QUESTIONING THE PROMISE OF INTERDISCIPLINARITY: AN ETHNOGRAPHY OF AN INTERDISCIPLINARY RESEARCH PROJECT

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Abstract

Interdisciplinarity has been portrayed as the research approach of choice by funders in Europe and the UK. As it is lauded as the necessary research configuration to reach ‘holistic’ solutions to complex problems such as sustainability, researchers and institutions organise their projects accordingly. Interdisciplinarity has become a research topic in itself. However, existing research has principally focused on the reasons why interdisciplinarity research is needed and the challenges to doing it successfully. The popularity of this research approach, coupled with the continued challenges of ‘doing’ interdisciplinarity, suggests that more research is needed to investigate the experiences of the researchers themselves.

This research investigates interdisciplinarity in practice by conducting an ethnographic study of academics from both the natural and social sciences at a UK university charged with studying urban sustainability. The research is based on thematic and interpretive analysis and theories from Science and Technology Studies. The data collected between 2016 and 2019 drew from field notes, participant observation, semi-structured interviews, self-recorded diaries and document analysis.

The findings from this research suggest that despite the motivation to work in an interdisciplinary way, the lack of a unified definition or incentive to do interdisciplinary work prevented researchers from viewing interdisciplinarity as a primary, integrated objective. In addition, due to the lack of evaluation measures, it was difficult to measure a successful interdisciplinary collaboration; therefore, expectations to meet an interdisciplinary ‘goal’ were unmet. This thesis argues that practising interdisciplinarity within an academic environment makes it difficult to create the incentives necessary to pursue interdisciplinary collaborations and that, in embracing conflict and experimentation, an appreciation for the practice of interdisciplinarity rather than a focus on the outcomes can be achieved.

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Chapter 1: Introduction

My curiosity about the interdisciplinary process started before I embarked on my PhD. Like many who come across the term ‘interdisciplinarity’ before actually experiencing it in practice, I was swept away by its novelty and lofty promise to deliver exceptional research findings. Whilst I was working in a market research agency in London, my team was asked by a trust to deliver an evaluation project from a recently launched funding scheme and project they had recently started. As it was the first time this trust had funded an interdisciplinary project where they provided a space within their own building to conduct the research, they were interested in the experiences of the awarded research team. By finding out what did and did not work well, they hoped to improve upon their award for future collaborations.

The evaluation project consisted of multiple individual interviews with all of the project’s collaborators; we spoke with each person twice, once in each of the two research phases. The first wave of interviews took place at the start of the project, and the second wave at the project’s end. We found a qualitative difference between these two phases in the research participants’ attitudes and experiences. While the research participants started out hopeful and excited to embark on their new project award, their enthusiasm for the particular interdisciplinary dynamics of the project waned considerably towards the end.

One of the reasons for the change in tone was a difficult experience in a workshop after the first phase of the research. Workshop attendees included my team members, employees from the funding body and funded research participants from the project. In the first half of the workshop, my team gave a presentation outlining the findings and perceptions of interdisciplinarity from the first interview phase. The funder found these initial research insights interesting; however, the funded research participants found the presentation personal and exposing.

What I, my team and the funder had failed to appreciate at the time were the power dynamics at play that put the funded participants in an awkward position. In practice, they found collaborating and communicating quite difficult and emotionally draining; overall, they found the process harder than expected. These negative experiences of interdisciplinarity were laid out in the workshop for everyone to see. The whole process of the evaluation, the interviews, and the workshop created an expectation around their interdisciplinary work. The participants felt they needed to deliver (or show they were delivering) fruitful connections and novel research approaches to the research questions. The gap between the research participants' expectations and experiences of the project created an additional dimension of interdisciplinary working; it meant they felt they needed to perform or do interdisciplinarity in the 'right' way.

Interviewing the participants the second time felt very different. Many of the participants were now guarded in their responses, fearing any negative feedback might reflect badly on the project. Interestingly, though some of the participants felt that they had not quite 'cracked' this interdisciplinary puzzle, they were still quite happy with the diversity and quality of articles, books, talks, workshops and seminars that resulted from the research. One question from a conversation with a participant that stuck with me was: "How useful is this interdisciplinary label anyway?"

Though singular and anecdotal, this experience is by no means an isolated one. When comparing the discourse around the idea of interdisciplinarity with the actual experiences of those who try to employ it, this disconnect is seen again and again. Interdisciplinarity has been described as a buzzword in the academic world (Dzeng, 2013) and the private sector, though in business it tends to be described as collaborative working outside of silos (Gleeson, 2013). Interdisciplinarity is thought to hold the key to novel and innovative solutions (Research Councils UK, 2014) due to its holistic nature and approach (Frank,

2017). This promotional language creates high expectations for the research that will come from it.

However, the words used to describe the experience of interdisciplinary working are very different. Collaborators reflect on their ‘challenging’ experience (Lach, 2014; MacLeod, 2018), the conflicts arising from misunderstandings (Brinkmann, 2018) and the amount of time in interdisciplinary projects that feels unproductive (Albert et al., 2019). And although some of these descriptors are communicated in a positive tone (a career-driven, ambitious researcher would describe a research challenge in a positive tone (Nancarrow et al., 2013)), discussion of the experience of interdisciplinarity is usually mixed. Interdisciplinarity is an important issue because whilst simultaneously being praised and adopted across diverse working environments, it faces repeating underlying challenges to being employed in practice.

About six months after that evaluation project, I came across a studentship that advertised this PhD project proposing the study of the interdisciplinary process. I felt I was more familiar than most with the actual experiences of interdisciplinarity. I recognised some of the lofty terms in the job description, such as the “far-reaching implications” associated with interdisciplinary working, and I thought that my previous insights from the evaluation project had prepared me for the inevitable challenges and frustrations that would pop up.

In that previous market research project, my team took a snapshot of a few of the project’s specific touchpoints, missing much of the day-to-day intricacies of collaboration. The ethnography approach outlined in the studentship meant I would be present throughout the project and find out along with other researchers how and when attitudes about interdisciplinarity changed. Being embedded within the interdisciplinary project as an insider/collaborator meant I would know the context of the dynamic interdisciplinary experience. This thesis is a documentation and analysis of those experiences.

1.1 Research contribution

This thesis studies interdisciplinary research practices and experiences in the context of urban sustainability research. Much of the literature reviewing interdisciplinary research projects in the sustainability realm discusses how this research should be done. Fewer authors explore *how* interactions between the scientific systems and the human systems currently operate. Tellingly, in the literature documenting the practicalities of interdisciplinary research, much of the discussion centres around the difficulties and challenges experienced by interdisciplinary researchers (Albert et al., 2009; Bracken & Oughton, 2006; Clark et al., 2017; Lach, 2014; Lyle, 2016; McBee & Leahey, 2017; Shinn, 2006). Despite all of the literature outlining how to do interdisciplinarity, work continues to be published discussing the challenges to doing 'real' interdisciplinarity. This pattern implies a failure to share experiences or understand the inner workings and dynamics of an interdisciplinary project. Further, there is little research documenting how researchers themselves understand interdisciplinary work, how this understanding changes over time, and what (if any) reflexive observations occur about researchers' practices.

Rather than focus on the evaluative approach in interdisciplinary research, this thesis aims to go beyond a discussion of how researchers from different disciplines interact with each other. Instead, this thesis aims to understand how participants imagine interdisciplinarity as a concept itself and how this expectation determines their research approach. This project studied the process of knowledge production in an interdisciplinary academic environment by studying the narratives told by the researchers; by studying the narratives used to define interdisciplinarity, an understanding of diverse approaches to collaboration can be understood.

Studying different interpretations of collaboration is important because an increased understanding of interdisciplinarity as a concept, as well as an exercise, would help researchers increase their 'interdisciplinary

competence,' and improve their experience of working in an interdisciplinary environment. Brassler and Dettmers (2017) discuss how researchers lack the skill of working with others from different disciplines because training opportunities are few and far between. The assumption that interdisciplinary research 'just happens' contributes to a lack of training opportunities. As a result of this assumption, participants in interdisciplinary collaborations often experience confusion during research and have vague expectations for how interdisciplinarity should develop.

As a contribution to knowledge, this thesis: 1) contributes to the field of interdisciplinarity by documenting the lived experiences of researchers in an interdisciplinary project, including the practical operations and their implications; 2) contributes methodologically by providing an embedded researcher's perspective over the duration of the project instead of as a secondary reflection after the project has finished; and 3) combines theory from Science and Technology Studies (STS) with interdisciplinary empirical evidence by applying the New Production of Knowledge theory (Gibbons et al., 1994) to the thesis's empirical findings to understand the interdisciplinary configuration of the sustainability project. Understanding how researchers themselves understand interdisciplinarity and their approaches to conducting it clarifies the role of interdisciplinary research in the sustainability science realm. It also increases the understanding of interdisciplinarity research, which will add to its appropriate application and efficacy in the future.

1.2 Research aims and questions

In reflecting on the above needs in interdisciplinary research, this thesis focuses on the practices that researchers perform to identify and make sense of interdisciplinarity, and therefore how they approach interdisciplinary collaboration. The study takes an ethnographic research approach.

To this end, this thesis investigates a case study of urban

sustainability researchers within a university who received funding for their collaborative and interdisciplinary approach. This ethnography comprises thematic and interpretive analysis of data from participant observation, project documents, published work, semi-structured interviews and diary entries from late 2016 through early 2019.

Thesis aim: To investigate and document collaborative interdisciplinarity within a team of researchers to understand approaches, expectations and perceived outcomes of their collaboration in their attempt to reach new and innovative research methodologies, theories and findings.

To explore this, the thesis focuses on these research questions:

1. How did the researchers on the project understand interdisciplinary working? What did researchers see as important aspects to include in an interdisciplinary project?

2. How was interdisciplinarity experienced by researchers on the project?

3. How did researchers assess the interdisciplinary element of the project, and how did they come to those conclusions?

4. How can we understand the research in light of theoretical frameworks?

1.2.1 Scope and boundary of the study

For the sustainability project investigated in this study, its researchers remain anonymous and only a few details pertaining to the analysis of the study are present. Names have been changed to protect confidentiality. The project was a temporary configuration of a group of researchers based at the University of Nottingham, after being awarded

a grant to conduct urban sustainability research over five years starting in 2014. The data collection for this thesis took place between late 2016 and early 2019, with the bulk of the interviews conducted from November 2017 through March 2018. During this period, some researchers were still being recruited to the project, so this time captured some of the researchers' on-boarding, whilst some project initiatives were already underway.

This ethnography presents a range of data, interactions and discourses for studying interdisciplinarity, team collaboration and human psychology. However, due to time, funding and constraints on my own expertise, this study focuses on the interactions between researchers as representatives of their disciplines. For example, a researcher with a background in engineering would be analysed in reference to their engineering discipline, rather than analysed according to their personality traits such as shyness. It also focuses on their interactions from the perspective of their positions in the academic hierarchy (PhD student, postdoctoral researcher, senior academic). This study does not include any individual researchers' psychological or personality traits; this dynamic, though interesting, proved outside of my academic expertise to analyse.

This thesis is also not an evaluation of the team's interdisciplinary efforts. The research project's short time period lent itself to studying the dynamics of collaboration as it happened. A more accurate evaluation of the project would ideally take place sometime in the future when papers have been published and researchers have gone on to work in other research endeavours. In addition, a specific definition of 'interdisciplinarity' would be required to conduct an evaluation. Sticking to a 'gold standard' of interdisciplinarity would have unfairly held the researchers to a standard of interdisciplinarity that they may not necessarily have adhered to. This thesis seeks to understand the researcher's conception of interdisciplinary working and takes an explorative and flexible approach to the definition.

1.3 Thesis outline

Following the introduction, **Chapter Two** outlines the relevant literatures in interdisciplinary research, sustainability science, dynamics in team collaboration and STS theories. This chapter describes the various definitions and terms used to describe interdisciplinary research, revealing the multiplicity of its applications and uses. Various actors involved in the promotion and definition of interdisciplinarity are described to give the current trend of interdisciplinary research a wider context. This chapter also investigates how different perspectives understand the relationship between interdisciplinary and disciplinary research approaches. Different configurations of applying interdisciplinary research approaches and the empirical studies that document and evaluate the outcome of recent interdisciplinary research projects are also explored. As this thesis tracks an interdisciplinary project focusing on urban sustainability, this chapter provides a review of sustainability science literature and its relationship with interdisciplinary research. The project investigated in this thesis tracks individuals over a long period of time during work hours at a university institution; a brief overview of collaborative dynamics in interdisciplinarity captures this dimension. Finally, a review of STS literature is provided to understand how STS scholars imagine new configurations that produce knowledge and scientific studies.

A brief history and review of ethnographic research and its use by STS scholars in the study of science are given in **Chapter Three**. This is followed by a description and outline of the case study approach and an ethnographic account of the case study's development. Considerable attention is given to the ethics of conducting this case study research, as it was complex to navigate. A detailed description of the different avenues of data collection is given, including participant observation, interviews, document analysis and self-recorded diaries. Given the unusual set-up where I was a member of the research project that I was

simultaneously studying, reflexive thoughts are provided throughout this chapter.

In **Chapter Four**, I introduce a metaphorical interdisciplinary building made up of different building blocks to explain what pieces comprised the interdisciplinary project. The rationale to using a metaphor draws from the understanding that metaphors are implicated in conceptual understandings and shape the very meaning of the abstract concepts they illustrate (Brown, 2003; Taylor & Dewsbury, 2018). This building metaphor is used to reflect the researchers' understanding of interdisciplinarity. It also shows how an understanding of interdisciplinarity can determine how interdisciplinarity is approached and illustrates the expectation that interdisciplinarity would occur in this building. Each individual building block is named and its function described.

The next chapter opens the door, entering the interdisciplinary building to find out what happens inside—i.e., how the interdisciplinary project functioned in practice. In **Chapter Five**, the metaphorical building blocks are referenced in relation to their expected and actual functions in interdisciplinary work. This chapter outlines the three main themes describing the balance that researchers experienced when trying to conduct interdisciplinary collaborative work. An ethnographic critical incident (Bradley, 1992) is narrated at the end of this chapter to contextualise the themes and experiences of researchers within the interdisciplinary building. The expectations of interdisciplinarity are compared with the actual experiences of doing interdisciplinarity from the researchers' perspective.

I investigate this gap between the expectations and reality of interdisciplinary working specifically within the context of a university environment in **Chapter Six**. Here, I recount the researchers' perspective of how much interdisciplinarity was achieved. Their verdict and reasoning behind their conclusions are provided, as well as the evidence presented to reach their decision. This chapter investigates

evidence of successes to try to understand where standards of success come from and how they were applied in this research project. Another critical incident is narrated at the end of this chapter to ground the researchers' observations within the story from multiple perspectives.

Gibbons et al.'s (1994) New Production of Knowledge (NPK) theory is used as a framework to try to understand the knowledge configuration of this project, how it was 'built' and why it was perceived to have 'failed'. In **Chapter Seven**, I detail each of the five main characteristics that differentiate Mode 1 and Mode 2 research in the NPK theory. In mapping the characteristics of the interdisciplinary project studied, these focal points are used as a guide to understand the research configuration of the project and how it was structured. This chapter also focuses on the academic university as a central meeting site of knowledge production and questions what Gibbons et al. understand the role of the university to be in Mode 1 and Mode 2 research.

I revisit the empirical findings and theoretical understandings of interdisciplinary project outcomes in **Chapter Eight**. In this discussion chapter, I revisit the research gaps and focus on the important interdisciplinary themes identified in this case study and outline my contribution to the field of interdisciplinary studies and STS. I introduce new interdisciplinary themes, detail my contribution to methodology as an embedded researcher and discuss the advantage of applying a theoretical framework against the empirical findings.

I conclude this thesis by bringing together the previous chapters' collective findings and discussing how interdisciplinarity has been conceptualised by the researchers themselves, and why. **Chapter Nine** also uses Gibbons et al.'s (1994) theory of knowledge production as a lens to unpick the different characteristics of this project and the role of the university environment in determining and prioritising research streams. Empirical comparisons to the outlined body of literature are provided as well as practical implications and suggestions for future interdisciplinary collaborations, using the lessons from this research

project. On the back of lessons learned, suggestions are made for how new research projects could be approached in the future.

Chapter 2: Literature review

2.1 Introduction

In continuation of the scene set in Chapter One, this chapter starts with the relationship between interdisciplinarity and the wider field of sustainability science. This chapter then discusses the various definitions of interdisciplinarity and explores the concept of a 'discipline'. A review and example of previous studies of interdisciplinary research are offered to understand the rationale for this thesis's research approach. It then provides a short review of relevant team dynamics literature related to collaborative practices and STS theories and frameworks of scientific research configurations. Lastly, this chapter reviews existing trends and debates in interdisciplinary research and identifies the gaps where my research makes a contribution.

2.2 Sustainability science

The 'sustainability science' field of research is a multi-disciplinary field of study that tries to understand the connections between the natural and social systems that define sustainability (Bettencourt & Kaur, 2011; Hutchins Bieluch et al., 2017; Kates, 2011; Wiek et al., 2012). Sustainability science aims to approach research by starting with the "problems it addresses" rather than the "disciplines it employs" (Clark, 2007, p. 1737).

Sustainability science considers both the natural and social systems that exist in the sustainable development field of study. It is a "Post-Normal Science" (Funtowicz & Ravetz, 1993; 1994) in that it is characterised by its relationship with other forms of expertise (such as non-academic audiences and members of the public) and the high uncertainties present within the research itself (Brandt et al., 2013; Fiksel, 2006; Hutchins Bieluch et al., 2017; Kates, 2011; Wiek et al., 2012). The agenda of sustainability science is action- or goal-oriented in

its approach of combining theory, scientific evidence and policy (Bettencourt & Kaur, 2011; Kates, 2011).

Inherent in attempts to understand sustainability science is recognition of the complexity of addressing environmental issues and the uncertainty that comes with a diversity of scientific opinions and multi-disciplinary outlooks (Jasanoff, 2007; Miller et al., 2014; Sarewitz, 2004). The nature of sustainability science is multidimensional; it not only involves the natural sciences that study and make sense of the environment but also includes social sciences such as anthropology to understand the human aspects that shape (un)sustainable behaviour and outcomes (Wiek et al., 2012). The complexity lies not only in the combination or number of disciplines and ways to study sustainability in a single case study or topic but also in how these areas of expertise relate, complement or directly contradict each other (Funtowicz & Ravetz, 1994; Miller et al., 2014). For example, the encouragement of economic growth as it is currently imagined cannot be reconciled with the 'limits to growth' discourse found in ecological environmentalism, which discusses Earth's finite physical capacity (Dovers & Handmer, 1993). The unlimited combinations of disciplines that speak to the multiple issues in sustainability science makes this field of research complex.

Additionally, sustainability studies suggests that scientific evidence contributes to the uncertainty in this field. Sarewitz (2004) discusses how scientific evidence is not itself unified or in agreement, although scientific study is tasked with answering questions that exist in the 'natural world' (Jasanoff, 2007). An example of this is the issue of scientific consensus in climate change science. Although scientists broadly agree that anthropogenic global warming is underway, the details of this phenomenon—that is, how much of the weather variation is due to human causes versus natural causes and what will happen to the planet in the future—are disparate (Pearce et al., 2017). Not all

scientists are in agreement about what should be done to solve such sustainability problems.

A contributing factor to the divergence of scientific opinion is the close relationship between scientific evidence and policy. Sarewitz (2004) argues that scientific research is always inherently political, as it is studied by people who have their own values, world outlooks and disciplinary orientation. Hutchins Bieluch et al. (2017) describe how politicians and scientists “manage the boundaries between science and policy” (p.89) to try to maintain separate spheres of work; unlike Sarewitz, they assume that the two can be separated. This is an example of “boundary work”, which is defined as the processes, negotiations and language used by scientists to demarcate their field of expertise from other forms of knowledge (Gieryn, 1983). In this context, scientists consider ‘other forms of knowledge’ to come from policymakers. This management of boundaries between science and policy is constantly being negotiated and renegotiated by the actors involved in policymaking, impacting how science itself is conducted.

Policy creation demands policy recommendations from scientists and conclusive and binary ‘yes’ or ‘no’ answers when scientific evidence is contested (Salter, 1988). As Salter (1988) describes, this ‘mandated science’ includes legal and ethical considerations in their scientific findings, which are necessarily value-laden but framed as ‘objective’ scientific fact. Due to the inability to clearly demarcate scientific evidence from policy or value positions, scientific opinion necessarily diverges as scientists occupy varying positions along a policy spectrum.

Researchers in sustainability science advocate for transdisciplinary research approaches that include stakeholders and interests who are not scientists (Collins & Evans, 2002; Hara et al., 2012; Hutchins Bieluch et al., 2017; Lang et al., 2012; Stock & Burton, 2011; Wiek et al., 2012; Yarime et al., 2012). Transdisciplinary research is described as the integration of expertise, speciality and information between scientific researchers and other stakeholders from varying parts of

society (Lang et al., 2012; Pohl, 2005). The rationale to include members of the public and other stakeholders is that they possess direct experience regarding the relevance of any proposed sustainability solutions and help connect the science lab to the 'real world' (Darbellay, 2015). More comprehensive approaches to integrating information and knowledge from stakeholders are key to enhancing solutions meant to improve sustainability (Wiek et al., 2012). This literature within sustainability science discusses how such research should be done, but there is less research regarding *how* the interaction between scientific and human systems currently operate in sustainability science research projects.

Interdisciplinarity and transdisciplinary research approaches are seen as vital to the success of sustainability research and the field of sustainability science. While transdisciplinary research as described above can include expertise from scientists and non-scientists, interdisciplinarity refers to integrating theories, data, and methodological approaches from a diversity of scientific disciplines (Rafols & Meyer, 2010; Schoolman et al., 2012). The importance of interdisciplinary approaches to sustainability research is urgent (Holling, 2001), and it is an opportunity for researchers and policymakers from diverse backgrounds to learn from each other outside of their respective disciplinary lenses (Kates et al, 2001). Given this urgency and priority, many researchers urge that this integrated mode of working be codified into institutions and research practices (Koehler & Hecht, 2006; Jerneck et al., 2011).

The focus of this thesis is interdisciplinary approaches in sustainability science, as the subjects of the study were scientific experts within the university environment (expanded on in Chapter Three). The next section outlines definitions and approaches to interdisciplinary research.

2.3 Interdisciplinary research defined

In combining both natural and social systems as a focus of research, sustainability science in its nature is multi- and interdisciplinary (Hutchins Bieluch et al., 2017; Wiek et al., 2012; Yarime et al., 2012). The interdisciplinary approach to solving sustainability problems by 'bridging the gap' and 'integrating' these two systems is seen as the key to realising researchers' various future visions of sustainability. Therefore, an investigation of what is considered interdisciplinary research is important.

A central challenge to studying interdisciplinary research is the lack of uniform usage of the range of terms that could refer to 'interdisciplinary' working (Cooper, 2012). Sometimes, it is used interchangeably with 'multi-disciplinary', 'transdisciplinary' and 'cross-disciplinary', and there is an overall lack of consistency in the treatment of these terms across funding bodies and academic institutions. For example, Lam et al. (2014) discuss how the term interdisciplinary can broadly encompass all of the above terms, while Klein (2010) categorises multi-, inter-, and transdisciplinarity respectively on a sliding scale according to their increasing level of disciplinary integration. In Huutoniemi et al. (2010), both 'interdisciplinary' as a specific and overall catch all term are acknowledged and accepted. Across the board, 'interdisciplinary' has different definitions, making it difficult to pinpoint the nature of an interdisciplinary collaboration.

Interdisciplinarity is also pluralistic in nature and varies in how it is applied methodologically, theoretically and epistemologically in research (Bibri & Krogstie, 2017; Darbellay, 2015; Newell, 2001). Common examples of 'interdisciplinarity' include various researchers from multiple disciplines working together on a single project, a single-discipline research project that integrates methodologies from another discipline and engagement with participants outside of the academic realm to utilise their expertise. The heterogeneity of interdisciplinary studies also lies in the breadth of disciplines involved in a particular study. For example, an interdisciplinary study that brings together

neuroscientists and psychologists will work very differently from a study that requires historians and physicists to work together. This heterogeneity contributes to the difficulty of studying interdisciplinary research as a single entity.

I use the terms ‘interdisciplinary research’ and ‘interdisciplinary study’ interchangeably in the rest of the chapter. I also use the terms ‘interdisciplinary work’ and ‘interdisciplinary working’, which are closely related but refer more specifically to the processes and dynamics of individuals working in an interdisciplinary way rather than the actual interdisciplinary research itself.

2.3.1 Interdisciplinarity and the disciplines

To understand interdisciplinarity, it is important to review how the literature defines a discipline and how interdisciplinary research is related to disciplinary research. As the name suggests, some of the literature about interdisciplinary research considers it to be the overlapping space, or borders of engagement, between two disciplines (Castán Broto et al., 2009; Callard & Fitzgerald, 2015). This narrative puts the concept of the discipline at the forefront and as a reference point for identifying interdisciplinarity. However, in the literature on interdisciplinarity, the discipline is often assumed as pre-existing or presented as static, without a definition.

There exists a narrative that interdisciplinarity is the countermovement against the historical process of disciplines becoming more specialised and specific, which has been happening over the years and is not a new or singular phenomenon (Castán Broto et al., 2009). Papers tracking and studying the history of disciplines point out that some subjects which are now considered separate originated from a singular mode of study (Barry et al., 2008; Weingart, 2010). Barry et al. (2008) argue that interdisciplinarity is not new and that research studies have rarely taken place in one space or discipline, but have always been influenced by various knowledge sources. However, if research projects

do take place across disciplines, new disciplines can emerge from the process, and disciplinary practitioners continue to draw boundaries to differentiate their work from others. Where this separation and specialism lies between the disciplines is vague and not well outlined within the literature about interdisciplinary studies. For example, to what extent do researchers demarcate closely related subjects with a certain degree of overlap, such as molecular biology and genetics? This continuously changing differentiation of the disciplines also illustrates the fluidity of interdisciplinary research. As more disciplines continue to emerge in this process of differentiation (Stichweh, 2003) and specialisation (Casadevall & Fang, 2014) of knowledge, interdisciplinarity is a constantly moving target, impossible to describe and study as a single state over time (Wagner et al., 2011). These narratives recognise the diversity within disciplines and their dynamic nature as they change over time.

In light of this constant disciplinary differentiation and specialisation process, some disciplines are more specialised or theoretically based than others. Van Rijnsoever and Hessels (2011) distinguish *strategic* disciplines that have a more practical application, such as geography, and *basic* disciplines that aim to learn more about theories or matter, such as chemistry. The argument is that strategic disciplines which are, to a certain degree, already applied do not have to stretch far to be extended when applied to more problem-centred interdisciplinary research. Therefore, researchers with these backgrounds are more likely to be amiable to interdisciplinary working.

There are also examples like sociology which is inherently heterogeneous and, as a result, more flexible to multiple ways of working (Frickel et al., 2017), which may lend itself to more fruitful interdisciplinary collaborations. Such inherent heterogeneity in some disciplines means that they are not more specialised but broader and more encompassing, countering the assumption that disciplines become more specialised and narrow over time (Barry & Born, 2013).

There are arguments that, as a prerequisite for conducting interdisciplinary research, full mastery of a discipline is needed to ensure the correct ontological application and use of methodology (Jacobs, 2013). As outlined above, interdisciplinarity is not a single subject or even entity but a way of organising research, necessitating knowledge of a discipline at a basic level. Counter-arguments attest that due to disciplinary structures and long years of training, unless instruction in more than one discipline occurred at the onset of education, it is virtually impossible to conduct truly interdisciplinary research in a meaningful way if one is trained in a single discipline (Fish, 1989). In this narrative, the discipline takes on the function of determining worldviews.

If research adopts Fish's (1989) approach of learning more than one interdisciplinary 'language', it does not necessarily lend itself to straightforward interdisciplinary working. For example, in Kuhn's theory of incommensurability, different concepts and inherently incompatible paradigms exist within disciplines. They have "no common measure" even though they can all be considered 'scientific' or part of the same 'discipline' (Kuhn, 1970). These paradigmatic differences exist *within* disciplines, where different concepts and measurements are applied to address similar problems; therefore, it limits communication across diverse disciplinary foundations as well (Kuhn, 1970). Though Kuhn's work historically refers to the paradigmatic differences within the natural sciences, the incommensurability thesis has been applied to study the challenges in interdisciplinary research collaborations by describing the disciplines' differing characteristics (Politi, 2018). For Politi (2018) and MacLeod (2018), this development of 'domain specific expertise' results from disciplinary-specific training, creating siloed disciplinary concepts, measurements and approaches to research. By acknowledging, addressing and overcoming this incommensurability, interdisciplinarity can take shape, but not without significant challenges.

The assumption of a ‘mastery’ of a discipline fails to recognise these paradigmatic differences within a discipline (Kuhn, 1970) and how disciplines change over time. Disciplines such as geography (Bracken & Oughton, 2009) and economics (Amariglio et al., 1990) themselves are heterogeneous and internally divided (Clifford, 2005). Other disciplines, such as data science, are considered amalgamations of previously existing disciplines that created their own fields of study and journals on the topic (Smith, 2006). Though assumed a given in much of the literature on interdisciplinarity, the concept of a discipline itself is a dynamic entity.

It is clear from the above arguments that interdisciplinarity often starts from, and is defined by, the working relationship between disciplines. However, internal diversity within disciplines makes both individual disciplines and interdisciplinarity a constantly moving target.

2.3.2 Promoting interdisciplinarity

The number of inter- and transdisciplinary research projects and their funding has increased in sustainability research over the past ten years. This is indicated by the number of citations that appear across disciplines over time and the types of grants and British research council funding calls for ‘interdisciplinary approaches’ (Brandt et al., 2013; Cuevas-Garcia, 2015; Lam et al., 2014; Larivière & Gingras, 2014; Schoolman et al., 2012; van Noorden, 2015). Interdisciplinary funding priorities in the UK are evident across the national research councils. For example, the Engineering and Physical Sciences Research Council encourages research collaborations with industrial partners that ‘make a real impact’ (EPSRC, 2017), and the Research Council UK reiterates its already established commitment to interdisciplinary research on its website:

> As a part of its commitment to research innovation and ‘excellence with impact’, RCUK wishes to support an enhanced culture of interdisciplinary

> and multi-disciplinary research in the UK and to ensuring that its peer review and funding infrastructure is supportive of such work. (Research Councils UK, 2014)

The surge in calls for interdisciplinary research projects coincides with literature that increasingly calls for interdisciplinary approaches to sustainability projects. The rationale is that, due to the inherent complexity of the subject, a ‘holistic’ approach is necessary to encapsulate all of the issues that should be included when we talk about sustainability, and yet disciplines are inherently limited in their ability to embrace such a holistic approach (Frank, 2017; Lam et al., 2014). Newell (2001) argues that a researcher cannot understand the wider implications of multifaceted problems unless they collaborate with a diversity of disciplines.

The promotion of interdisciplinary research in the literature is responding to its positive rhetoric. According to Frodeman and Mitcham (2007), interdisciplinary research is on the rise because it is a more relevant form of research to address complex problems such as climate change. The argument is that the global nature of such issues plus their range of consequences (social welfare, economics and environmental health) necessitate a research approach that spans the disciplines. It is seen as the modern bridge between traditional disciplinary academic research and the societal needs of today, which mostly reference health issues (viral outbreaks and diseases) and environmental issues (climate change and environmental pollution) that are global and complex in nature (Hirsch Hadorn et al., 2010).

The platforms that promote interdisciplinary research reinforce the authority and priority of interdisciplinary approaches in the research landscape. For example, the Organisation for Cooperation and Development states in an introduction to a report that “it [interdisciplinarity] may provide an important key to the innovations required in universities” (OECD, 1972, p.1), signalling its perceived

importance in the research landscape to university management and staff. Science Europe (2012), an association of major research funding organisations, clearly seeks to fund interdisciplinary research, stressing its potential to reach ‘breakthroughs’ in research. Academic research is then encouraged to organise in an interdisciplinary manner to gain access to funding for future research endeavours.

These bodies of authority also play a role in the positive narrative that surrounds interdisciplinarity. In an article titled “Team Science” in the magazine *Nature*, Ledford (2015) describes the dichotomy between interdisciplinarity as ‘all the rage’ in current research structures and existing ‘barriers’ to it in current university and academic departments. She quotes from scientists, researchers and professors who feel increased pressure and encouragement to bid for funding in conjunction with other university departments (Ledford, 2015). This illustrates that university departments are indeed responding to the interdisciplinary direction of funding agencies.

This desire to fund interdisciplinary projects can also be linked to the trend towards big science. ‘Big science’ describes megaprojects with generous budgets that large, established universities have the resources to bid for and smaller research institutes have difficulty competing for (Tickle, 2015). In an effort to gain access to these large funding pots, smaller institutions and social scientists often team up on collaborative projects with natural scientists and industry (Lewis et al., 2012). These large teams are often interdisciplinary in nature, as they comprise a mix of research institutions and disciplinary expertise.

Gibbons et al. (1994) explicitly discuss the underlying rhetoric of the ‘evolution’ of more relevant research in interdisciplinary approaches in their description of Mode 1 and Mode 2 research configurations. Mode 1 scientific research is characterised by its disciplinary structures, the increasingly narrow specialisation of scientific study and established training mechanisms and procedures. Gibbons et al. (1994) argue that science is evolving to a Mode 2 type of scientific research,

characterised by a problem-oriented nature, contextualised approach to specific problems and flexible transdisciplinarity. The argument is that science is evolving towards Mode 2 forms of knowledge production, implying that Mode 2 is the future of research and disciplinary research approaches are thus of the past. Further analysis of the Mode 2 theory will come later in this chapter, as it is considered a possible theory to frame the research findings. The next section considers the different configurations research projects take when organised with interdisciplinarity in mind.

2.4 Interdisciplinary configurations

Interdisciplinary work can be configured and organised in multiple ways, either purposefully or because of the disciplinary expertise on a project. A common way to categorise an interdisciplinary endeavour is to describe it in terms of the perceived level of *integration* between the participating disciplines or working groups on the project. For example, Klein (2010) and Darbellay (2015) both provide taxonomies of 'interdisciplinarity' that categorise multi-, inter-, and transdisciplinarity on a spectrum according to the depth of disciplinary integration. For Klein (2010), disciplines in a multidisciplinary project coordinate with each other or conduct the project in separate sequences. The next level of integration is interdisciplinarity, an interaction or 'blending' of one or more aspects of the participating disciplines (Klein, 2010). Finally, Klein (2010) describes as transdisciplinarity as transgressive, in which existing paradigms are done away within the research and new paradigms are created. It can also be described as transcendent, as old theoretical and methodological frameworks of existing disciplines are transcended by the creation of new frameworks as a result of disciplinary interaction. Transdisciplinarity is thus the ultimate evidence of the creation of integrated knowledge.

Darbellay's (2015) taxonomy mirrors Klein's categorisation of interdisciplinarity, but with a differentiation in an additional definition of transdisciplinary research. Darbellay references multidisciplinary

research as “sequenced” and says there is no “real interaction” between the unconnected disciplines (2015, p. 165). For Darbellay, interdisciplinarity goes further because there is a dynamic interaction between the participating disciplines in the space between disciplinary expertise (2015). Finally, transdisciplinarity is either “transcendent”, much like Klein’s definition, or “practical.” The practical definition of transdisciplinarity is participatory, in which other knowledge experts outside of scientific disciplinary fields contribute to the knowledge generation of the project. Again, this taxonomy is based on the level of integration amongst the participating disciplines.

Implicit in the descriptions of these modes of interdisciplinarity is the greater desirability and novelty of research as it moves along (or ‘higher up’) the interdisciplinary spectrum. For example, Darbellay’s description of multidisciplinary research “reflects the traditional institutional juxtaposition” of disciplinary communities, indicating a lack of novelty (2015, p. 165). Klein describes multidisciplinary research as encyclopaedic in form and a “weak” or “false” form of disciplinary integration (2010, p. 17). For Darbellay, transdisciplinary research is at the top or furthest along the “progressive” spectrum (2015, p. 166). Klein discusses how transdisciplinary research transcends “the narrow scope of disciplinary worldviews” and is “holistic in intent” (2010, p. 25). Transdisciplinarity, therefore, is harder to reach and more ‘progressive’, ‘transcendent’ and ‘holistic’ in nature than ‘lesser’ forms of disciplinary integration.

Barry and Born (2013) also reference the above taxonomy of multi-, inter- and transdisciplinarity; however, rather than reify these categories, they introduce modes of interdisciplinarity. Their modes do not indicate the extent of disciplinary integration (as the taxonomies above), but instead indicate how the disciplines in question work together. The first mode of interdisciplinary research recognises the assumed integration element of interdisciplinarity, as described by Darballey (2015) and Klein (2010). This *integrative-synthesis* mode of

interdisciplinarity is just one way that disciplines interact and produce new knowledge. The *subordination-service* mode of interdisciplinarity describes the common configuration in which one or more disciplines have a subordinate or service role to another discipline in a research project, creating a hierarchical dynamic (Barry & Born, 2013). The authors point out that this could also be an 'integrated' form of interdisciplinarity, as these modes are not mutually exclusive. This configuration is usually thought of as the service discipline filling in any gaps left by the other dominant discipline. The third mode is called *agonistic-antagonistic* and is different from the previous two modes as it does not start from the building block of disciplines and therefore is not irreducible to composite disciplines. By starting from an undisciplined platform, agonistic-antagonistic forms of interdisciplinary collaboration desire to "transcend the given epistemology and/or ontological assumptions of specific historical disciplines" (Barry & Born, 2013, p. 12). By outlining *how* different interdisciplinary workings can develop, Barry and Born offer an alternative to the hierarchical mode of an interdisciplinary taxonomy: disciplines can be the antecedent of interdisciplinarity, but an undisciplined starting point is also possible.

2.5 Studying interdisciplinarity

Case study research, bibliometric analysis, surveys and individual interviews have been undertaken to understand interdisciplinary configurations and document the outcomes of interdisciplinary working in sustainability projects. These studies are used to capture the interdisciplinary 'best practices', reflections after the end of an interdisciplinary collaboration and possible factors associated with interdisciplinary approaches to research. Examples of such studies are discussed below.

