDR/TDR can make to solving societal challenges, the academic literature suggests that there is often a perception that humanities researchers have little to offer and that their potential contributions are difficult to understand and difficult to integrate (Callard & Fitzgerald, 2015; Fitzgerald et al., 2013; Fitzgerald et al., 2014; B. Robinson et al., 2016).

The literature analysed so far shows little dialogue between AHSS and STEMM disciplines, although the problem, the gap and need to bridge them are widely acknowledged (Aldama, 2008; Kagan, 2009; Quan-Haase, Suarez, & Brown, 2015).

The label AHSS (or SSH) needs to be problematised and how each field can contribute to IDR/TDR analysed. Factors that contribute to successful IDR/TDR need to be analysed in a field-dependent fashion to consider means for transforming obstacles into enabling opportunities.

The literature on AHSS integration is scattered and each discipline presents the problem of integration from a different perspective. Klein (2005) has carefully analysed the rhetoric of interdisciplinarity in the Humanities as it has changed over time, noting that “plurality” and “heterogeneity” have replaced “unity” and “universality”; “interrogation” and “intervention” have supplanted “resolution” and “harmony”; “synthesis”, “holism” and “integration” have become pejorative notions, and “interdisciplinarity” has been challenged by new “anti-“, “post-“, “non-“ and “de-“ disciplinary stances. This reflects critical perspectives on knowledge production different from the problem-solving discourses prevalent in research policy.

The literature reveals a range of ways in which individual Arts, Humanities and Social Sciences disciplines grapple with the question of IDR/TDR integration. Further research is needed on these differences but a number of examples illustrate the range:

- **Geography:** Lau and Pasquini (2004) have found that researchers are concerned with natural scientists adopting and co-opting the vocabulary and methods of the discipline, with little interaction with geographers, meaning that integration does not take place.
- **Philosophy:** Philosophers have positioned themselves as providers of questions and new insights in IDR/TDR. This ranges from methods for mapping ontologies and epistemologies in an interdisciplinary team (O'Rourke, Crowley, & Gonnerman, 2016; B. Robinson et al., 2016) to the construction of sub-disciplines such as the Philosophy of Interdisciplinarity (Mäki, 2016) or Philosophy as/for interdisciplinarity (Hoffmann, Schmidt, & Nersessian, 2012).
- **Archaeology:** Authors discuss paths to make Archaeology a more "interdisciplinary" discipline (Osborne, 2013). This means that epistemological and methodological changes should be carried out from within Archaeology. Interdisciplinarity is seen as a product of the inner changes the discipline engages in and not as the outcome of the integration of different bodies or fields of knowledge.
- **Art:** Rust (2007) highlights that artists and designers adopt a different approach to research and problems than do researchers in other academic disciplines, for instance they may present a problem to an audience for interpretation without framing it beforehand as researchers may do. Further, research outcomes and products may be evaluated in terms of aesthetic value rather than utility in a more conventional sense (Leach, 2011).

Even as policy reports advocate for the expected contribution AHSS disciplines and IDR/TDR can make to solving societal challenges, the academic literature suggests that there is a perception that the potential contribution of researchers in the humanities is difficult to understand and integrate (Callard & Fitzgerald, 2015; Fitzgerald et al., 2013; Fitzgerald et al., 2014; B. Robinson et al., 2016). This means that few in the sciences are aware of what the humanities can contribute, and moreover, few in the humanities are aware of it either (B. Robinson et al., 2016).

B. Robinson et al. (2016) suggest that the lack of interdisciplinary interaction involving scientists and humanities researchers is less about hostility and more about mutual ignorance. The literature analysed so far shows insufficient dialogue between AHSS and STEMM disciplines and few suggestions for bridging the gap, although the problem, gap and need to bridge them are widely acknowledged (Aldama, 2008; Kagan, 2009; Quan-Haase et al., 2015).

As discussed above, the label AHSS (or SSH as it is more often termed) needs to be problematised and how individual disciplines can contribute to IDR/TDR analysed in greater detail. Factors that contribute

to successful IDR/TDR need to be analysed in a field-dependent fashion to consider means for transforming obstacles into enabling opportunities.

5. Conclusions

The plurality of understandings of ID/TD do not merely reflect theoretical disagreements, but differences in experience and differing views of the purpose of research and education, the role of disciplines and the role of critique. The challenge is to build dialogue between different understandings, recognising their differences but also building understandings adequate to the current state of knowledge.

Acknowledging the differences in purpose and roles is important for funders and policy makers in both reflecting on the potential of ID/TD in each context where it is encouraged or advocated for, and in and clarifying expectations.

While we are not yet in a position in this preliminary report to make definitive statements, it is plausible that imbalances in roles and the expectations of contributing in limited and predefined ways to scientific projects (e.g. ethical oversight or public engagement) discourages greater AHSS involvement. This will be subject to further examination in the next stage of our research.

A promising emerging 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 various contextual circumstances at play in a project. This merits further exploration with the potential to inform the development of tools and recommendations (in Work Package 5) for transforming factors from problematic to enabling in the research process.

Both the qualitative and quantitative analyses confirm that AHSS is a problematic label, obscuring the differences between a set of disciplines with very different disciplinary cultures. The finding that SS disciplines connect with more numerous and diverse STEMM disciplines than do AH disciplines in journals where IDR/TDR is discussed reinforces a pattern of AH underrepresentation seen elsewhere, for instance in the European Commission's SSH Monitoring Reports. While AH connects strongly with Engineering and Computer Science, SS connects to these and others, most notably Environmental Science and Medicine. Substantial research is needed to explore AH integration as a challenge in its own right. The kind of discourses that AHSS disciplines construct (based on critique, for example) might be colliding with the current tendency to adopt a problem-solving approach to all complex issues.

In the academic literature, IDR and TDR are considered as (following Barry and Born, 2013): (i) an object of conceptual and empirical investigation: this demands the co-construction of concepts; (ii) a method

of working: this understanding requires the traceability of processes; and (iii) a phenomenon subject to historical and geographical variation: this justifies the mapping of understandings (following Barry & Born, 2013).

What seems to be necessary is a clear connection among these three understandings and their implications for inter- and transdisciplinary research and AHSS integration. Research policy may also need to take this into consideration to better address the needs and expectations that lie behind efforts to support and encourage IDR/TDR.

Since the terms ID and TD are rarely defined in the grey literature sample reviewed so far, the range of understandings in these texts is difficult to untangle. However, it is worth cautioning that these terms should not be used interchangeably and should be clearly defined when first used in this type of document. This would improve links between the academic and grey literatures.

To contribute to addressing these gaps, a number of the SHAPE-ID learning case workshops organised in Work Package 3 (WP3) will focus on the role of AH integration. Two workshops (Dublin, December 2019 and Zurich, May 2020) will explore this question more broadly in the context of research addressing societal challenges, while two more will focus on areas within the humanities that have developed into strong new interdisciplinary research clusters, namely, Environmental Humanities (Edinburgh, January 2020) and Digital Humanities (Warsaw, April 2020). Health Sciences will be strongly represented by participants at the first workshop in Dublin, enabling more in-depth consideration of some of the thematic areas that have emerged as being strongly connected with the Social Sciences but less so with the Arts and Humanities.

6. Next Steps

This report presents progress so far in accomplishing the objectives of Work Package 2 and outlines emerging findings. In the coming months these findings will be substantiated and validated in connection with other Work Package 2 activities (the survey) and the first learning case workshops (Work Package 3). In March 2020, the work will be completed and a full report on the findings prepared, complemented by a Policy Brief presenting the most important recommendations from the point of view of stakeholders in research funding, policy making and university decision-making roles.