Case study research projects document the experiences of working in an interdisciplinary project, and a body of literature has begun to collect best practices, challenges and motivations of researchers working on these projects (Binder et al., 2015; Castán Broto et al., 2009; Felt et al.,

2016; Gardner, 2013; Lotrecchiano et al., 2016; Lyall & Fletcher, 2013; McBee & Leahey, 2017; Muhar et al., 2013; Smith-Doerr et al., 2017; van Rijnsoever & Hessels, 2011). This literature has focused on the challenges that researchers experience on these projects and how many have failed to exhibit 'true' interdisciplinary working. There is less emphasis on other aspects of working on a project, such as how the researchers themselves understand their roles within the project, how (if at all) this changes over time, what they understand to be interdisciplinary working and which factors lead to this conclusion.

Case study research that tracks specific interdisciplinary projects on an individual basis can differ from the other modes of study listed above, as they concentrate on the processes of interdisciplinary research rather than the outcomes or results of interdisciplinary interactions (Gardner, 2013). Felicity Callard et al. (2015) document their experience working on an interdisciplinary project and discuss the role of shared spaces and the social dynamics of cross-disciplinary collaborations in their study. They find that although formal efforts to facilitate interdisciplinary collaboration were helpful (such as a workshop), some of the most interesting projects were born from interactions in the informal spaces.

Bibliometric analysis is another methodology used to track the occurrence of interdisciplinary research projects and the nature of the literature about interdisciplinarity. According to Brandt et al.'s (2013) review of inter- and transdisciplinary research literature of sustainability science and projects, over half of the published literature until 2013 proposed interdisciplinary approaches or developing best practice methods for an interdisciplinary research project (Barry & Born, 2013; Maiello et al., 2011). Nearly all of the remaining literature is related to the application of interdisciplinary research in real-world case studies (Brandt et al., 2013). They document the range of disciplines included in the field and track the disciplines that tend to collaborate more with one another. For example, in Nučič's (2012) study of interdisciplinarity in

sustainability research, she picks up that environmental science and technology remain central to interdisciplinary research projects and that their presence has actually increased over time. These efforts to build empirical characteristics of interdisciplinary projects aim to find and track the ingredients for successful interdisciplinary collaboration.

Quantitative surveys and qualitative interviews are a common avenue to explore interdisciplinarity. For example, van Rijnsover and Hessles (2010) conducted a survey in 2006 to build a list of possible factors commonly associated with interdisciplinary study. Factors include types of disciplines that are more likely to be included in interdisciplinary collaborations and the researchers' career histories.

The inherent inefficiencies of interdisciplinary projects and difficulties in publishing from interdisciplinary projects are challenges identified in Santamaría's (2015) work on interdisciplinary collaboration between social scientists and engineers in climate change research. Another challenge that researchers discuss in this realm is the difficulty to create a true interdisciplinary working environment; this implies that all researchers across disciplines should have a symmetrical contribution to the overall research project (Blättel-Mink & Kastenholz, 2005) or that an insufficient level of integration has taken place throughout the lifetime of a project to merit true participation amongst members of the research team (Schäfer & Kröger, 2016). In Callard and Fizgerald's (2015) book documenting their interdisciplinary research endeavours, they express disappointment with the quality and conservative nature of existing projects that claim to be interdisciplinary, revealing their thinking that 'good' interdisciplinary research should be ambitious and profound.

Power asymmetries that exist within academia are often replicated within the confines of an interdisciplinary project. This challenge refers to the hierarchy of disciplines between the natural sciences and the social sciences due to epistemological frameworks in the natural sciences being more valued by academic institutions (Callard &

Fizgerald, 2015; MacMynowski, 2007). This asymmetry can result in those from the social sciences feeling the need to constantly reaffirm their role in research projects beyond 'public engagement' (Callard & Fizgerald, 2015) or only examining the social or ethical implications of the work of the natural sciences, which is known as the ELSIfication[1] of social science (Calvert, 2013; Viseu, 2015). It is challenging to constantly reiterate the value of one's research methods with those working both within and outside of a project (Albert et al., 2009). Power asymmetries between the social and natural sciences present collaboration difficulties in interdisciplinary projects.

2.5.1 Evaluating interdisciplinary sustainability research

Research projects that explore sustainability issues such as energy, urban studies and climate change often organise multiple disciplines together in order to address the multiplicity of issues relevant to such complex research subjects. A focus on these sustainability topics is common in interdisciplinary research configurations. Sustainability issues are viewed by researchers and funders as more appropriately and commonly tackled through interdisciplinary means due to their inherent complexity (Kates, 2011). As interdisciplinary approaches in sustainability research are the focus of this thesis, this section focuses on examples of project evaluation.

As an outcome of their experiences, a number of large-scale research projects have published the results of their efforts to collaborate. Examples in the UK include the UK Energy Research Centre (UKERC) (Winskel et al., 2015), the Tyndall Centre's strategy for climate change research (Hulme, 2006), the Rural Economy and Land Use (Relu) programme (Lowe et al., 2013) and the Transition Pathways consortium (Hargreaves & Burgess, 2009). The headline findings from these

[1] ELSIfication is a term that arose during the introduction of 'Ethical Legal and Social Issues' into science work (Guston, 2006).

projects are covered in this section, and further analysis of the findings from this research is in Chapters Six and Seven.

These projects were selected as comparative projects for this thesis based on three criteria: all of the projects were of an interdisciplinary nature that spanned the natural and social sciences; the subjects of study were broadly related to environmental sustainability; and, although there were other interdisciplinary projects with a similar subject matter, these four projects reported on their research findings and provided more detailed information regarding the configuration of the research and some reflexive experiences related to collaborating. These reflections make the following comparisons possible.

UKERC and the Tyndall Centre are examples of major European funding councils pulling together to coordinate their funding efforts across different disciplinary focuses. Both centres combine resources from the NERC, EPSRC and ESRC to fund interdisciplinary strategic objectives within the established centres. In 2015, Winskel et al. published a review of their interdisciplinary research efforts at UKERC between 2004–2014. The review focused on the strengths, weaknesses and opportunities for improved interdisciplinary working in the future. This report also outlined the role funding bodies have in shaping and supporting “interdisciplinary research capacity and achievements” (Winskel et al., 2015, p. 2). Hulme (2006) published his thoughts on interdisciplinary research collaboration in the UK after leading the interdisciplinary research strategy at the Tyndall Centre through the years 2004 and 2005. Hulme’s reflections focused on the existing barriers to recognising, funding and evaluating interdisciplinary research (Hulme, 2006). Like Winskel et al.’s review (2015), Hulme also pointed to the importance of research councils in setting the interdisciplinary research agenda. However, he called for an improved capacity of these councils to evaluate interdisciplinary research proposals (Hulme, 2006). These post-project reflections point to many of the practical, operational and contextual challenges that interdisciplinarity faces in the UK today.

This leads to an assumption that if these practicalities are improved, researchers desiring to do interdisciplinarity would then be free to do so. Considering the contextual challenges for interdisciplinarity is important because even if a will and desire to do interdisciplinarity are present, contextual factors will influence collaboration outcomes.

Lowe et al. (2013) published takeaway lessons on interdisciplinary from the Relu programme. The Relu programme aimed to deliver "interdisciplinary research to advance understanding of the social, economic, environmental and technological challenges faced by rural areas, and of the relationships between them" (Lowe et al., 2013, p. 2013). The Relu programme funded over ninety projects between 2004–2012, with the principal aim of inviting collaborators from the social sciences into traditionally natural science projects. Their evaluation of the research collaborations focused on the motivations to conduct interdisciplinarity and the challenges encountered. While recognising the need for a supportive institutional context for interdisciplinarity, Lowe et al. (2013) also focused on the researchers' individual challenges. The researchers all had different disciplinary training and epistemological differences across scientific disciplines (Lowe et al., 2013). In including the experiences of the individual researchers, this study went a step beyond the wider institutional implications implicit in interdisciplinary research collaborations. Publishing the experiences of interdisciplinary participants is important so that future projects can build on the findings and learn from experience.

The Transition Pathways consortium was a research project which aimed to find social, economic, technical and political pathways to a low-carbon energy economy in the UK. The EPSRC provided the funding for the project with E.On, a power and gas company. The project included researchers from several universities across the UK and recruited researchers from engineering, the social sciences and economics. In the 'Pathways to Interdisciplinarity' report, which outlined

interdisciplinary researchers' experiences over the first 18 months of the project, Hargreaves and Burgess (2009) documented observations of the process and tensions. In a mapping exercise across the projects, the report illustrated a clear divide between the engineers and the economists/social scientists on the project (Hargreaves & Burgess, 2009). Participants also experienced confusion at the early stages of the project, as it was unclear what roles the different disciplines were to play on the project. Hargreaves and Burgess (2009) viewed this confusion negatively and as a potential barrier for further interdisciplinary collaboration. The confusion experienced by the participants reflected the novelty of interdisciplinary experience amongst researchers in the group. This 'new' way of configuring research means many researchers come to interdisciplinary collaborations without previous experience. Therefore, sharing best practices and findings across projects is important to fill this gap.

2.5.2 'Doing' interdisciplinarity

In my study of existing interdisciplinary research projects, common themes emerge across projects within and outside the academic environment and across a range of disciplines. After conducting the "snowball" method (Lecy & Beatty, 2012) of literature review to identify some of the most cited interdisciplinary studies, I perused this body of literature to find the most common themes associated with interdisciplinary research and coded them with the labels in the table below. I included interdisciplinary studies that proposed best practice methods based on interdisciplinary experience and the application of interdisciplinary research in real-world case studies. This table provides a brief description of the most commonly occurring themes.

Theme	Description	Sources
Time	Interdisciplinary projects require longer lead times at the beginning of the project and take longer to complete overall. The delay in getting work started and finished makes interdisciplinary projects seem more ‘unproductive’ as a result.	Datta, 2018; Freeth & Caniglia, 2020; Goulden et al., 2017; Lotrecchiano et al., 2016; McBee & Leahey, 2017
Shared spaces	Shared physical and metaphysical spaces for disciplines to connect are integral to interdisciplinary working. Shared spaces encourage informal interactions, facilitating trust and collaboration.	Blättel-Mink & Kastenholz, 2005; Callard & Fitzgerald, 2015; Callard et al., 2015; Freeth & Caniglia, 2020; Kaygan & Aydınoğlu, 2018; Lyle, 2016; Oughton & Bracken, 2009
Trust	Trust amongst collaborators is a prerequisite to interdisciplinary working, because it is impossible for all researchers to become experts in the range of disciplines involved in an interdisciplinary study. Trust is also important because interdisciplinary projects can make researchers feel insecure about the validity of unfamiliar research practices.	Balmer et al., 2015; Castán Broto et al., 2009; Harris & Lyon, 2013; Santamaría, 2015; Trussell et al., 2017
Communication / Language	Working with different disciplines is often referred to as working with others who speak a foreign (disciplinary) language, particularly between disciplines that have little shared vocabulary or research methods. Speaking different disciplinary languages can be seen as a ‘challenge’ to overcome with communication strategies or an inevitable obstacle because researchers cannot realistically become ‘fluent’ in a new disciplinary ‘language’.	Albert et al., 2009; Bracken & Oughton, 2006; Collingridge & Reeve, 1986; Darbellay, 2015; Datta, 2018; Fish, 1989; Fujigaki & Leydesdorff, 2000; Gibson et al., 2019; Hadfield-Hill et al., 2020; Knorr-Cetina, 1981; Smith & Carey, 2007; Villeneuve et al., 2019

Diversity of project goals	Differences in ontological backgrounds in disciplines can result in diverging or conflicting project goals between different disciplinary collaborators. Different interpretations of what makes an 'interdisciplinary' collaboration may also exist in a project, creating a mismatch in interdisciplinary practices amongst collaborators.	Cairns et al., 2020; MacMynowski, 2007; Miller et al., 2008; Prainsack & Riesch, 2017
Personal motivation	Researchers cite the personal challenge of doing interdisciplinary work as both a motivator and positive outcome of working in an interdisciplinary team. Motivation to do interdisciplinarity can be either personal (emotional desire) or practical (acquiring a new skill).	Boix Mansilla et al., 2015; Castán Broto et al., 2009; Guimarães et al., 2019; Lotrecchiano et al., 2016
University environment	Interdisciplinary projects face unique challenges in the university environment and the Research Excellence Framework (REF), which are both organised by disciplinary departments. This structure reinforces disciplinary-oriented academic careers and fails to value interdisciplinary publications or an interdisciplinary academic identity.	Blättel-Mink & Kastenholz, 2005; Cooper, 2012; Cuevas-Garcia, 2015; Frickel et al., 2017; Guimarães et al., 2019; Harris & Lyon, 2013; Kläy et al., 2015; Knorr-Cetina, 1999; Lyall, 2019; Lyall & Meagher, 2012; McBee & Leahey, 2017; Nelson, 2011; Ozkan et al., 2019

Table 2-1: Summary of main interdisciplinary project themes

The above themes feature repeatedly in the literature on interdisciplinarity. They also feature in evaluation reports of interdisciplinary research projects. The data chapters of this thesis compare this research project's findings with the above themes to ascertain a convergence or divergence of these themes. Interdisciplinary *shared spaces* and the *university environment* feature in the interdisciplinary infrastructure described in Chapter Four. The *university environment* features again in relation to how *time* is spent on interdisciplinary projects in Chapter Five. The role of *personal motivations* to do interdisciplinarity is contrasted against these two themes in Chapter Five to understand how participants approached research collaborations. *Communication/language, diversity of project goals* and *trust* are interrelated themes that contribute to the challenges to interdisciplinary cooperation detailed in Chapter Six.

2.6 Team dynamics in interdisciplinary work

Interdisciplinary collaborations can take many forms across different locations, proximity of disciplines, and types of institutions. While institutions can play a large role in how an interdisciplinary collaboration manifests, personal relations and team dynamics play a part in how interdisciplinarity is approached. As researchers are unfamiliar with foreign disciplines on a project, a personal relationship goes a long way to trust the other disciplinary experts to do their work with adequate rigour and diligence (Chakrabarti & Schneider, 1990).

Studies that document the lived experience of interdisciplinary researchers point to the challenges of understanding other disciplinary approaches and the "emotion work" (Hochschild, 1979, p. 561) involved in navigating tensions that inevitably arise when researchers try to collaborate whilst maintaining their own disciplinary research integrity. Many academics are inexperienced in interdisciplinary collaborations and must learn as they go (Freeth & Caniglia, 2020), navigate feelings of uncertainty and anxiety (Callard et al., 2015; Hillersdal et al., 2020) and play along with the "knowledge politics" that occur among

participants from different disciplinary expertise (Morris et al., 2019). Interdisciplinary researchers must also find ways to maintain their research integrity without being co-opted into other research objectives (Goulden et al., 2017; Holmwood, 2010) and (re)examine what they mean by ‘success’ and ‘failure’ (Cairns et al., 2020).

As the above literature suggests, interdisciplinary research has not been an easy and straightforward endeavour, and inevitable conflicts arise from collaboration along multiple dimensions. In interdisciplinary collaborations, sources of conflict can arise from epistemological, ontological, and value differences (Repko & Szostak, 2017). How such conflict arises and how it is addressed are important points of study in interdisciplinary collaborations. There are many ways a researcher can respond to conflict, and each option is associated with different outcomes.

Conflict can be seen as a constructive tool in interdisciplinary working because it signposts potential research breakthroughs and innovations (Barsky & Wood, 2005; Freeth & Caniglia, 2019). Freeth and Caniglia (2019) argue that embracing this conflict or tension head-on through discussion and dialogue maintains a sense of ‘we’ throughout the project and frames the conflict as a collective team issue. Conflict acts as a source of learning; when new ideas are presented by others, deeply held assumptions about research are challenged (Freeth & Caniglia, 2019).

Reframing a conflict from a disagreement to a multidimensional problem is also presented as a way to address or even diffuse conflict. Working with an interdisciplinary approach will inevitably lead to stark differences in opinion, leading researchers to believe they are disagreeing. However, Creamer (2005) reframes this disagreement as researchers addressing an issue from their individual perspectives, to move away from qualifying a research approach as ‘right’ or ‘wrong’ to simply understanding it as different. Demonstrating respect for multiple

standpoints helps to maintain trust in a team and prevent an adversarial quality to the conflict in question.

Addressing conflict by negotiation requires active dialogue and communication. Rather than reframing the conflict, a direct negotiation is confrontational and recognises that two positions are in opposition and a resolution is desired. A negotiation could start with airing an emotional grievance, therefore making the collaborator's position visible and directly addressing the conflict (Datta, 2018). A confrontation can also occur via a mediator who does not have a stake in the conflict and is tasked with finding common ground for researchers (Welch, 2017).

However, as conflict in interdisciplinary projects can stem from incommensurable differences between the disciplines, a resolution is often not possible. Therefore, another avenue of approach is to stay with the conflict (Haraway, 2010) by reflecting on the conflict, how it makes participants feel and how it could be addressed more constructively in the future (Datta, 2018).

Staying with a conflict by way of accepting undecidability is a recommendation by Welch (2017). 'Undecidability' is a concept that recognises that competing paradigms each have their own centre of truth and reality. Different disciplines have their own senses of reality and measurement techniques to reach (or not) that reality. 'Undecidability' is described as a 'state of mind' that interdisciplinary collaborators can adopt to develop common ground and prevent researchers from having to choose a side in a complex issue (Welch, 2017). By recognising that different sides of an issue can simultaneously exist, negotiations that permit multiple perspectives to coexist can occur.

Avoidance of conflict altogether in interdisciplinary collaborations also occurs when conflict is perceived as a negative and destructive collaboration experience (Appelbaum et al., 1999). Avoidance can occur for several reasons, from a personal aversion to conflict, the lack of a

work culture that embraces conflict (Morrison & Milliken, 2000) or a response to perceived power dynamics in the interdisciplinary team (Barsky & Wood, 2005). In these instances, the choice to avoid the conflict is assessed as the best option as it prevents perceived negative outcomes of addressing the conflict, such as a negative reaction from a superior on the team. In the short term, avoiding conflict promotes autonomy (De Long & Seeman, 2000). For instance, if a researcher disagrees with a particular approach to a problem, they can avoid presenting their disagreement and continue working autonomously in their chosen manner.

Silence is a tactic to avoid conflict, as it prevents others from detecting a conflict. A tactful and constructive way to communicate conflicting views and experiences is preferable to silencing the matter altogether, as silence functions in the short term to avoid the conflict but does not work to make the conflict go away (Verouden et al., 2016). In a case study exploring conflict in an interdisciplinary setting, silence contributed to embedded polarisation in the research project, as those who did not voice their opposition inadvertently closed future interactions and allowed latent conflicts to fester (Verouden et al., 2016). This type of conflict avoidance can also lead to participants feeling unheard or undervalued in the project, leading to feelings of dissatisfaction and disengagement within a team (Mathieu & Zajac, 1990). Keeping silent in this instance did not function to address the conflict or make it go away, but only functioned to conceal it from others, allowing it to persist.

Overall, if a conflict is related to the project's shared goals or different disciplinary approaches rather than personal issues, the literature frames conflict as necessary and even an opportunity to explore differences and reach new research insights.

2.7 Conceptual framework – Science and Technology Studies

Table 2-1 summarises the themes from this chapter's study of interdisciplinary collaboration. However, the literature on

interdisciplinarity is largely prescriptive (how it should be done) or empirical (what happens in collaborative projects); a theoretical comparison with empirical data of interdisciplinarity is missing. This thesis addresses this gap by using theories from Science and Technology Studies (STS) literature to better understand the complex dynamics of interdisciplinarity.

In STS literature, there is a focus on explaining how the production of scientific facts takes place within a social context (Collins, 1985; Knorr-Cetina, 1981). For example, a researcher's choice of one relevant methodology over another is dependent on social interactions and conversations between research practitioners rather than an entirely objective and rational choice (Knorr-Cetina, 1981). STS literature describes how scientific research methods are socially situated (Bauchspies et al., 2006; Law, 2008; Sismondo, 2009), which helps explain the variations in research findings when experiments and tests are replicated and the diversity of opinions within scientific disciplines (Collins, 1985; Law, 2008). The point is that scientific research is conducted by people, who have specific available resources, career choices, previous contextual knowledge and experiences which are all significant variables in the outcome of scientific research studies.

Two key themes in the STS literature are the laboratory's role as a space to conduct science and the role of language in the process of doing science. Latour and Woolgar (1979) describe how the lab is used to explain causation in experiments and therefore produce facts. The specific context, processes and tools (machinery and resources) within a lab each have a role in determining the end result of an experiment or simulation (Collins, 1985; Knorr-Cetina, 1999; Sismondo, 2009). That end result is determined to be the 'fact' or the 'truth'. A key part of this research is how the practitioners themselves understand the tools and their uses, any indicators or criteria they choose to calibrate these tools, and why.

The shared language amongst scientists within a discipline is intelligible to those within that group, reinforcing the statement from STS that science is social. In dialogue with one another, scientists use language to build their points and use rhetoric against dissenters to reinforce their position and increase buy-in from their social circle (Knorr-Cetina, 1999; Latour & Woolgar, 1979; Latour, 1987). Shared language, how it is used and the confusion it can create are focal points in interdisciplinary projects (Bracken & Oughton, 2006; Fujigaki & Leydesdorff, 2000). The interdisciplinary research literature investigates the challenges of building new knowledge in the absence of a unified peer group with a shared language.

There is a focus in STS literature on using ethnographic methods to observe scientists in action whilst they develop methodologies, conduct fieldwork and analyse their findings (Knorr-Cetina, 1999; Latour & Woolgar, 1979). Though this has been applied to studies of scientists in laboratory settings, there are fewer examples where these methods investigate interdisciplinary studies and are based on additional methods apart from ethnography. I have tried to develop a research method to study interdisciplinarity and, in doing so, to find the limitations and benefits to applying this method and build on the literature of various forms of knowledge production outside of the natural sciences.

In addition to applying methodologies used to study science from an STS perspective, STS also provides wider debates and theories about the state of science and scientific research in modern and post-modern times. These ideas are relevant for understanding the above assumptions about interdisciplinarity and its ability to do research differently. The theories that I draw from in this debate are ‘Post-Normal Science’ (Funtowicz & Ravetz, 1993), ‘Triple Helix’ (Leydesdorff & Etzkowitz, 1996) and ‘Mode 2’ research (Gibbons et al., 1994).

2.7.1 Post-Normal Science

'Post-Normal Science' describes scientific issues that are highly consequential as well as very uncertain in prognosis (Funtowicz & Ravetz, 1993). According to Funtowicz and Ravetz (1993), Post-Normal Science occurs when "uncertainties are either of the epistemological or the ethical kind, or when decision stakes reflect conflicting purposes among stakeholders." (p. 750).

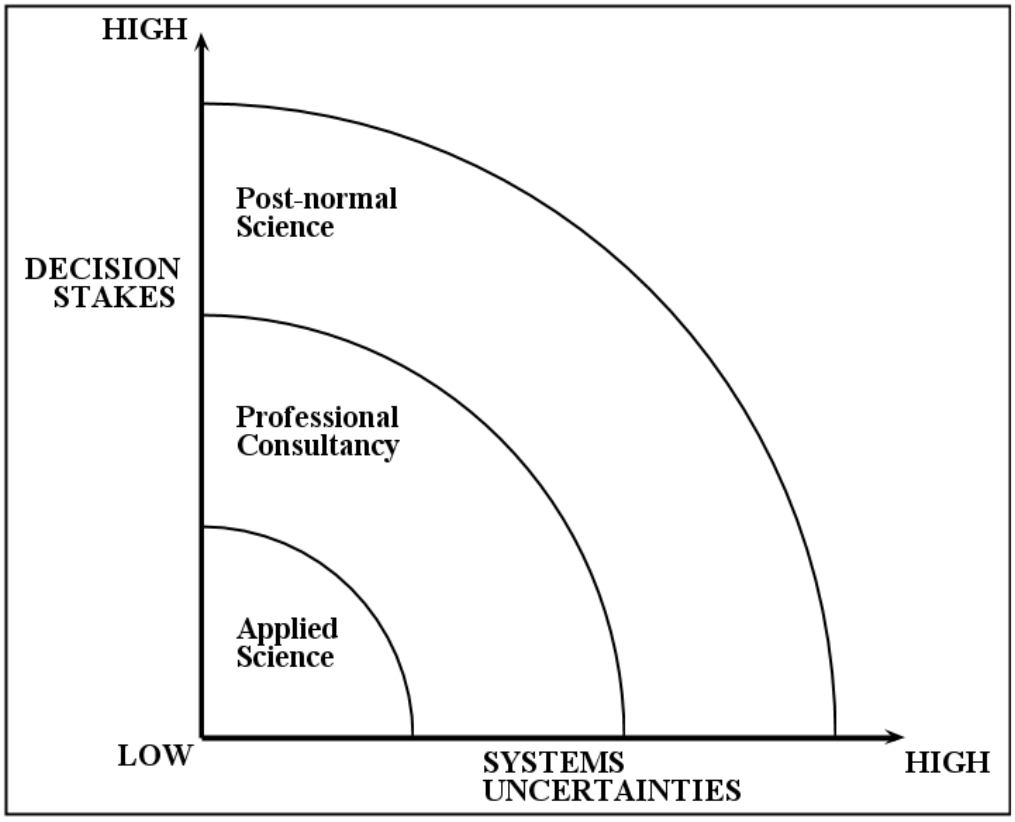

Figure 2-1: Problem-solving strategies (Funtowicz & Ravetz, 1993)

The figure above illustrates Funtowicz and Ravetz's (1993) problem-solving strategies using two dimensions of scientific problems: the extent of knowledge uncertainty present (*x*-axis) and the decision stakes or values involved (*y*-axis). "Systems uncertainties" captures the quality of understanding or managing an issue as inherently complex and multifaceted. "Decision stakes" refers to the values and perceptions present in issues amongst various stakeholders (Funtowicz & Ravetz, 1993). Along the axis emerge three discrete intervals, as decisions stakes are higher and have increased system uncertainty.

Post-Normal Science in this continuum has the highest levels of uncertainty and includes other considerations beyond professional expert opinion, such as ethical considerations, that cannot be answered by experiments in a laboratory (Funtowicz & Ravetz, 1993; 1994). For Funtowicz and Ravetz, science can no longer happen in the ivory tower as the real policy implications of scientific findings require additional assessment criteria, judged by members of the public and key stakeholders who may be affected by scientific findings (1993; 1994). These authors also acknowledge the entanglement of scientific findings and policy implications, and therefore, scientific knowledge as fact-finding is no longer enough; science should be done for something, particularly society.

Recognising the values implicit in the science-making process allows Post-Normal Science to acknowledge a plurality of positions in problem-solving processs outside of the lab. Funtowicz and Ravetz (1993) differentiate Post-Normal Science from other forms of problem solving in that soft values are the dominant factor in problem solving, rather than hard facts. An example of Post-Normal Science is the debate around adaptation projects in the wake of climate change effects. In preparation for rising sea levels, scientists, policymakers, and affected stakeholders must consider decisions that should—and can—be implemented. It is uncertain how much sea levels will rise; therefore, it is unclear how many people in an area should be evacuated to higher ground. Migration from affected areas will consequently create economic and social impacts in the surrounding communities receiving the evacuees. Though the response to this migration is uncertain, a policy response must consider both populations. In Post-Normal Science, the relationship between facts and values is inverted to put values as the dominating decision-making factor, and they cannot be separated from the facts of climate change. In this example, the welfare of multiple populations needs to be considered; even more complex is taking into account the welfare of other species, both plant and animal, as well as that of future generations that do not yet exist.

Weingart (1997) critiques Post-Normal Science as an ideological stance rather than a description of a new trend in science. main criticism but their ideological basis. Weingart purports that the label of Post-Normal Science applies to a small subsection of scientific knowledge rather than scientific knowledge production as a whole, and is therefore an ideological position for what all science should be rather than a description of what it is (1997). For example, scientific knowledge sectors that tend to already be more value-laden, such as research related to technologies or human sciences, have characteristics of a Post-Normal Science model. However, there is a lack of evidence that changes to the scientific method or increased public participation in science-making appear to the same extent in more 'traditional' natural sciences. For Weingart (1997), Post-Normal Science describes institutional changes rather than real revolutionary changes to traditional science-making.

2.7.2 'Triple Helix' model of innovation

Another model explaining the changing position of science in society is the 'Triple Helix' model. This model references the three main bodies involved in modern systems of scientific making: the government, industry and academic institutions. This model of science systems claims that industry, university and government are increasingly intertwined in the process of science-making as they all have resources to contribute to one another to make scientific projects successful (Etzkowitz & Leydesdorff, 1998; 1995; Leydesdorff & Etzkowitz, 1996).

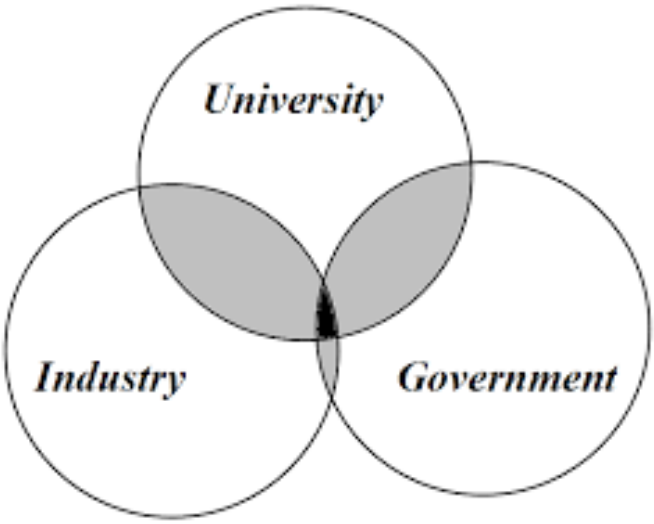

Figure 2-2: The Triple Helix model (Leydesdorff & Ivanova, 2016)

The helix part of the name references the “spiral model of innovation” that “captures the evolution of the multiple linkages at different stages of the capitalisation of knowledge” (Etzkowitz & Leydesdorff, 1998, p. 205). Spiral helix imagery is offered in contrast to a linear model of scientific research, where innovation flows in a linear direction from “fundamental to applied research and to product development” (Etzkowitz & Leydesdorff, 1998, p. 205).

Etzkowitz and Leydesdorff offer four dimensions to illustrate the evolutionary character of this model. First is the transformation that takes place within the industry, university or government entity. Second, one of the three factors influences another through its relationship or connection. For example, an industrial entity may recruit or call upon the expertise of academics to contribute to a science problem. Third, a new overlay or norm is created based on these relationships. To expand on the previous example, the practice of recruiting academics to contribute to industry solutions then becomes a normal relationship, which solidifies a tie between university and industry. Finally, these previous steps happen again and again, creating new ties and relationships between the three of these ‘helices’ or entities, and therefore creating a new norm for addressing scientific problems and solutions (Etzkowitz & Leydesdorff, 1998). The visualisation of this

evolutionary process is a helix that grows longer and longer in length. The Triple Helix model's other characteristic is that it is ever-changing and dynamic, which prevents the structure from becoming stable (Leydesdorff & Meyer, 2006).

Figure 2-2 above shows the established ties created between entities highlighted in grey and black. However, a large part of each entity remains independent of each other. For example, if an industry connects with a university by establishing a programme of work for certain science problems, the university still maintains its peer-review standards and autonomy for its academic projects. A new established creation can be evolved upon, but to a large extent, the original structure of the university remains intact.

Criticisms of the Triple Helix model of innovation cite its Western and regional specificity. For the Triple Helix model to apply, several prior conditions need to be present within a country for the evolutionary relationship between the industry, government and university bodies to develop. These conditions include policy and fiscal measures that support start-ups and university research institutes, a market and growth-oriented culture, and a civil society that values knowledge (Cai et al., 2015). In other regions in the world, including Africa, South America, and South Asia, innovation development follows a different pattern. For example, in Africa non-governmental organisations play a much larger role in innovation in the agricultural sector than large industry corporations, and they tend to value and support the abilities and knowledge of small shareholder farmers (Williams & Woodson, 2012). The focus is then on small and medium enterprises who, in this context, actually account for a much larger agricultural output than larger industrial farms. As non-governmental organisations can make use of international funding and unofficial networks, they can play a part in innovation in society that national governments cannot (Williams & Woodson, 2012). In countries outside of North America and Western

Europe, the Triple Helix model does little to explain innovation patterns or the relationship between science and society.

2.7.3 'Mode 2' knowledge production

In Mode 2 research, Gibbons et al. (1994) describe a new form of knowledge production in reference to what they call Mode 1 research. Gibbons et al. (1994) characterise Mode 1 research as traditional forms of knowledge production where scientists pursue knowledge for knowledge's sake. The methods in Mode 1 research follow "sound scientific practice", wherein the scientific method is followed and experiments are used to validate a theory (Gibbons et al., 1994, p. 2). In contrast, Mode 2 research is described as a transformation in the process of knowledge production and is carried out in the context of application, rather than 'pure' scientific process and abstract theory. Mode 2 research is "a distinct set of cognitive and social practices" (Gibbons et al., 1994 p 3). According to the thesis, Mode 2 knowledge production evolved from Mode 1. However, these two modes continue to exist alongside each other, rather than Mode 2 completely taking over Mode 1.

The 'evolution' of Mode 2 research is a result of transitions that Gibbons et al. (1994) argue are occurring and will lead to a future "knowledge society". In this Mode 2 knowledge society, a "distinct set of social and cognitive practices are beginning to emerge" (Gibbons et al., 1994, p. 3), and these practices demand more accountability and access to knowledge-making processes that have historically been characterised by exclusivity.

Mode 1 and Mode 2 are contrasted from each other against five different characteristics, as illustrated in the table below:

Mode 1	**Mode 2**
Problems are set and solved in a context governed by academic interests or interests of a specific community	Problems are carried out in context of application

Disciplinary-oriented	Cross-disciplinary and transdisciplinary
Homogeneity and hierarchal structure	Heterogeneity and organisational diversity
Accountable to disciplinary rigour	Socially accountable and reflexive
Peer-review quality control	Transient and situated quality controls

Table 2-2: Attributes of Mode 1 and Mode 2 knowledge production from Gibbons et al., 1994

In Mode 1, research is carried out in the context of an academic scientific community. Problem focus and problem solving are carried out according to set disciplinary processes. In contrast, Mode 2 research is carried out in the context of application, whereby the methods chosen to carry out the research are determined by the context of the problem in question (Gibbons et al., 1994).

In Mode 1 research, a problem's final solution will indicate the disciplinary approach that was applied. For example, if an engineer and an anthropologist were to investigate a problem simultaneously, the researchers would diverge in their approaches and initial problem statements, informed by their disciplinary training. In Mode 2 research, solutions are an amalgamation of a variety of disciplinary approaches, potentially creating new validation practices and research frameworks. It is also transdisciplinary in the sense that the sharing and diffusion of results extend beyond the traditional scientific community and take place via other experts who participate in the knowledge-making (Gibbons et al., 1994).

Mode 1 research is organised along a centralised hierarchy of processes, indicating an exclusive group of people who can determine the 'correct' processes to carry out research and validate the knowledge that resulted from the research. In contrast, the nature of Mode 2 research is heterogeneous and flat, with multiple and diverse organisations contributing to knowledge production. Gibbons et al. (1994) stress that legitimate research is increasingly taking place outside of the university, with multiple sites linking and communicating together informally and electronically. These new forms of connection expand the scope of research configurations beyond geographical borders. These multiple organisational structures are more responsive

and flexible as they can communicate quickly; they are also characterised by their temporary structures, which can assemble and disassemble according to the research needs (Gibbons et al., 1994).

While researchers conducting Mode 1 research are accountable to their peers and the traditional scientific standards of rigour, Mode 2 research is accountable to contemporary policy agendas and members of the public who have a stake in the research problem. Examples of more 'socially accountable' research problems include those that address environmental issues, public health concerns and privacy protection (Gibbons et al., 1994). Conducting socially responsible research makes the researchers and other participants in question more reflexive during the process because "the issue on which research is based cannot be answered in scientific and technical terms alone" (Gibbons et al., 1994). In other words, reflexivity comes because researchers must stop and take the time to consider the positions and standpoints of all those concerned and involved.

Finally, Mode 1 research is evaluated with traditional processes of quality control, such as peer review. Gibbons et al. consider this an exclusive process that is insular and self-perpetuating. On the other hand, Mode 2 research has extended, dynamic and multiple avenues of quality control. While Mode 1 research is evaluated on scientific rigour, Mode 2 research evaluates knowledge production based on ethical, economic and social concerns. Extending the criteria for knowledge production necessitates an extended group of evaluators for that knowledge, including participants in research, members of the public who could be affected and policymakers (Gibbons et al., 1994).

Hessels and van Lente (2010) critique the Mode 2 thesis on the basis that Gibbons et al. are "conflating interrelated yet independent trends" in research (p.65). One may observe two Mode 2 'trends', such as increasing transdisciplinarity in a research project correlating with researchers on the project being more reflexive in their research. Though these two treads may be related, they may operate

independently of each other. For example, a transdisciplinary project where scientists engage with members of the public does not necessarily lead to scientists being more reflexive in their research; scientists could still choose to remain only accountable to their profession's disciplinary standards. This conflation of trends then renders the demarcation between Mode 1 and Mode 2 research arbitrary, as examples of research projects and initiatives can exhibit both characteristics of Mode 1 research (accountability to disciplinary rigour) and Mode 2 research (transdisciplinarity). Although Gibbons et al. (1994) say that Mode 2 research "constitutes a distinct mode with its own set of cognitive and social norms" (p.14), this distinction between Mode 1 and Mode 2 research fails to account for or describe a research mode that is a combination of characteristics of both modes.

The other critique of the Mode 2 thesis is its focus on theoretical ideas which are ungrounded in empirical examples or research. Though in *The New Production of Knowledge*, Gibbons et al. (1994) claim to report on the emergence of new socially-distributed research configurations, the text is light on specific empirical examples that demonstrate an emergence of Mode 2 research configurations. Shinn (2002) states that "almost no concrete evidence is given for the assertions advanced" (p. 603). In writing a diagnosis of the shift from Mode 1 to Mode 2 research, Hansen asserts that Gibbons et al. (1994) "[…] seem to be writing about everywhere and nowhere in particular, giving no indication of the scope or validity of their analysis." (Hansen, 2009, p. 72). In Jansen's (2002) tour of a South African university that reorganised to follow a Mode 2 model, the reorganisation experiment failed to structurally change the university configuration or incentive system. Therefore, the New Production of Knowledge (NPK) thesis reads more as an aspirational manifesto, illustrating where the authors imagine the research landscape to go, rather than an account of changing research configurations.

2.7.4 Comparison of theoretical frameworks

To place my research project in context and provide focus, I decided to choose one of these theories. To understand the relevance of these theories for this project, in this section I analyse the university's role and engagement with cross-disciplinary research against each of the three theories. To be expanded on in Chapter Three, the university environment with its implied structures features heavily in this research case study and is, therefore, an important analytical point.

In 'Post-Normal Science', the university continues to be a site for scientific knowledge production. However, the traditional peer-review methods associated with the academic environment are no longer adequate (Funtowicz & Ravetz, 1993) and need to be complemented and/or expanded to include customers and affected publics. In addition, Post-Normal Science's first priority is no longer the 'traditional' ways in which 'core science' is done in a university environment, where the pursuit of knowledge and a rigorous methodology are the only criteria for 'good science'. Science must also respond to the urgent priorities of the day and to wait for scientists to make incremental advances in scientific knowledge using the standards of an "ideal of rationality" is no longer acceptable in all situations (Funtowicz & Ravetz, 1993, p. 754). In Post-Normal Science, it is acceptable and even necessary to approach knowledge production with the tools and resources available, however incomplete scientists may view them to be.

In Triple Helix, the value of the university is less its ability to create and evaluate knowledge and more on what it is *for,* its "third mission", which describes theadditional initiatives with industrial entities that the university can engage in beyond its original missions of teaching and research (Etzkowitz & Leydesdorff, 1998). In this model, universities are seen as an important source of knowledge for industries to gain a global competitive advantage, particularly knowledge in biotechnology and software (Etzkowitz & Leydesdorff, 1998). The new role of the university is its ability to contribute to economic development. In this model, the

institution of the university remains largely the same but with an additional mission, rather than a fundamental change to its inner workings.

In the Mode 2 thesis, the university's focus in this new production of knowledge is not only its changing priorities but also the changing configuration of university structures. Sources of these changing pressures are the public's external accountability demands and changing funding priorities of governmental and private funding sources. Like the universities in Post-Normal Science and the Triple Helix model, the university in Mode 2 no longer conducts scientific research for its own sake, but increasingly for societal priorities as part of the "new utilitarian science regime" (Nowotny et al., 2001, p. 76). The university is still a principal site of knowledge production as its role is to produce 'experts.' However, the structure of the university is "stretched" to become more democratic and vocational (Nowotny et al., 2001, p. 80). Nowotny et al. describe the university of the 'future', which is 'de-institutionalised' into more vocational configurations. Examples include a corporate or private university with clear priorities aimed at the corporate focus for which it was founded. An increase in online programmes and universities will occur, illustrating the "blurred" barrier between the university and the outside world (Nowotny et al., 2001, p. 90). Rather than these barriers remaining intact with changing or additional institutions missions or priorities, the very nature of the university in a Mode 2 world is restructured and de-institutionalised. As a result, the modern university as we know it will be weakened.

In addition to understanding how these theories engage with the university structure, it is also necessary to understand how they conceptualise interdisciplinary research. Funtowicz and Ravetz (1994) characterise the emergence of Post-Normal Science in response to the complex nature of problems today. It is in the context of these complexities that the "traditional oppositions" between the 'hard' and the 'soft' sciences are being overcome" (1994, p. 1881). According to

Funtowicz and Ravetz, because the world is complex and dynamic, the reductionist worldview that disciplines offer lacks a “synthetic and humanistic approach” to research (1994, p.1881). In other words, disciplinary approaches are unable to address these ‘new’ complex and dynamic world problems. By pitting the disciplinary approach against a ‘humanistic’ approach, Funtowicz and Ravetz turn the research focus from a methods-focused research outcome to an application or problem-focused outcome that could be addressed in a variety of different ways, which could include disciplines or not. Disciplines in this theory are losing their boundaries and influence, favouring more undisciplined and bottom-up approaches to address complex issues.

The Triple Helix model engages less explicitly with the interdisciplinary question but considers different disciplines within the university structure as a combination of resources for industry and government to draw upon as and when needed. Transdisciplinarity, or the configuration between university-government-industry institutions, occurs in the form of ‘translations’ (Leydesdorff & Etzkowitz, 1996). For example, specific relationships between the institutions take place when an individual from the university learns a new legal language and can therefore capitalise on this new skill to establish a connection across institutional boundaries that make patenting and invention more feasible. Disciplines in this model remain largely intact, but with different ways of engaging with each other and working together.

‘Transdisciplinarity’ is an explicit characteristic of Mode 2 research. Gibbons et al. (1994) define transdisciplinarity in terms of a discipline, a concept they assert existed first. Therefore, transdisciplinarity ‘evolved’ from disciplinary configurations of producing knowledge, partly as a consequence of “dysfunctionalities and breakdowns of disciplinary modes of problem solving” (Gibbons et al., 1994, p. 29). Similar to today’s complex social problems, as asserted in Post-Normal Science, interdisciplinary projects are positioned as a natural evolution of science-making in light of current times.

In describing the transdisciplinary characteristics of Mode 2 research, Gibbons et al. (1994) also engage with different forms that interdisciplinarity can take and the difficulty associated with integration. In their theory, Gibbons et al. (1994) differentiate transdisciplinary research from multi- and pluri-disciplinary research configurations. According to Gibbons et al. (1994), transdisciplinarity has a transformative quality whereby there is a “mutual interpenetration of disciplinary epistemologies”, leading to a transformed and mutually accepted theoretical foundation in a research project (p. 28). This understanding of transdisciplinarity is similar to the taxonomy of interdisciplinary research of Klein (2010) and others, discussed previously. This transformative element of transdisciplinarity, where the resulting research is more than the sum of its parts, is hard to attain. This integrative quality of transdisciplinary research is consistent with the dominant perspective of the literature on interdisciplinarity as described in sections 2.3 and 2.4.

In light of these theoretical summaries and analysis, I discuss the findings of this project within the context of Mode 2 research, and use this as a theoretical framework in Chapter Seven of the thesis. The ‘Post-Normal Science’ theory encompasses the changing and more ‘undisciplined’ nature that characterises science research; however, a strong policy development element was largely absent from the sustainability project I studied. The ‘Triple Helix’ theory is based on the role of industry and government as principal influencers in the changing university research landscape, and these two sectors were not a visible influence in the sustainability project I studied. The Mode 2 theory has a clear focus on the university as a changing site of knowledge production. It also explicitly focuses on cross-disciplinary collaboration as one of its five characteristics and comments on the difficulty to attain a truly disciplinary integrative state of research collaboration.

2.8 Conclusion

Having reviewed the main debates in the interdisciplinary field and the theoretical frameworks relevant to new scientific research configurations, I conclude by summarising the literature gaps that this thesis addresses. First, the thesis contributes to the interdisciplinary thematic table (Table 2-1) developed in this chapter to compare the existing themes and identify new themes. The interdisciplinary themes that feature heavily in the literature mostly speak to challenges occurring in interdisciplinary collaboration, telling a different story from the promotional narrative that interdisciplinarity is more problem-centred and holistic and therefore desirable. This thesis documents the experience of interdisciplinarity against these themes to understand the reoccurrence of these challenges despite the positive narratives surrounding interdisciplinarity.

Second, after analysing theoretical frameworks that describe knowledge production structures, I take forward Gibbons et al.'s (1994) New Production of Knowledge (NPK) theory as an analytical framework to understand interdisciplinarity as a new research configuration based on its engagement with the university system and cross-disciplinary collaboration. This analysis provides a theoretical application to the empirical, interdisciplinary data from the sustainability project, an application missing from the literature.

Chapter 3: Research design and methods

3.1 Introduction

This chapter outlines the methods used in this research project, which draws on ethnography to explore sense-making in interdisciplinary research endeavours. The case study, a research project at a university in the UK, is outlined and discussed in relation to ethnographic research in laboratories in Science and Technology Studies. As a participant observer working alongside the participants in my research, I paid particular attention to my choice of approach, my lens of analysis and my inevitable influence and impact on the project itself, as well as the power relationship that resulted from my position as a 'researcher of the researchers'. The first section of this chapter introduces ethnography and outlines some of the methodological debates regarding its role in scientific research. I then give a narrative account of the case study and the evolution of my research thinking and approach over time. The last section discusses the methods employed and why, followed by the analytical approaches chosen to interpret the data.

3.2 Ethnography

Ethnography is a methodology used by anthropologists and researchers in other disciplines to study the social, cultural and daily interactions of a group of people over time, and in turn, interpret how they understand and make sense of their reality (Denzin & Lincoln, 2011; Hammersley & Atkinson, 2007; Hesse-Biber, 2017). Ethnography is explorative and seeks to understand natural human phenomena rather than start with a hypothesis or a question. The data collected in ethnography is unstructured and iterative, with the researcher or group of researchers conducting the analysis from their interpretive perspectives (Atkinson & Hammersley, 1994; Campbell & Lassiter, 2015; Geertz, 1973; Hammersley & Atkinson, 2007; Reeves et al., 2008). This flexibility in ethnography allows for a range and different combination of methods to

be used in ethnographic research, including field notes, observations, written and oral accounts from participants, interviews, visual data such as video and photography, collection of cultural artefacts, focus groups and informal conversations between the researcher and participant(s) (Reeves et al., 2008). Since its start in anthropology, ethnographic methods have been used in other disciplines such as sociology and human geography. Central to an ethnographic research study is the immersion of the researcher for an extended period with the research subjects in the field (Atkinson, 2015; Hammersley & Atkinson, 2007) and the investigation of the meanings of actions and language of the people in the field (Brewer, 2000). The plethora of data collection options and the use of ethnography by practitioners from multiples disciplines mean that it does not have one standardised meaning or method of implementation.

Early ethnographic research studies attempted to emulate the natural sciences in the sense that the researcher would aim to be outside of the research itself (even though immersed in the field), be objective in his/her analysis and come to an ultimate 'truth' about the cultural practices of the studied participants[2] (Denzin & Lincoln, 2011). Ethnography as a field of study has developed to recognise that the researcher has to immerse himself/herself in the research in order to understand cultural phenomena as an 'insider' rather than as an 'outsider' (Denzin & Lincoln, 2011), the rationale being that any documented interpretations will be more accurate than external representations of the studied culture.

Ethnographic studies work with interpretivist and naturalist stances to research (Atkinson, 2015; Campbell & Lassiter, 2015; Hesse-Biber, 2017). A naturalist approach encourages research to take place as much as it can in an organic state, without controls or variables in place, never removing data from the context in which it exists (Creswell, 2014;

[2] Two canonical examples being Malinowski's (1922) *Argonauts of the Western Pacific* and Mead's (1928) *Coming of Age in Samoa*.

Hammersley & Atkinson, 2007). Interpretivist perspectives in ethnography recognise the inability to separate the researcher from the researched, as those conducting the study will inherently see the world through their values, cultural meanings and beliefs about world order. Therefore, researchers are always interpreting the research or stimuli rather than objectively observing it (Hammersley & Atkinson, 2007).

These epistemological assumptions that underpin ethnographic research are also the basis of critiques of ethnographic and qualitative methods by researchers who subscribe to positivist processes that claim to establish reliability and validity (Brewer, 1994; LeCompte & Preissle Goetz, 1982; Seale, 1999) as well as objectivity and representation (van Maanen, 1988). Positivist theory in sociological research is characterised by its quantitative research methods, the testing of hypotheses, use of survey research for statistical significance (Punch, 2005) and following the logic of a scientific experiment to try to arrive at generalisations (Hammersley & Atkinson, 2007). These critics view ethnographic research as too specific and descriptive, and at best providing a good starting point to explore questions and theories that can be later validated by quantitative methods of inquiry (Brewer, 1994).

Reliability refers to the extent to which research results can be replicated and reproduced by a different researcher under similar circumstances, deeming the method legitimate and rigorous. As ethnography is often based on a single researcher's interpretation and highly contextual, the researcher's credibility comes under scrutiny. In ethnography and other types of qualitative research, reliability is established through a process of reflexivity—i.e., positioning oneself and one's own interpretations in the research and creating an internal dialogue (Hesse-Biber, 2017). This internal dialogue aims to make the invisible visible by recognising and exploring personal interpretations and how they impact research findings. Campbell and Lassiter (2015) reject the notion of objectivity in ethnographic research outright because it is neither possible nor desirable in research; to them, objectivity

obfuscates alternative and rival worldviews, perspectives and experiences. Hammersley and Atkinson (2007) reiterate this stance: that the positivist approach attempts to eliminate the researcher through "objectifying the level of inquiry" (p. 6). Ethnography fully embraces the subjective by accepting and positioning the researcher and their resulting relationships within the research over the course of study (Atkinson, 2015; Campbell & Lassiter, 2015).

Generalisability is also a source of critique, especially for positivist researchers who insist on 'representative sampling' (Brewer, 1994). The specific nature of ethnographic research is considered a too small 'sample' to generalise across similar situations. Atkinson (2015) argues for a definition of generalisability that takes a *nomothetic* approach, which refers to "the aim of generating law-like generalities" (p.36). The aim of ethnography is to adopt an idiographic approach to "thickly" describe (Geertz, 1973) the specifics of the situation and also to develop generic high-level concepts that can be applied across a range of social situations. For example, in this research, the concepts that arise from studying interdisciplinary research dynamics in an academic setting can also be explored and applied in different corporate or work settings.

Other researchers with reservations about ethnographic methods point to the potential of an ethnographer's values and ideology to determine the interpretation of ethnographic events (Brewer, 1994). Another criticism is the potential to 'other' the people who are studied and written about in ethnography (Atkinson, 2015) or create a separation between the one who studies and those who are studied. This implies that an ethnographer's interpretation is somehow more valid than those interpretations of the researched (Brewer, 1994). However, this argument is still based on the ideal of objective research, where the researcher is positioned as a neutral outside observer to their surroundings without influence or judgement. Reflexivity places the researcher and the potential implications of the ethnographer's values

in the research data and interpretations, while also functioning to make clear that research findings are the result of the researcher's interpretations, rather than superior 'facts' or 'truth'.

3.3 My ethnographic approach in the university

As the focus of my research to understand interdisciplinary research projects by tracking social dynamics as they change and are negotiated over time within an urban sustainability project, ethnographic observations over time gave me the context and understanding of how those dynamics develop. Taking an ethnographic approach to this research study meant my research was explorative and iterative and allowed me to study areas that had not been extensively investigated. As mentioned in the literature review in the previous chapter, though interdisciplinary research has been lauded for innovative and 'holistic' research approaches, evidence of the mechanics and preferential results of interdisciplinary working is under-documented. The grounded theory fundamentals of ethnography necessitate that theories and findings are derived from the data itself rather than the other way around (Glaser & Strauss, 2006); ideally, concepts about interdisciplinary working can come from this research.

Throughout this ethnographic research project, I found it useful to focus on issues of critical incidence. Flanagan (1954) originally developed this concept to identify and categorise successful behaviours of US Air Force pilots. The critical incident technique is a set of qualitative research procedures used to collect accounts of human behaviour and translate them into useful practices to solve problems. The principles underlying the technique are: 1) collecting participant accounts of an event with the aim of finding the consequences of the event; 2) using these accounts to identify specific reasons for behaviours; and 3) applying inductive techniques rather than pre-existing judgements to categorise these incidences and behaviours (Bradley, 1992). In my research, I used this technique to identify interactions that were characterised by controversy or that resulted in conflicting

understandings. These events and interactions acted as a ‘red flag’ that understandings of the norms of conducting research were not universally shared, therefore indicating to me that disciplinary norms were questioned or challenged. Two examples from the research illustrate my use of this technique.

One example is the process of developing a co-authoring policy for papers that resulted from project work. After three PhD students drafted a paper, they found out that co-authoring practices differed across the natural and social sciences. Though the researchers agreed that a PhD student’s supervisor would be named as an author on the paper if the supervisor had a ‘significant contribution’ to its development, the definition of ‘significant contribution’ varied across the participants. A ‘significant contribution’ could range from the supervisor guiding the intellectual development of the ideas to the supervisor drafting sections of the paper itself. As students from the natural and social sciences drafted the paper, these practices seemed at odds with each other, and discussions ensued to adopt a policy that could be used consistently throughout the project. For me, this incident flagged how academic disciplinary practices vary across the university and that this difference was not addressed until joint papers were already drafted. This implied that there was an assumption that practices would be more or less similar across the board.

Another example of relevance for its reflexive quality is how different researchers in the sustainability project perceived my role as the ethnographer of their project. I interpreted my research project as an investigation of how interdisciplinarity was understood and negotiated by different researchers throughout the project, whilst others in the project interpreted my role to be almost evaluative in nature. For example, they assumed that any findings of interdisciplinarity that I came across would be actively fed back into the group to improve collaboration. Though this understanding did change over time, the perception of my practical role to ‘improve interdisciplinary working’ in

the project continued, as opposed to an understanding that the case study would tell us more about how researchers negotiated interdisciplinarity. Navigating these different perceptions of my research was interesting for me; they indicated how different researchers understood the 'value' of research in terms of visible impact and the expectations of what an ethnographic project can contribute to research.

This example also highlights the co-creation process of ethnography itself (Atkinson, 2015). Members saw my interpretations of the events, interactions and discourse of the study and constructed their own understandings of and feedback on my interpretations. For example, I gave practice research presentations to the group prior to conferences and seminars. The presentation of my work was received and critiqued by the group, thereby feeding into the data I had already collected about the researchers' narratives of the research project.

I accept the interpretivist approach in ethnographic research. Of the multiple narratives about the project, my own interpretation is just one of many. These examples of my approach highlight what I, as a sociologist, view to be important indicators of interdisciplinary understanding and working. These events of 'critical incidence' were not the sole focus of my research but sit alongside my daily observations over time.

3.3.1 Studying situated knowledge: Ethnography in Science and Technology Studies

In Hammersley & Atkinson's (2007) *Ethnography: Principles in practice*, they discuss how ethnography questions positivism in the context of Thomas Kuhn's work (1970) in the philosophy of science. Hammersley and Atkinson outline Kuhn's argument that scientists think of science as a linear and progressive path towards objective truth, and yet many facts developed in the positivist mode of scientific research have been replaced with new paradigms of scientific thought. Both the old,

discarded findings and the new ones were developed following the scientific method of research. Therefore, none of these facts can be understood as based on the rational and objective collection of evidence, but instead arise from wider social paradigms created by networks of scientists (Hammersley & Atkinson, 2007; Kuhn, 1970). The argument demonstrates the constructivist roots of the philosophy of science and ethnography mean that these areas of study understand that meanings are plastic and constantly negotiated by actors (scientists in this case).

In the realm of STS, the practise of ethnography was established in studies of the laboratory, characterised by social scientists positioned as the 'outsider' in a laboratory (Knorr, 1977; Latour, 1987; Latour & Woolgar, 1979). More recently, laboratory studies include scientific research initiatives and programmes (Calvert, 2013; Viseu, 2015) in which social scientists are increasingly more embedded, both as a participant in the actual research conducted and as an observer of the processes of constructing research. These science studies document and investigate the practical and social aspects involved in science-making, particularly in understanding technology as more than just 'objective' tools used in science-making but as tools whose use and interpretation are controlled by humans (Latour & Woolgar, 1979). The overall theme of ethnography in the laboratory is not necessarily that science is entirely socially constructed, but that the norms, practices and methods deployed by scientists are contextually situated and cultural (Hess, 2001), and that these social aspects have an impact on the scientific facts and findings that result from scientific research.

Ethnographic studies of science-making have increasingly moved outside of the single site of the laboratory and into other sites of scientific research, including conferences (Krauss, 2009), office meetings, and fieldwork sites (Stephens & Lewis, 2017). This "multi-sited" approach (Marcus, 1995) recognises that science is not just made in the lab but also in important performative spaces such as

conferences where experts in the field meet, in media coverage of scientific studies, and in published research in which scientific findings are reified and legitimatised. This thesis looks at science-making—not in a traditional lab, but in an office specifically co-located to facilitate interdisciplinary work. In ethnographies, both of the lab and the office, knowledge-making is understood as situated and contextual, and ethnography is the tool that makes the social context visible.

3.3.2 The case study

In keeping with the iterative nature of ethnography, this section is structured to follow the chronological changes in the case study and my reflections on the focus of the research, the data being collected and my own role in these changes and progressions. This section sets the scene of the research project I worked with and the physical setting of the research space.

The case study for this PhD was a research project based in a university in the UK. The project was funded by a trust, and its principal aims were to take a holistic approach to understanding sustainable cities by using an interdisciplinary project team and skills.

The researchers on the project came from a range of disciplines, including but not limited to sociology, economics, geography, physics, engineering, mathematics and computer science. At its inception, the project work was divided into six ‘themes’: 1. Environmental, 2. Social and Cultural, 3. Economic, 4. Measurement and Data, 5. Modelling and Optimisation and 6. Policy and Governance. Within all six themes of the research project, there was a Co-Investigator who co-led the theme with one or two postdoctoral Researchers and one or two PhD students working on research within that theme. In the initial application, a visual chart illustrated how the Environmental, Social and Cultural and Economic themes would develop conceptual and simulation modelling to understand, produce and compare different visions of a sustainable urban environment (including its inhabitants and existing infrastructure).

The Modelling and Optimisation team would oversee these three themes to optimise and create the models while the Measurement and Data theme would provide and validate the data needed for the multiple models. Finally, the Policy and Governance theme would investigate how these models could support decision making in the city. The final simulations could then be run to test how different policy, social, economic or environmental initiatives would impact that city. Figure 3-1 below is an illustration of how these different project themes were meant to 'fit' together:

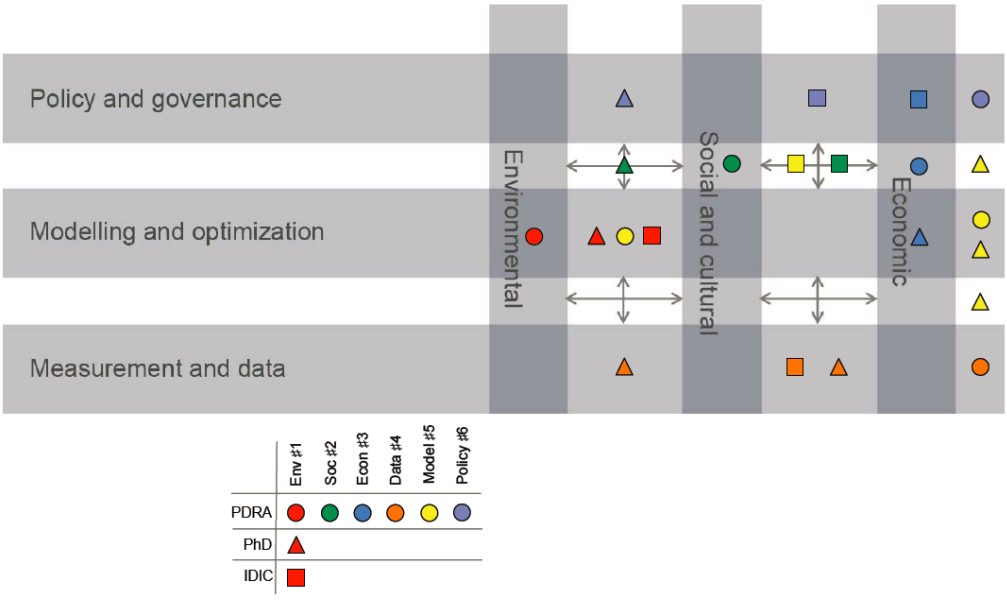

Figure 3-1: Thematic mapping of the project

The ethnographic role in this research project came predefined and written into the initial grant proposal, with the intention that it would be undertaken by a PhD student. It was initially imagined that the role of the student ethnographer would be functional; the original funding proposal stated that the research would "shed light into the effectiveness of the research process and may lead to improved communication within the team". Therefore, I shared funding with others

on the project, and my selection for the position was determined by academics working within the project.

Initially, my work and progress were overseen by senior academics on the project. However, as I started working on the project and took some STS courses, I developed the PhD research to focus more on interdisciplinarity as a phenomenon, using the sustainability project as an in-depth case study to investigate current theories and assumptions surrounding interdisciplinary research. As explained in the previous literature review chapter, the field of STS focuses on explaining how the production of science, as well as the machinery, process mechanisms and language used in the production of scientific experiments, take place within a social context (Collins, 1985; Knorr-Cetina, 1981). STS researchers are interested in how scientific projects are constructed and how they are ultimately implicated in research findings. I began to think about why and how the research project was pitched and structured specifically as interdisciplinary, and what expectations that would imply for the researchers within the project, both in their ways of working and the project's outputs. This case study is relevant to studying interdisciplinarity in practice because not only was the project itself organised in an interdisciplinary manner but it also aimed to tackle sustainability, which in itself is considered a 'complex' and interdisciplinary problem (Collins & Evans, 2002; Hara et al., 2012; Hutchins Bieluch et al., 2017; Lang et al., 2012).

Following the researchers' experiences as a case study over time helped to answer the multiple 'how' research questions. These questions are explanatory in the sense that I aimed to make links between participant perspectives and outlooks with their resulting collaborative approach and behaviour. Tracing these links over time lends itself to case study research approaches (Yin, 2009).

Case study approaches also allow for an analysis of non-linear processes over time. This conceptual view of phenomena accommodates the complex real-world dynamics that occur in research,

including conflicts, unintended consequences, changing personal relationships and diverse perspectives within a project team (Geels et al., 2017). For example, multiple factors could determine an individual approach to interdisciplinary collaboration, including previous research experience, personal goals or preference and institutional factors. A combination of individual approaches determines collective approaches and dynamics of interdisciplinary collaboration. The in-depth case study approach allows for an analysis of these complex dynamics and factors.

In my discussions with other researchers on the project about doing case study research and qualitative research in general, questions about bias and the desire to research 'objectively' came up, particularly with the natural scientists. They focused on the number of interviews each person would have and wondered if a longer interview with a certain person would bias my findings towards their perspective as I was collecting more data from them in the form of time spent responding to questions. This quantitative-oriented thinking stemmed from the desire to ensure data and findings were representative of the wider study and therefore generalisable across similar research projects. Flyvbjerg (2006) addresses this concern about making findings 'generalisable' by advocating for a focus on the detail and minutiae in specific case studies. Flyvbjerg (2006) argues that the depth and the complexity that the context provides becomes lost if findings are summed up into neat, presentable results. By detailing the narrative in the case study, the multiple facets and perspectives are preserved. Complexities and nuances remain because traditional ideas of systematic research and positivist parameters of rigour do not constrain the type of data collected and therefore oversimplify the findings.

The data from my research investigates the dynamics and inner workings of interdisciplinarity rather than evaluating the success of the research project's interdisciplinarity. Taking the evaluation route would have necessitated a more action research and interventionist approach. 'Action research' would have involved a more formal feedback and

reflection process between myself and the team, and a systematic observation of any possible changes in ways of working as a result of this exchange (Gray, 2004). Given the limited time period of my PhD and the precarious nature of measuring and directly attributing changes in behaviour to my interventions, I deemed this approach unfeasible for the PhD project.

Given my role on the project was written in from the start, this made for a unique scenario in which my position was chosen by the very academics I then studied as research participants. This situation created a few interesting circumstances. As my position was devised and recruited internally, there was automatic buy-in and support from senior members of the project, thus bypassing any complex negotiations to gain access to internal meetings, interview all the participants, and find available senior researchers to discuss project findings. Conversely, this scenario also presented a potential conflict of interest. My work would be reviewed and evaluated by those who had an interest in how the project was presented in the thesis and in any potential publications arising from my research. Though I trusted the professionalism of the academics on my team, steps were taken to rearrange the makeup of my supervisory team, and an ethnographer from the School of Sociology was added to provide both methodological guidance and feedback on my work.

I also noticed that my position had a clear effect on the behaviour of those within the project. Having a dedicated researcher to study the interdisciplinarity of the project indicated that the researchers were expected to work with each other on the project. For example, when I first joined the project, a researcher told me, “I think we may have started to have these meetings because we knew you were coming, and we thought we better start working together a bit more.” This comment signposts the fact that my recruitment in the project came with some indicators regarding expectations of interdisciplinary working.

At the start of the project, it was envisaged that four case study sites would be the focus of the researchers' efforts to provide an empirical basis: two 'growth' cities in China (Chengdu, Shanghai) and two established cities with clear sustainability objectives in Europe (Nottingham, Stuttgart). As the project developed, the main focus of the research efforts focused on Nottingham and to a lesser extent Shanghai, with only a few researchers conducting research in Stuttgart. The case study city Chengdu was dropped from the study completely. This change in research focus occurred within the second year of the research project in an effort to be more realistic as the original plan was deemed too ambitious; there was some difficulty recruiting students from China to help conduct research on the ground and an overall delay in recruiting for other academic positions in Nottingham for the project.

For all of the case study cities, the project proposal stated that researchers would be principally based in a building on campus with some travelling abroad to conduct fieldwork. The physical boundary of my ethnography was limited to the team based in Nottingham, with some of the researchers accounting for their fieldwork in other locations via interviews with me or more informal conversations. Funding constraints on travel to Shanghai or Stuttgart kept me in Nottingham. I also discussed with my supervisors my opinion that an element of cultural background and expertise would have been necessary to observe researchers based in China to understand cultural norms around communication and interactions in the workplace. My lack of Chinese languages also made it difficult to justify my travel budget to record conversations in a language I did not understand.

The project initially started in February 2015; however, I only joined the project in September 2016. Due to recruitment issues and challenges filling the various roles in the research project, the addition of various team members, including myself, was staggered rather than starting all at once. This presented challenges, not only for new team members trying to understand the project whilst others had already ascertained

their research focus, but also to my work. Ideally, I would have started on the project from its inception to capture its development throughout. Though I had access to report documents and records created before my arrival and I took accounts from that time period in individual interviews, I am aware of this limitation in my research.

To recap, I joined the interdisciplinary project as a PhD student after the project was underway. Though at the outset my project was envisioned as providing practical feedback regarding the efficiency of the research process, I evolved the position to encompass a more STS approach. I sought to investigate how the researchers in the project understood interdisciplinarity and what expectations that might entail for their work and the project's outputs. My position as an ethnographer was unique in that it was written into the project initially with specific support from senior academic members of the team. Given this potentially precarious arrangement, steps were taken to ensure that I was able to conduct my work in a way to preserve my research project's integrity.

3.4 Ethics

The university ethics committee approved my research project in February 2017. The rationale for obtaining ethics approval within the first six months of starting in the research project was so that I could include my observations as research data sooner rather than later. I was in the unusual position of being immersed in my research project from the outset. Co-located with the other researchers in an office on campus, I was already working with them and attending their meetings. I wanted to capitalise on the opportunity to use my initial understandings and observations of them as evidence and data in an ethical manner. Being included and recruited from 'within' the research project as the resident ethnographer also presented a couple of unique ethical issues around confidentiality and consent, which needed to be explored and addressed at an early stage.

A principle ethical consideration was always the confidentiality of the researchers on multiple levels. Firstly, the confidentiality of their comments and reflections from others working on the project, and secondly, the confidentiality of their accounts if any of this research became published in the public realm. Thirdly, as I worked within the project and two of my supervisors worked within the project as well, I had to ensure that my participants' confidentiality was protected when including accounts from participants in chapter drafts reviewed by my supervisors. Working with an external expert in ethnography that was not involved in the project helped prevent confidentiality breaches.

As the sustainability research project aimed to impact and work with the local city council, its public nature was inevitable. Basic information about the project and a blog written by the researchers were available online; therefore, information such as who was working on the project was accessible to members of the public and other research institutions. Reviewing quotes and accounts with the respective participants before any work was published was essential to ensure that the researchers were not unnecessarily implicated in any way in the write up of my findings.

Along with the confidentiality of individual researchers, the anonymity of other aspects of the wider researcher project was also heavily considered. There were a few things that were not anonymised for practical and analytical reasons. Firstly, the funder Leverhulme Trust is named and associated with the research project. After considering whether to refrain from naming them, it became clear that it would be impossible to do so on a practical level, given the need to acknowledge them for the funding and opportunity to carry out the research. On an analytical level, there were characteristics about the Trust that were directly relevant to the analysis of this ethnographic study; being specific about the Trust was necessary to make sense of this analysis. Also, I have revealed Nottingham as the city where this research took place, and therefore the University of Nottingham and Nottingham City

Council (the reason to mention these locations will be clear from the analysis). As this PhD will be published on the university website and associated with this university (the university is also named on the cover page of this document), it is clear that this is the location to which I am referring throughout the PhD. This is not to say that this decision was made for purely practical reasons; I constantly revisited and consulted with my supervisors about these ethical dilemmas. As a result of these conversations, I determined that finding the balance between being specific enough to conduct the analysis whilst broad enough to protect the confidentiality of the research participants was a constant negotiation that sometimes could be 'resolved' but always must be acknowledged and actively engaged with.

Throughout the thesis, I have used pseudonyms for the participants to tell the story of the project. There are different positions in qualitative research regarding the use of pseudonyms, including the view that pseudonyms do not always guarantee anonymity because of the richness of ethnographic data (Surmiak, 2018). However, after thinking through different approaches, identifying the participants as *'Respondent 1, 2, 3'* etc. removed much of the emotion and feeling that I wanted to preserve in the thesis, particularly given the large role that emotional affect played in their interdisciplinary interactions, as further explored in Chapter Five. To preserve the humanity of the participants while keeping them anonymous, I assigned pseudonyms that would not hint at identifying the respondents by ethnicity, nationality, or age. For example, I assigned someone the name of Ingmar, inspired by the late Swedish director Ingmar Bergman. There was no one on the project of Swedish descent (or who was a film director).

Another key issue regarding ethics was the complicated nature of consent. Though a consent form was obtained from every research participant and a detailed sheet explaining the research and use of the data was provided to everyone, the issue of un-coerced consent required more careful consideration. Though it was advantageous to

have buy-in from senior academics on the project, senior academic support could also mean implicit pressure on other researchers on the project to participate in my research, even if they felt uncomfortable doing so. To ensure full, informed consent, I first presented my proposed research to the entire project in a meeting and handed out the consent forms for participants to take away and sign in their own time. I also spoke with some of the participants individually outside of open project meetings to gauge their interest and level of comfort and to ascertain their understanding of what my project was. In addition, prior to every individual interview, I spoke with each individual privately before I started recording to ask if they had any additional questions or concerns regarding the research or how the data would be used.

Although the above steps were taken to ensure informed consent, once the research was underway, it became clear that ethical standards were not universal but varied, depending on different disciplinary traditions. In one particular instance, a natural scientist on my supervisory team proposed that I place microphones in the shared office spaces of the project in order to capture conversations taking place amongst office members that might eventually lead to an interdisciplinary idea or interaction. This highlighted a disciplinary methodological difference in that the natural scientist wanted enough ‘data’ from office conversations and saw recordings as a way to provide a representative sample of all the conversations that took place in the office space. This would provide evidence of how interdisciplinary collaborations were started and maintained. For an ethnographic project, however, tracking interdisciplinary developments in a linear process like this is a lesser concern and not necessary to capture the dynamics of interdisciplinary working.

The suggestion to record conversations in the office space also highlighted an ethical concern for social scientists. By the standards of the natural scientist who suggested this data-capturing method, no ethical boundaries would be crossed as long as the researchers were

aware that the recording devices were present and consented to their placement. However, from a social science perspective, as highlighted in more than one of my annual reviews that assessed my project, this would violate norms of social science practice and be seen as unethical. The researchers deserved the right to feel safe in a normal office environment, to come to work daily without having every interaction and conversation recorded. The question of informed consent would be raised again because it would be difficult to ascertain if researchers really had consented to be recorded or if they felt they had to consent because it had been suggested by a senior researcher. After researching the ethics surrounding office recordings and receiving helpful feedback and comments from my review examiners, I deemed it would be unethical to carry out this method. It also would be an inefficient method to capture data of interdisciplinary interactions as it would result in hours of recordings. The time it would take to sift through reams of discussion to find anything useful was not feasible for this PhD project.

3.5 Research design

Much of the data for this research project was obtained from participant observation. Within this, I have included day-to-day observations in the office from both the PhD student office and the office where postdoctoral researchers were located. I also included semi-structured interviews to access reflections of participants on their own, document analysis of outputs from and about the project to understand the narratives told in those documents, and, finally, self-recorded diaries as an experiment to capture data from the participants without my presence, in the spirit of curiosity that it might reveal something new. As previously done in the case study section, here I explicitly discuss the iterative nature involved in selecting and developing these data collection methods.

Given the inherently specific nature of ethnographic studies and methods, triangulation was important to provide a range of different

types of evidence to support conclusions, help recognise common categories across multiple data sources and improve the validity of the research procedure (Aull Davies, 2008; Creswell, 2014; Hignett & McDermott, 2015; Gray, 2004; Marcus, 1995; Thomas, 1993).

3.5.1 Participant observation

As an ethnographer in the sustainability project, I was considered a 'participant as observer' (Hesse-Biber, 2017) as I was fully integrated; I sat amongst the other PhD students in the shared office and attended all Progress and Integration meetings, and everyone on the project was fully aware of my role as a researcher of their practice of interdisciplinarity.

Participant observation in ethnography is used to capture and document the representation of phenomena in a social setting (Sánchez-Jankowski, 2002). Rather than observing participants throughout the entirety of their lives, I focused on the parts of their lives related to interdisciplinary work. This included observing participants during normal office work and meetings. I kept a field note diary to document exchanges and capture spontaneous conversations and interactions. Field note documents were used to ascertain whether an incident was part of a wider pattern or isolated (Sánchez-Jankowski, 2002). A voice recorder was used in meetings, both those with the entire project team and the smaller side meetings among team members. All recordings were transcribed to accurately capture the discussions that took place. I also took photographs of the setting as appropriate, including diagrams, charts and maps drawn on the office whiteboards to explain concepts.

Data collected from participant observation allowed me to keep track of not only verbal interactions but also the nonverbal cues, body language and behaviours that also portray meaning (Kawulich, 2005). For example, in these Progress and Integration meetings, I observed the research participants' attention and behaviour. By counting the number of open laptops in the room and getting a glimpse of what they were

interacting with on the screen, I could ascertain whether a researcher was fully engaged in the meeting at a given moment or more engaged in the emails he/she was responding to on the screen. I did not assess this behaviour as good or bad; rather, I was trying to understand the priorities of the researcher and the role they played during meetings. This engagement could reflect their understanding of interdisciplinarity or how they perceived their role in any interaction or collaboration taking place at the moment.