The analysis to date has begun to disentangle understandings of IDR and TDR in the academic and grey literature and identify factors that can help or hinder successful IDR/TDR. These understandings will inform the design of activities in the forthcoming series of learning case workshops in WP3, where preliminary and emerging findings will be validated and tested in discussion with stakeholders from

multiple backgrounds engaging in participatory discussion and activities to explore IDR/TDR approaches and challenges. The attempts undertaken to classify different understandings of and factors for helping or hindering IDR/TDR are being incorporated into the evaluation exercise the WP3 team will develop as part of the validation process (described in deliverable D3.1).

The next step of the current ongoing task is to complete the qualitative analysis of academic and grey literature samples and further quantitative analyses of the SHAPE-ID corpora. The focus of this analysis will be the connection between different understandings of IDR and TDR and the factors that hinder or help AHSS integration (Objective 2.3). Having now collated a database of suitable documents, the grey literature review will continue to analyse a wider range of European and national reports. Further analysis of the grey literature is needed to explore European national contexts and important thematic areas for AHSS integration.

Factors that help or hinder IDR/TDR will be clustered once the qualitative analysis is complete. We will then address the remaining objective of Work Package 2, namely, to clarify which understanding of IDR and which factors of success and failure are specifically relevant for integrating AHSS in IDR.

Once these analyses are complete we will be in a position to explicitly interconnect the different analyses, qualitative and quantitative, and to synthesise results from the literature review with the results obtained from the survey and exploratory interviews as these emerge.

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Appendices A – I

Appendix A Working Understandings of AHSS and STEMM

The list of SSH disciplines in the Horizon 2020 Programme is adapted from the UNESCO International Standard Classification of Education (ISCED 2011):

- **Social and behavioural sciences:** economics, economic history, political science, sociology, demography, anthropology (except physical anthropology), ethnology, futurology, psychology, geography (except physical geography), peace and conflict studies, human rights.
- **Education science:** curriculum development in non-vocational and vocational subjects, educational policy and assessment, educational research.
- **Journalism and information:** journalism, library and museum sciences, documentation techniques, archival sciences.
- **Business and administration:** retailing, marketing, sales, public relations, real estate, finance, banking, insurance, investment analysis, accounting, auditing, management, public and institutional administration.
- **Law:** law, jurisprudence, history of law. - Humanities and the arts
- **Humanities:** religion and theology, foreign languages and cultures, living or dead languages and their literature, area studies, native languages, current or vernacular language and its literature, interpretation and translation, linguistics, comparative literature, history, archaeology, philosophy, ethics.
- **Arts:** fine arts, performing arts, graphic and audio-visual arts, design, crafts.

SHAPE-ID uses the term STEMM to capture the following understanding of STEM disciplines including some disciplines that are often excluded, i.e. “medicine, structural engineering and sports science”:

> ‘Core’ STEM subjects typically include: Mathematics; Chemistry; Computer Science; Biology; Physics; Architecture; and, General, Civil, Electrical, Electronics, Communications, Mechanical, and Chemical Engineering.[10]

[10] EU Skills Panorama (2014), STEM skills Analytical Highlight, prepared by ICF and Cedefop for the European Commission. https://skillspanorama.cedefop.europa.eu/sites/default/files/EUSP_AH_STEM_0.pdf