In keeping with the iterative nature of ethnographic work, I began with the idea to record the larger Progress and Integration meetings that took place twice a month in the project office. As the meeting's title implies, its purpose was to facilitate the integration of different parts of the research project by raising awareness about different streams of work and attempting to think of ways to connect two (or more) previously disconnected workstreams. As this was one of the few times all of the researchers and senior academics were in the same room together to discuss the project, this was an obvious meeting to record and attend.

After sitting in the PhD office for a few months, I noticed that some PhD students were working together on a stream of work to define sustainability and were having their own meetings about this work. Recognising this as an interdisciplinary endeavour, I asked to tag along to the meetings and eventually began to record them as well. Soon, other small collaboration working groups appeared—for example, to model social policy and the behaviour of firms in Nottingham. I attended and recorded those meetings as well. By sitting in the PhD room, I was exposed to meetings that just the PhD students would organise from time to time; they were not organised for any particular collaboration purpose, but just a chance to get together and chat about the project in an informal space.

I also had the particular advantage of joining the board meetings organised and attended by the project's senior academic leads—

postdoctoral researchers and PhD students could not attend these meetings. Discussions and decisions in those meetings related to budget issues, adoption of project stances on publishing norms and other key aspects of the project's direction.

Field notes of my observations of office interactions and day-to-day chat were mostly from the perspective of my desk in the PhD office, where I had dedicated space. However, I would occasionally migrate to the office where the postdoctoral researchers were based and observe interactions from a different perspective.

3.5.2 Interviews

Though they are not always part of ethnographic research, I included interviews in this study to get personal and individual reflections of interactions with other researchers and individual perceptions of collective events or meetings in the project. In qualitative research, semi-structured interviews are the preferred way to collect data that is exploratory and deemed too complex to capture in a quantitative survey (Aull Davies, 2008; Gray, 2004). Interviews are also an important way to understand how participants make sense of their experience. I used interviews as a tool to understand the participants' respective reality rather than interpret the interview data as *the* account of reality (Aull Davies, 2008). Asking questions such as 'why is this narrative told?' and 'what is the position of the storyteller and how is this implicated in their narrative?' helped me make sense of the narrative itself as data to understand the broader dynamics of the researchers on the project (Schegloff, 1997).

Though it is more time consuming to conduct fieldwork and analysis after interviews, this approach to fieldwork was manageable given the small number of participants. A semi-structured interview approach also allowed me the flexibility to adjust my topic guide according to the individual interviewed and to change direction or topics whilst the interview took place (Gray, 2004). Given that I followed the same group

of researchers over time and was interested in how their perceptions and ways of working formed and changed, I followed up with some select respondents in informal conversations after their interviews in order to collect additional information, provide some clarity on their statements and investigate further questions that arose during the thematic analysis stage. Serial interviews were appropriate as they provided sufficient time for me and the participant to explore the difficulties and inconsistencies that tend to exist in interdisciplinary work environments (Crang & Cook, 2007). The discussion guides were influenced and structured based on initial observations and questions I had from meetings, my presence in the office and conclusions from the document analysis.

The first set of semi-structured interviews with every individual employed by the project was conducted from December 2017 to February 2018. Before conducting the interviews, I gave the participants a pre-task to complete via a Microsoft Excel sheet, to be filled in electronically and emailed back to me prior to the interview. The participants were informed that it would take no longer than ten minutes to complete.

The pre-task was a short ranking exercise. Each participant was given an electronic Excel sheet via email with the first names of all of the people on the project listed in a column. They were then asked to rank the level of collaboration they perceived that they had with that individual from zero to five, with five being the highest level of collaboration. I did not quantitatively analyse the results of this exercise, but rather used this as a warm-up to get people thinking about how they worked with other individuals on the project prior to our meeting.

The general points in the topic guide I developed for the interviews were informed by the literature review of the earlier chapter and my observations of the office environment. For example, there is some talk in the literature about what is considered ‘real’ interdisciplinary working, and I recognised this discourse coming from participants during my

office observations, so I wanted to understand their definitions of interdisciplinarity and where their ideas stemmed from.

I specifically wanted to explore and investigate:

- respondents' perceptions of the project and project progress,
- respondents' understanding of their perceived role in the project,
- respondents' understanding of the perceived role of other researchers in the project,
- respondents' personal assessment of any collaborations within the project, and
- respondents' personal views and definitions of interdisciplinarity and where this understanding came from.

In addition to the more formal approach of arranging a meeting, using a recorder and asking questions in a private room during the semi-structured interview process, I also conducted informal interviews to clarify comments, ask questions about certain events that took place and get more information on the researchers' different workstreams.

All of the interviews I conducted were transcribed in full by either myself or an external transcription company. The transcription was done from the start of the interview process in December 2017 and was completed in April 2018.

3.5.3 Document analysis

To ensure a range of different data sources and build a multidimensional story, I also analysed documents developed by the project. This type of data is useful as it shows the 'end result' of interactions and project work, and the information is much less influenced by how I choose and pose questions in a semi-structured interview or how I record or interpret the data collected in observations (Bowen, 2009; Gray, 2004). Analysing documents also helps build on narratives found in interviews and observations.

Through these documents, I was able to identify dominant and competing narratives about the project regarding positions on sustainability, the key issues that had been prioritised, and what had been considered successes of the project itself. For example, the foundation of the project was based on defining sustainability within a conceptual framework with three pillars: economic, social and environmental. However, some members of the project rejected this compartmentalised view of sustainability and began to draft a discussion paper that advocated for a more integrated approach. Tracking how these competing narratives were published helped identify the power relations at play and how sustainability was understood in the project.

Document analysis was included in this study originally as an artefact of the ethnographic project. However, as I listened in the office and spoke to the researchers in the project about their published papers and conference proceedings, it became clear that these outputs were also seen as indicators in themselves of the extent of interdisciplinary endeavours. For example, if a paper had multiple authors from various disciplines, this was seen as evidence of successful interdisciplinary collaborations within the project.

The types of documents I reviewed included:

- published articles authored by members of the project,
- project working papers that were stored online in shared folders and workspaces,
- presentations given by members of the team,
- conference proceedings about the project, and
- regular project status updates provided to the funder.

3.5.4 Self-recorded diaries

I decided to include an open format diary to allow participants to reflect on their experiences as they came to mind, rather than have my presence or questions determining the focus of their discussion. While

scoping previous literature and accounts of conducting self-recorded diaries (Corti, 1993; Crosbie, 2006), I saw that a key challenge was the arduous nature of regularly keeping a diary. Therefore, I suggested participants use a recorder to capture a voice or video account of their experiences. Other challenges such as response rate, diary incompletions and a self-selecting bias were improved through this audio approach to a self-recorded diary.

This method of data collection was implemented in an opportunistic manner rather than systematically. I considered this collection method as an additional experiment, and collected diaries in an *ad hoc* manner when I thought there was a good opportunity to capture data. Asking participants to record something off the cuff without much prompting was a very difficult way to derive useful data, so I decided to ask for reflections from individuals shortly after particular events or meetings. In one example, three participants from the project attended a modelling and analytics study group in the mathematics department to try to examine if it was possible to derive a representative distribution model of incomes in the city of Nottingham to understand the social sustainability landscape. Prior to the meeting, I asked if they would be willing to record their reflections about the study group's format and experience, which they agreed to and did. As these three researchers came from different disciplines, I wanted to capture their thoughts on the meeting’s collaborative approach.

In another instance, a postdoctoral researcher who had started on the project at its beginning left the project to start a new job. As he was one of the first researchers to leave the project, I asked him to provide his overall thoughts on the project and collaborations from the perspective of someone who had been there from the start. He wrote me an email with his reflections to include as data for the project.

Another diary entry came in the form of an email from a PhD researcher who had just received feedback from his first-year review. This came unsolicited from the researcher, who decided to forward me his

reflections on his contribution to the project. He was asked to write a reflection on his first-year review and feedback as part of the administrative process to meet the requirement of a PhD, and his thoughts ‘gravitated’ towards interdisciplinary working. He then forwarded me these reflections for my research.

A final diary entry came in the form of recorded voice messages from a researcher who arrived after the project had been going for over two years. As she arrived at the project very late and many research projects were already underway, I asked her to provide an account of her experience of interdisciplinary working and how she imagined her research to fit into the wider research of the project.

3.6 Reflexivity

Throughout this thesis, I have included reflections on my presence within the sustainability research project and its implications for aspects of the research. I outline some overall aspects of reflexivity here. An important point I considered during my research was my dual roles as 1) an outsider, as a researcher of the interdisciplinary practice, and 2) an insider, as a researcher within the project itself. Navigating the dual insider-outsider position poses particular ethical difficulties when the inside researcher must then step outside to analyse and write up the data. Revealing interpretations of relationships that were mutually built within the project poses the risk of disturbing or even breaking those relationships and the trust that allowed the data to evolve in the first place (Eyben, 2009). Therefore, active navigation and journeying between these two positions was needed throughout the project to balance observation with participation (Freeth & Vilsmaier, 2019; Humphrey, 2007). Reflecting on my positionality helped me make decisions about where to move along the insider-outsider continuum in order to make ethical decisions, maintain trust with the research participants and ensure the integrity of the ethnography.

Additionally, it was inevitable that I would feel uncomfortable in trying to navigate my insider-outsider position in the project. My discomfort centred particularly on managing my own perceived role as the interdisciplinary investigator with the role imagined by some of my research collaborators, particularly when these were very different. My discomfort also centred on navigating my research participants' trust and sharing, as this ethnography aims to tell a story that reveals interdisciplinary dynamics without revealing too much of any individual's experiences. I used these feelings of discomfort as an emotional data point, taken from Callard and Fitzgerald's (2015) approach to using the emotions of others and themselves as data. Callard and Fitzgerald suggest staying *with* feelings and emotions, rather than "always labouring with the assumption that things need to be addressed or resolved." (2015, p. 128). Hillersdal et al. (2020) explore the emotional affect (jokes, unease, scepticism) present in interdisciplinary collaboration and what role that plays in how research participants approach interdisciplinary problems. I continued to use the 'emotion as data' approach in my methodology and throughout project reflections to help understand underlying perceptions about collaboration and how researchers approached the 'problem' of interdisciplinarity.

Within the project's proposal, my research was presented as a project in itself, so my role was defined from the proposal stage. The inclusion of my participation in meetings, document sharing, and feedback of findings were considered part of the project data. I continuously examined how my presence in the research environment and involvement in the study were implicated in its knowledge production (Thomas, 1993). For example, I examined how my presence brought heightened awareness to interdisciplinary working amongst the participants, and therefore more deliberate efforts to conduct interdisciplinary collaborative research projects and ways of working.

To be clear, the focus of my research was not an assessment of individual's performances or actions during their post in the project.

Throughout the course of my research, I made explicit efforts to ensure that my work was not misinterpreted in this fashion by my colleagues, which would have created different social and power dynamics. To maintain trust and close-to-'normal' ways of working despite my presence, I made this clear to the respondents in the project. For example, avoiding feedback to the group that brought individual actions and choices to the forefront was one way to keep my study's true purpose and nature.

I understood that having access to most of the information related to personal perceptions about and within the project put me in a unique 'all-knowing' position. I viewed my research as an all-encompassing narrative documenting the happenings over a significant part of the larger research project, with certain events, interactions and confrontations brought to focus based on my sole control over interpretation and choice of focus (Van Maanen, 1988). This position of power did not escape me, and I was reminded of my unique access to all of the researchers on the project when discussions with me took on a hushed quality, project members hesitating to reveal a secret or a statement about themselves or others for fear that the confession might be published.

Though I did not assess my colleagues' work or outputs, I kept my observations confined to work hours. Any exchanges or discussions that took place out of work hours, including social trips to pubs after work, holiday socials and group chat messages (Facebook messenger and WhatsApp, for example), were not included in the study as data. Analysing work practices by observing private interactions would have created an ethical issue regarding privacy.

Grounded in the interpretivist approach to ethnography, I accept that my account and narrative of the project are grounded in my sociological approach and lens. My narrative is just one account of the interdisciplinary process in sustainability research. Therefore, as a sociologist, my research findings and observations focus on personal

interactions, use of discourse and how these interactions and use of language reflect wider sociological structures.

In addition to my disciplinary background, I suspect that other individual traits also impacted my access to certain information and how the other researchers responded to my presence in observations and interviews. For example, as a PhD researcher, my junior status might have prohibited me from accessing certain information or made other researchers hesitant to share certain information with me. Being seen as an outsider—a social scientist in a natural science dominated project with positivist epistemological foundations—could have also impacted how the other researchers interacted with me (Albert et al., 2009). For example, a ‘care’ role is often given to female social science researchers in interdisciplinary projects by other researchers (Viseu, 2015); such dynamics could have influenced how the team interpreted my role and received my feedback and analysis.

I must also recognise that all data was filtered through my own notes, observations and descriptions (Kawulich, 2005). This describes the limitations of my personal reach within the project, as I could not be in multiple places at once, and there were surely some key interactions and meetings that I was not present for. Therefore, the narrative that I provide is a snapshot of the social dynamics that took place over the course of my fieldwork.

3.7 Analysis

To help collate and organise all of the documentation, I used NVivo software. Previous qualitative research using this software (Houghton et al., 2017; Zamawe, 2015) points to the ability of the software to facilitate a systematic approach to the different types of data that are collected in one place, allowing for easy cross-reference of themes and codes across data sources.

I first conducted a thematic analysis, “a method for identifying, analysing and reporting patterns (themes) within data” (Braun & Clarke, 2006, p. 79) and a broad way to categorise factors such as experiences, the recurring vocabulary used and shared, key events and interpretations (Hignett & McDermott, 2015). Thematic analysis is appropriate to this research project because the method is flexible enough to allow for multiple iterations and visitations of the data and for codes and themes to develop and change over time. It is also broad enough to be used across visual, verbal and textual data, allowing one to capture themes across different types of data collection methods. It is recommended to ensure that the themes are not so broad and unstructured that they do not apply or address the stated research questions or the theoretical foundation that the research is built upon.

To analyse the data, I inputted all project reports, interview and meeting notes and transcripts, diary entries, field notes and published work into the NVivo software and manually coded them according to themes I detected in the data. The individual themes I categorised as Nodes in the research totalled over fifty. They ranged from themes that were informed by the literature of previous empirical studies of interdisciplinarity (such as ‘time’, ‘language’ and ‘trust’) to common vocabulary that appeared in the data (including ‘leadership’, ‘outputs’ and ‘publishing’) and abstract concepts related to reflexivity in the research process (‘epistemology’, ‘assumptions’ and ‘expertise’ for example). I then manually grouped themes together using a mind map to investigate the strength of the relationship between two or more themes. For example, ‘outputs’ were discussed as an important impact measurement for a project’s success and ‘publishing’ was a closely related theme that determined the success of a participant’s academic career.

I fed preliminary analysis and findings back to the research group and conferences during the data collection phase. This cyclical feedback process further developed my analytical perspective after hearing the

perspective of the research participants and STS researchers at conferences. For example, in the 15-minute presentation I gave as preparation for an STS conference in 2018 (Lewis, 2018), I received overall positive feedback from members of the research group who were present in the meeting. Many researchers agreed they found it difficult to find time to prioritise interdisciplinary working, for example. However, one researcher's feedback was that he expected different comments from my presentation. Specifically, he wanted an analysis of particular aspects that made an interdisciplinary project a success from an objective perspective, rather than interpretations of interdisciplinarity from the group. These reflections further informed my study about what the researchers considered my role to be in the project, as well as how they understood interdisciplinarity as a goal to be achieved. These comments and analysis of my work were then fed back into NVivo, in the form of additional data and evidence.

3.8 Conclusion

In this research project, I used ethnography, informed by STS approaches to studying knowledge and sense-making. The ethnographic method enabled me to investigate a small group of people over a long period of time and understand how they made sense of their and others' roles. A combination of participant observation, semi-structured and conversational interviews, document analysis and participant diaries triangulated the research. The following analytical body of the thesis documents how all of this data together constructed the interdisciplinary approaches taken by participants in the team. The following data chapters also seek to understand how perceptions of interdisciplinarity determine approaches to and evaluation of interdisciplinary work.

Chapter 4: How do you ‘build’ interdisciplinarity?

4.1 Introduction

This chapter introduces the metaphorical device I developed to illustrate and understand how researchers on the sustainability project approached interdisciplinarity interaction and how those experiences compared to their expectations. To those ends, this chapter asks: ‘How did the researchers on the project understand interdisciplinary working?’ and ‘What did researchers see as important aspects to include in an interdisciplinary project?’

This empirical chapter pulls from project documents, interviews, field notes and meeting transcripts. All of these documents were uploaded to NVivo and coded using thematic analysis. Much of the data from this chapter was coded as ‘definition of interdisciplinarity’, ‘interdisciplinarity as a goal’, ‘structure of interdisciplinarity’ and ‘geography of disciplines’. By examining the corresponding extracts from these codes, I was able to see the relationship between how the project was structured and the researchers’ expectations of interdisciplinarity.

A general finding of my research is that researchers on the sustainability project struggled to define interdisciplinarity. They came up with diverse meanings to help make sense of the term. However, this chapter shows that, despite a range of different definitions, a dominant undercurrent of desire to successfully ‘do’ interdisciplinarity emerged.

In attempting to ‘achieve’ interdisciplinarity, the main strategy was to structure the project at the start in a specifically interdisciplinary manner. In this chapter, I introduce an analytical framework in the form of a metaphorical ‘building’ to make sense of how the researchers understood interdisciplinarity to be built in the project. This idea came

after listening to interviews and meeting recordings where researchers described their disciplines and interdisciplinary working by using place, geographical and architectural metaphors. For example, in instances where I asked in an interview how they would define interdisciplinarity, phrases such as ‘bridging gaps’ were used. When I came across this language, I used thematic analysis and coded it as ‘geography of disciplines’ or ‘structure of interdisciplinarity’, depending on the context of the quote, and I selected the quotes from these codes to describe a metaphorical interdisciplinary ‘building’.

According to Brown, conceptual metaphors play an “extensive role” in science communication (2003, p. 49). Rather than their function being limited to language or communication, metaphors are implicated in conceptual understandings and shape the very meaning of the abstract concept they illustrate (Brown, 2003; Taylor & Dewsbury, 2018). Brown argues that metaphor actually grounds abstract concepts in the concrete experience and therefore “influences our thought patterns and actions as well as the ways in which we express ourselves.” (Brown, 2003, p.49). Essentially, a metaphor functions to shape how we understand an abstract concept itself, and therefore, ultimately, how we study or treat that concept by grounding it in an accessible sensory experience.

Interdisciplinary research projects have a history of using metaphors to describe interdisciplinary collaboration (Boix Mansilla, 2010); for example, disciplines meet at a ‘crossroads’ and interdisciplinarity is the solution needed to ‘bridge’ disciplines (Repko et al., 2017; Klein, 2005). In this chapter, I reflect on the metaphors used by the researchers and the literature to illustrate and bring to life the importance put on the structure and organisation of the project as an enabler for interdisciplinary working. I also introduce metaphors to explain how the researchers understood different factors in ‘making’ interdisciplinarity. The components that make up this interdisciplinary ‘building’ are: ‘columns’ of disciplinary experts, ‘dry-walling’ of multi-disciplinary

supervisory teams, a ‘diary room’ in the form of an interdisciplinary researcher, ‘dancefloor’ or shared spaces for disciplinary integration and ‘Lego blocks’ as an integration tool for disciplinarians to work together.

4.2 Defining interdisciplinarity

As outlined in Chapter Two, a clear definition of interdisciplinarity eludes many researchers as the term is not uniformly applied across different research collaborations. For example, interdisciplinary research is often used to broadly encompass projects that are ‘cross-disciplinary’, ‘multi-disciplinary’ or ‘transdisciplinary’ in nature (Lam et al., 2014). Klein (2010) and Darbellay (2015) provide a clear taxonomy of ‘interdisciplinarity’ and clearly categorise multi-, inter-, and transdisciplinarity on a spectrum according to their depth of disciplinary integration. However, even in describing this taxonomy, Darbellay (2015) outlines two main definitions associated with transdisciplinarity. As various terms are applied to a range of different ‘interdisciplinary’ projects, labelling a project as interdisciplinary does not alone succeed in indicating the type of disciplinary integration that is taking place.

In addition, what constitutes an interdisciplinary piece of work can be understood or implemented in multiple ways. Interdisciplinarity can happen by combining research methodologies (Newell, 2001), it can be used to describe the application of theories from other research disciplines (Bibri & Krogstie, 2017), or it can be an epistemological integration (Boix Mansilla, 2010; Darbellay, 2015). Therefore, labelling a project ‘interdisciplinary’ does little to indicate at what level, subject area or form the interdisciplinarity takes place. For example, a single researcher utilising and integrating research methods from more than one disciplinary practice can be a way to practice interdisciplinarity, whilst working together with another researcher from a different discipline can also be considered interdisciplinary collaboration.

In the sustainability project, researchers displayed a range of definitions and examples of what made a project ‘interdisciplinary’:

> It’s bridging the gap between previously unrelated disciplines. And that always moves what interdisciplinary means in terms of what you are working on, so what happens is that if something becomes well melded together, I would then say that is a unique discipline in and of itself. – *Sebastian*

> Perhaps other people would define it more by academic, well previous academic, perhaps more to do with departmental disciplines, I guess. […] I think you have a problem to solve in previous underconnected flows of work and anything interdisciplinary is basically bridging those gaps. – *Richard*

> [...] you work with people whose understanding of the world, their understanding of epistemologies and that, are different to yours. But you work on a problem or solutions, a research question together, but your worldviews are sort of-, you bring very different set of skills and expertise to the project. I think that is how I would define it. I wouldn’t be hung up on academic disciplines because they are constructs within their own right. – *Elisa*

> Inter-disciplinary research means that you put all your methods that you know from your research into one pot. You stir it and you get a new product out of that that embeds all the different components. – *Tristan*

These quotes are extracted from interviews with both junior and senior researchers to demonstrate the range of understandings of interdisciplinarity across the board. Interdisciplinarity could be defined by the process of working together. For example, Elisa focused on the process of interdisciplinarity and described it as bringing people together with different understandings of the world. Interdisciplinarity could also be defined by the result of the research collaboration, as exemplified in Tristan's quote about a "new product […] that embeds all the different components". Interdisciplinary could be defined in reference to academic disciplines, or not; it could create a new discipline at the end of the integration, or not. Definitions of interdisciplinarity and even descriptions of what aspects would be included in an interdisciplinary project were varied among the researchers themselves.

In discussions with these same researchers, though they individually described their understanding of interdisciplinary working, they expressed this understanding with hesitation and reluctance:

> For me, I guess, [pause] well I don't know, in the current context, put it this way, and this is really contextual, and I think a reasonable working hypothesis at the start is where two different workstreams which have previously not connected, you could vaguely regard those as two different disciplines. And bridging that gap would be interdisciplinary work. – *Sebastian*

> If that makes any sense, I'm not completely sure on definitions here, which doesn't help, perhaps, for example, but even within our own work it is set up with six different themes, which are broadly based on academic, all the definitions of academic disciplines are essentially by

> department almost, I deal with less of that […] – *Richard*
>
> Gosh it's so hard [pause] [...] I organised a seminar [...] to come and talk about this and-, I think it does mean that you bring expertise to the table from outside of your own sub-sphere of knowledge. – *Elisa*
>
> If you look – and I wrote it down at some point because I always got mixed up with this. Multi-disciplinary research means that you have multiple disciplines contributing to one project that has still identifiable components of each of the disciplines. [...] But overall, so the platform development I think is less inter-disciplinary and more multi-disciplinary. Although that also might be not true – *Tristan*

In the above quote samples, the struggle and hesitation to define their understandings of interdisciplinary work were clear in the pauses in their speech and the reluctance to fully commit to a definition. By commenting that "it's hard" and that they are "not sure what is meant", researchers indicated their own struggle and difficulty with assigning a definition to the term or even describing what interdisciplinarity would look like. Tristan talked about doing some research on the definitions because he got "mixed up". For him, the multiple terms associated with cross-disciplinarity working were confusing. Not only were the descriptions of interdisciplinarity varied, but they were also opaque to the researchers themselves.

Despite the varying definitions of interdisciplinarity and what constitutes an interdisciplinary project, there is an underlying dominant narrative in the literature that an interdisciplinary approach will lead to innovations and is ideal for the changing future demands of research. The rationale that the 'real world' is not neatly compartmentalised into specific

disciplines leads to the assumption that the more ‘holistic’ approach of interdisciplinary research can address the complexity of such issues, particularly issues in environmental sustainability and sustainability science (Frank, 2017; Lam et al., 2014; Petts et al., 2008).

Interdisciplinarity is strongly linked with the field of sustainability science as outlined in Chapter Two because the method (interdisciplinary) and the subject (sustainability) are both seen as complex and multifaceted. The association between interdisciplinarity and ‘complex’ research fields like sustainability science is established because disciplinary approaches are considered inherently limited in their ability to respond to complex demands (Bursztyn & Drummond, 2013). Eishof (2010) writes of the ‘transformative’ power of interdisciplinary research and thinking, in that it allows students to be educated in an interdisciplinary manner to understand the various connections that need to be made to create a more sustainable world. In the literature and in the sustainability project studied for this ethnography, the understanding was that the nature of the subject of study (urban sustainability) necessitated an interdisciplinary approach.

This dominant narrative of the achievements of interdisciplinarity is consistent with the literature on interdisciplinarity as a progressive way of working (Lakhani et al., 2012), as argued in Chapter Two. Many researchers' underlying understanding is that they should do it because it is inherently progressive and aspirational. Interdisciplinarity is commonly thought of as ‘more than’ regular research collaborations or as an enhanced way of working. Specifically, in the field of sustainability sciences, interdisciplinary research is seen as necessary to conduct relevant research, implying that mono-disciplinary approaches by their very nature are lacking. Researchers on the project echoed this sentiment or recognised the upward trend of interdisciplinarity:

> That is a good question. You grow up in the UK higher education system and funders and publishers everyone saying ‘interdisciplinary work

> is good' full stop. The ESRC for example wants interdisciplinary research, we are told interdisciplinary papers have higher citations so there is this big drive to do it. – *Tristan*

> It made me realise we kind of take the interdisciplinary aspect for granted a bit, I think it can be applied in so many ways and it is kind of a popular thing right now, if you are applying for a grant or research, you need to have the word 'interdisciplinary' in the title basically, but it could be so many things it could be an anthropologist working with a sociologist, or it could be an ethnography working with the physicists, it could be so many different things. – *Lottie*

These two quotes are from interviews with postdoctoral or more junior researchers on the project. Interestingly, here they discussed how they "are told" interdisciplinarity is good and that "it is kind of a popular thing right now". From their position, they recognised they were told how they should feel about interdisciplinarity and what they needed to do when applying for research grants. They said that interdisciplinarity is a good thing because they were told it is by others in higher education from a funding perspective or in order to be a successful academic. Senior academics on the project seemed more likely to buy into the inherent value and benefits of interdisciplinary research:

> Personally, I think interdisciplinary areas tend to be more fertile anyway, they have more opportunities, and there are more interesting effects and things to be studied.
>
> […]
>
> Well often where the disciplines meet there are problems that haven't been considered by either

> community because it is too difficult, or what is perceived to be beyond their reach. And that is where the overlap can produce some very surprising results. – *Sebastian*
>
> And, you know, then you might want to conclude that with a discussion about why interdisciplinary, why an interdisciplinary research programme is absolutely essential for the analysis of cities and their sustainability. You can't do that in any other way. – *Pete*

In the above quotes, these senior academics illustrate the 'essentialist' attitude towards interdisciplinary research, either because disciplinary research alone cannot "reach" the conclusion or interdisciplinarity goes hand in hand with the topic or problem that is being investigated (urban sustainability). Compared to the quotes from the junior researchers, interdisciplinary research was defined less in relation to their personal career. In the original funding proposal drafted by the Principal Investigator and other senior academics on the project, the outlined problem or challenge is similarly described:

> **There is an urgent need to envision and investigate approaches to sustaining urban habitats; to transition existing cities in developed countries and to accommodate further growth in developing countries.**
>
> But whilst this need is understood, real progress has been hampered by a lack of holistic interdisciplinary research. Past efforts tend to have focussed on environmental, economic or social factors in isolation; employing either quantitative or qualitative methods; addressing either developed or developing countries.

The bold lettering in the quote above is an emphasis in the funding proposal. It accentuates and acknowledges that existing research has been attempted, but claims that mono-disciplinary approaches have held back “real progress”. This project promises to make real progress because of its interdisciplinary nature, which is “holistic” and multi-modal. We *need* interdisciplinarity for advancement.

The emphasis on interdisciplinarity in the funding proposal was written to match the priorities of the funder. In the funder’s stated approach to grant-making, they say:

> Many of the Trust’s schemes allow for, indeed encourage, the study of research problems that cross established disciplinary boundaries. This is an intended consequence of applying the key criteria mentioned. It does not therefore follow that ‘lack of cross-disciplinarity’ of itself precludes an application to the Trust. Here, as elsewhere in our approach to grant-making, the originality and quality of the intended study are paramount. However, the Trust does not work within a disciplinary framework, and we particularly welcome proposals that are not bound by conventional disciplinary understandings. (Leverhulme Trust, 2018)

Implicit in this statement from the funders is an understanding that cross-disciplinary work tends to be more aligned with their ethos and organisation. By welcoming proposals that are “not bound”, they imply that a disciplinary silo is a constraint on research thinking. They also describe disciplinary understandings as “conventional”, signalling that they are an unconventional funder and think outside of the box. From this funder’s perspective, interdisciplinarity and original research go hand in hand, as originality is hard to reach within disciplinary confines.

This sort of statement from a funder reinforces the aspirational nature of interdisciplinary research. A funder has an influential role in encouraging the organisation of a project to be more inter- or cross-disciplinary in order to increase chances of winning research funds. As a result of the combination of the dynamics of the funder, the way the project proposal was structured and the wider discourse surrounding interdisciplinary research, interdisciplinarity itself was an implicit yet important objective for this project. Although the importance and desirability of interdisciplinarity were established, a clear understanding of what it meant and a shared definition were lacking within the sustainability research project.

4.3 Interdisciplinarity as not desirable

Though the aspiration to achieve interdisciplinarity is a dominant theme, a counter-narrative exists that interdisciplinarity is not desirable. This counter-narrative discusses interdisciplinarity as risky, both in the context of personal career development but also for the legitimacy of knowledge and expertise within a discipline.

The phrase ‘jack of all trades (master of none)’ is expressed in the literature to illustrate the feeling that interdisciplinary work is superficial and lacks the intellectual depth needed to gain expertise in a field of study— an unwanted reputation for an interdisciplinary researcher (Cuevas-Garcia, 2015). Early-career health researchers working in an interdisciplinary context expressed the lack of a feeling of legitimacy and a disciplinary ‘home’ for their research (Carey & Smith, 2007; Lyall & Meagher, 2012). Establishing academic credentials is seen as a principal challenge amongst researchers in the field of geography who pursue interdisciplinary subject interests (Lau & Pasquini, 2006). In this context, pursuing interdisciplinary research endeavours is perceived as risky for academic credentials in disciplinary structures because the breadth of interdisciplinarity is assumed to lack the depth of disciplinary thinking.

For some of my research participants, working in an interdisciplinary manner did not have much appeal in the long term. Despite the narrative from funders and the project's leadership that interdisciplinarity was necessary to solve complex and real-world problems, some researchers did not see benefits to their own career progression. For example, during an informal conversation with me in the office kitchen, a postdoctoral researcher stated that he did not see the benefit in being a 'jack of all trades' interdisciplinary researcher. He found it more beneficial and enriching to really specialise in his field of study. Disciplinary depth and focus were preferable to him rather than the breadth of an interdisciplinary approach.

Further, for some researchers, the interdisciplinary aspect of the project existed only in name. It did not reflect 'true' interdisciplinary collaboration. One researcher's previous experience working on an interdisciplinary project contributed to his scepticism:

> So, you start realising that it's all just bureaucracy like that, all that matters is that you get the certificate, whether it is in civil engineering or not. That's all that matters. So maybe that creates a slight, jaded perspective of me working on that kind of interdisciplinary project. I know it is challenging and you really need to focus on that at the start and pull it all the way through to make it truly interdisciplinary and maybe people aren't going to have the experience in doing that or there's just going to be a lot of learning as you go along on how to achieve that, which will be extremely inefficient and frustrating and stuff […]
> – *Richard*

The interviewee was recounting his experience of working on an interdisciplinary-based PhD; because the interdisciplinary aspect was encouraged by the funder, certain aspects of the project were built to

facilitate interdisciplinary working. However, he considered the interdisciplinary aspect of his PhD to have been bureaucratic and that ultimately getting his PhD was the principal priority. As a result, his perception of working on interdisciplinary projects was that they take a lot of time and are difficult to truly achieve in the end. Working on a project that is labelled as interdisciplinary could create undue added frustrations to a project by creating an extra, difficult objective, distracting from other higher priorities.

In the above two examples, both researchers were considered junior academics in that they were postdoctoral researchers on the project rather than theme or project leaders, which played a part in their priority of gaining disciplined research experience. From the perspective of these researchers, at their stage in career it seemed more important to gain specialist skills that they could use for their next stage of employment. Acting as a Principal Investigator to a large-scale research grant, a stage when it appears interdisciplinarity is more valued, was not going to be their next career move. The UK's current academic environment is widely perceived as precarious; in such a context, a more senior academic is more able to shoulder the perceived career risk associated with interdisciplinary working (Byrne, 2014).

4.4 The interdisciplinary 'building'

At the beginning, researchers set out to try to build the sustainability project in a way that would allow interdisciplinarity to happen. To do this, they recruited disciplinary experts, established interdisciplinary supervisory teams, recruited an ethnographer to study interdisciplinarity in real-time, set up meetings in shared spaces and assumed that 'integration' would take place in the modelling aspect of the project.

I use the term 'build' specifically because the project was constructed and structured to facilitate interdisciplinarity; indeed the way the project was built was the principal strategy used to achieve interdisciplinarity. To demonstrate the concept of constructing an interdisciplinary project,

I use architectural and building metaphors drawn principally from the fieldwork and secondarily from the literature on interdisciplinarity to illustrate the role of each of these constructive elements. ‘Columns’ represent skeletal structures that have the ability to stand alone but also serve as the main support structure for the project. The ‘dry-walling’ is the connective structure that joins these columns together and creates an extra space or a ‘room’ for interdisciplinarity by creating walls. A special separate ‘diary room’ reflects the watchful and all-knowing eye of the interdisciplinary researcher. A ‘dancefloor’ is a space where different people can come, meet each other and choose to interact further. Finally, the ‘Lego blocks’ represent a structure that must be built by connecting multiple pieces to create a result that is more than the sum of its parts.

4.4.1 Columns – Disciplinary experts

Disciplines, especially in academia, are often referred to as ‘silos’ (Stirling, 2014). Some see disciplinary silos as inherently closed off or ‘limiting’ (Jacobs, 2013), while others consider them necessary to reach a certain depth of understanding in a subject that would be impossible to do by other research means (Crossley, 2015). The stand-alone ‘silo’ is also used to reference organisational departments that “do not wish to share information with others in the same company” (Glesson, 2013, p.1). The understanding of a silo in these examples is of a structure that has been reinforced over time, giving it a strength and history that makes it difficult to change under new influences. The silos in the above examples are also independent in that they do not welcome outside influence and have the desire to stand alone; they are insular.

There are arguments that as a prerequisite for conducting interdisciplinary research, full mastery of a discipline is needed at the onset to ensure the correct application of ontology and use of methodology (Jacobs, 2013). Interdisciplinarity is not considered a single subject or even an entity but a way of research organisation, which necessitates knowledge of a discipline at a base level. Combining

heterogeneous disciplines to make one interdisciplinary research project is a common practice. The concept of a heterogeneous collection of disciplines and how this collection represents new knowledge production is further investigated in Chapter Seven. For this chapter, it is only necessary to know that a collection of different disciplinary expertises is seen as a requirement for interdisciplinarity.

Though we currently see ‘interdisciplinarity’ as a concept used by research funding bodies and research institutes, there is no strong argument that an interdisciplinary mode of research will eventually become the dominant norm for knowledge production. Interdisciplinarity and disciplinarity will continue to coexist, which is evidenced in organisational structures at the university level (Gibbons et al., 1994; Jacobs, 2013; Weingart, 2010). As disciplinary ‘silos’ in academia have a strong history, disciplinary knowledge production is here to stay. The presence of disciplinary knowledge in interdisciplinary projects cannot be denied, however ‘problem focused’ the research project aims to be. This was the case with the urban sustainability research project.

Interdisciplinary project or not, a key characteristic of working in a UK academic environment is separate demarcated departments existing along disciplinary lines. Researchers are incentivised to think of themselves along disciplinary lines. For example, academic publishing structures value disciplinary contribution and expertise (Boon et al., 2014). A clear example of this is the Research Excellence Framework (REF) in the UK. It is a system that assesses the quality of research in higher education institutions. Of the three assessed elements, one is the quality of ‘outputs’ produced by academics, including the rankings of the academic journals they have published in. In addition, criteria assessment panels are organised into disciplines, which are grouped into four main categories: medical science, natural science, social science and humanities (REF, 2021). Important structural and evaluation processes in academia are still strongly discipline-oriented, influencing how research is conducted at the university.