Appendix B Query Schema for Scopus and WoS

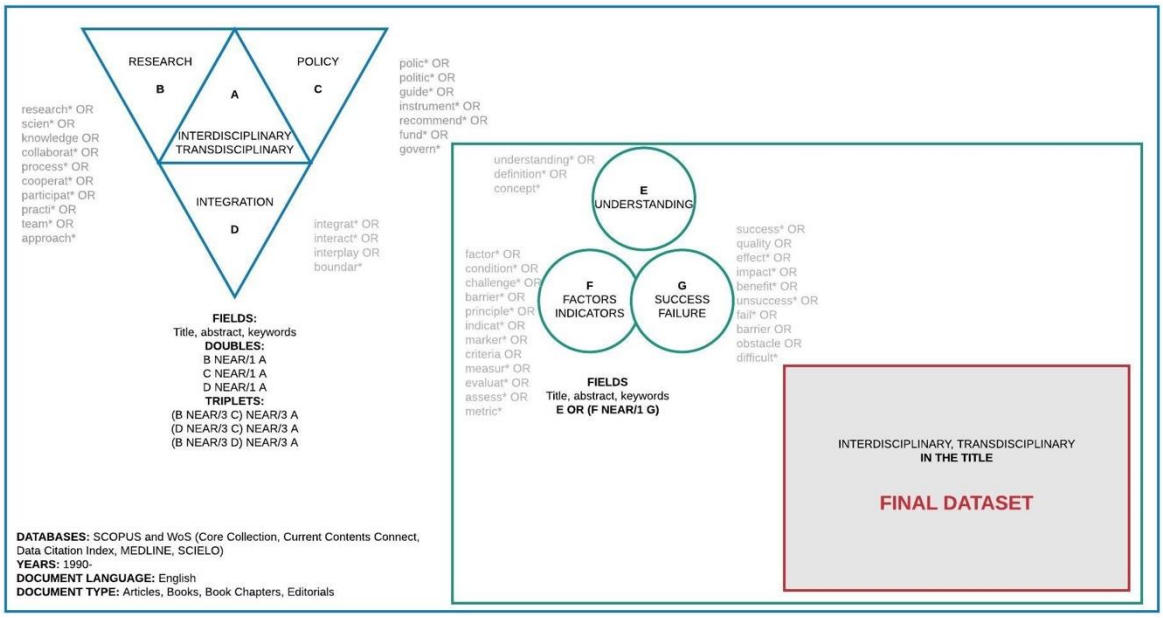

Figure 8 Query schema for Scopus and WoS.
Blue rectangle represents Step 1, green represents Step 2 and red represents step 3. Additional constraints (Step 4) are listed in bottom-left corner.

Appendix C Sets of Keywords for the Academic Literature Review

Table 5 Sets of keywords for the academic literature review.

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

Appendix D Inclusion and Exclusion Criteria for Academic Literature Selection for Qualitative Analysis

Table 6 Inclusion and exclusion criteria applied to the systematic literature review of academic literature.

Topic coverage	All documents had to contain: ID MD or TD
Scope	Key terms derived from the research questions
Exclusion criteria	• Title or abstract is not in English • Presents STEMM perspectives on integration with no connection to AHSS (STEMM alone)
Inclusion criteria	• Discusses AHSS roles in IDR or AHSS+STEMM integration processes. • Survey of AHSS research in Europe or discussion AHSS research infrastructures ((e.g. Academia Europea, 2012; ALLEA-RatSWD, 2014)
Document type	All documents must meet at least one of these criteria: • Outlines concepts/frameworks of ID/MD/TD research (*interdisciplinary, multidisciplinary, transdisciplinary, collaborative) (e.g. INTREPID, 2017) • Discusses indicators* of successful transdisciplinary research (*measures, markers, criteria) (e.g. EC, 2015, 2017, 2018) • Explores factors* that hinder/enable successful transdisciplinary research (*conditions, principles) (e.g. ESRC Innogen Centre, 2011) • Describes challenges of ID/MD/TD research • Presents AHSS integration processes and examples of good practices or reflect on how to perform this integration (e.g. EC, 2015, 2017, 2018) • Analyses and/or evaluates research projects/programs empirically and/or derive recommendations for designing, conducting, evaluating ID/MD/TD research (e.g. STIS, 2011; TD-NET, 2011)
Geographic barriers	No geographic barriers (language: English)
Period of time	Publication year between 1990 – 2019
Source	Scopus; Web of Science; Jstor; Open Grey; SSRN; Bielefeld Academic Search Engine (BASE); research organisations' websites

Appendix E Inclusion and Exclusion Criteria for Grey Literature Selection for Qualitative Analysis

Table 7 Inclusion and exclusion criteria applied to the Grey literature selection for the qualitative analysis.