At its inception, the sustainability project was organised and structured with disciplinary expertise at the forefront, with thematic structures outlined that were deemed necessary and relevant for an urban sustainability project. The six themes were labelled: 1. Environmental 2. Social and Cultural 3. Economic 4. Measurement and Data 5. Modelling and Optimisation and 6. Policy and Governance. These themes were presented at the application phase, and this diagram can be found on the website:

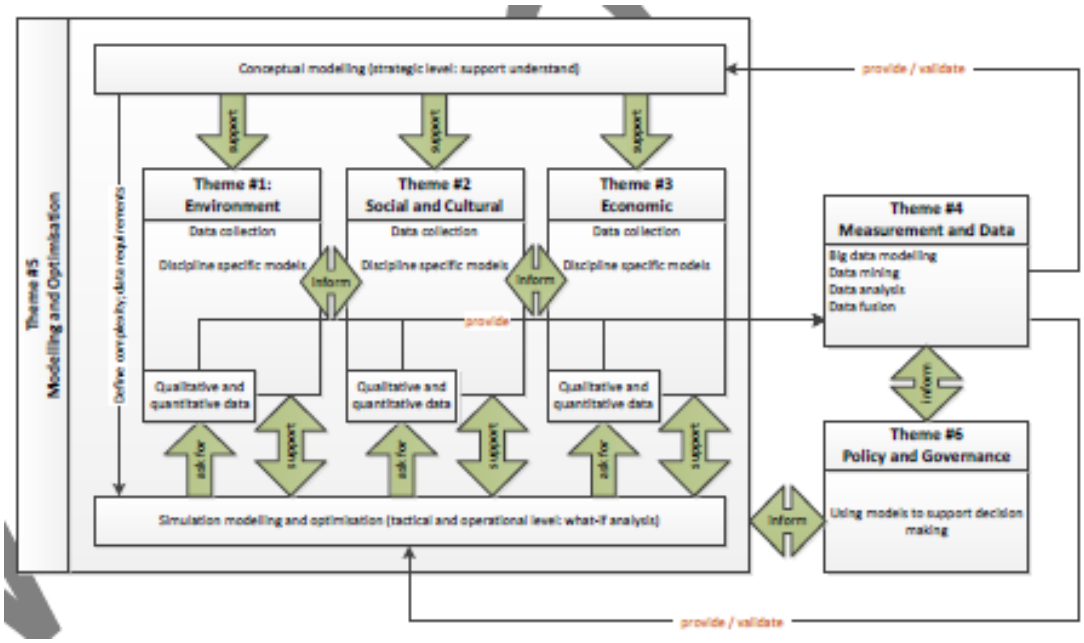

Figure 4-1: Diagram of project themes

Visually, the themes are largely organised in their enclosed boxes with their specified role in the wider project, with interaction taking place between them (as indicated by the directional green arrows). Integration was thought to take place within the Modelling and Optimisation theme.

These themes reflected and mirrored the disciplinary School structure set up by the university's academic departments, further reinforcing the disciplinary orientation of the project at the onset. Researchers that were brought on to the project were assigned or categorised into a 'theme' that reflected their School affiliation at the university. For example, the PhD student, the postdoctoral researcher and the Co-Investigator that led the Policy and Governance theme were all affiliated with the School of Sociology and Social Policy.

This disciplinary expertise was considered the first requirement of an interdisciplinary project. In an interview, Xavier, one of the senior academics, mirrored this understanding when asked to define 'interdisciplinarity':

> "To me it means people with strengths in their particular disciplines coming together to answer

> problems or questions that require inputs from more than one discipline".

In this quote, Xavier first mentions the "strengths" of people as a prerequisite of interdisciplinarity. This expertise in a particular discipline is what is required to answer problems that require an interdisciplinary approach.

The disciplinary themes built the main skeletal structure for the organisation of what were called Progress and Integration meetings. As implied by the title, the purpose of these meetings was to update everyone on research progress. The assumption was that, as a result of knowing what other researchers were doing, connections would be realised between existing research strands to 'integrate' previously disconnected pieces of work. Updates at the Progress and Integration meetings were given according to a researcher's affiliated theme. The themes that were considered to be more natural science (Environmental, Modelling and Optimisation, and Measurement and Data) would give their updates in the same meeting. The next week, the other three more social science themes would provide their updates. This format changed intermittently from time to time, but many of the meetings were organised in this manner to minimise their length. This decision to organise the meetings thematically reflected the importance placed on disciplinary expertise, how researchers imagined which themes belonged together and how closely related they imagined certain disciplinary themes to be. The Environmental, Modelling and Optimisation and Measurement and Data themes were considered to be more like one another, to have more in common and speak the same 'language'. Researchers in these themes included computer and data scientists, physicists and engineers, to name a few. The other three themes (Social and Cultural, Economic and Policy and Governance) were referred to as the 'social' themes by the researchers. Researchers in these themes had backgrounds in geography, sociology, urban studies, politics and policy. The meetings were divided

to save time; however, it is telling that they were divided by the leadership along perceived epistemological lines between the natural and social sciences.

In addition to influencing the structure of the Progress and Integration meetings, the themes' affiliations with academic disciplines had implications for how researchers identified their own roles and the roles of others in the interdisciplinary aspect of the overall project. Researchers from each discipline were seen as the experts in their field, and therefore it defaulted to them to provide information from their field. Once the different disciplinary representatives were brought together, then interdisciplinarity could take place. For example, during my initial months on the project, project members met with me to discuss their experience and progress to date. At least three researchers informed me that interdisciplinarity had yet to start because they were waiting for the right people or for all of the missing (disciplinary) positions to be filled. There was a sentiment that researchers first needed to 'get up to speed' on the project and their roles before 'integration' could take place on an interdisciplinary level between researchers. This suggests that to create an interdisciplinary project, first one needs to have the right, established disciplinary experts all in place.

In Progress and Integration meetings, as well as other, smaller meetings attended by the researchers on the project, researchers would default to the (perceived and actual) expertise of others on the project. For example, Eric, one of the natural scientists on the project, wanted to gain an understanding of the behaviour of private businesses in the city for his modelling project. As Eric and other natural science researchers on the project perceived this to be an economics issue, the postdoctoral researcher for the Economics theme, Tristan, was asked to provide a literature review to summarise key points and improve their understanding. Rather than looking into this research himself, Eric deemed this knowledge outside of his expertise and called on the

economics expert, Tristan, to contribute. Interestingly, Tristan did not consider himself an economist, but specialised in issues related to transport in the urban environment.

In this metaphor, the column represents the disciplinary silo. Although I largely adopt the metaphorical concept of the silo for my framework, I use the word ‘column’ to align with the broader theme of a metaphorical building. The understanding of a disciplinary silo as described in the literature (Crossley, 2015; Glesson, 2013; Jacobs, 2013; Stirling, 2014) was largely reflected in the language and narrative of the sustainability project and the researchers on it. A discipline is a strong column that has been built up and reinforced over time with disciplinary theories. The column is also built using particular methods of conducting research and based on specific epistemologies. These disciplinary silos are both represented and reinforced by university departments, which have their own administrative standards, disciplinary requirements to gain academic qualifications and publishing practices. In this thesis, I also use the column to represent the disciplinary expertise of a researcher on the project. Each researcher represents their discipline by subscribing to its respective ethical practices, research methods and theories, to name a few aspects. The understanding of this structure as a column or silo is important because it illustrates a reliance on disciplinary experts to bring their depth of disciplinary expertise as the first step towards interdisciplinarity. Without it, interdisciplinarity can not happen.

4.4.2 Dry-walling – Interdisciplinary supervisory teams

Another aspect that was considered important for interdisciplinary working was the establishment of interdisciplinary supervisory teams. These supervisory team meetings would serve as a space for interdisciplinary exploration and possible connection by ‘walling off’ and creating a separate space for interdisciplinarity. Although the makeup of some supervisory teams changed over the course of the project, this was due to some project members leaving and/or joining over the

course of the project. The intent was that the supervisory team would be consistent over the lifetime of a PhD.

The set-up of an interdisciplinary team of supervisors also shares characteristics with the ‘columns’ aspect of the project in that it was built using disciplinary experts. The supervisory teams of about three people (though this varied) were from different disciplinary Schools. For example, a PhD student from Sociology had a team of two supervisors from the Sociology department and one supervisor from the School of Geography. The rationale behind this structure was that discussions during supervisory meetings and feedback to students would have intellectual input and critique from a discipline outside of their own school of thought.

Although an interdisciplinary team of supervisors was a project requirement for PhD students, assignment of who would be on the interdisciplinary teams was done *ad hoc*. Supervisory arrangements were determined partly based on the desire of the supervisor and on the requirement that one supervisor should be from the home School. For example, some supervisors would volunteer to be on certain PhD projects out of personal interest, rather than utility for the PhD student. In addition, departmental administrative practices also dictated the makeup of the supervisory teams. For example, each PhD student’s ‘principal’ supervisor would be from their respective School and these practices had to be complied with. For the students based in Computer Science, a requirement was that two supervisors on their team had to be from their department, so they had one supervisor from the project who was based in Computer Science and another supervisor who was not working on the interdisciplinary project but was also based in Computer Science.

To describe my own supervisory team as an example, my lead supervisor was from the School of Sociology, and the other two supervisors were on my team because they wished to be involved in my project and were specifically interested in my work. The Principal

Investigator was one of my supervisors, and he imagined his role as a practical one in which he would provide overall insight and input from other aspects of the project that I might potentially overlook. The third supervisor was based in Computer Science and specialised in agent-based modelling and building simulations that modelled human behaviour. His interest in my research was how a group organised in an interdisciplinary manner would behave under certain arrangements or circumstances. From my insights, he imagined that he would be able to build a model of some sort and potentially write a paper on that strand of work. Thus, although my supervisory team was interdisciplinary in nature, the supervisors were either self-selecting based on their own research interests or assigned based on the School's administrative requirements. It was not necessarily thought through how their disciplinary expertise would contribute to or influence my ethnography. Later I initiated a change to this supervisory team, as outlined Chapter Three; however, the story of the initial supervisory team reveals how project members imagined the structure interdisciplinarity would take at that level.

Though the project labelled urban sustainability as its subject, that the research structure was built through disciplinary experts demonstrates a strong disciplinary orientation and approach. In supervisory meetings, the principal supervisor on the team would be someone from the PhD's home School to fulfil administrative requirements of that department. Though other researchers were encouraged to discuss and think about how those in other disciplines might approach a problem, the legwork of a specific workstream was left to the expert who was brought on to the project for that purpose. This is reflected in the narrative that interdisciplinarity without the disciplinary experts present could not yet take place. Interdisciplinarity needed to wait for them. In this project, in order to build interdisciplinarity, the researchers understood that it must first start and be built with disciplines.

‘Drywall’ connects the disciplinary ‘columns’, or posts, in a building. The project was thought to establish an environment where interdisciplinarity could grow, both by connecting disciplines and by creating a space where interdisciplinarity could happen. In creating this ‘walled off’ space, the project leaders assumed that interdisciplinarity would ‘flow’ within it. This interdisciplinary ‘flow’ is compared against a theoretical framework in Chapter Seven to ascertain its role in interdisciplinary research collaborations. For the purposes of this chapter, it is just assumed that this ‘flow’ will occur. Again, there is an underpinning assumption that to make interdisciplinarity happen, first one needs a team of disciplinary experts put together on a project (a PhD thesis) and in the same place (supervision meetings) so they can interact with each other.

4.4.3 Diary room – Interdisciplinary practitioner

Besides collecting and bringing together various researchers from select disciplines, another of the project’s building blocks to create an interdisciplinary environment was having an interdisciplinary researcher on-site. The role of the interdisciplinary researcher was to research and understand interdisciplinary working and dynamics using an ethnographic perspective.

As the person in this role, I was a social science researcher using ethnographic and observational methods to observe interdisciplinary processes and behaviours of the other researchers. I was not an ‘interdisciplinary researcher’ in the sense of having a breadth of knowledge of different disciplinary theories or methodologies to apply to my research project (Smith & Carey, 2007). This thesis is not a mixed methods interdisciplinary research project.

Ethnography is a research methodology that has been used in interdisciplinary research settings to understand the relationship between co-production and policy making (Lövbrand, 2011), compare personal experiences across different interdisciplinary research projects

(Monteiro, 2018), and provide recommendations in future collaborations between natural and social scientists (Goulden et al., 2017). Research reflections of such ethnographies centre on an ethnographer being in a ‘unique position’ to see multiple angles and perceptions of researchers within their respective projects. This unique position speaks to the “threshold” that ethnographers balance between dual insider–outside positions (Eyben, 2009, p. 72).

To describe the role of an interdisciplinary researcher on a project, Repko (2012) employs a metaphor based on an Indian parable about a group of blind researchers trying to examine an elephant. One researcher can feel the wrinkly trunk, another researcher examines the smooth tusk and yet another studies the bristly attributes of the tail, yet none of them can see the elephant as a whole. To extend the metaphor, Repko (2012) suggests adding an additional blind researcher to question the others and lead them to a more coordinated conclusion of the elephant as a whole. The rationale is that by forcing coordination and efforts, the blind researcher will be able to find and understand the whole picture of the elephant. This additional blind researcher is the missing link to create a coordinated and holistic research project where interdisciplinarity is concerned.

As outlined in Chapter Three, my role as a researcher of interdisciplinarity was written in at the application phase of the project. In addition to studying interdisciplinarity from an ethnographic perspective, the interdisciplinary researcher was imagined to be very practical and action-oriented. As quoted from a version of the grant application, my role was to “shed light into the effectiveness of the research process and may lead to improved communication within the team.” In my ethnography, reflecting on my all-knowing position is important to understand the research dynamics. I also want to reflexively engage with my role as an unintended motivator and prompter of interdisciplinary working.

As a PhD student, my role was to facilitate interdisciplinarity amongst the team members and make suggestions for how they could do better. In the project, this was the principal active approach to recognising and ensuring interdisciplinary collaborations in the project (in comparison to the more 'passive' approach of the Progress and Integration meetings). Having an interdisciplinary practitioner on-site is just one possible approach to facilitating interdisciplinarity. For example, the project could have implemented training sessions from experienced interdisciplinarians, adopted particular toolkits (Buckley et al., 2012) or instituted reflexive exercises for researchers to do together (Eigenbrode et al., 2007). The tool used to reflect on and engage with interdisciplinarity on this project, though, was the ethnographer/researcher of interdisciplinarity.

As the resident interdisciplinary practitioner, my initial presence created the expectation that I would inform the other researchers how to better conduct interdisciplinary working, initiate actions to change existing behaviour, and use my all-knowing position to create connections across different existing workstreams. For example, in an early conversation I had with a postdoctoral researcher on the project, he mentioned that he was disappointed that my role so far had been mostly a 'passive' observer; he had been hoping or expecting that I would feed more insights into the group regarding my assessment of their existing ways of working and suggest what they should do to work together better. By 'better', he meant more interdisciplinarily. In addition, in one of my first supervisory meetings, I was told it would be useful to get my take on how the researchers were functioning and to think about how they could function 'better', and about how the physical (sciences) and social (sciences) could come together in the project.

By creating a research role whose main purpose was to explore interdisciplinary working to ensure that it happened, the project leaders elevated the objective of interdisciplinary cooperation. Senior leadership on the project clearly communicated that they supported my research

and would enquire about my observations with interest. As a result, my presence on the project made participants conscious of their interdisciplinary efforts and acted as a motivator for some. When I first joined the project, a small group of postdoctoral researchers and PhD students assembled to try to model social phenomena such as access to public transport networks in response to hypothetical city policy initiatives and scenarios. The initiator of this working group said to me in passing that since I came, he thought he might start trying to do some interdisciplinarity. My role as the resident ethnographer had the effect of making researchers feel watched; therefore, they felt the need to perform interdisciplinarity to meet perceived expectations by senior leadership, who explicitly created and supported my project.

Another example explicitly refers to my role in anticipation of my arrival on the project:

> I think partly as well, it was we were encouraged because this was just before you started and we were like, oh there is someone coming in to look at us working interdisciplinarily, but where is that happening? So, they are going to be really disappointed, especially because they live in London or wherever, so they're moving here. So, we went, right let's try and encourage some work together. – *Ingmar*

Even before I arrived, my anticipated arrival made Ingmar both reflect both on any existing interdisciplinary work in the project, ("but where is this happening?") and want to perform or do some interdisciplinarity to prevent any "disappointment'"on my part.

Rather than adopt Repko's blind researcher metaphor, I use a Big Brother-style 'diary room' metaphor to illustrate my imagined all-knowing position in the project and the feeling of the researchers being watched by me. In the diary room on Big Brother, viewers of the show

have access to confessions and information that other contestants in the house do not. In addition, the camera in the diary room' reveals how the contestants on the show feel as they watch the other contestants in action.

In some ways, I did occupy an all-knowing position on this project, I attended both formal and small informal meetings, was present in the office where PhD students worked and was encouraged to occasionally work in the office where the postdoctoral researchers were located. I collected data from my supervisory sessions, where explicit reflection on interdisciplinarity took place. There were even discussions at the beginning about my possibly attending other supervisory sessions of my PhD colleagues, in case interdisciplinary seeds started gestating there. I was the only junior researcher allowed to attend project board meetings in case I could pick up on useful information that I could pass on to other colleagues that would enable them to work in a more interdisciplinary manner.

The 'diary room' illustrates the active and simultaneous insider-outsider positions (Eyben, 2009; Humphrey, 2007) I occupied in the project. Like on Big Brother, the 'diary room' is located within the larger house—as I was a researcher within the project. Inside the project, I observed office work and meeting conversations that revealed narratives and working dynamics. Also like on Big Brother, the 'diary room' is external to the project, in that it is an observation of the project itself from an external perspective. Who I related to at that period in time determined my positionality and illustrated its complexity. For example, I was allowed inside access to project board meetings, which was a forbidden space to outside postdoctoral researchers and PhD students. Yet, I was not an active contributor to those meetings as an insider, but remained relatively outside based on my PhD status. Upon exiting those meetings, I reflected on what pieces of information were important to include in the thesis and what information I would leave 'inside' the meeting to maintain ethical integrity and participant confidentiality. This

example illustrates that I not only actively moved along the insider-outsider continuum, but I also occupied multiple places simultaneously, depending on who I was relating to. This unusual reflexive quality of the research project is explored further in the context of a theoretical framework in Chapter Seven. In that Chapter, the relationship between interdisciplinarity and reflexivity is further explored.

The ‘diary room’ metaphor also reflects the panoptic quality of the interdisciplinary researcher. A panoptic view describes the ability to see all parts or elements of a project from the central watchful vantage point of Foucault’s panopticon (1975). It was a panopticon in the sense that researchers felt watched by me in their meetings. More than once, a researcher in a meeting would jokingly turn to me and say “don’t record that!” or ask me “is this what you will write in your thesis?” Perhaps the most telling comments were from a particular researcher, who repeatedly joked with me about my role as the “spy” in the project. He would say things along the lines of “how is the spying going?” or “here comes the spy”. Ultimately, the interdisciplinary researcher was a panopticon in the sense that my role elevated the objective of interdisciplinary working in the project. Researchers were motivated to attempt it and reflect on their own progress of it as senior leadership clearly wanted it to happen and employed someone to ensure that it did.

It was believed that interdisciplinary understanding would come from my research and observations. My disciplinary expertise became interdisciplinarity itself. Since researchers were not necessarily required to have prior interdisciplinary experience as a prerequisite for their positions nor required to attend training of any sort to gain skills to work in an interdisciplinary way, the expertise of interdisciplinarity and how best to approach it fell on me.

4.4.4 Dancefloor – Co-location

A dedicated space for interdisciplinarity is seen as an important aspect for interdisciplinary collaborations; proximity and formal and informal interactions between researchers are seen as important for building mutual understanding and efficiency (Callard et al., 2015; Gaziulusoy et al., 2016; Stokols et al., 2008). Shared physical spaces are needed to increase the efficiency of communication through nonverbal cues and informal interactions that foster a sense of personal trust within a team (Gaziulusoy, et al., 2016). In the literature, conducting an interdisciplinary project within shared physical spaces is always perceived as preferable to conducting interdisciplinarity across disparate geographical space.

The physical space of the shared offices and the Progress and Integration meeting times were the two principal shared spaces where interdisciplinarity was meant to occur. There was a tacit understanding that being in the same shared space would spark connections; clear evidence of this was the suggestion by one of my supervisors to run audio surveillance in the office spaces during work hours. During the methodology development phase of my research project, this idea was explored first with my supervisors and then with the wider group. Capturing hours of daily audio conversations in the office for weeks at a time was thought to provide accurate evidence to trace interdisciplinary collaborations to conversations amongst peers in the everyday office environment. Though not implemented due to the ethical and pragmatic reasons outlined in Chapter Three, the suggestion from senior academics that this type of methodology would be useful reveals the importance placed on co-location and informal conversations in facilitating interdisciplinary working.

In addition to the physical shared space, the large Progress and Integration meetings acted as a space in time when interdisciplinary research was meant to take place. It was assumed that once researchers heard about the progress of other team members, they

would then be able to see and understand how other strands of work could be connected with their own work. On occasion, this format of meetings would change and specific workshops around an issue would take place. For example, a workshop could be centred on a question such as: “What factors do people use in choosing where they will live and settle?” In these breakout sessions, again it was assumed that connections would be realised regarding how different disciplinary strands of work were related. The meetings were meant to provide a space for interdisciplinarity to happen by creating a formal space where team members were required to interact and connect. However, a reflective discussion about how interdisciplinarity itself would be realised in the meetings was not on the agenda. The Principal Investigator assumed that connections would be made in the meetings and then spur integration.

I use the ‘dancefloor’ metaphor to bring to mind a shared physical space where people attend, mingle and interact. Like the ‘walled off’ space that interdisciplinary supervisory teams were meant to create, ‘dancefloor’ spaces were thought to allow information to ‘flow’ between the disciplines. The spaces were important because they removed the traditional ‘barriers’ of different offices and academic buildings, facilitating flow between disciplines. The relationship between interdisciplinary research and information flow is further explored within a theoretical framework in Chapter Seven. For this chapter, the focus is on the building mechanisms that were put in place to create this flow. The ‘dancefloor’ space represents the meeting space and the event of the regular Progress and Integration meetings. Moving from place to place to meet other ‘dancers’, the researchers would find a partner or even a small group to conduct research with. A researcher may not have just one partner the entirety of their time there or even one small dance group; they may try something and then move on to another research priority. Though interactions could be dynamic and impromptu, the underlying idea was that the space of the meetings was always present.

4.4.5 Lego blocks – Models as integration tools

It is important to differentiate inter- and multi-disciplinary research, the latter being assumed a lesser form of integrated research. The more integrated the disciplines are, the more research becomes interdisciplinary rather than multi-disciplinary (Krishnan, 2009; Repko, 2012). Strategies and frameworks have been described and proposed to achieve integration (Repko, 2012; Tobi & Kampen, 2018) or to engage in different types of integration to achieve interdisciplinarity (Krishnan, 2009). In an interdisciplinary collaboration, it is useful to adopt a strategy or toolkit for integration to ensure it happens.

Computer modelling and simulation are seen to play a role in addressing, predicting and solving sustainability issues by incorporating the complexities of real-world issues into modelling programmes and getting projected results of different scenarios. Complex simulation models are seen as cooperation tools amongst different disciplines, as different information from various fields of research is required to accurately capture the real world (Chi, 2000). From this view, modelling is seen as a key integrator of disciplinary knowledge and facilitator of interdisciplinary working.

While the role of Progress and Integration meetings was to allow the researchers to find connections in the research, the particular strategy developed to 'synthesise' the connections and integrate the research findings was the project's conceptual and computational modelling theme Modelling and Optimisation. In the project, integration was recognised as a key indicator of interdisciplinarity. Discussions in the Progress and Integration meetings reflected the understanding that integration would happen within this theme:

> Pete: Carter quite rightly pointed out that really there's a spectrum, so it's neither one nor the other, but our goal is perhaps, by breaking this problem up into its component parts to end up

> with a properly integrated understanding. Does anybody else have any views on that?
>
> Bruce: So, breaking it down means being analytic and then synthesising again?
>
> Pete: Possibly.
>
> Bruce: Well, that's the current design, right? That's how we have visualised it and there is this integration being done by one [Modelling and Optimisation] theme.

Here Bruce outlined the "design" of the research project and how and where the integration was thought to take place. Also, Pete predicted that at the "end" a "properly integrated understanding" would develop. So, not only would modelling be the site and tool for integration, but an 'integrated' understanding of the problem would result, which would reflect the desired outcome of an interdisciplinary project.

In this quote, the directional references to "breaking it down" and "breaking this […] up into […] parts" also speak to the disciplinary prerequisite in the building of interdisciplinarity. The strategy for interdisciplinarity here meant separating the work and analysis into its composite disciplinary parts to be "synthesised" and "integrated" using modelling. The "analytic" work would be done by the respective disciplinary experts on the project before being brought together again.

As outlined by Figure 4-1 above, modelling was considered an important, even foundational, aspect of the project. The Principal Investigator considered this to be one of the main tools that would act as an integration point and tie the disciplines together in the end, therefore achieving interdisciplinarity. The main strategy for interdisciplinarity integration was to combine knowledge into a model that would both be the tool of integration and the result of the integration itself. This would not be a single model; rather, many models would

simulate heating and energy in buildings, optimise public transport routes and predict and simulate population choice in urban areas, to name a few. The model(s) would then also act as an output or evidence of integration and therefore of interdisciplinarity itself.

When asked to describe the project to a hypothetical person, researchers in their brief description often brought modelling to the forefront and indicated that it would be the site for integration:

> Probably a kind of, it's a difficult one, (pause) modelling? Probably, that is the broadest possible thing you can put it in. I know just mentioning the modelling is just referring to the non-social science things and the social science things are, it's kind of split between those two things. I would still consider all of those things to be a part of urban modelling, urban studies. Don't have a better synonym for those things, experiments? – *Richard*

When asked how he would describe the project as a whole, Richard described it as a "modelling" project. After acknowledging the divide between the natural and social sciences, Richard still considered the social science contribution, ultimately, to feed into urban modelling.

In another interview, a researcher described the perceived frustration of another researcher when trying to understand how interdisciplinary integration would happen in the project:

> So, I feel that [frustration], or I hear grunts and noises, and the way he [Pete] breathes. So, it's like, probably in my, what he—he thinks it's standard faults with an outcome, where you resolve these issues, it will be done through modelling, if you don't fulfil that, we have failed,

> and we haven't done interdisciplinary work. –
> *Bruce*

These quotes illustrate that though modelling was part of the natural science area of the project, social science was still considered part of urban modelling. In addition, any "issues" in the project would be "resolved" through the modelling, and this tool would be the avenue for interdisciplinary work. In the last quote, Bruce described the frustration he could sense from Pete, a natural scientist, because of Pete's desire to resolve issues through modelling to demonstrate interdisciplinary work. The emotional aspect of the desire to achieve interdisciplinarity is clear to Bruce in this quote. The role of modelling in achieving interdisciplinarity is also clear in this quote.

Though other interdisciplinary projects and collaborations of a different nature were welcomed, the priority was to use the Social and Cultural, Economic and Policy and Governance themes to feed into the sustainability models in the form of knowledge and/or data. The assumption was that this information would make the models a closer representation of the real cities of Nottingham and Shanghai, as well as create more accurate models of hypothetical cities as well. Researchers from these themes were expected to contribute to the models in this fashion, but not necessarily contribute to the building of the model or choose which type of model to use. Rather, the thinking was that based on their expertise, they would contribute to the choice of criteria included in the model or provide input on the kind of phenomena most useful or relevant to the model.

However, predictive modelling of the environment and sustainability scenarios come under criticism for their inability to adequately include and account for human factors in their mapping. Current models that guide policy and explore future sustainability scenarios include limited metrics of human factors, such as population data estimates (Motesharrei et al., 2016). As a result, these current models cannot account for realistic feedback dynamics, particularly irrational,

unpredictable or unintended outcomes that characterise real-world dynamics (Motesharrei et al., 2016). Although many social scientists in the group echoed these criticisms, I include modelling as a building block for interdisciplinarity because the construction of the project assumed that modelling would be the project's key integrating mechanism. Perceptions of its adequacy and efficacy are explored in later chapters; for the purposes of the interdisciplinary building, modelling is considered the 'Lego blocks' of the project.

I use 'Lego blocks' as the metaphor for integration to describe social simulation and modelling. It implies that different disciplines have a piece to contribute to the larger building structure. It also illustrates that participating in this project would create an output or a complete model (both the metaphorical 'toy' model and the actual predictive model), which would act as evidence of the integration and construction that took place. These 'Lego blocks' represent the modelling aspect of the project, where the integration of different disciplinary research was meant to create a working model or picture that would represent and predict the behaviour of a modern urban environment.

An example illustrates the dynamics between the natural scientists and the social scientists around modelling. Eric, a social modeller, called a meeting with Stella, a social science researcher. In this meeting, Eric asked Stella if she had some 'social sustainability' indicators to outline to him as the most important to prioritise and add to his model. From her perspective, it was clear that he had misunderstood her work, as she was "not working towards an indicator approach". She also said that choosing "the most important" indicators was a very normative statement, that a ranking of indicators would never be universal, and that in the social sciences they did not approach the world in this way. Finally, at the end of the meeting, she questioned the integrative nature of the modelling approach because of its positivist roots, and said that, from her perspective, just giving data as a 'service' to the natural

scientists to help do their work was not sufficiently integrative or interdisciplinary working.

This perception of the role of the social science themes seemed to be clear among the social science researchers:

> I think that is the difference between the physical sciences and the social sciences that we haven't overcome, they've [the modellers on the project] interpreted that's how we do our work. [That] we are just a repository of economics data, social data, so we can't integrate because we don't work like that it is not what we are doing. - *Ingmar*

> And my contribution to that is a social science contribution, and there are other colleagues within social science who also make a contribution. But at the moment how that contribution sort of contributes to the core of the project is currently yet undefined. So, I think that is a challenge. – *Elisa*

This interpretation of how the modellers perceived and understood the role of the social scientists on the project enforced an understanding that modelling would be the principal integration method of the disciplines and that this was the point at which interdisciplinarity would occur. When Elisa stated that "how that contribution sort of contributes to the core of the project is currently yet undefined", it reveals that another mode of integrating the disciplines had not been explored or thought through by the other researchers. Without the modelling and everyone working in the same positivist manner, integration would not be able to happen. Also, in Elisa and Richard's quotes, they considered the core of the project to be the modelling aspect of the research, with other disciplinary knowledges contributing to it or on the periphery. Integration made sense mostly from the modelling and natural science

perspective. Researchers in the social sciences struggled to see not only how they could contribute integrative pieces to the model but also how integration would take place overall. Even if the researchers on the project did not agree on the tools or strategy for integration, all agreed that there needed to be some plan for integration to ensure interdisciplinarity would happen.

Ingmar's statement that "we can't integrate because we don't work like that" initially reads that integration was unable to happen because the ways sociologists and economists conduct their work are fundamentally different from the ways that modellers do. However, sociology and economics do conduct work by selecting key indicators to understand a larger phenomenon at more basic levels. For example, economic indicators of sustainability are used to 'rank' sustainability of a spatial area over time (Lai & Leung, 2004), and social sustainability indicators can be used to determine the societal risk of manufacturing processes (Husgafvel et al., 2014). To further unpack this statement, it is actually more a position of resistance to the modellers on the project as there was a risk of being perceived as being of 'service' to another discipline. As mentioned previously, this disciplinary rift between the social and natural sciences was understood from the beginning in the split arrangement of the Progress and Integration meetings. It was then reinforced through the modelling aspect of the project, where social scientists were unable to understand how they could contribute and resisted the risk of becoming of service to it.

This resistance by the social science researchers on the project hints not only at the disciplinary divide between the natural and social sciences but also the disciplinary hierarchy that was perceived to exist. This speaks to the wide perception that, within the sciences, natural sciences sit at the top of the disciplinary hierarchy, above social sciences, due to their perceived higher level of consensus and speed of advancement (Cole, 1983). In interdisciplinary research projects that include both natural and social scientists, these is often a perceived

danger of the social sciences becoming of service to the positivist framing and work of the natural sciences (Ribes, 2019). In this project, the Principal Investigator had a background in physics and drafted the project proposal with a clear focus on predictive modelling methods. These factors implied to the social scientists on the project that their work existed within a wider positivist research framework and would therefore have to work within this to participate in the research project.

4.5 Conclusion

This chapter has outlined the construction of the interdisciplinary project and the rationale for why specific aspects of the project were set up the way they were. By having a single location for the integration of researchers and a primary integration tool, interdisciplinarity was expected to gestate in this environment. The metaphors in this chapter serve to illustrate and represent the ways in which researchers on the project tried to construct a research project that would lend itself to interdisciplinary working and what role each part of the building played in interdisciplinarity.

Conducting a research project on urban sustainability is important and relevant. However, it was almost just as important to the project leaders that the research conclusions were reached specifically by interdisciplinary means. Though not explicitly defined or listed in the project aims as a goal, conducting the work in what was perceived as a truly integrated and therefore interdisciplinary way became an objective in and of itself. The importance of the interdisciplinary element was communicated by the funder, the senior academics on the project in their funding application, and the establishment of my own role as the resident interdisciplinary researcher. This importance resulted from the narrative that interdisciplinarity is an innovative way to conduct original research, even a necessary approach for complex problems and issues such as urban sustainability. Because of this perceived importance and value inherent in interdisciplinary research, the project was constructed in a specifically interdisciplinary way to ensure that interdisciplinary

integration would happen and project outputs would themselves embody interdisciplinarity.

By labelling the project in the title “interdisciplinary” and assigning an interdisciplinary researcher to “improve researcher ways of working”, the project leaders made researchers on the project more aware of the desire to work and be seen as working in an interdisciplinary way. My presence contributed to others reflecting more on their work and personally questioning whether they were doing enough collaboration with others on the project and doing interdisciplinarity.

To summarise, the building blocks constructing the interdisciplinary project were considered the main facilitator of interdisciplinary working. By bringing disciplinary experts together in shared office and meeting spaces, it was assumed that interdisciplinary connections would be sparked. In addition, by appointing a specialist in interdisciplinary working, it was thought that previously unseen potential connections would be seen by this practitioner and communicated to the rest of the team. Finally, a strategy for integration (modelling) was inserted as the main tool to ‘integrate’ the knowledge. This particular strategy of modelling would also serve as the evidence or output of interdisciplinary collaboration.

While this chapter outlines the beginning and the construction of the research project in the expectation that interdisciplinarity would take place, Chapter Five describes events and happenings whilst the project was underway. In Chapter Five, the attempt to conduct an interdisciplinary research project within a university environment is described in detail.

Chapter 5: Finding balance inside the interdisciplinary ‘building’

5.1 Introduction

This chapter engages with the structure of the metaphorical interdisciplinary building by opening the door and watching what happens inside. It addresses the research question: ‘How was interdisciplinarity experienced by researchers on the project?’

In observing and participating in interdisciplinary collaborative working, I noted three main themes that occupied the researchers: the time commitment, PhD priorities, and challenges around publishing within a university environment. Time and how the relationship with time in an interdisciplinary project is perceived as different from a single-disciplinary project were two concepts the researchers were constantly aware of during the lifetime of the project. The chapter then focuses on PhD students and their different commitments, including contributions both to the project and to their disciplines in the form of a PhD. I describe the publishing practices that took place within the project, a significant factor to highlight as publishing is a key indicator of completion and success in academia. Given this thesis’s focus on the structural aspects of building an interdisciplinary project in a university environment, focusing on the academic publishing challenges and norms helps to further understand the power of these structural influences.

To contextualise these three themes, I narrate a critical incident (Bradley, 1992) in which three PhD students from the natural and social sciences tried to co-author a paper. The Critical Incident Method is a flexible qualitative research approach that captures perspectives and data surrounding a specific positive or negative consequential event in research projects (Bradley, 1992; Edvardsson & Roos, 2001; FitzGerald et al., 2008; Simmons, 2018). This narrative is highlighted because of

the amount of focus dedicated to addressing this ‘issue’, the concern expressed by senior academics around this paper and the length of time it featured in the project.

5.2 Interdisciplinary balance, disciplinary choice

5.2.1 Time

From the beginning of the project, there was an acknowledgement that it would be necessary to take the time to understand what other researchers did and how that contributed to the wider project, even if it might not be directly related to one’s own work. For example, when new researchers joined the project, hours were taken to meet with them either in small groups or individually to explore their research interests, what they imagined their role in the project to be, and how their own research could fit in. At the very start of the project, regular meetings happened between three PhD students to compare their literature reviews from their respective disciplines to reach a clear understanding of sustainability. This quote from a senior academic on the project explained how much of this ‘extra’ work was necessary for an interdisciplinary research project:

> It’s also an expectation of an interdisciplinary project, right, that some of the time you are going to be dedicating to activities that are beyond your strict remit, I mean that’s the nature of the beast.
> – *Pete*

This quote referred to the work that a new researcher, Tabitha, would have to undertake as a consequence of being on an interdisciplinary project. This is in the context of Tabitha using her resources and talents to collaborate with others on the research project in addition to what she considered her own work within her own remit.

Though the necessity of taking time to speak and try to understand one another was understood and welcomed at the beginning of the project, there was still the perception that interdisciplinarity was slow to the start. PhDs and postdoctoral researchers commented that “progress had been slow” on the interdisciplinary collaboration front, indicating that they expected it to start sooner. Although there was an acknowledgement that this could have been expected, there remained a clear frustration about how long it took to get things going and how much further along they expected to be:

> So, it’s getting very late, and things are very much delayed already, and that caused a problem that all the interesting things that I’m interested in, I was promised actually, might be crossed out. Like Shanghai crossed out.
>
> […]
>
> So, it’s going mainly into their direction, which was meant to be the foundation. But if you are in the third year of the project which runs for four years, and still working on the foundation, it’s not so satisfying for the others. - *Genghis*

The perception of the amount of time that was spent developing interdisciplinary pieces of work was particularly frustrating for this researcher because it took time away from other more “interesting” aspects of research; other parts of the project were sacrificed or taken away in the interest of producing something within the project’s time limits. Time here was seen as a limited resource and a zero-sum game. This quote also illustrates Genghis’s *personal motivation* and desire to do more “interesting” interdisciplinary work, but the “promise” would not be fulfilled because too much time had passed.

Some researchers thought that more time should be given at the start of the project so that one did not 'run out' and could gain the necessary background to work on interdisciplinary collaborations:

> Again, it is a problem of resource, because even though the project calls itself interdisciplinary it hasn't been resourced in that way. […] it requires extra effort which hasn't been costed in so therefore the collaboration opportunities aren't actually massively encouraged or perhaps not realistic to people because they have to deliver that thing there are doing and to do something else to expand it in that direction, which would be to bring in social science thinking or for me to bring in my work and to bring in some other thinking is extra work that is not costed in. – *Elisa*

> No, but I believe that we could achieve a lot in six months if we all had the time off and just worked together, we can achieve much; because we have all these ideas, but we don't have time to link them. And it's difficult to explain your ideas to a research fellow and a research fellow works for two or three people and then you have to try to organise to get one thing finished. – *Genghis*

To conduct the interdisciplinary aspects of the project and do them justice, more time 'resource' should have been costed into the project, which was not the case here. In addition, ideas were generated, but additional time was needed to organise them to finish something. This extra time did not exist for the project and was seen as preventing interdisciplinary collaborations.

As the project continued, taking the time necessary to understand the role of all of the disciplinary experts on the project became less feasible

for the researchers, and a feeling of urgency developed; they felt the need to get on with their work. Completely knowing or understanding everyone's role became less necessary:

> I think as the project has gone on, I've personally found it harder to maintain that dialogue, as the pressure to actually deliver research has increased, we've kind of kept more of a dialogue going with the social science more broadly, but hours of engagement with the physical sciences less than it was at the start. – *Isolde*

The dialogue that Isolde highlighted was between the social and the physical sciences, pointing again to the perceived disciplinary divide between these two approaches to research. Engaging in a dialogue with researchers that speak a similar language is much less effort than engaging with researchers from a different school of thought. The quote also illustrates how her personal motivation to engage in that dialogue at the start of the project waned due to time pressures.

The time spent trying to explain one's own research to others was perceived as an important aspect of the project, especially at the beginning. However, as the project continued, researchers prioritised work they thought would produce outputs rather than spending time discussing with each other and reaching mutual understanding. It was no longer considered time well spent.

Time spent in Progress and Integration meetings was considered a big commitment with little return, especially towards the end of the project. As mentioned in Chapter Four, these meetings were initially imagined to be a shared productive place where researchers would come together and make fruitful connections between their respective strands of research. However, as the project went on, some researchers began to almost dread these meetings, and jokes were made about how they could get out of them or how they wished the meetings would be much

shorter because they tended to be boring. Perceptions of the meetings changed from useful for integrating work to time taken away from more productive endeavours.

As described in Chapter Four, the first part of the meeting usually started with researchers from three of the six themes updating others about their research progress and work. As the project went on, other researchers that were not related to the strand of work being discussed made fewer efforts to understand and interpret what the other researchers were thinking about. Once researchers felt that there would never be enough time in the project to fully understand how other parts worked, they stopped enjoying spending time in the room drywalled off for interdisciplinarity, and felt their time was not being utilised well:

> And the other thing that was, still is, my least favourite bit is that when there are lots of long technical conversations, you have to listen to that and can't contribute to it. That is also time consuming. And time is limited; that is my least favourite [activity] at the minute. – *Elisa*

> It's interesting but also a little bit frustrating. Sometimes we would get stuck on a word, and then spend 30–40 minutes either physical scientists talking about a modelling word that just went straight over my head but was clearly very important to them and vice versa. – *Isolde*

Rather than engaging with and trying to understand the technical language or why researchers would get "stuck on a word", such efforts were seen as a burden and time not well spent.

During these meetings, I observed the body language and attention given by the academics in the room. Many of them brought in their laptops to look through emails, continue computational coding or write up some of their work. Their full attention was not given to the updates,

but rather, they seemed to try to use this time in meetings for their own work. Making the effort to attend long meetings and ask other researchers to constantly stop and explain their terminology took substantial time and intellectual investments without enough reward in the form of an actual understanding or a clear output from such engagements. Initially developed as a productive space to make connections, Progress and Integration meetings were not perceived as time well spent; therefore, negative feelings became associated with its required attendance. The personal motivation to do interdisciplinary work waned when the effort to actually engage with another discipline became too burdensome on participants' own research priorities.

Time spent on the project became viewed as a massive investment and a scarce resource. For example, there was the perception that time was wasted if efforts to work together on a project did not result in an output such as a published paper. This output was a key indicator that work, and specifically *interdisciplinary* work, happened. If nothing resulted from discussions, meetings or collaborations, they were not seen as time well spent.

> […] like if you don't get something done, it can lead to a lot of time discussing things that don't get achieved. It's not frustrating at the time because your brain is engaged in entertaining this idea that you want to explore but then time goes on and then nothing happens and you've kind of left it by the wayside and you look back three months later, and think, we spent all that time – even if it's just an hour or something like that- about something that could be done, it is kind of time wasted in effect. – *Sandy*

Here, Sandy outlined the expectation that engaging in a discussion with another researcher would lead to something getting done or an output that would have made that time worthwhile. In the academic context,

researchers repeatedly considered this “something” to be a published paper of some kind, as this was the clear priority in the university environment in which they worked.

As outlined above, the literature makes clear that more time is needed for an interdisciplinary project to be more effective or successful. This was also reflected in this project. However, to go a step further, researchers on the project also struggled to find a good time to collaborate and ‘do’ interdisciplinarity. As mentioned in Chapter Four, researchers waited for the right disciplinary expertise to board the project so that interdisciplinarity could begin. However, in practice, it did not automatically come together when all of the expertise was recruited. Researchers also waited to ‘get up to speed’ on the project and had meetings with individuals or small groups to understand what work had already occurred and make sense of what they would be doing. They built on what previous disciplinary knowledge they knew using the methods and literature they were familiar with to prepare to collaborate on the project. For example, in an early meeting between a computer scientist who had just joined the project and a physicist who had been working on the project for two years already, they discussed some similar research interests and what types of conceptual modelling they planned to use for their own research contributions. At the end of the meeting, they decided to go away and develop a bit more their own thinking and approaches; it was perceived that it was ‘too soon’ to collaborate just yet, they needed to sort out their own thinking first.

Simultaneously, researchers advocated for collaborating from the start so that interdisciplinary integration would be more legitimate and embedded in the research. The rationale was that once one had gone ‘so far’ in one’s own thinking and work, one would be unable to adjust a research approach to fit with another researcher. For example, a computer scientist on the project wanted to build a conceptual model on social sustainability. He initiated a meeting with Stella, a social scientist on the project. His idea was to develop a social model using system

dynamics to understand how some aspects of social behaviour would affect the sustainability of an urban environment. From his perspective, he needed the ‘expertise’ of a social scientist to outline and prioritise the most important indicators of sustainability from a social perspective to include within the model’s parameters, as it would be impossible to include every aspect of social life within the model. Bringing her expertise and work into the model would also tick the box of an interdisciplinary collaboration from his perspective.

For her, it would be a mountainous task to conduct the research required in order to feel confident about recommending the social and behavioural aspects to include in his model. In her opinion, it would take up too much time and she would not be able to finish the task quickly enough for him to be able to use her indicators in the model. More importantly, this task did not correlate well with her existing work, so it would have been *in addition* to the workstream she had already embarked on. Therefore, in her case, interdisciplinarity could not happen because it was *too late*; she was already too far along in her own work.

Researchers not only perceived interdisciplinary projects to be more time consuming, particularly at the start of the collaboration; it was also difficult for them to navigate when interdisciplinarity should happen. Many confirmed that they thought it should be embedded throughout the lifetime of the project to be considered a ‘real’ interdisciplinary collaboration. Yet, there were times when they did not feel they could do interdisciplinarity because it was too soon, either because the right expertise was not present or because they needed to understand their own research first. However, this line between being too soon for interdisciplinarity was very thin before it crossed over into being too late for interdisciplinarity because researchers had already embarked on a research path in their work.

To unpick this further, a clear right or wrong time for interdisciplinarity to happen does not exist. For anyone to prescribe or determine when

interdisciplinarity starts is too deterministic and goes against the lateral dynamic of an interdisciplinary collaboration. The argument that it was not the right time for interdisciplinarity here reads more as ‘I do not have time for interdisciplinarity’. The time they put into their own research had already been invested, and they did not feel they could adjust or go back to change it. Time for collaborations was an additional investment they could not, or would not, give. The statement reads more as a legitimation for not wanting to invest the extra time rather than an actual assessment on correct interdisciplinary timing. The perceived limited amount of time in the interdisciplinary project pushed researchers to choose between getting on with their work or, as a separate objective, engaging in interdisciplinary working.

The difficulty in navigating a time for interdisciplinarity was not surprising given the uncertainty and diversity in defining interdisciplinarity within the research group, as established in Chapter Four. Without a clear understanding or objective of what interdisciplinarity would look like, navigating the task of determining when to conduct interdisciplinary work with another researcher became more difficult. In addition, under the tacit understanding that connections were made in shared spaces and meetings, researchers were waiting for an ‘Aha’ moment or the right time for interdisciplinarity that might never arrive.

5.2.2 Balancing the PhD with project commitments

Another difficult aspect to navigate was the balance between spending time working on an individual academic project stream and contributing to the wider interdisciplinary project. As demonstrated in the analysis of ‘time’, this became two separate objectives for many of the researchers. One situation that highlighted this split in priority was the work of the PhD students on the project. While other researchers desired to have outputs such as published work or conference papers, the students needed to complete a PhD, the ultimate goal that motivated many of them to join the project in the first place.

Though appearing very little in the literature, the challenge of conducting interdisciplinary work at the PhD level has been outlined by Balaban (2018) and Graybill et al. (2006) in their studies of PhD students in specialised interdisciplinary training programmes. Though the programmes studied prioritised training and knowledge from different areas for the fellows, those interviewed for the study expressed the challenges of trying to incorporate all fields of knowledge into their PhD and the burdensome feeling of trying to create their own structure within such a diverse environment (Balaban, 2018). PhD students also struggled to find an intellectual or scholarly 'home' to identify with and subscribe to (Graybill et al., 2006). At this very junior level, interdisciplinarity is difficult to navigate due to the lack of an established intellectual foundation to draw from and the extra insecurity this entails.

As described in Chapter Four, the PhD students on the sustainability project were each associated with a School at the university with administrative requirements that needed to be fulfilled to be awarded the qualification. This aspect often did not align with the interdisciplinarity demands of the project. To be awarded a PhD, students needed to ensure that they were receiving the right intellectual input to be well-versed in their own disciplines. This was enforced in the annual review meetings held at their School. Academics from the School analysed a piece of the student's work in the meetings and assessed if the student had progressed satisfactorily. Recommendations were also made to ensure that students kept on the right track to completion.

During my first year on the project, I spoke with a PhD student in Sociology about her first-year review. A recommendation was made that she spend more time at her allocated office space in the School of Sociology as it was deemed more intellectual exposure to approved sociological theories and methods of research would benefit her journey and work. This meant more time in Sociology but less time in the

shared office space where interdisciplinarity interactions would take place. Getting the PhD was the priority, so she obliged.

My own experience of my first-year review brought up a similar theme. My submitted written work was deemed untraditional in that I described the process of how I came to be on the project, that it was deliberately an interdisciplinary project and that my previous background met the requirements of the studentship advertised for my position. I did not initially pass the review because my report structure did not comply with the expectations of the department. I was given three months to amend my written work to better align with how a ‘sociology PhD’ was structured and what it should look like as per my feedback. Once I submitted my amendments, my pass mark was awarded and I was confirmed as a PhD student and able to move on to the next phase.

After a PhD annual review meeting, a computer science student sent me his reflections via email unprompted, as the issue of being on an interdisciplinary research project had featured in his concerns:

> Being a member of an interdisciplinary team has provided both challenges and significant benefits. Being able to draw on the perspective and expertise of a broad range of areas has enriched my understanding of the target domain, as well as the standard tools used for research in these domains. Interdisciplinarity has however provided some challenges, as often the requirements of the project will not align neatly with the requirements for a computer science PhD. Project objectives are likely to focus more on results of a simulation than the simulation method or development process, with some pressure to conform to and apply standard methods used in the domain rather than building on or replacing them with new tools. Similarly, the requirements of the School of

> Computer Science can often seem both strict and poorly defined. Phrases such as 'interdisciplinary ravine' are uttered as warning, requiring constant vigilance and objective realignment. The incentive structure of the PhD requirements have led to my erring on the side of my home School while still attempting to satisfy research group objectives where they come up. – *Hanson*

Here Hanson discussed his attempt to find a balance between two mostly competing issues of work: to contribute to the project that would provide results for the researchers to use or to do something that was considered a new intellectual contribution according to the standards of the School of Computer Science. In balancing these two seemingly competing ways of working, he said he was “erring on the side” of his home School, tipping the balance of work towards his goal of being awarded a PhD. Further analysis of academic peer review and evaluation is given in Chapter Seven. For this section, the important point to highlight is that the incentive structures for interdisciplinary contribution and the disciplinary PhD are different and separate.

In an interview with the same PhD student, he further discussed the “split” between his PhD work and research contribution to project work:

> It’s on my mind all the time that basically the things I’m currently doing are not acceptable to the rest of the group. I wouldn’t say I’m wasting my time, but it’s like I almost have these two – I’ve got the group projects here that I need to do, because [...] that’s what’s going on. And then also I’ve got my School and department who don’t really care about that, they just care about like, “You’ve got to do a computer science PhD.”

> And so, it feels like I'm either working for one or the other at any given moment. […] And so, there is a certain conflict of interest between the two at that point that I'm always acutely aware of, because I both want to contribute to the project, and I want my PhD at the end. So, I've got those conflicting issues. – *Hanson*

In the previously discussed email, he addressed the challenges of being able to simultaneously meet the requirements of his School and the project. In this interview extract, he explicitly discussed the two objectives as "conflicting". This direct conflict implied that there must be a choice between one goal and the other, rather than imagining an ability to meet both.

The balance the PhD students had to navigate was such an issue that other research fellows on the project also recognised it:

> I think the PhDs are really in an interesting dilemma on this project. […] you'll see from that the PhD UK economic theme is meant to be closely aligned with the modelling. And then obviously we appointed [Ingmar] because we really liked him and then he did his work and said he wanted to research the sharing economy, so 'yea-totally', so we spent six months protecting him in a way-, I remember thinking-, we would have these project meetings and it was always about protecting him from the PI basically, because [the PI] understandably wants-, […] that it has to fit in the project, and that is understandable, but you have to protect your PhD, your thesis. Because you got to defend that and [the PI] knows this balance but it doesn't stop it being an issue and I remember thinking that […]

> […]
>
> […] you've got to protect your PhD and defend it in your School as a geographer, or a sociologist, whilst still contributing. I think the PhDs have it quite tough really. – *Tristan*

Though not a PhD student, Tristan recognised the unique "dilemma" experienced by PhD students on the project and equally framed 1) contributing to the project and 2) conducting legitimate PhD work as two separate objectives that required 'balancing'. He also prioritised the PhD thesis, as he expressed his efforts and desire to 'protect' that work from project commitments.

This dilemma was not experienced by all within the group. Some PhD students had work that directly contributed to the project; for example, a computer scientist contributed to finding out how to use cloud computing to help spread the computing time and cost needed to run modelling simulations. This new development in computing work directly contributed to the project and fulfilled the requirements of his PhD. However, it is worth nothing that he did not consider his work to be particularly interdisciplinary. He was contributing on a computer science front with other modellers and developers in the project.

Interestingly, though the project required PhD students to have an interdisciplinary supervisory team to facilitate interdisciplinarity in the form of 'dry-walling' to create space for it, this did little to actually create an interdisciplinary thesis. At best, receiving feedback from a supervisor from a different discipline forced the student to think through a strong argument for their disciplinary approach, a useful skill for their research career. At worst, it was received as irrelevant feedback because the supervisor that was not in their discipline did not understand their work in the first place, so the students felt they could ignore it. Rather than integrating different knowledge forms, it actually functioned to further strengthen the 'column' of the discipline. From the supervisor's

perspective, supervising a student from a different discipline was described as interesting and engaging, but it never functioned to change existing ways of thinking. In addition, although a 'dancefloor' in the form of Progress and Integration meetings was also meant to create a space for interdisciplinarity, some PhD students were protected from having to engage in the wider interdisciplinary objectives of the project in order to focus on their own disciplinary endeavours, as outlined in Tristan's quote. The space alone did not ensure that interdisciplinary collaborations happened. Overall, the 'building' mechanisms in place to create an interdisciplinary project were not enough to ensure interdisciplinary integration.

In short, trying to conduct interdisciplinary research or contribute to the project in an interdisciplinary way became an extra time commitment on the project, particularly for PhD students whose first priority was being awarded their PhD qualification. Rather than being an integral part of many peoples' work, it became an add-on or an extra commitment to be done after one's own primary research priorities were addressed or fulfilled. In these dilemmas of trying to balance these two commitments, researchers discussed how they attempted to discern how to do both, yet what started to happen was that their balance was actually a choice—they needed to *choose* which commitment they would fulfil according to their priorities and interests. Given the original incentive to be awarded a PhD, the 'choice' was to contribute to their disciplinary fields.

5.2.3 Publishing in academia

For PhD students, their clear priority was to be awarded a PhD. For other academics on the project, particularly more junior postdoctoral researchers trying to establish their careers, the key incentive for work was the 'output' it generated. Published work is important to establish a research career, and journal articles are ranked according to quality by

academic peers. Quantity of authored papers is highly correlated with increased chances of becoming a Principal Investigator on a project (van Dijk et al., 2014). Publishing in a high-ranking journal is important to establish an academic career, and such journals tend to be disciplinary-oriented (Rafols et al., 2012) as the impact factor of interdisciplinary journals is usually small (McLeish & Strang, 2016). In addition, the strongly disciplinary-oriented Research Excellence Framework further reifies publishing norms along disciplinary lines (Cooper, 2012; REF, 2021). On these grounds, there is little incentive to collaborate with someone else outside of one's discipline.

Clear tensions arise here. On the one hand, it is clear that initiating interdisciplinary interactions with others increases chances of receiving funding from funding bodies. Demonstrating the ability to win funds is a key indicator for success in the academic environment. On the other hand, there is also the narrative that interdisciplinary research presents a difficultly for academic careers. For example, working on an interdisciplinary research project can take much more time to reach the stage where published work is produced, meaning that there is the chance of fewer outputs at the end of the project, which is not considered ideal in an academic career.

In interviews I conducted with researchers on the project, they also expressed the tendency, importance and desire to publish individually as a researcher in their recognised area of expertise.

> I think that is the case with any research project. Because the academics and the people who work on a project, they always have to be measured by publications and the nature of publishing is you don't publish a wholesale picture of the whole thing. It is never complete, so you always have to publish on small aspects of things. It is always a balancing act, doing individual papers and forming an overall picture. – *Sebastian*

> I probably think the pull back into your own discipline, particularly around the publishing side of things. The-, because you belong to in a School of whatever, do you feel you should then be publishing in that recognised arena? So, perhaps some people would be quite sensitive to that. – *Tristan*

In addition to the recognition that a researcher gets from writing something in their research field, there is also the comfort that researchers feel when writing about something and submitting it to a familiar journal that they recognise. This is even clearly indicated by the term ‘home discipline’ used by participants in the project. Returning to a previous quote from Hanson, a computer science student: “The incentive structure of the PhD requirements have led to my erring on the side of my home School while still attempting to satisfy research group objectives where they come up.”

His home discipline was the place where he belonged, and it seemed like where he would stay in the future. To be awarded a PhD would ensure that, if he so chose, he would be able to have a career in that home discipline.

In a Progress and Integration meeting, a research fellow discussed the potential to be named on an academic paper as a result of a collaboration she had done with some natural scientists on the project. She expressed her uncertainty with understanding all of the aspects of the paper and wanted further explanation and assurance before she felt comfortable enough to put her name on the paper as a contributor.

> Elisa: […] but to go back to the simulation question or what may be in this project, it may be an output of collaborative work from this project which may be a combination of […] modelling, with some social science on fuel poverty and

> population characteristics. There are some core tensions around assumptions, around scientific method. […] Not that this is something that we can't overcome, but the ultimate problem for me is credibility. So, I could spend several afternoons in a workshop with colleagues here, come up with very imaginative solutions to these problems but I don't want to lack credibility when it goes out to-, because I haven't got the expertise to scrutinise it, this sort of creativity that I am talking about. I could see that this can be done, but I would need assurances that this type of exercise is one that is accepted and not-
>
> Hanson: Accepted by who?
>
> [Laughter]
>
> Elisa: Exactly, well, this is it, this is the real problem -
>
> Genghis: The social simulation community has not got any problems with this type of method
>
> Elisa: Okay well maybe this is the outlet for this paper then
>
> Hanson: I was going to say that Genghis and I are probably a lot more comfortable with these notions than other disciplines would be
>
> Elisa: Exactly, this is the core tension, this is the core insight from working in something like-, but these are the anxieties that people like me and Henry have […]

As a social scientist, she feared that any assumptions or ethical practices used to create the paper would come back to her, as those

concepts in the social sciences might be contested, and her reputation in her field could be challenged. She was highlighting that what may be acceptable assumptions or practices used by natural scientists would be held to a different standard and/or not acceptable in her own discipline. As noted by Hanson, he was more “comfortable” with the modelling used in the paper, while Elisa and Henry experienced more “anxieties” around this method.

They also used terms such as “social simulation community”, and “people like me”, and “other disciplines”, which further illustrates where the perceived disciplinary divisions occurred in the project. Elisa explicitly recognised that there is not just one way to research an issue but that different methods are considered credible to different disciplinary communities, largely between the natural and social sciences. This ‘us and them’ sentiment highlights the strength of the ‘columns’ present in the project. The disciplinary experts came to the table not only with their relevant expertise but also their disciplinary cultures and customs.

Negotiating co-authorship across disciplines did not occur very often in the project, as many researchers prioritised publishing in their fields and establishing their reputations in their disciplines. However, when some researchers did collaborate on published work, tensions arose around fair credit and recognition of efforts. This is another example of how a perceived balance between two objectives (collaborating on published work and being adequately recognised for contribution) required a choice from disciplinary experts. The narrative below focuses on these tensions.

5.3 Critical incident – the ‘Three Pillar Paper’

As discussed in the previous section, researchers started to feel the pressure and frustrations of keeping the balance between interdisciplinary commitments and producing disciplinary outputs, and eventually many reached a point where they needed to choose between

competing interests rather than attempting to balance both. Limited time and competition between interdisciplinary project commitments and disciplinary contributions made this balance difficult to maintain.

This section follows a single critical incident that developed over three years. I include it here as it illustrates the intersection of the three outlined themes in this chapter: the long length of time and subsequent difficulty to maintain momentum on interdisciplinary collaborations; tensions between PhD qualification commitments and contributions to the wider project; and the different publishing cultures and practices within different disciplines. This incident is the Three Pillar Paper.

The Three Pillar Paper started when three PhD students from both the natural and social sciences started to meet informally to discuss their literature reviews, which were required for their first-year review meetings. The title, ‘Three Pillars’, derived from the Three Pillars of sustainability: economic, environmental/ecological and social. Overall, the project took this theoretical framework as a given, and the project themes had been organised with this framework in mind.

In these meetings, the PhD students found that it was difficult to disentangle what could be considered just an aspect of ecological sustainability and observed a lot of overlap between indicators of sustainability across the three pillars. For example, how could one categorise pollution as only an aspect of ecological sustainability when it also had such a big impact on the social well-being of the people exposed to it? Also, was it not clear that the economics of capitalism contributed to the pollution being produced in the first place? It was in these informal meetings that the three researchers started to conclude that the three pillar conceptual framework did little to help their understanding of sustainability and that something less siloed or disciplinary-focused would do more to capture the complexity of some of the indicators of sustainability.

Then, in a supervisory meeting with natural scientists, Carter, one of the PhD students, updated his supervisors on what he had been working on and informed them of these meetings with the other PhD students. Pete, his supervisor, seeing an opportunity to develop this thinking into a paper, wanted to be involved in developing the work. Pete then initiated a meeting with himself and the three PhD students to outline what he thought the paper should look like. He developed a mind map that included assigned tasks for each individual who would contribute to the paper and sent it around to the other researchers working on the paper to use as an outline.

The controversy started when Carter mentioned that this supervisor expected to appear as a co-author on the paper for his contribution. His co-authors, Ingmar and Stella, argued this was not the normal authorship practice in their own disciplines. At that point in time, Pete had not contributed anything written to the paper that the three of them had started to draft, so for Stella, this credit of authorship was undue. Interested in finding an authoritative stance, the PhD students approached the Course Director in Sociology to ask his opinion of the practice. He agreed that unless a substantial written contribution had been made to the paper, a contributor would normally not be named author in the social sciences. The penny dropped at this point that different disciplines have historically different practices when it comes to co-authoring academic papers.

This situation put Carter in a difficult position when he had supervisory meetings. He felt the need to avoid the topic of the paper, lest Pete ask to contribute or see drafts of it for comment and therefore, according to the publishing culture in the natural sciences, be justified as a named author. Though Carter understood that this would be considered the normal and fair practice in his discipline, he also felt the need to be fair to his social science colleagues who found this practice unfair and not aligned with their own disciplinary cultures. Carter was trying to balance

the tensions between being fair to his co-authors and fair to his discipline and supervisors.

This incident was considered serious enough to be a topic of conversation over the course of a few project board meetings as a result of the paper disappearing from the vision of Carter's supervisors. Why were the senior academics no longer being included in the development of this work? There was also concern regarding a paper being published under the management of the wider project that would not be reviewed or even seen by them. What if the position of the paper did not reflect the position or the values of the wider project as a whole, and how would this mismatch look?

> Sebastian: In this particular case I think that may be counterproductive, because the three students grouped together, tried to write a paper, now because they want to exclude us, they don't feel they can send the paper to us for proper editing. All they're going to do is to flash it to us maybe a week before they submit it and say, what do you think? That's okay for me to submit? That's all.
>
> […]
>
> So, we need to avoid that situation. It's a very bad situation for us all concerned.
>
> Pete: It sets a very disappointing precedent, it does.

This was viewed as an issue and a problem to be solved, lest it create further problems in the future with other researchers wanting to publish work jointly. This issue needed to be addressed and agreed upon amongst senior academics. Pete proposed to draft an authorship policy document that would be shared and adhered to by all in the project. In these project board meetings, he sought agreement from all of the

senior academics on what the policy should say. From a lengthy conversation in a board meeting about how the policy should be drafted, a discussion followed among the Co-Investigators about how to maintain fairness in authorship practices for students who would go on to try and find careers in their respective fields and yet also provide recognition for the efforts of the supervisors who guided them in their work:

> Bruce: I don't think there is social science practice that are [sic] different from the other disciplines. So we acknowledge co-authorship, that's not the issue. The issue is that practices whereby an institute's director or a theme leader or whoever automatically appears as a co-author is seen as not legitimate in sociology at least. We have been discussing this recently and there was an issue of some, they didn't name names, but there was a case where the PhD student felt exploited that way, and there was a member of staff who tried to force themselves upon a publication. Now I can see the pros and cons, we won't solve that, the problem is that these cultural expectations are so strong that it's like violating a taboo.
>
> […]
>
> Bruce: You see, so this is an interdisciplinary project where these clashes happen, but the – it's made up of disciplines and people will go on to try to get jobs and the cultural norm in sociology is – still is, I mean you can be against it or see it critical, that at some stage they will count your sole author publications. Because I've seen that in my own career, that people have said, ah he has many co-authored things so he's a weak

> candidate in comparison to someone else who has a sole authored book and a sole authored article. And if that culture persists, we will not change it, we will not do a favour to someone who comes out of the project. Because they might encounter an environment where they say, well, she was part of a huge project and there are lots of publications, in fact, I'm surprised there are not more. And then it's to the detriment to the student who comes out of the project. So I think we have to live with these different expectations and cultures.

In this discussion, Bruce maintained that he could theoretically agree that it could be, arguably, an objectively fair practice to include supervisors as co-authors on PhD student publications as a recognition of their intellectual contribution and time commitment given to them. However, the culture of work in social sciences could not be changed. Supervisors' efforts were not recognised in this way, and to adopt a different recognition style in authorship would not translate into the same meaning in social sciences. If anything, this would translate into an unfair practice for the student and their future career endeavours.

The senior academics acknowledged and agreed that different cultures of work existed between the social and natural sciences. However, many found it difficult to adjust or adapt their own ways of working to suit different cultural expectations. This discussion continued over several meetings, and in a separate meeting, a senior academic from the natural sciences asserted:

> […] in the future, that they should not expect too much help from supervisors to look over future drafts if they do not want to add additional credit [in the form of authorship] to the paper. […] explained that funding is very hard to get and that

> as part of the reward of working on hard projects, that getting papers out of it should be part in parcel. – *Sebastian*

Here Sebastian proposed a hypothetical scenario where supervisors would refrain from providing as much assistance and guidance on paper drafts to students if they were not recognised for their contribution to that piece of work. To him, students should not expect this help from supervisors who would not be recognised in the form of co-authorship on the paper. He also illustrated that in exchange for the hard task of finding and providing funding, authorship is "part in parcel" of these efforts. Co-authorship is the reward of working on those hard projects.

As the discussion and the debate continued in board meetings, the senior academics seemed to come to an agreement that supervisors should be recognised if there was a significant "intellectual contribution" to a piece of work:

> Pete: I think we can probably, as a bunch of academics, agree that there needs to be some intellectual contribution to warrant appearing on the list.
>
> Multiple: Yeah.
>
> Pete: I certainly would not expect to appear as an author on everything in this project that would just be obscene, I think. But if I've made a meaningful intellectual contribution then to me that ought to be recognised. And that's the kind of default approach as we've been saying in sciences and engineering.
>
> […]
>
> Xavier: I wasn't thinking of the sociologist to be honest, I was thinking, why would a pressured

> PhD student, who gets no credit in their discipline for being the fourth author of a ten-author paper, give up any time when they ought to be sitting down sweating over the latest publication from a professor from MIT, to work out how they can add to that discourse in a part of chapter four of their thesis. There's nothing in it for the PhD student in the model that you just proposed for the social science. In the natural science there's everything in it. For the social science there's nothing in it.
>
> […]
>
> Bruce: No. Well, you must have single author pieces, yes, but if you have co-authored papers, that's fine. There is not a principle against co-authorship, but it's not seen as the normal thing to do, like having loads of co-authors and some of them doing relatively little work because they were just enabling or providing the money or providing the initial stimulus or whatever. It needs to be a proof of contribution, that's what we go by.

In this discussion, they all agreed that supervisors should be named as authors if they added an intellectual contribution to a piece of work. However they still disagreed as to the definition of an "intellectual contribution" or "proof of contribution". The academics working in the traditional social science culture recognised drafting a significant section of the text as an intellectual contribution. Academics from the natural sciences argued that providing a funded project, intellectual input from meetings and feedback on documents could all independently be considered examples of a significant contribution. Bruce made it clear that having several co-authors implied doing little work on the paper and that providing funding or initial ideas did not fall into this category of proof of contribution in the social sciences. Indeed,

simply appearing as an author on a paper does little to outline exactly the contribution that is given to the paper; a contribution could range from technical data analysis to drafting an entire first draft (Tsai et al., 2016).

Meanwhile, while these discussions continued over a period of months, the three PhD students who had begun to draft the paper had their own work and priorities to balance. As they did not continue to discuss the Three Pillar Paper with any of the supervisors, the supervisors were unclear or unaware if they were continuing work on the paper, what draft form it was in or if they were going to submit it. In reality, though the students avoided talking about the paper to bypass an inevitable confrontation, they also did not have the time to continue working on this extra piece of collaborative work. As time passed, the students focused on preparing for their second-year reviews, starting fieldwork and revising their own individual papers for publishing. The Three Pillar Paper principally disappeared from their own visibility because they did not have time for this interdisciplinary work; getting their qualification was the priority.

To date, this piece of work remains unfinished and unpublished. The PhD students have either run into their ‘thesis pending’ or fourth year of work and have relocated, found full-time work or are spending time applying for additional funding. A funding end date acts as a clear timestamp to motivate researchers to prioritise and make decisions about what realistically can be done, and peripheral work tends to fall by the wayside.

Publishing practices within their own Schools and disciplines made it difficult to collaborate on shared work across disciplinary boundaries. In the example of the ‘Three Pillar Paper’, the senior academics from the natural sciences viewed the silence around the paper as a withdrawal from collaboration in order to abide by the authorship practices of the social science disciplines. To quote Pete, it went against the “spirit of collaboration”. Interestingly, this seemed to go both ways. As Sebastian

stated above, PhD students should not expect much “help in the future”. Although time commitments and other work priorities prevented the paper from being prioritised, avoidance of mentioning the paper for fear of confrontation occurred when there was a mismatch of expectations around what was considered substantial intellectual contribution. Rather than openly sharing work, it was easier to hide this project to avoid a confrontation for which a solution was never reached.

In addition to highlighting the importance of time constraints and the strong desire to have published work as an output of efforts, the debate surrounding the Three Pillar Paper again demonstrates the disciplinary divide between the natural and the social sciences in this project. Not only were they separated in updates during Progress and Integration meetings, but they largely took opposing stances to the question of recognising authorship in published work. The incident also highlights the power of established systems of quality control in respective disciplinary camps. To adopt a different practice of recognition would risk being unfair to a student who wished to pursue a career in their academic discipline.

In this instance, it seemed the interdisciplinary ‘building’ was not enough to overcome these obstacles and foster collaboration. The ‘dry-walled’ space that the interdisciplinary supervisory meetings were meant to provide did not address the different disciplinary norms for co-authorship. As outlined earlier, the disciplinary expertise provided by the ‘columns’ in the project also came with strong disciplinary-specific behaviour and cultures that governed fair and equitable practice. These seemingly conflicting practices across the disciplinary divide between the natural and social sciences reached a stalemate in the project rather than an accepted solution or compromise. The initial personal motivation to collaborate with others waned once researchers felt they were being treated unfairly by their colleagues.

5.4 Interdisciplinary tensions

These incidences illustrate the tensions that run through an interdisciplinary project. They highlight the challenges of time, shared spaces, and academic institutional boundaries identified in the literature on interdisciplinarity. Such challenges to doing interdisciplinary work are inevitable within an academic environment where short-term contracts, limited funding and high-pressured publication ranking systems have such a high impact on career progression. In this section, the time and university environment themes are compared with findings from the literature on interdisciplinarity.

The aspect of time is an established point in the literature on interdisciplinarity. Issues related to the longer period of time required for an interdisciplinary project versus a mono-disciplinary project, especially for researchers to get up to speed, are documented (Goulden et al., 2017; Lotrecciano et al., 2016; McBee & Leahey, 2017). Sufficient time to build relationships in order for collaborations to occur is also an extra consideration in an interdisciplinary project (Nancarrow et al., 2013). This literature references more ‘time’ required, but what is really being prioritised is the importance of team dynamics and mutual understanding. The space that the additional time creates is thought to facilitate the necessary meshing of the team to make interdisciplinarity work. This is why the lessons on extra time requirements in the literature, reinforced by these project findings, should be pushed to the fore of a project.

Indeed, in this project, participants pointed to a lack of time as a barrier to conducting interdisciplinary work. Researchers perceived that mutual understanding and learning needed to take place between disciplines prior to interdisciplinary work. This extra task of mutual understanding was seen as an additional requirement of interdisciplinary research collaboration. Although the personal motivation to engage in these additional tasks was high at the start of the project, the motivation to collaborate waned as pressures to deliver outputs increased over time.

In addition to discussing the length of time, use of time is also a common theme in the literature on interdisciplinarity. Specifically, there is a common perception that interdisciplinary work is considered less productive (McBee & Leahey, 2017). This productivity point compounds the time pressures experienced by academics who are hard-pressed to work on outputs so crucial to their academic standing. Time spent sitting in Progress and Integration meetings or understanding concepts that exist outside of one's disciplinary understanding was considered unproductive in that it failed to connect to an output that could be used by the researcher. There was an observed resistance to fully engage in Progress and Integration meetings or to collaborate with other researchers under the guise that the 'right time' had passed for an interdisciplinary interaction. These observations were especially visible towards the latter half of the project lifetime when feelings of urgency set in.

In addition to the perceived lack of time, the dynamics of coordinating with others to see academic outputs to completion created an added layer of tension. In this project, outputs were synonymous with published work in the university incentive structure. A documented barrier to publishing interdisciplinary work is the challenge of getting interdisciplinary work published in academic journals. Difficulties in finding adequate peer reviewers and an evaluation process for the work are cited as reasons perpetuating this challenge (McLeish & Strang, 2016). Although research has begun to propose best practices for new quality assessment of interdisciplinary published work (Lyall & King, 2013), systems have yet to be established to provide legitimate and recognised evaluation frameworks. Traditional institutions of quality control are still very strong and present in academia, making recognition of these interdisciplinary outputs harder to come by. A further investigation of peer-review systems and their role in knowledge production is given in Chapter Seven. For this discussion, it is important to note the tensions between a personal motivation to do

interdisciplinary work and the lack of incentive structures in academia to do so.

Strongly reflected in this project was the challenge of working with other authors across disciplinary boundaries to publish a piece of work. This publishing challenge is unique to projects working within a university structure. Co-authorship is seen as an indicator of collaboration in many bibliometric studies (Tsai et al., 2016), and indeed, in the Three Pillar Paper, senior academics perceived it as an important output and, if completed, evidence of interdisciplinary working and collaboration. However, establishing fair credit for how contributions are recognised when authors from multiple disciplines with varying norms of authorship collaborate together on a piece of work is difficult and requires negotiation (Smith & Williams-Jones, 2012), especially in the absence of wider agreed-upon standards or guidance in interdisciplinary papers.

In the case of the Three Pillar Paper incident, this negotiation to ascertain the norms of collaboration took place on two levels: 1) at the PhD-supervisory level to determine who would be named on the document and 2) at the senior academic level to determine a shared project policy on co-authorship going forward. Indicatively, both of these projects are currently unfinished. Perceptions of limited time and choices to pursue something more productive certainly played a part. However, the inability to come to a mutually-agreed solution also halted progress.

Meetings and discussions about the Three Pillar Paper also highlighted hierarchical structures that set the backdrop for conflict avoidance in organisations or universities. Subordinates, or PhD students in this case, tend towards avoidance due to the lack of perceived power they have in the dynamic. Avoidance is preferable because a conflict could likely end in an undesirable outcome for them if they challenge a superior (Barsky & Wood, 2005) or, in this instance, a supervisor. A more in-depth look at how hierarchical structures determined working relations within the project is given in Chapter Seven. For the purposes

of this section, it is important to note how hierarchical structures were implicated in how PhD students chose to address the conflict around the Three Pillar Paper.

While the above themes (time and university environment) featured heavily in this project and appear in the literature, a theme noticeably missing in this project was the importance of informal spaces and interactions in facilitating interdisciplinary working (Bridle et al., 2013). In Callard et al.'s (2015) experience working on an interdisciplinary project, they found that although formal efforts to facilitate interdisciplinary collaboration (like a workshop) were helpful, some of the most interesting projects were born out of interactions that happened in informal spaces. Projects that require collaborators to work in shared spaces do so under the assumption that personal contact promotes interdisciplinary working, as it heightens the probability that informal interactions will occur and therefore make connections across disciplinary lines (Blättel-Mink & Kastenholz, 2005) or create inclusive (or exclusive) dynamics within a team (Knorr-Cetina, 1999).

In this project, there was no classification from the researchers regarding the importance of formal versus informal spaces for interdisciplinarity. Although both spaces existed within the project in Progress and Integration meetings (formal) and shared office space (informal), neither were differentiated in terms of their effect or importance for interdisciplinary working. From my own observations, the important informal connections that were made in the meetings leading up to the Three Pillar Paper, for example, were eventually codified into a formal initiative. This, as a result, elevated the importance of the initiative into an output that would evidence the interdisciplinarity that was taking place on the project.