Topic coverage	All papers had to contain: interdisciplinar* or transdisciplinar*
Scope	Key terms derived from the research questions
Exclusion criteria	• Publications that relate to Teaching and/or Education • Publications which title or abstract is not in English • Presents STEMM perspectives or integration with no connection to AHSS (STEMM alone) • Papers that analyse the interdisciplinary trajectory of a person or researcher
Inclusion criteria	• Contain references to AHSS or AHSS+STEMM integration process (e.g. Callard & Fitzgerald, 2015). • All papers that present "Studies of ID or TD" perspective (either they refer to AHSS or just to STEMM integration alone). The latter might provide new insights to answer the research questions. If the abstract included usable and practical outcomes, these titles were also included also if they just included STEMM (e.g. Buettel, Brook, Cole, Dickey, & Flies, 2018). • Examples of interdisciplinary areas or fields of knowledge that integrate AHSS. For example, Migration Studies or Gender Studies.
Document type	All papers must meet at least one of these criteria: • Outline concepts/definitions and/or understandings of ID/TD research (*interdisciplinary, multidisciplinary, transformative, participatory, collaborative, applied). • Explore factors* that hinder/enable successful inter- and transdisciplinary research (*conditions, principles) (e.g. Boix Mansilla et al., 2016). • Describe challenges of inter- and transdisciplinary research (e.g. Lang et al., 2012). • Presents AHSS integration processes and examples of good practices or reflect on how to perform this integration. • References that analyse and/or evaluate research projects empirically (quantitatively and/or qualitatively) and/or derive recommendations for designing or conducting inter- and transdisciplinary research (e.g. Luthe, 2017).
Geographic barriers	No geographic barriers. Balance between countries represented in the analysed corpus was pursued
Language	English
Period of time	1990–2019
Source	Scopus, Web of Science, Jstor and SHAPE-ID partners inputs