On the surface, these observed tensions related to the established structural commitments to academic life and disciplinary norms. However, a strong undercurrent of emotions and feelings underlined these tensions and were crucial to the dynamics of the project. In

workplace and team studies, research exploring the role of emotion at work ascertain its role in determining work coordination and performance (Ashkanasy & Daus, 2002; Miller et al., 2007). However, this emotional element, so present in this interdisciplinary collaboration, is to a much lesser extent explored in its own right in the literature on interdisciplinarity (Boix Mansilla et al., 2016; Callard & Fitzgerald, 2015; Hillersdal et al., 2020), hence its absence in the thematic table (Table 2-1) introduced in Chapter Two. This is likely influenced by that fact that emotions are allowed little space in academia, where decisions are meant to be based on reason, logic and evidence. Boix Mansilla et al. (2016) discuss emotion mostly in the context of interpersonal connection and individual excitement as predictors of successful interdisciplinary collaboration. This thesis takes a different approach and focuses on participants' emotions as a source of information about interdisciplinary perception and understanding.

Callard and Fitzgerald (2015) focus on emotions not just as a side effect of doing interdisciplinary working, but also as a data point to be investigated in and of itself. Callard and Fitzgerald (2015) acknowledge that added time pressures and the difficulty of being understood by other disciplinary researchers can be "psychologically, practically, and emotionally exhausting" (p. 128). Callard and Fitzgerald argue that this "affective weight" of interdisciplinarity should be "as much a datum to be considered as a situation to be managed". (p. 128). In doing so, Callard and Fitzgerald use their own emotions and the emotions of their collaborators to learn from the tensions existing on the project and understand how interdisciplinary knowledge is produced. Understanding these aspects is one way to identify what blocks interdisciplinary progress.

These "affective tensions" (Hillersdal et al., 2020, p. 68) in interdisciplinary collaboration play a large role in how participants approach interdisciplinary collaboration and how researchers engage with their own disciplinary research. The affective situations illustrated

in Hillersdal et al.'s research (2020) are used as clues or "markers of difference" (p. 71) in interdisciplinary collaboration. Making jokes about different disciplinary approaches was an "affective expression" of unease with difference (Hillersdal et al., 2020, p. 72), which then created the catalyst to develop a logbook within an interdisciplinary team to share information and different definitions. In the sustainability research project, the effect of suspicion was research collaborators withdrawing from sharing work or offering expertise, specifically in the case of the Three Pillar Paper.

Though project members identified different disciplinary cultures as the underlying reason for difficulty collaborating and navigating co-authorship, a separate emotional element was clear in this conflict. In this interdisciplinary project, emotions and tensions ran high when trying to avoid uncomfortable conflict and maintain feelings of fairness and reciprocity. For example, academics in the natural sciences perceived that they were being treated unfairly by PhD students who 'hid' work from them. The spirit of reciprocity was violated when they were denied a publication after securing funds for the research project and taking time to supervise work. Conversely, PhD students and academics in the social sciences felt it unfair to automatically add supervisors as named authors, as this would potentially diminish the merits of the efforts that went into writing the paper and lead to inadequate recognition by peers in their fields of research. They considered that supervising PhD students was part of the job description of senior academics, who therefore should not expect additional recognition in the form of authored publications. In this example, it was clear that researchers would adopt new working relations going forward in response to participant feelings.

Avoidance as a strategy to deal with areas of conflict often involves a clear element of silence regarding the issue and how conflicted parties are feeling. Silence has a pragmatic purpose in interdisciplinary collaborations—to keep the peace and prevent damage to internal

relationships (van Dyne et al., 2003). However, silence also functions to keep any potentially contentious views from surfacing, preventing potentially useful engagements with the issue to take place. Silence can also have a disintegrative effect on the group in the form of suspicion or cynicism (Morrison & Milliken, 2000), leading to a further withdrawal from the difficult cooperation that seems to characterise interdisciplinary collaborations. Silence, in this case, also allow misunderstandings to fester. Keeping silent about the paper meant that the senior academics on the project were under the impression that work was still being done on it, when in fact the PhD students felt there was not enough time to spend on it.

Confrontation, voicing the issue or directly negotiating an alternative solution about authorship of the Three Pillar Paper did not occur. Although dialogue and confrontation are often cited as preferred ways to deal with conflict in interdisciplinary settings (Datta, 2018), the power relations between the PhD students and their supervisors played a role in keeping students silent about the paper. The priority was to avoid confrontation with supervisors who insisted on the legitimacy of their own (natural science) disciplinary culture, which held that supervisors would be automatically named on student work if they provided ideas, funding, review or comment. As these supervisors exerted pressure to see the paper, using the wider disciplinary practices to legitimise adding their name to the paper, the students did not feel they had the bargaining power to propose a different authorship model that worked for their project.

Understanding the emotional landscape of an interdisciplinary project can help determine which collaborations gain traction in interdisciplinary projects and which ones receive little engagement (Callard & Fitzgerald, 2015). Indeed, Parker and Hackett (2012) discuss how, in interdisciplinary collaborations, feelings of trust and commitment to other ideas are necessary to successfully collaborate and overcome scepticism. Feelings and emotions ran high in interdisciplinary

collaborations in instances where researchers tried to maintain a sense of fairness and reciprocity. For example, when Sebastian in section 5.3 asserted that students should not expect help from supervisors unless they were given adequate recognition for their work, his approach to his potential future behaviour towards students was a way to restore a sense of ‘fairness’ in the relationship at the expense of future engagement. In this example, positive emotions and a feeling of reciprocity actually were a prerequisite for engagement. Given the important role that emotions and feelings play in interdisciplinary projects, it should be a data point to further explore and explicitly address in research collaborations going forward.

Investigating these feelings of fairness with the clashing interdisciplinary cultures brings another theme to the surface: collaborative *expectations.* The main source of tension surrounding the Three Pillar Paper was the lack of shared expectations for authorship practices. While the natural science senior academics expected to be named on the Three Pillar Paper, they were genuinely surprised that the social scientist PhD students had a very different expectation of who would be named authors. It was when these initial expectations were not met in either camp that the conflict began.

Researchers also expected to see some outputs evidencing their interdisciplinary connections in the project, as the university work model creates the expectation that researchers show their work in the form of academic publications. The researchers expected to have something to show for their efforts when they tried to collaborate. When this evidence failed to materialise, they felt uncertain whether they had approached interdisciplinary collaboration the right way to meet the goal of successful disciplinary integration.

This idea of interdisciplinary as its own objective is tied to the initial project configuration. Because senior academics built the project with the intention to foster interdisciplinary integration across the natural and social sciences, there was an explicit expectation that the researchers

should develop their knowledge about urban sustainability in an interdisciplinary way. This configuration, combined with my presence as the researcher of interdisciplinarity, meant that researchers felt pressured to fulfil this expectation. This expectation, combined with the uncertainty surrounding how to fulfil it, contributed to feelings of frustration and unease.

As a result of perceived limited time, academic priorities and outputs such as being awarded a PhD and publishing in reputable disciplinary journals were the primary objectives for researchers on the project. In this shift, the *personal motivation* to collaborate with others from different disciplines waned because the expected outputs from the exchange were missing. As these outputs are codified within an academic incentive structure, interdisciplinarity became a secondary, not integrated research objective. As the project progressed and interdisciplinarity increasingly became merely a nice thing to have, efforts to collaborate and do interdisciplinary work went by the wayside.

5.5 Conclusion – "I knew it would be hard, just not this hard"

The quote above is taken from an interview with a researcher on the project. It was in reflection on the expectation of working on an interdisciplinary project versus her actual experience. She anticipated that it would be more difficult than a mono-disciplinary project or even an interdisciplinary project where the researchers were closer in research practices and understanding. However, in reality, it was harder for her to navigate than expected.

This chapter looked inside the interdisciplinary 'building' carefully constructed by the academics on the project. Inside the space where interdisciplinary work was meant to happen, expected challenges and unexpected occurrences took place; but to the disappointment of many of the researchers, not as much interdisciplinarity happened as they would have liked. Frustrations arose around the lack of time to adequately connect interdisciplinary projects and the amount of time

wasted on discussions and work that did not lead to fruitful outputs. Time as a scare resource also led to researchers to try to balance perceived competing demands of work, and ultimately led to choices being made between interdisciplinary collaborations and disciplinary contributions to their own fields of research. Due to clear incentive structures in the university, it is not surprising that publishing in a specialist field or getting a PhD within a specific School became the priority.

The issue of co-authorship further highlights the ‘disciplinary divide’ between the natural and the social sciences. In addition to the disciplinary grouping in Progress and Integration meetings that both reflected and created a division between the natural and the social sciences, the practices around authorship revealed another characteristic of this divide. These practices also revealed the strength of existing disciplinary institutions in academia to perpetuate different practices and cultures. Despite the clear desire to cooperate and do interdisciplinary work, existing disciplinary structures provided stronger incentives to produce disciplinary knowledge. Therefore, interdisciplinary collaboration became an unintegrated research objective secondary to disciplinary contribution.

The emotions involved in doing interdisciplinary work, combined with conflicting project expectations, contributed to the feelings of disappointment in not reaching the expected goal of ‘interdisciplinarity’ that the project promised to fulfil. Feelings of unfairness and inadequate recognition meant that interdisciplinary collaborations were avoided to prevent feeling used or cheated in an interaction with another researcher.

After chronicling some of the tensions inside the interdisciplinary building, the next chapter discusses some of the reasons why researchers considered interdisciplinarity to have failed at the end in the project.

Chapter 6: The challenge of interdisciplinarity: Lessons from the project

6.1 Introduction

Chapter Six reflects on the researchers' assessments of interdisciplinary collaboration in the project and on the perceived failure of the interdisciplinary building to deliver on its promise. The term 'promise' refers to the aspiration reflected in the discourse that interdisciplinary approaches are the key to holistic, relevant research that engages with complex problems (Burawoy, 2013; Polk, 2014). With this in mind, this chapter answers the research question: 'How did researchers assess the interdisciplinary element of the project and how did they come to those conclusions?'

This chapter explores the perception that interdisciplinarity largely failed in this project. It explains what researchers considered 'attempts' at interdisciplinarity, attempts that had no outputs to evidence the extra time commitment put in. It also describes a perceived disciplinary asymmetry, which contributed to researchers not feeling that the collaboration was a success.

This chapter narrates a second critical incident which followed a mini-project in which researchers from the natural and social sciences tried collaborating on a smaller scale. It was called the Policy to Model to Output working group. This incident illustrates what is meant by an interdisciplinary attempt, a project output and disciplinary asymmetry, all which contributed to a perception of failure.

6.2 A 'failure' to do interdisciplinarity

Largely towards the end of the project there was an overall conclusion that interdisciplinarity had not been achieved. It was perceived by some that it was an unachievable goal in the first place, and many expressed disappointment that interdisciplinarity had not appeared as expected.

Instead of successful interdisciplinary collaborations, what existed were *attempts* at interdisciplinarity. They were considered attempts because of the lack of outputs that came from the interactions.

Although collaborations occurred between researchers from different disciplines, some of these were not recognised as true interdisciplinary work. 'True' interdisciplinarity in this project meant a meaningful collaboration between the perceived large divide between the natural and the social sciences. In an interview, a social scientist reflected on his previous interdisciplinary experience as a reference for interdisciplinarity:

> I really didn't think of it as interdisciplinary at the time, it certainly doesn't compare with this project, and this is much more interdisciplinary I think – or multi-disciplinary. Or interdisciplinary in terms of who's involved. You know, you've got computer scientists and sociologists and geographers and physicists. It wasn't that degree of separation of disciplines, but still was interdisciplinary. – *Tristan*

Although in this quote Tristan was still trying to navigate what he considered the correct terminology to use for the sustainability project, he referenced a "degree of separation of the disciplines" to indicate the increased level of interdisciplinarity that he considered this project to have. The larger the divide, the truer the resulting interdisciplinary collaboration would be. Below, I discuss how researchers understood true interdisciplinarity to mean effective communication. 'True' interdisciplinarity also meant clear evidence or outputs resulting from interdisciplinary initiatives and disciplines contributing equally on projects.

6.2.1 The inability to translate

In the literature, respondents from interdisciplinary research projects described communication difficulties as "speaking different languages"

(Looney et al., 2015, p. 751). To address these difficulties in communication, three approaches have been outlined in the literature. One approach is to integrate disciplinary languages in order to reach mutual understanding (Klein, 2011; Klein, 2005), governed by the idea of consensus or “sameness” (Holbrook, 2013, p. 1871). Another approach is to accept the “incommensurability” between the disciplines caused by the lack of shared measures between scientific domains (Kuhn, 1970). Incommensurability describes the (almost impossible) task of becoming an expert in another discipline or ‘language’ in order to truly understand its terminology and context (Holbrook, 2013). Rather than a ‘translation’ of terminology from one discipline to another, this refers to learning a whole new language. There is a middle point between these two approaches in which Galison (2010) describes how researchers from different domains can work together in neutral “trading zones” without having to subscribe to another domain’s language, practices or ideas. Researchers on this project understood interdisciplinary communication across the range of this spectrum.

In interviews and conversations, various definitions of interdisciplinarity were offered, although not confidently; overall uncertainty was obvious. In many attempts to describe interdisciplinarity, researchers offered examples and metaphors of language, translation and being understood.

I asked a junior researcher to reflect on the project in a self-recorded diary entry. An aspect that was important for him to reflect on was the challenge of multiple languages that existed in the interdisciplinary project:

> I guess I understood that we would be […] effectively speaking a different language particularly contrasting between the social scientists and the physical scientists. But I didn’t appreciate how significant that would be and how much of a barrier that would be, especially at the

> start of the project. I think that some people were more willing to adapt to the different terminology that people used, whereas some others were quite stuck in their ways I guess and inflexible. […] occasions quite early on where there was clearly a misinterpretation of a term that was used, it meant different things to different disciplines and it's just creates a barrier […] – *Tristan*

In the above quote, again the divide between the social and natural sciences was highlighted, particularly regarding language in the form of different terminology. Tristan observed that language was more of a challenge than he anticipated, and that a willingness to adapt different uses of terminology was needed to overcome the barriers to working together. A compromise was necessary here to be flexible about terminology to remove barriers to collaboration. This aligns with Klein's (2010, 2015) approach to 'translation' in interdisciplinary projects, an attempt to compromise and converge from different disciplines to a shared common ground.

In addition to language being considered a principal barrier to interdisciplinary working, there was the sentiment that, to overcome this obstacle, there needed to be an agreement or at least a mutual understanding regarding language terms in multiple disciplines. At the start of the project, a senior academic suggested that researchers create and contribute to a shared document listing a glossary of relevant terms with multiple meanings in order to translate the terms to the various disciplines around the table. Here the focus was on creating one shared document so that everyone could converge on shared meanings. It is worth noting that although it was suggested multiple times that they create and share this document, this initiative was never taken up or realised.

Here, the focus on language as a barrier highlighted the desire for researchers to translate a definition into their own discipline or create a mutually-shared definition for the same word. However, in practice, this never happened; a strong affinity with the language they were familiar with prevented researchers from being flexible enough to work with other definitions. In an interdisciplinary project, this is a challenge. To change your definition, or even to create a new one, removes the disciplinary-specificity of expertise that researchers felt was required in the first place for interdisciplinarity to work.

Not all researchers strove to reach a shared understanding of terminology. In an interview, Oscar, a junior researcher and computer scientist, echoed the key challenge of interdisciplinary as understanding the language of other disciplines:

> I find it a bit difficult to try to, without being from this other discipline, which is, this call for example, psychology, is to understand a lot of the language that's being used, and that is one of the biggest barriers in interdisciplinarity, is the language. – *Oscar*

For Oscar, the key to interdisciplinarity was a lack of understanding of other research disciplines, due to not being able to understand the terminology. For him, the ability to understand other disciplines was necessary to engage in interdisciplinarity. However, he then went on to question the extent to which one can understand a discipline and be 'rigorous', which is an important measure for good research:

> […] we are expected to be doing very specialised, very cutting-edge research, so we need to have a solid understanding of what we are doing. But how much solid understanding do you have to have of the other disciplines, to be able to say, what we are doing is solid, or is rigorous? That's

> what I find also very difficult in interdisciplinarity; is you're relying on, what do you call it, portion of knowledge of each discipline, […]. With […] implied knowledge or implied dependencies, which means that you have more room for miscommunication, misunderstanding; so, it becomes a bit difficult. – *Oscar*

For him, the difficulty of interdisciplinarity was not only the barrier that language creates in understanding another discipline but the potential for *misunderstanding* and an inability to determine if research is rigorous or not. However, the term rigour also has different meanings and manifestations across disciplines. A way to measure rigour in one discipline can be irrelevant in another, so it is very possible that an interdisciplinary project is not considered rigorous by all the participating disciplines' standards. This researcher's interpretation of disciplinary language recognised the more incommensurable nature of the disciplines (Kuhn, 1970). A "solid understanding" of a whole other discipline would prevent probable misunderstanding caused by a superficial knowledge of the other discipline's language.

Another example of a difference in language signalling a potential difference in what was considered rigorous research was in discussion of the term 'case study'. In an interview, one of the senior geographers recalled discussions about the term 'case study' in collective meetings early on in the project:

> Early discussions where computer scientists, modellers and engineers tried to talk to social scientists and those meetings were quite stimulating, even our basic language wasn't shared. So we would use the word case study and for us that means a certain set of things and that rapidly became apparent that it didn't mean the same thing to engineers and modellers. That

> feeds through to research design, how you do the research, how things are written up for publication; it feeds through to everything.
>
> […]
>
> […] you are faced with the real challenge of trying to explain, like the word case study, I remember we said we were going to do a case study, and this was quite a concern to Pete and Sebastian, 'is it generalisable? Is it applicable beyond this case? Why have we chosen this case?' These aren't necessarily questions you would get asked in geography—you would—but I think in geography it is assumed that case study research is fine and it's robust so having to actually think about how you would justify that quite elemental part of research design is quite challenging. – *Isolde*

Again, the location of miscommunication was between the natural and social sciences. She recalled the "concern" shown by two members of the project who were natural scientists and their desire to understand how the "case study" would be considered generalisable. However, their understanding of "generalisable" stemmed from the standards within their own disciplines of physics and engineering. By the standards of geography, on the other hand, case study research is considered "robust". The task of translating what that would mean to another discipline without understanding their measures or definitions of rigour was an impossible task.

As a result, the geographers were content that it was a robust methodology by their own disciplinary standards and took measures to avoid any difficult conversation about the term in the future. As Isolde explained: "For a while we consciously didn't use the word 'case study'

we sort of carried on doing the same research, but in the project meetings we decided we would not use the word ‘case study’.”

Not only was there a lack of mutual understanding, but the conclusion was that a mutual understanding could not be reached. In this sense, there was a withdrawal from engagement with the natural scientists, and therefore a withdrawal from engaging in an interdisciplinary endeavour. There would not be a bridge between the interdisciplinary divide in the case study methodology. Further, although this discussion took place in larger Progress and Integration meetings, researchers sometimes chose to not use the space for disciplinary integration in the form of mutual understanding. In this case, they opted out of what appeared to be a futile effort to make their meaning of case study understood. A withdrawal of engagement in the form of silence about the term case study seemed easier and preferable in order to get on with work.

This silence about the definition of case study in Progress and Integration meetings is important because it demonstrates that although space was provided to conduct interdisciplinarity (the ‘dancefloor’), it did not automatically happen. Researchers could choose to engage or disengage in conversations whilst being in that environment. If the engagement was perceived to be too challenging or not useful, it was shied away from for the sake of getting research work done.

A tension then existed between bringing someone on to the project for their disciplinary expertise and the desire that they be flexible and compromise on their disciplinary terminology. This compromise can seem like a ‘dumbing down’ of one’s discipline, thereby compromising the very research integrity of one’s work. The same geographer in the project who discussed the difficulty of using the term ‘case study’ articulated the challenge of ‘translation’ as:

> I guess it’s probably an internal quandary, like do you dumb down your social science to like an

> educated lay person's level, but if I did, would a physicist think, oh I can just read a newspaper about that it isn't really helping me. – *Isolde*

Here the challenge of translating concepts meant that the integrity and specificity of a concept was lost in its simplification. This reductionism in interdisciplinary endeavours is often given as a caution (Stein, 2007). This quote reflects the view that the very act of translation is a miscommunication of a concept that will end up being misunderstood by the other disciplines. If she "dumbed down" her social science concepts, Isolde feared that the true meaning would get lost in translation, demonstrating again a view of incommensurability between the disciplines regarding language.

By bringing different disciplinary experts who were strong in their fields on to the project, it was imagined that all of the right expertise would be present. However, the disciplinary 'columns' represented the strong silos that characterise disciplinary practice, knowledge and understanding; to request flexibility or compromise in disciplinary practices was a big ask. A cross-disciplinary project predicated on disciplinary expertise necessarily creates tensions between abiding by the standards of rigour in one's own discipline and adopting other disciplinary practices into one's research work.

Many agreed that language and communication were a large part of interdisciplinary collaboration and the key to success. However, different understandings and approaches existed within the project regarding what could or should be done about the language communication barrier. In some initiatives (such as the shared glossary), Klein's shared language approach was seen as an ideal way to reach consensus. However, from the perspective of some researchers, the fear that communication could lead to a dumbing down or misunderstanding of concepts illustrated a Kuhnian 'incommensurability' between the disciplines, highlighting the perceived risk of conducting research not rigorous enough. These two examples

show the difference in understanding of where the problem lay in lacking shared language; they illustrate that researchers either thought that others did not compromise on their vocabulary or that they were unable to for the sake of disciplinary integrity.

6.2.2 Interdisciplinary attempts

When interdisciplinarity was expected to start on the project, researchers communicated their discomfort that not enough interdisciplinary interactions had taken place. During an informal conversation, Stella, a social science researcher, said she had tried to make interdisciplinary connections throughout the project. She stated that “she would not be held responsible” if no interdisciplinarity took place because she felt she had made an effort. In her opinion, the project came up short in creating a truly interdisciplinary collaborative effort.

To create a truly interdisciplinary project was an ambitious goal. When asked, ‘How does the experience of working on the project compare with your expectations?’, a postdoctoral researcher said:

> Well, not favourably. I think there is still a disconnect between what the project looks like on the outside and what is going on on the inside. From the outside when I joined the project, like most people probably had, a much more ambitious picture in their head about what kind of collaboration would happen. What kind of interdisciplinary work would be happening? – *Elisa*

Elisa expected a different kind of interdisciplinary work to happen in the project: work that was more “ambitious”. Her view on the project and its level of interdisciplinarity was not favourable, illustrating her disappointment that more or a different kind of interdisciplinary collaboration should have taken place.

In an interview, another social scientist, Tristan, also echoed these sentiments about a lack of good connections or true interdisciplinary working, hinting that he didn't consider any of the existing connections or collaborations interdisciplinary enough. He mentioned the term "real interdisciplinary working" and, when asked to expand, said:

> I supposed what the question is what do I think is real interdisciplinary working? It would be those joint, setting up an actual task to do together and to put in your different viewpoints into that to produce something that everyone can claim a bit of ownership of. I think that is what Reese had an attempt at but nothing actually came out of it. That is the closest we got to real interdisciplinary working from my point of view. If you had to put it in a bracket what exists currently is multi-disciplinary, or as I said adjacent disciplinary working, working on different things just next to each other. – *Tristan*

There was an acknowledgement of attempts to do interdisciplinary working, but they ultimately came up short and settled with less ambitious multi-disciplinary collaborations. Tristan's understanding of interdisciplinarity as an important goal reflects the general understanding that it is the highest form of cross-disciplinary collaboration (with interdisciplinary work located above multi-disciplinary work). Interdisciplinarity is harder to achieve, giving its accomplishment more value and making it a desired space to reach in academic research.

Whilst the project ticked along, researchers were aware of attempts by others to try and link different subjects or methodologies to create an interdisciplinary collaboration. In an interview, a data scientist recalled how difficult it was to make connections:

> And I think we should probably have bit the bullet and accepted compromise from both sides on getting on with some things. But I think that was partially down to no one came up with any good subjects that properly combined. [...] I think there were some attempts to do it, but I don't think they were ever entirely. So Tristan did a few things trying to link, you know, house prices on the Tram and things like that. It's difficult to find one where there isn't an easy link and there aren't things that get in the way […]. – *Henry*

In his reflections on attempted connections, Henry made it clear that they were ultimately unsuccessful. From his perspective, perhaps a way of turning these attempts into successful connections would have been to ultimately concede, compromise and create good connections between subjects.

While some cross-disciplinary discussions and interactions took place, researchers did not consider these to be true interdisciplinary collaborations. Rather, they were classified as *attempts* to do interdisciplinarity, and researchers expressed disappointment that this higher level of integration had not been reached. True interdisciplinarity was considered ambitious and more difficult to reach, whereas multi- or cross-disciplinary projects seemed like less exciting projects.

6.2.3 Evaluating interdisciplinarity

An issue with recognising true interdisciplinary working was that many efforts were labelled *attempts* at interdisciplinarity rather than accomplished interdisciplinarity because of a lack of a tangible outputs to evidence interdisciplinary collaboration. To revisit Tristan's quote above, he recalled "an attempt at, but nothing actually came out of it." Having a clear, tangible output was necessary to jump from attempts at

interdisciplinarity to actually completing it; something needed to come out of the attempt.

During a discussion about a pre-task I had sent to researchers prior to our interviews to assess their perception of collaborations with others on the project, I discussed a score that Carter, a junior researcher, gave to rank his collaboration with another junior researcher. He scored a two out of five because there was not an evidenced output from the collaboration, saying: “I nearly gave Victor a three because we have sort of have almost come closer to like working together at several points but there is never actually—nothing has ever actually emerged from it.”

The telling point which would have pushed Carter to score his collaboration with Victor higher than a two was if something tangible had “emerged” out of the collaboration. A tangible output would indicate that they had worked on something together.

The Three Pillar Paper from Chapter Five was lauded as an important publication in the project due to its interdisciplinary nature. During a meeting where senior researchers reviewed a draft progress report to be sent to the funder, they documented the status of various publications underway in the project, including the collaborative Three Pillar Paper.

> Xavier: But it also makes the joint paper, the sustainability [Three Pillar] paper, whatever you’re going to call it, actually strategically really important. So if you can have—at the time when you submit your report—if ideally you can say it’s been submitted, you won't have an answer but it might give us a kick up the backside to do something. Because that is the only integrating paper. Everything else is kind of bricks. The only integrating idea is that paper.

That this would be published and of good quality was more essential than the other disciplinary-focused publications discussed in the meeting. It was the “only” integrating paper, which highlighted the lack of evidence of interdisciplinary integration elsewhere in the project. This priority of doing work in a specifically interdisciplinary way elevated the importance of this piece of work, and therefore it was often mentioned within project board meetings.

In an interview, a social scientist recalled a workshop she organised around interdisciplinarity early on in the project. By inviting a speaker who had done his research on interdisciplinarity, she wanted to get a better understanding of the experiences involved in interdisciplinary collaboration. Getting the team together to discuss interdisciplinarity was a good exercise. However, she still expressed a disappointment that there was not an associated ‘output’ with that exercise:

> But to talk about interdisciplinarity in particular […] it was broader and more philosophical questions around interdisciplinary science and collaboration. So that was my pet project, and I am still proud of it and I still haven’t done anything with it which is a shame*.* – *Elisa*

Though she was “proud” of the work, it was a “shame” to her that she had not “done anything with it”, implying that it had not resulted in a paper to document findings from the workshop—the ultimate goal of conducting academic research.

Here, the strength and influence of the interdisciplinary ‘columns’ reared its head again. In order to continue to be recognised as an expert in a disciplinary field, continued contributions in the form of ‘outputs’ or publications need to be made in a disciplinary field of knowledge. This practice of needing outputs to measure work and effort arises from the university system.

The desire to have ‘outputs’ as evidence for interdisciplinary collaboration highlighted a tension. An academic career highly depends on a proven track record of publications. However, as pointed out in Chapter Five, publishing work on an interdisciplinary project presents challenges, both in the difficulty to publish in recognised journals that tend to be disciplinary-oriented and in the extra negotiation required for co-authored publications. In addition, given the extra time demands and lack of an incentive structure in the university environment to collaborate on interdisciplinary endeavours, interdisciplinary outputs were not prioritised. Therefore, if published work tended to materialise along disciplinary lines, how much could the researchers expect to have key outputs that reflected interdisciplinary endeavours?

6.2.4 Collaborative (a)symmetry

In this project, a source of contention was interdisciplinary collaboration in which one disciplinary group was perceived as providing a service to another. This *subordination-service* dynamic was not considered to be truly interdisciplinary. To revisit social scientist Stella’s interaction with the natural scientist Eric from Chapter Five, she was resistant to provide him with important social sustainability indicators to include in his model. As outlined previously, she felt the time commitment to do the work was too much to fit into her existing priorities. She also felt resistant as it would not qualify as a real research contribution to his work and therefore would not be a genuine interdisciplinary collaboration. Her rationale was that social scientists have different aims in their research and that ‘choosing the most important indicators’ was a very normative statement from her perspective that needed unpicking and justifying in and of itself. For her, investigating the underlying politics behind the choice of what would be considered important social indicators for sustainability purposes was real research work. However, providing a list of the most important social indicators to input into a model did not qualify as conducting equal research on the project. She saw this as performing a service.

Similarly, Joseph, a senior social scientist, insisted in an interview that his theme should be recognised as a real research contribution to the project, rather than being of service to natural scientists:

> We are studying policymakers just like the engineers are studying structure of a building, we're studying agency and structure within an administrative section. We are gathering data, analysing it and interpreting it. We are social scientists, we are equally scientists to their scientists, yeah. And that's what we do. […] I think to some extent his understanding of what the priority was that we would almost market, because we understand policymakers. Market this model we come up with to policymakers in cities. […] And so I had to say, 'no, we don't have any marketing emphasis at all. We don't engage with policymakers like that. In this case we're actually studying policymakers like you're studying transport or whatever.' – *Joseph*

In this quote, Joseph recounted his conversations with a natural scientist on the project in which he had to explain his work because, from his perspective, there was a clear misunderstanding. In this instance, he compared the work of social scientists to that of "engineers who study building structures" to elevate the research credibility of social science. He clearly rejected the initial idea of "marketing" the model to policymakers and did not consider that a 'true' interdisciplinary collaboration. Collaboration for him was an equal standing of the natural and social scientists and contributing more equally to the project.

Regarding my own research as the interdisciplinary practitioner, there was an expectation, especially amongst the natural scientists, that my service to the group would be to facilitate interdisciplinary working or to take a more functional role of telling them how they could work better. In

a presentation I gave to the team, I discussed the elusive goal of interdisciplinarity and how researchers characterised it by how a project was structured or in reference to the different languages that different disciplines speak. I received a comment from a natural scientist in the group about my presentation:

> Well you're trying to discretise it, you're trying to sort of identify it as a sort of discreet sort of outcomes, or yeah, I'm not sure, I'm not even so sure that's—
>
> […]
>
> But I'm, it's interesting to understand what the attributes, so what are the ingredients for successful interdisciplinary work; and that's one of the things that we are trying to get to the bottom of. – *Pete*

For Pete, understanding the building blocks of how the researchers understood interdisciplinary working was much less relevant than finding the "ingredients for successful interdisciplinary work", i.e., explicit recommendations to make the project successful. An academic investigation of how researchers defined interdisciplinarity was not a useful contribution to the wider project. I am not sure how resistant I was to this idea from the natural scientists. In the end, my project was very much an investigation of the experiences of researchers in an interdisciplinary project, rather than a practical list of successful interdisciplinary ingredients. This exchange still illustrates how the natural sciences imagined a practical contribution from myself, a social scientist, rather than a theoretical or conceptual contribution in the form of unpicking the very perception of what interdisciplinarity means.

Researchers imagined the models would act as the integrative strategy, like using 'Lego blocks' to build a coherent structure. And the interdisciplinary practitioner was to function as the facilitator of

interdisciplinary communication by revealing hidden connections in the ‘diary room’. However, as illustrated above, these two aspects were sites that highlighted the disciplinary divide between the natural and social sciences rather than integrating them together. In their perception that they were only serving the natural scientists and the model in promotion, data provision or team facilitation, the social scientists did not feel they were considered equal partners in the intellectual research tasks of the project. As a result of this perceived ‘demotion’ in status, the social scientists resisted collaborating in this manner. Instead, they insisted on pursuing directions that they perceived merited their intellectual efforts; these were not necessarily considered interdisciplinary endeavours.

Researchers were fairly aligned that outputs were needed to evidence the occurrence of interdisciplinarity and that a lack of shared language was a big barrier to interdisciplinary working. However, researchers were more divided on what constituted a ‘true’ interdisciplinary collaboration; this division also unintentionally served as a barrier to interdisciplinary collaboration, as it created feelings of inequality and hierarchy, especially amongst the social scientists in the group. To embed these conclusions, below I narrate a critical incident.

6.3 Critical incident – Policy to Model to Output working group

In an explicit attempt to do interdisciplinarity, an initiative was instigated by a computational physicist on the project. His objective was to understand how urban sustainability initiatives could be modelled and then to create a small project model or output to illustrate how this could be done. The purpose of this initiative was to 1) make sure some interdisciplinarity occurred on the project by working with disciplines that were perceived as being far from each other (social policy and modelling), 2) help those in the policy theme understand how modelling works and what it can be used for, and 3) create momentum and instil motivation in the team by working towards a small ‘output’.

The two leaders of the initiative were a computational physicist, Reese, and a social policy researcher, Lottie. The idea came to fruition after conversations in their shared office about what modelling does and what it can do. From Reese's perspective, the best way to get social scientists to understand the capacities and limitations of modelling was to work on a mini-project to show how it could be used in practice. To provide a focus, they decided to use the case study of building a city transport model on a small scale.

From there, PhD students in the project who seemed to have relevant expertise or related interest were recruited to join the initiative. This included PhD students from social policy (Jenna), engineering (Victor), physics (Carter), geography (Ingmar) and sociology (Stella). After getting wind of these potential exciting interdisciplinary connections, I asked if I could sit in on the meetings.

In trying to build this interdisciplinary project, Reese pulled together existing experts in their respective fields to make interdisciplinarity happen. In these meetings, Reese repeatedly tried to defer to the disciplinary expert whenever any subject-specific knowledge was required:

> Reese: It's on there, okay, cool. I'll leave Lottie to discuss the possibilities on the policy side, she knows way more about it. I guess it comes up to how you – what sort of policies you would try, would it be regulatory or financial or whatever. Lottie's in a much better position on that.
>
> Lottie: Okay.
>
> Reese: And then Carter, we thought you might do some environmental analysis. So depending on—well, this is first indications, but if you want to help out with some of the other stuff that's great as well.

Although presumably Reese and Lottie had discussed the possibility of modelling some policy initiatives, he felt more comfortable leaving her with the task as she was in a “much better position”. He also tasked Carter with the environmental analysis, as this was perceived to be Carter’s expertise. The rationale was that the right disciplinarians should speak on behalf of their discipline and impart their knowledge to others. This initiative seemed like a reproduction of the building process of the wider project; the instigators started with a modelling project in mind, recruited the experts they thought were relevant and put them together in meetings, expecting that interdisciplinarity would then occur.

Though the initiative was appreciated as an interdisciplinary endeavour, Stella found the additional tasks required as a member of this working group a bit daunting:

> Stella: It’s really interesting. But this is a lot of work already, if you think that through. I mean, that means, okay, you need to assess which data are there, you need to get the dataset. You need to get familiar with the dataset and do kind of a factor analysis or something like that, cluster analysis. And I just think this is a lot of work already [nervous laughter].

In this quote, Stella was not coming right out and saying that she would not contribute to the project, but she still tried to make it clear that she was uncomfortable with what was expected of her. By indicating to the team how much work she perceived would be involved, she was setting them up for the possibility that she may not be able to commit to that workload.

During this initiative, which lasted about seven months, researchers met to discuss policy documents in their respective fields and give presentations on their areas of expertise. It was thought that by getting everyone up to speed, they would reach a mutual understanding of

modelling concepts and social policy definitions. Work could then start on modelling some policy initiatives to understand how certain policies could influence or affect the uptake of public transport systems.

However, the initiative came to a halt when Reese announced that he was leaving the project to start a new full-time job outside academia. Without him to initiate the meetings, no one picked up the work, so it was left without any meaningful wrap-up. In addition, there was a question mark about how 'useful' the study would have been for the others in the project:

> I guess, it's not really-, it was the transport study I am sure is interesting for everyone, but it doesn't clearly fit in to Stella or Ingmar's PhD work, it's not really something they can take and actually use. I know that they are limited for time and they are asked to do other things in the project as well. I think at that point, it wasn't such a high priority that I really wanted to say, 'you have to put a lot of time into this.' – *Lottie*

Here, Lottie prioritised disciplinary-focused PhD work over the interdisciplinary collaboration and did not pick up the initiative after Reese left. To justify carrying on with the project, it needed to be useful for everyone. Tellingly, Lottie points out that the modelling project did not fit with the work of Stella (from sociology) or Ingmar (from geography), both from the social sciences. From her perspective, she could see how the social sciences served the modelling project by providing social insight and data, but the exercise seemed much less useful in the other direction.

Elaborating on the perceived usefulness of the project and what they were trying to accomplish with it, she said:

> I think it is hard to find-, I think Reese and I were also trying to check that box that we were

> collaborating on something. It would be hard to find a topic that was narrow enough that could fit for everyone to really use. I'm sure it is interesting for everyone but not so useful. – *Lottie*

Here she referred to the interdisciplinary collaboration as a tick-box exercise and an interesting initiative to take part in. However, she expressed that the usefulness of the collaboration was limited to a portion of the researchers in the working group. This idea of usefulness is linked to the objective of having clear outputs. As stated before, Reese imagined the outputs to be small-scale models working on some simple issues. This type of output was considered less useful from Lottie's perspective for the social scientists in the group. Social scientists serving and feeding into an output that would ultimately be a model for natural scientists reflected a dynamic of social scientists contributing to work for others without a clear reciprocal output for themselves.