Appendix F Concept Mining comparison of SHAPE-ID Corpora

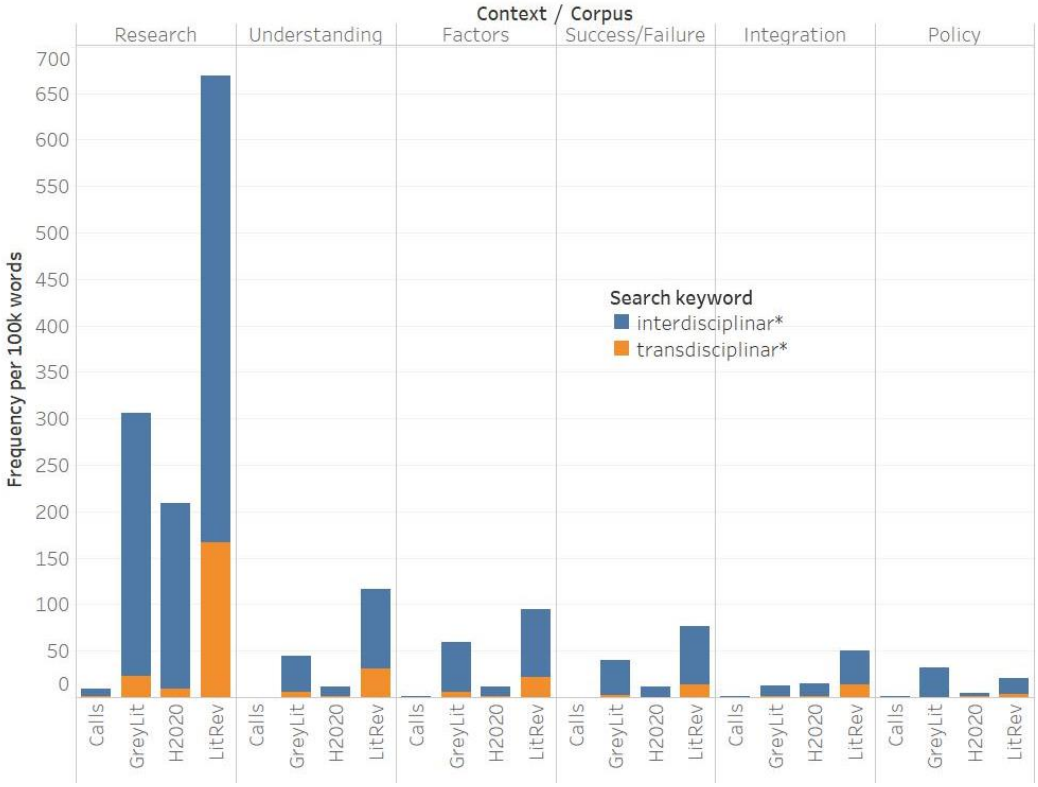

Figure 9 SHAPE-ID context keywords frequency per 100k words by corpus.

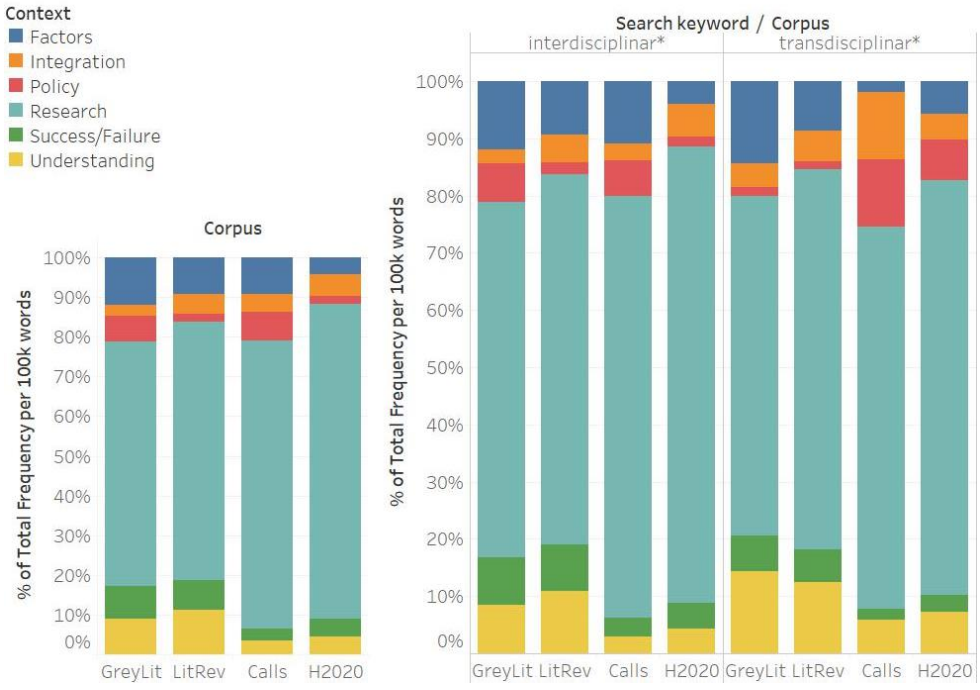

Figure 10 Percentage distribution of SHAPE-ID keyword normalised frequencies in corpora.

Comment: Figures 9 and 10 display the distribution of SHAPE-ID focus areas in the collected corpora, based on frequencies of words that appear in the context of the project's keywords (see Appendix C for more detail). Figure 9 clearly shows that interdisciplinarity is significantly more often discussed than transdisciplinarity. Two graphs in Figure 10 show the percentage distribution of SHAPE-ID context keywords across all corpora. The graph on the right represents separate results for inter- and transdisciplinarity, while the graph on the left shows combined frequencies.

The LitReview corpus, collected through explicit targeting of the search keywords is the richest, as well as the GreyLit corpus. The H2020 project abstracts contain relatively few references to IDR/TDR issues (as mentioned above, a mere 8% of projects (1912 out of 23,155) mentions those keywords explicitly). While the context of research was understandably the most prominent in all samples, we may note that "factors" keywords are mentioned more often in the LitReview and GreyLit corpora. The GreyLit dataset also mentions "policy" keywords more frequently, as do H2020Calls (especially regarding TDR). "Integration" keywords seems to be mentioned more often in the context of transdisciplinarity, especially within the H2020Calls and GreyLit datasets.

Appendix G Overview of Disciplinary Affiliations and Frequency of Publications in Literature Review Sample

Table 8 The overview of AHSS disciplinary affiliations of the SHAPE-ID Literature Review sample.

Processed sample	Records	% Records	Journals	% Journals
Processed Sample (PS)	3244	**100,0**	1853	**100,0**
Social Sciences (PS)	1494	**46,1**	775	**41,8**
SS without Education	983	**30,3**	533	**28,8**
Arts and Humanities (PS)	626	**19,3**	371	**20,0**
Arts (PS)	64	**2,0**	40	**2,2**

Table 9 Frequency of publications on IDR/TDR in Social Sciences, Arts and Humanities in journals. Presence of AH diminishes drastically among journals that publish on IDR/TDR most frequently.

Journals by frequency	Records	% Records	Journals	% Journals
1-10 Records	2802	**100,0**	1826	**98,5**
Social Sciences	1297	**46,3**	764	**41,2**
AH	594	**21,2**	369	**19,9**
11-20 Records	359	**100,0**	24	**100,0**
Social Sciences	143	**39,8**	9	**37,5**
AH	16	**4,5**	2	**8,3**
21-29 Records	83	**100,0**	3	**100,0**
Social Sciences	54	**65,1**	2	**66,7**
AH	0	**0,0**	0	**0,0**

Appendix H Statistics on the Network of Relationships between Disciplines in the Literature Review Sample

Explanation: The statistics in Table 10 were computed in Gephi. Degree stands for a number of connections (edges) of each node. Weighted degree is a similar measure, also based on the number of connections but taking into consideration the weight of those connections. Closeness centrality represents how close a node is to all other in the graph, i.e. how central it is for the network. Betweenness centrality represents how often a node acts as the shortest connection between two other nodes. It is a measure that tells which disciplines are central to communication between disciplines that otherwise do not connect very well. If a discipline has strong betweenness centrality, it is because journals affiliated to that discipline are a gateway to a relatively greater number of other disciplines that are not connected through journal affiliations with other disciplines. Journals affiliated to Medicine, Social Sciences, Agricultural and Biological Sciences, Arts and Humanities, and Computer Science are central for networking other disciplines represented in our data sample.

Table 10 Statistics of the Network of relationships between disciplines in Literature Review sample. The higher the discipline's degree, the more interconnected it is with other disciplines in terms of journals combining two or more disciplinary affiliations.

Discipline	Weighted Degree	Degree	Closeness Centrality	Betweenness Centrality
Social Sciences	5494	23	0.896552	29.564159
Environmental Science	3101	17	0.742857	7.53162
Arts & Humanities	2102	17	0.742857	13.896861
Medicine	2047	24	0.928571	51.195707
Business, Management & Accounting	1827	13	0.666667	3.649603
Agricultural & Biological Sciences	1554	18	0.764706	14.844282
Engineering	1079	19	0.787879	8.258802
Biochemistry Genetics & Molecular Biology	872	18	0.764706	12.357973
Computer Science	848	21	0.83871	13.62785
Economics Econometrics & Finance	744	9	0.590909	2.687933
Energy	474	10	0.619048	0.691342
Psychology	374	9	0.604651	0.775794
Nursing	373	8	0.590909	0.737734
Earth & Planetary Sciences	310	11	0.634146	0.92619
Decision Sciences	229	10	0.619048	1.02702
Health Professions	147	12	0.65	3.17381
Neuroscience	141	12	0.65	3.60873
General	114	3	0.5	0
Mathematics	82	16	0.722222	7.575234
Pharmacology_Toxicology_and_Pharmaceutics	82	10	0.619048	0.934524
Chemistry	77	12	0.65	1.301623

Immunology & Microbiology	31	8	0.577778	1.438131
Materials Science	28	11	0.634146	1.163131
Physics & Astronomy	27	11	0.634146	0.957937
Chemical Engineering	27	13	0.666667	3.074008
Veterinary	10	4	0.530612	0
Dentistry	8	1	0.490566	0

Comment: If we look at the importance of particular disciplines in our sample we see that Medicine and Social Sciences are connected to most of the other disciplines (24 and 23 out of 28). However, if we take weights into consideration (in our case, the number of articles featuring particular disciplines), Environmental Sciences and A&H feature as more important than Medicine, but less than Social Sciences. Judging from the importance for the network we may conclude that 9 disciplines seem to be mostly featured in the sample: Social Sciences, Environmental Science, Arts & Humanities, Medicine, Business, Management & Accounting. Agricultural & Biological Sciences, Engineering, Biochemistry Genetics & Molecular Biology, Computer Science. Among journals that discuss IDR/TDR and that combine two or more disciplinary affiliations, these disciplines are most interconnected with other disciplines.

Appendix I Disciplinary Connections in Literature Review Sample

Explanation: The weight of an edge represents the number of connections as well as the centrality of the connecting node (the higher the centrality, the more valuable the connection), i.e. the extent to which a discipline is connected to other disciplines). Closer proximity of a node to the center and the edge thickness represent the higher weight, i.e. stronger connection.

Table 11 Weight of disciplinary connections of Arts & Humanities in Literature Review sample.

Arts and Humanities	Weight
Social_Sciences	1329
Engineering	200
Computer_Science	198
Economics_Econometrics_and_Finance	92
Business_Management_and_Accounting	76
Psychology	53
Multidisciplinary	42
Medicine	34
Environmental_Science	23
Biochemistry_Genetics_and_Molecular_Biology	17
Nursing	11
Neuroscience	10
Pharmacology_Toxicology_and_Pharmaceutics	9
Agricultural_and_Biological_Sciences	3
Earth_and_Planetary_Sciences	2
Mathematics	2
Health_Professions	1
Chemical Engineering (all)	0
Chemistry (all)	0
Decision Sciences (all)	0
Dentistry (all)	0
Energy (all)	0
Immunology and Microbiology (all)	0
Materials Science (all)	0
Physics and Astronomy (all)	0
Veterinary (all)	0

Table 12 Weight of disciplinary connections of Social Sciences in Literature Review sample

Social Sciences	Weight
Arts_and_Humanities	1329
Environmental_Science	1290
Business_Management_and_Accounting	1027
Medicine	522
Computer_Science	363
Engineering	199

Economics_Econometrics_and_Finance	141
Psychology	137
Earth_and_Planetary_Sciences	102
Agricultural_and_Biological_Sciences	69
Chemistry	49
Biochemistry_Genetics_and_Molecular_Biology	46
Nursing	46
Multidisciplinary	36
Pharmacology_Toxicology_and_Pharmaceutics	27
Neuroscience	25
Mathematics	24
Energy	23
Health_Professions	21
Decision_Sciences	8
Physics_and_Astronomy	5
Chemical_Engineering	4
Materials_Science	1
Immunology and Microbiology (all)	0
Veterinary (all)	0
Dentistry (all)	0