It seemed clear from Reese's perspective that those working in the social policy theme did not have a clear understanding of the objective of modelling:

> On the other hand, though, perhaps something that we didn't on the modelling side appreciate so much was how difficult it was trying to understand social processes, so this is a field that hasn't been particularly well researched. So, I think that there are two columns there, perhaps from the social side, not properly understanding our approach and how that could lead to an outcome, and eventually hopefully the same outcome as you would actually see. And then being able to predict new outcomes. And that's where the power comes in, you could say, 'well what happens if we tweak this slightly?' and then see what new

> outcome occurs. But also, perhaps us not understanding, perhaps the reason why they take this approach is that some of those social processes are very difficult. I think one of the problems perhaps is where social modelling is at and where perhaps social theory for social sciences is at two different stages. So perhaps neither understand the other particularly well enough. So, yea there are problems on both ends. – *Reese*

This quote illustrated the perceived interdisciplinary divide between the natural and social sciences and the priority to try and close this gap to make progress on the project and do interdisciplinarity. For Reese, the problem lay in the respective scientists not understanding each other, and therefore his responsibility was to communicate the modelling concepts and language to the social scientists. The assumption underlying this quote is that if the social scientists understood what models actually did, they would be more able and willing to work with them.

However, from the social science perspective, the disciplinary divide was actually a difference in world outlook, which is a more difficult problem to solve. In an interview with Lottie, who was also leading this initiative, her scepticism towards a modelling approach did not seem to wane, even as the initiative ended:

> Lottie: […] I think it was something I was a bit apprehensive about because I critique the modelling side in that I think we place a lot of hope that the modelling will fix some of our problems. So I thought it would be good for me to do this project I would be getting more insight into the way that modelling works and their ideas

> about it and how they actually go about developing these models. […]
>
> […]
>
> Moderator: Going back to what you said, about being critical about the modelling stuff, you thought it would be good for you to understand it, now that you have done that, has that had any impact on that thinking at all?
>
> Lottie: No (laughter) I still think I am very critical of it actually.

Lottie was still very critical of the use of modelling in social policy research projects. While Reese understood that social scientists did not fully understand what modelling could do, Lottie did not perceive a lack of understanding to be the main barrier to incorporating modelling into her work. She considered the gap to be that modelling methodologies lacked capacity to understand social problems.

That it was unfinished put this initiative in the category of an interdisciplinary ‘attempt’ rather than successful collaboration because no clear outputs or evidence of the collaboration came from the meetings:

> Reese, that was an interesting one, he was really active in trying to get us together and work interdisciplinarily. I think he did really well in that, he really, really tried genuinely.
>
> […]
>
> Reese really tried yea, but now he’s leaving, but that is how things go. It is a pity. I think it still looks really difficult, but I found it really interesting to see how he would build a model and how he would go about things and I would have been

> open to doing something. It would have then been small questions tackled with data and things, but don't know if there is potential to tackle any social justice issue with that. – *Stella*

In this interview, Stella stressed twice how much Reese *tried* to do interdisciplinarity with the group, implying that ultimately it was unsuccessful. Again, she discussed how interesting the work would be for her to see and understand how a model functioned. However, her ability to see how it could connect with the work she was interested in, social justice issues, remained unclear for her and therefore not as useful. In the end, since a model was not created because of these meetings, this initiative was categorised as an *attempt* at interdisciplinarity rather than reaching a successful conclusion.

This smaller initiative served as a microcosm of the interactions that took place in the wider project. It was an attempt to do interdisciplinarity by those who were motivated. However, since nothing (no outputs) resulted from the interaction and social science researchers categorised the nature of the interaction as a service dynamic, the experiment was ultimately deemed a failed attempt.

6.4 Interdisciplinarity 'failing' to live up to its promise

When a lack of shared vision or even a clear individual understanding of interdisciplinarity was combined with an overall desire to reach the goal of interdisciplinarity, that goal inevitably became elusive and impossible to reach. The researchers' elevation of interdisciplinary research as a gold standard aligned with Stein's proposed evaluation of interdisciplinary projects (2007). This taxonomy of interdisciplinarity is illustrated as an explicitly hierarchical structure, with more complex (or transdisciplinary) research projects on top and less complex configurations (multi-disciplinary) at the bottom (Stein, 2007). This spectrum of integrated collaboration is echoed in the literature about the taxonomy of interdisciplinarity, where Klein categorises multi-, inter-,

and transdisciplinarity respectively on a sliding scale according to an increasing level of disciplinary integration (2010). Researchers understood interdisciplinarity as higher than multi-disciplinary or cross-disciplinary research. Their desire was for the project to reach the integration level worthy of the title ‘interdisciplinarity’. When it was perceived that the research project’s characteristics fell short of this level, researchers were disappointed.

Attempting to reach an interdisciplinary goal created a dynamic of success if attained and failure if not. The researchers experienced emotional anxiety because they felt not enough interdisciplinarity had occurred. This anxiety was echoed in the Sussex Sustainability Research Programme. In this project, Cairns et al. (2020) documented feelings of frustration that expectations had not been met, not only due to opaque expectations of what success would look like, but also the diversity of indicators considered by project participants to constitute a successful collaboration.

By assigning interdisciplinarity as an objective, researchers expected that it would be made clear at some point. However, due to the difficulty of maintaining meaningful engagement with distant disciplines and disagreements over the process of interdisciplinarity, clear outputs of interdisciplinarity were hard to find. Without this evidence in the recognised form of outputs, interdisciplinary engagements were classified as attempts rather than successful outcomes.

6.4.1 Beyond ‘language’

One barrier that researchers clearly identified was difficulty in communicating across different disciplinary languages. Communication is a clearly documented theme of interdisciplinary working in the literature, usually described as a principal challenge to engaging with other disciplines (Bracken & Oughton, 2006; Gibson et al., 2019; MacLeod, 2016; Robinson, 2008) who speak a different language (Darbellay, 2015; Knorr-Cetina, 1981). Disciplines have not only their

own norms that serve to identify them from other disciplines but also their own terminology as well (Henkel, 2000; Repko, 2012). Here, it is important to note both uses of the word ‘language’. It can be used metaphorically, as in the inability to understand another disciplinarian. But ‘language’ can also be used in the literal sense, in that different words and terminology are used or the same terminology is used across disciplines but with different definitions.

In this project, the researchers’ explanations of how they understood interdisciplinarity align with the literature about disciplinary language. Many of the researchers described both the process of interdisciplinarity and the challenges of doing it successfully in terms of ‘language’ and ‘communication’ as they discussed issues of not being understood or interacting with disciplines whose terminology was inaccessible. Some researchers had ideas about how to converge their definitions to reach a shared understanding as a step to move forward in the process of collaborating. Other researchers questioned whether it was possible or desirable to do so at all. Both of these stances are reflected in the literature; the first attitude aligns with the consensus approach and the latter can be seen as reflecting a belief in the incommensurability of different disciplines. However, in this project, it was telling that initiatives to converge definitions into shared meanings were not followed through.

Though it was agreed across the board that researchers had difficulty understanding each other and that this was due to different disciplinary backgrounds, there was not a clear or unified approach for how this communication challenge should be addressed. There was also a concern amongst some researchers that inevitable misunderstandings would arise, leading to a lack of rigour in the research project and thus threatening their disciplinary credibility. Researchers on the project did not have the time or ability to become ‘multilingual’, which would have been needed to legitimately speak and understand another language. This acceptance of the incommensurability of the disciplines functioned

as a legitimate reason to continue to work within the boundaries of a familiar discipline.

However, reducing differences in disciplines to a matter of speaking different languages obfuscates that disciplines can vary fundamentally in their worldviews. For example, although Reese attempted to explain the value and function of modelling to social scientists on the project, scepticism of the value of that research methodology remained. Social scientists' views of modelling as a reductive representation of the real world meant that they saw no applicability for their research in the predictions of the models provided. Whereas for modellers, one of the main goals of their research was the ability to make predictions, as this was considered a functional output of research. They differed fundamentally on what research was *for,* rather than it being an issue of simply misunderstanding each other as they described.

Comparatively, in other interdisciplinary research project, a similar emphasis on language appears across the board. The research respondents in the UK Energy Research Centre (UKERC) report also discussed the importance of the "language barrier" in relation to the extra time needed for interdisciplinary working (Winskel et al., 2015). In that project, researchers commonly discussed the need for disciplines to adjust their terminology or to agree on a common language in order for everyone to be understood. In addition, allocating the time up-front to facilitate exchanges was deemed essential for the interdisciplinary process (Winskel et al., 2015). In the Relu programme, the challenge of language barriers focused less on the extra time commitments and instead centred on the epistemological divide that language highlighted between the natural and social sciences (Lowe et al., 2013). For the researchers in the Relu programme, it was easier for natural scientists to work with social scientists who approached their research quantitatively, particularly economists, because they perceived a shared language in the ability to integrate data sets (Lowe et al., 2013). In the Transition Pathways Project, engineers on the project also commonly

cited language as a challenge to interdisciplinary working and attributed this communication difficulty as a key reason for the extended time needed to conduct interdisciplinary research compared to mono-disciplinary research (Hargreaves & Burgess, 2009). This perspective differed from the social scientists on the project who perceived the challenge as running much deeper, to include differences in problem framing and conceptualisation of worldviews (Hargreaves & Burgess, 2009). In all of these examples, except for the social scientists in the Transition Pathways Project, language was discussed as a barrier that needed to be addressed in order for interdisciplinarity to occur. However, as discussed above, this focus on shared language does not fully capture the role that different worldviews play in collaboration efforts.

A way forward would be to reject the idea that a shared language will solve the problem of disciplinary translation and accept that languages will differ across different disciplines. As the imagined role of disciplines in interdisciplinary projects is to provide diversity in perspective and methods, embracing this difference in disciplinary languages would reflect the importance of this diversity. A working framework that employs Galison's (2010) concept of trading zones, or mutual collaborative spaces between the disciplines, would allow a way forward to collaborating whilst preserving interdisciplinary difference.

6.4.2 Measuring interdisciplinarity

The desire in funding councils for interdisciplinary-oriented projects is discussed in the literature (Brandt et al., 2013; Cuevas-Garcia, 2015; Lam et al., 2014; Larivière & Gingras, 2014; Schoolman et al., 2012; van Noorden, 2015), as well as how precarious it can be for junior researchers (Byrne, 2014; Cuevas-Garcia, 2015; Frickel et al., 2017; McBee & Leahey, 2017). However, the tensions these two issues can create between junior and senior researchers on a project is not often discussed. For some of the senior researchers, it was important for the interdisciplinary aspect of the project to shine through, demonstrating to

the funder that this objective was reached. However, the junior researchers on the project prioritised their disciplinary-specific PhDs and publishing in journals recognised in their subject areas.

A clear source of tension was the focus on outputs to evidence interdisciplinary work, as interdisciplinary outputs recognised by the academic environment are hard to come by. The university's disciplinary academic structure pressures researchers to publish within their field of expertise. This expectation of outputs as evidence is then applied to an interdisciplinary working structure, where there are fewer incentives to collaborate because it is seen as unproductive. In addition, depending on how far two disciplines are from each other, papers might not be accepted in a journal recognised in either field. The incentive structure to collaborate does not encourage interdisciplinary collaborations, and the ability to glean evidence of interdisciplinary collaborations is hard to come by. This translation of incentive structures from disciplinary expertise to interdisciplinary working sets researchers up for disappointment.

The need for outputs as evidence of interdisciplinary 'attempts' leads to interdisciplinarity both being desired and not desired at the same time. Interdisciplinarity is needed to gain funding, which is a necessity for academics on at least two counts. First, external funding sources are needed to conduct projects on university campuses that do not have permanent funds allocated for research, particularly in the social sciences and humanities. Secondly, academics (particularly senior academics) must demonstrate that they can attract funding, an important indicator for success. And yet, at the same time, the discomfort of venturing too far outside of a disciplinary home is perceived as risky, particularly for more junior academics. At the junior level, desire to establish credibility and build disciplinary expertise is incentivised through disciplinary-oriented academic departments which favour high quality published work in largely disciplinary-oriented journals. Publishing in a specific field and being awarded a PhD is not

seen as synonymous with interdisciplinary collaboration, and a choice must be made for one over the other.

The requirement of clear outputs in the form of published academic papers stems from the academic model of publishing work in a discipline to advance an academic career. This is an important metric for academia; however, translating this metric to measure interdisciplinary work presents a difficulty, as there are not existing pathways within academia to measure interdisciplinary work in the same way. Further analysis of academic peer-review and knowledge production is given in Chapter Seven. For the purposes of this chapter, it is important to note that the process of doing interdisciplinary work needs recognition in itself, because valuable collaboration does not always lead to published work.

In his reflections on working as the director of the Tyndall Centre for Climate Change Research during 2004 and 2005, Hulme (2006) called for establishing new systems that can recognise interdisciplinary research efforts. From his experience with that interdisciplinary sustainability project, Hulme identified the difficulty for research councils to adequately evaluate interdisciplinary research projects for funding. For him, the existing system in which disciplinary experts evaluate interdisciplinary proposals is a system that fails to capture the complexities of interdisciplinary research, causing the rejection of many deserving interdisciplinary projects. Also, importantly, he called for different ways to monitor the performance and impact of interdisciplinary approaches, as traditional measures of output are inadequate to capture their impact (Hulme, 2006). It was difficult for Hulme to get funding for interdisciplinary projects within the current disciplinary-oriented research environment and hard to assess interdisciplinary projects when awarded funding.

From a funding perspective, the research project I studied had a different experience. While Hulme identified the inadequacy of research councils in the UK at recognising good interdisciplinary proposals, the

Leverhulme Trust, which is not oriented along disciplinary lines, actively called for and welcomed non-traditional interdisciplinary approaches to research. Hulme's reflections were also published in 2006, before the establishment of many proactive measures by UK research councils to support interdisciplinary research efforts. From the perception of researchers on this project, interdisciplinarity was a way to attain research funding, not a barrier to it.

However, in the researchers' reflections of their experiences on this sustainability research project, they identified a need for new measures to recognise interdisciplinary efforts, if only for work morale and accountability purposes. As in Hulme's reflections, the academic environment in this case only assessed and validated good research from a disciplinary perspective. As potential interdisciplinary interactions did not directly result in academic papers or contribute to obtaining PhDs, interdisciplinary touchpoints were not deemed a successful part of the research project. In Hulme's reflections, he asked if ways of measuring the actual use of new interdisciplinary science developments in policy making could replace citation statistics as an indicator of success (2006). This research project raises the question of whether there are alternative measures to could gauge the level of input different disciplines have in influencing established research approaches, ways of thinking and methodologies?

6.4.3 Interdisciplinarity as 'service'

In the literature, a service dynamic is recognised as being on the spectrum of interdisciplinary collaborations. Barry and Born (2013) outline a *subordination-service* mode of interdisciplinarity, in which a discipline takes on a service role to other component disciplines on the project. In this mode, which is commonly occupied by the social sciences in mixed social and natural science interdisciplinary projects, the discipline in service is seen as filling in holes or providing a puzzle piece for the other master disciplines (Barry & Born, 2013). Klein (1996) describes this mode of collaboration as instrumental interdisciplinarity,

where a (usually social science) discipline is only brought in for a methodological contribution and not recognised for its epistemological, theoretical or conceptual contributions. The social science researchers on the project perceived the interdisciplinary dynamic to reflect this *subordination-service* form, so it is highlighted for analysis here.

In the sustainability project, the social scientists occupied this space of service in a mixed natural and social sciences research project; however, it was not universally recognised as an interdisciplinary collaboration. Though the models ('Lego blocks') in this project were imagined to act as the integrating function of the disciplinary contributions, as explained in Chapter Four, they failed in practice to do so because the natural and social scientists disagreed on their integrative capacity. As the overall foundation of the project was based on working towards modelling outcomes, the natural scientists on the project sought interdisciplinary collaboration in the form of social scientists providing a different perspective to make their models better. However, this service dynamic was not recognised as a legitimate form of interdisciplinary collaboration by the social scientists in the group. They did not perceive that they were adequately recognised for their ability to contribute on an intellectual (epistemological, theoretical, conceptual) level by the natural scientists or the modellers. This failure to be recognised as equal partners in the research was perceived as a failure to do true interdisciplinarity.

These instances reflect the ongoing perceived disciplinary divide between the natural and social scientists on the project, as well as a perceived hierarchy of the disciplines that seems to characterise recent interdisciplinary projects (FET Advisory Group, 2016). For the social scientists, this can certainly carry a negative connotation. For example, in Ribes's (2019) analysis of Science and Technology Studies collaborations with data science, he describes the situation of becoming a service science as a "danger" (p. 517). In that paper, he advocates for a "broadening of the understanding and role of social science beyond

‘implications for design’ [Dourish, 2006]” (2019, p. 532). Indeed, in this project, the idea of being a service discipline held the same negative connotation and spoke to the emotional tensions in the project previously discussed in Chapter Five. Without recognition of the value of all team members or respect for diverse epistemological and conceptual approaches to producing knowledge, a collaboration between different disciplines can be harder to establish. A further analysis of hierarchical structures within research projects is given in Chapter Seven. For the purposes of this section, it is important to note how research projects on the micro-level reified the disciplinary hierarchy at the macro level.

However, from the perspective of the natural scientists on the project, the interaction with the social scientists on the project was a form of an *integrative-synthesis* mode of interdisciplinarity (Barry & Born, 2013). This mode of interdisciplinarity describes the integration of two or more disciplines on a relatively equal or symmetrical basis (Barry & Born, 2013; Mansilla & Gardner, 2003). For the modellers on the project, the integration would take place in the modelling, (or Lego building blocks). For the natural scientists, what was lacking on the project was that form of engagement by the social scientists: their work did not appear enough in the models and therefore did not make the project as interdisciplinary as it could have been. A disciplinary hierarchy was not perceived or reflected in any of my discussions with the natural scientists on the project.

Barry and Born (2013) recognise the *subordination-service* mode of interdisciplinary working as a legitimate form of collaboration. However, the social scientists on the project did not. A shift from thinking about how interdisciplinarity *should* function to recognising the different ways interdisciplinary projects can be organised may change the perception that a failure to reach an *integrative-synthesis* mode of interdisciplinary collaboration necessarily is a failure to do interdisciplinarity at all.

Researchers at UKERC directly engaged with these different interdisciplinary configurations in their reflections report. At UKERC, a *subordination-service* mode of interdisciplinarity was recognised in individual project collaborations, namely the Energy 2050 project. The Energy 2050 project took place during the first phase of UKERC's research programme and was explicitly designed to facilitate further integration of the different disciplinary teams, who were also organised into themes much like the project studied in this thesis. The Energy 2050 project also fundamentally had a modelling focus (Winskel et al., 2015). The researchers at UKERC considered this an exercise in interdisciplinarity in that it "forced interaction between modellers and social scientists" (Winskel et al., 2015, p. 68). Due to the strong focus on modelling, interdisciplinary interactions on the Energy 2050 project reflected a *subordination-service* variety as reported by the research participants. In that project, modellers focused on easier to model technical and environmental issues but neglected more difficult to model socio-environmental issues, such as public attitudes (Winskel et al., 2015).

In the project I studied, even though the natural and social scientists disagreed about how integrative the modelling methods were in assimilating the various disciplinary findings, they all expected that an integrated mode of interdisciplinarity was the preferred configuration. However, as Cairns et al. (2020) outlines, even assigning a preference towards an integrative form of interdisciplinarity is problematic, as this assumes a shared understanding of the 'ideal' research configuration. For the natural scientists, integration strategies operated at the computer modelling level and so came in later in the research phases; however, for the social scientists, the preferred integration method would have taken place sooner in the research, although it was unclear how or when.

The disciplinary divide between the modellers and the social scientists occurred in both this project and the Energy 2050 modelling project. In

both scenarios, the modelling aspect of the project was seen as the principal integration tool and functioned to encourage social scientists to engage with modelling principles and methodologies. However, due to the social scientists' subordinated role in contributing to the models, the exchange did little to encourage the modellers to understand social science methodologies or principles. Whilst UKERC's Co-Investigators explicitly engaged with the different modes of interdisciplinarity, researchers on the urban sustainability project did not. Therefore, the social scientists recognised the exchange as unequal, and did not consider the collaboration to be a legitimate mode of interdisciplinarity.

Participants in the urban sustainability project evaluated interdisciplinarity to have failed, given the perceived failure to communicate or reach shared definitions, the lack of outputs to evidence successful interdisciplinary collaborations and the asymmetry between the social and natural sciences. However, as illustrated in the discussion above, the perceived failure was more to do with a lack of codified evaluation structures in place, making it difficult to deem the interdisciplinary collaboration successful. Researchers experienced uncertainty when trying to work together, which is a characteristic of interdisciplinary collaboration and a shared experience amongst other interdisciplinary research projects conducting research on sustainability. Interdisciplinarity was an exercise in being uncomfortable.

6.5 Interdisciplinarity – an exercise in being uncomfortable

In the critical incident and the wider project, interactions proved to be uncomfortable for the researchers. The extra work to try to understand a different discipline and conflicting perceptions of social science's role in the project initiated tensions and pushback.

In the literature, interdisciplinary interactions are commonly described as working outside of one's comfort zone (Bridle et al., 2013). In an interdisciplinary study involving an underwater robot, venturing outside of one's disciplinary comfort zone and taking risks was cited as the

point at which the research advanced to interdisciplinary heights (McNair et al., 2015). The metaphor of a “home discipline” (Balaban, 2018) also describes the security that a strong ‘column’ of disciplinary expertise can provide. From this perspective, a disciplinary home is a space that provides a secure foundation where researchers feel comfortable, and interdisciplinary interaction is characterised by risk and uncertainty and therefore discomfort. Bokert (2018) sees this discomfort as inevitable and even a prerequisite for interdisciplinary collaboration. Overall, interdisciplinarity, as observed in this project, is an exercise in being uncomfortable.

Aligning with the literature above, my research documented sources of conflict, emotional tension and the inability to speak another disciplinary language as evidence that interdisciplinarity was uncomfortable. As this was such an important point, below I outline further examples of anxiety and discomfort.

As introduced in Chapter Four and detailed further in Chapter Five, a large disciplinary divide existed between the social and natural scientists regarding different administrative requirements and cultural practices. Throughout the project, it became clear that this divide also manifested along methodological lines. The social scientists perceived the modellers’ work as an oversimplified representation of the ‘real’ world by depending on assumptions of relationships between two or more factors. The natural scientists found it difficult to turn social science outputs and conclusions into useful information they could model or use as indicators for a model. During an interview, a social scientist recalled efforts to workshop together with the natural scientists at the beginning of the project using causal loop diagrams as an exercise. Though this was a completely foreign concept to her, she made efforts to understand the rationale and thinking behind this work:

> But then we would always get a bit stuck on something, partially because of the simplicity of some of the assumptions you have to make in

> models like that, just because it is too simplistic for social scientists. And I felt like you get pushed outside of what you actually know about if you start making claims about 'well if the price of this goes up then that happens.' Well, I don't know that there are people who dedicate their entire academic careers onto researching something like this whereas I did 10 minutes brainstorming. I don't feel confident to say that *x* will happen if *y* happens, and this is what causal loop diagrams assumes. They describe meta-relationships and you just say well the model can do this and if this is true in the real world that if this happens that happens then in the model. – *Elisa*

This quote speaks to how doing interdisciplinary work is not considered desirable for a career as a disciplinary expert. For Elisa, being a disciplinary expert felt more comfortable than having broad experience in multiple fields or being a 'jack of all trades'. For example, she stated that the assumptions made were "too simplistic for social scientists", implying that this work would not be considered rigorous or legitimate research in her field. She felt uncomfortable because working with these assumptions was outside of her expertise and also the social themes they were working with in the exercise were outside of her comfort zone. Other "people [social scientists] […] dedicate their entire academic careers" to work in these areas. To make conclusions or statements outside of her expertise made her uncomfortable.

Working outside of a disciplinary home means working outside of a comfort zone. There is no certainty regarding whether the research is done right and some hesitation around what experts would say about a researcher dipping into a different disciplinary field. In a Progress and Integration meeting, researchers discussed what social phenomena could be modelled. Some raised ideas around education in the city and

how educational attainment levels could be integrated into a social model. In response to this suggestion, a social scientist pointed out:

> Bruce: you have indicators of course, people not going to higher education, below average and so on, dropping out of school. But what do you do with that? Future strategies, I mean, we have no expertise and credibility in developing that.

A lack of the right “expertise” on the project speaks to the perceived need to have the right disciplinary ‘columns’ in place in order to engage with a disciplinary subject area. In this project, there was no social science expert on education or societal inequality; Bruce was speaking to the lack of disciplinary experts on these issues within the project who could credibly develop such a piece of work. Even more telling, Bruce’s concern at their lack of “credibility” if they engaged in issues of education indicated discomfort in attempting to engage with this stream of work. He felt more comfortable sticking with the disciplinary homes that were incorporated into the project.

The desire to keep working within their fields of expertise was clear for senior researchers themselves. In a debate about how to deal with any future issues regarding interdisciplinary co-authorship, senior academics reflected on hypothetical scenarios and how they would approach different situations:

> Otillie: I mean, I would say no if Stella was writing a paper and she came to me and said – you know, ‘because we’re on a project together you should be on this paper’. I would say no because I’ve not had that actual input that you could measure.
>
> Joseph: But not at the end, do you want to be on this paper, at the beginning, do you want to—

> Otillie: No, no, even at the beginning. Because when – as an academic you are known for *x, y, z,* I think it would be a bit of a stretch for me [laughs]—
>
> Xavier: You need to go and read this week's Times Higher then, about people writing totally outside their discipline. Very interesting.
>
> Otillie: I'm sure people will do that.
>
> Xavier: Yeah. But the point about an interdisciplinary project is you're actually dipping your toes into other epistemologies and other ways of doing things. And that's part of the interest and the reward of a project like this.
>
> Otillie: Yeah, but for me, me dipping my toe within the data theme was enough.
>
> Xavier: [Laughs] Okay, that's fine.

While Xavier recognised the "interest" and "reward" in working with approaches outside of his discipline, Otillie maintained that just "dipping" her "toes" into a disciplinary theme adjacent to her own was enough of a "stretch" for her. This statement implicitly differentiates between the ease of working with a discipline nearer to her and a social science discipline that she considered too far. The priority was to stick with what she was "known for" in academia, as it protected her credibility as a researcher. The danger of writing in another discipline meant that the research might not be recognised as legitimate. Sticking her neck out too much felt risky for her. So much so that she would decline an invitation to work with another researcher on the project if she did not have any measurable input to document a legitimate collaboration.

To revisit Elisa's quote from Chapter Five, she expressed anxiety when it came to co-authoring a piece of work with a methodology outside of her discipline because she was concerned with maintaining credibility in her academic discipline:

> Elisa: […] but to go back to the simulation question or what may be in this project, it may be an output of collaborative work from this project which may be a combination of […] modelling, with some social science on fuel poverty and population characteristics. There are some core tensions around assumptions, around scientific method. […] Not that this is something that we can't overcome, but the ultimate problem for me is credibility. So, I could spend several afternoons in a workshop with colleagues here, come up with very imaginative solutions to these problems but I don't want to lack credibility when it goes out to-, because I haven't got the expertise to scrutinise it, this sort of creativity that I am talking about. I could see that this can be done, but I would need assurances that this type of exercise is one that is accepted and not-
>
> […]
>
> Exactly, this is the core tension, this is the core insight from working in something like-, but these are the anxieties that people like me and Henry have […]

Like Otillie, stepping outside into a different disciplinary domain was anxiety-inducing, because the inability to understand the language of another discipline means that the researcher cannot adequately ascertain if a methodological approach is sound or robust. Existing modes of traditional quality control in the form of peer review within

academic disciplines do not provide avenues to evaluate approaches or methods outside of those disciplinary boundaries; trust is needed in order to overcome feelings of uncertainty.

In general, co-authors want to agree and support the intellectual findings that they put their name to. Within disciplines, there are various schools of thought that determine the trajectory of research findings. For example, an economics critique based on theories of rational decision-making will come to a different conclusion on the role of regulators in the financial system than a Marxist will. However, co-authoring across distant disciplinary creates an additional layer of tension if there is not a shared practice of evaluating rigour. This tension is unique to interdisciplinarity, and it had the power to discourage collaborations between distant disciplines in this project.

Here, the disciplinary 'columns' were strongly reinforced. Although outputs were desired to evidence interdisciplinary collaboration, the need for outputs ultimately incentivised work within specific disciplines. As disciplinary expert 'columns' were brought onto the project to provide and share their expertise, researchers expressed apprehension about contributing to knowledge outside of their own expertise due to credibility issues. The academic incentive structures and departmental norms that determine research rigour were regulated by disciplinary 'columns'. In this project, though disciplinary expertise was considered a necessity for interdisciplinarity, it seemed to function as a barrier to interdisciplinary working.

6.6 Conclusion

The overall sentiment of the project's participants was that it had not lived up to its promise of integrated interdisciplinary working. Interdisciplinarity did not deliver on its promise of incorporating new ideas or producing innovative solutions to the researchers' questions. In fact, from many of the researchers' perspectives, true interdisciplinarity was not reached on this project, as the social scientists did not accept

the *subordination-service* model of interdisciplinarity and rejected it in practice. It appeared that just building a project from the beginning was not enough to make interdisciplinarity happen, and even the desire and motivation to do interdisciplinarity was not enough to achieve it either. Therefore, in this chapter, the building metaphors were largely absent as they did not function as expected to make interdisciplinarity occur. Particularly notable was the imagined integrative function of the models ('Lego blocks'), as the social scientists on the project rejected the contribution of data or indicators as an inadequate research contribution and so did not participate in the model development. As a result, existing disciplinary divides and university incentive structures were prominent in this project and served as obstacles to interdisciplinary working.

As illustrated by the critical incident, interdisciplinary exchanges and outputs were difficult to measure, so it was hard to evaluate the success of the interdisciplinary nature of this project. In the absence of separate criteria to measure interdisciplinarity, researchers tried to apply output measures from academia to gauge interdisciplinary success. However, due to the inadequacy of the university system to facilitate and judge interdisciplinary work, these measurement criteria were inappropriate.

In attempts to do interdisciplinarity, researchers tried to converge their language to a central, agreed-upon meeting point, and they expected that their research methodologies would be on an equal playing field. However, as their attempts to do interdisciplinarity did not result in a shared language or equal participation in the development of methodologies, this was read as a failure to do interdisciplinarity. These assumptions failed to consider the diverse nature of the disciplines and other configurations of interdisciplinarity this project could exhibit. It was inevitable that working with different disciplines would result in miscommunication and diverse ways of working, and therefore, that doing interdisciplinary work would be uncomfortable.

In Chapter Seven, I unpick the dynamics of conducting an interdisciplinary research project within an academic environment by using a knowledge production framework to characterise interdisciplinary and disciplinary working structures.

Chapter 7: How can we understand the configuration and outcomes of this project?

7.1 Introduction

While the comparison of interdisciplinary research projects on sustainability in previous chapters provides a useful reference point for the sustainability study (Hargreaves & Burgess, 2009; Hulme, 2006; Lowe et al., 2013; Winskel et al., 2015), those reports' conclusions are empirical in nature. What is missing from the literature on interdisciplinarity is a theoretical explanation for interdisciplinary research project outcomes.

This analytical chapter considers this failed promise of interdisciplinarity and applies Gibbons et al.'s (1994) New Production of Knowledge (NPK) theory to try to understand the gap between the expectation of success and the perceived outcome of failure. It answers the research question: 'How can we understand the research in light of theoretical frameworks?'

After exploring three theories about modern knowledge production (Triple Helix theory, Post-Normal Science and NPK) in the literature review, I identified the NPK theory as having the most parallels with the configuration of this research project as the Mode 2 concept engages the most explicitly with interdisciplinarity and with the university as a site for knowledge production. This chapter takes this concept forward as a theoretical framework to understand this thesis's research findings.

In *The New Production of Knowledge,* Gibbons et al. (1994) introduce Mode 2 knowledge production. The authors argue that a way in which knowledge is being produced is transforming into a distinct knowledge formation called "Mode 2". By identifying new features of knowledge production such as increasing social accountability, the authors claim

that these changes are a reflection of changing social relations between traditional knowledge institutions (such as the university) and society.

Re-thinking Science by Nowotny et al. (2001) is a follow-up to the *The New Production of Knowledge.* It continues to describe the changing, dynamic relationship between society and science but goes further by focusing on re-thinking the social contract between science and society. They argue that science must be more accountable to society, to increase the connection between science and society. In this chapter, I refer to the two main seminal works on the NPK theory, *The New Production of Knowledge* (Gibbons et al., 1994) and *Re-thinking Science* (Nowotny et al., 2001), and their engagement with the modern university.

The NPK, as Chapter Two explains in detail, outlines specific characteristics of a Mode 2 knowledge configuration. Cross-disciplinary collaboration is emphasised as a feature of future research approaches. It also focuses on the changing role of the university as a site of knowledge production. The five characteristics of Mode 2 research are: context of application, transdisciplinarity, heterogeneity, heterarchical structures and a socially accountable approach to research (Gibbons et al., 1994).

By assessing components of the sustainability research project against the five characteristics of Mode 1 and Mode 2 research, I aim to understand how the project was constructed and how these constructions determined ways of collaborating. Within this analytical framework, I also compare this project to other interdisciplinary projects in the sustainability realm. Comparing and contrasting other similar project configurations help to contextualise this project's outcomes.

7.2 The New Production of Knowledge

In order to make sense of the gap between the expectations and outcomes of the project's interdisciplinary aspects, it is useful to

contextualise the findings within a theoretical framework that addresses how scientific knowledge is diagnosed, produced, reified and is understood. As this project was imagined to be ambitious and innovative, clear efforts to configure and build an innovative and ambitious project. Yet, there was an overriding consensus amongst the group that the coveted interdisciplinary aspect of the project failed to materialise. If all the project members were brought together, willing to work together and motivated by senior leadership and the presence of an interdisciplinary researcher, why did interdisciplinarity not happen?

Two modes of knowledge production, Mode 1 and Mode 2, are compared against each other. Mode 1 is largely described as knowledge for knowledge's sake, whereas Mode 2 has more criteria for undertaking a research project, including its relevance and utility for society (Gibbons et al., 1994). According to the authors, Mode 2 knowledge production actually grew from Mode 1; however, rather than overtaking Mode 1 forms of knowledge production completely, the two modes continue to exist alongside each other (Gibbons et al., 1994).

In *Re-thinking Science,* Nowotney et al. (2001) further build on the NPK thesis by describing the emerging dynamic relationship between society and science, which they theorise is the main cause for the shift from Mode 1 to Mode 2 forms of knowledge production. A Mode 2 society is characterised by increased uncertainty and complexity, which puts pressure on science to be more open, contextual and epistemologically sound. The existing standards to measure quality research in Mode 1 forms of knowledge production are no longer adequate to meet society's demands for a transparent and interactive relationship between science and society. Therefore, additional standards, including increased levels of societal participation, societal relevance and proven societal 'good' are additional research criteria required in Mode 2 science (Nowotney et al., 2001). This relationship between society and science in a Mode 2 world has a two-way dynamic, where science and society speak to and influence each other. Incorporating a two-

directional interaction erodes the demarcation between science and society.

In this two-way relationship, the space where science and society interact is called the *agora* (Nowotney et al., 2001). The agora is the public space where science meets the public and where the public then speaks back to science. In this space, the robustness of science is tested against the measurement criteria of a Mode 2 production of knowledge framework (Nowotney et al., 2001). Following the assertion that the demarcation between science and society is eroding, the agora represents a “plural and democratic environment” (Nowotny et al., 2001, p.55) where experts from all backgrounds meet and interact to evaluate scientific goals.

Nowotny et al. (2001) then turn to apply the NPK theory to the modern university. Nowotny et al. (2001) explain that although the university has historically been the principal site for knowledge production, it is increasingly becoming just one of many locations where legitimate knowledge is produced, alongside think tanks, research institutes and private sector partnerships.

In addition to being one of many sites of knowledge production, the university itself is undergoing fundamental change (Gibbons et al., 1994; Nowotny et al., 2001). Nowotny et al. (2001) argue that universities are undergoing a transformation in the way that they produce knowledge, moving from traditional, disciplinary institutions to more socially situated and distributed environments. One of the reasons for this transformation of the university is pressure from society and national governments on research councils to fund and contribute to ‘relevant’ research (Nowotny et al., 2001). Gibbons et al. (1994) state that “practices associated with the new mode [Mode 2] are already creating pressures for radical change in the traditional institutions of science, particularly the universities and national research councils.” (p. 31). Given the integral role that research councils play in providing funds for research and assessing research progress, these institutions

have significant influence on the direction of universities' research agendas. Therefore, universities that have traditionally embodied Mode 1 characteristics are now evolving to 'Mode 2' universities, reflecting their changing research focus, orientation and how they are assessed.

The description and development of these modes is highly theoretical, described by the authors as a reflexive exercise of the current state of knowledge production (Nowotny et al., 2003). This chapter attempts to take my empirical research study and hold it up to these two modes of research to find how they can be used as a tool to conceptualise the project's research configuration.

7.3 A Mode 2 research project?

Though the researchers on the project themselves did not engage explicitly with theoretical configurations of knowledge production such as Mode 1 and Mode 2 research, it is clear the project's developers meant to create new, innovative ways of producing knowledge about urban sustainability. A cross-disciplinary project influenced by the priorities of the funder and aiming to disseminate research outside of traditional academic channels, this project appears to reflect the Mode 2 research transition that Gibbons et al. (1994) describe. Interdisciplinarity was meant to provide a more 'holistic' view of assessing urban settlements compared to previous disciplinary research endeavours. The language of the project's funder that cross-disciplinary approaches are more appropriate for 'future' research matches the NPK thesis that Mode 2 is an 'evolved' form of research (Gibbons et al., 1994).

Through application criteria and assessment processes, a funder can influence projects to organise research in an interdisciplinary way. For example, the Trust "favours applications that surmount traditional disciplinary academic boundaries" (Leverhulme Trust, 2018). In addition, proposed projects must be "significant", in that they must have "relevance outside a single field, and [be] able to excite those working in other disciplines" (Leverhulme Trust, Our approach to grant-making).

The Trust also awards grants that “enable a refreshing departure from established patterns of working” (Leverhulme Trust, 2018), indicating that the Trust wants to push research out of traditional modes of working into something new. This relationship between the funder and the research project reflects the trends outlined in ‘Mode 2’ research. Responding to this clear priority for interdisciplinary-oriented projects, researchers shape themselves in an interdisciplinary way to be awarded funding in a competitive funding landscape.

The sustainability research project also aimed to extend its knowledge outside of the walls of the university by publishing findings and making models available to practitioners in industry. Though this external engagement was not required by the funder, the desire for impact was initiated by the project’s Principal Investigator. Engagement with stakeholders in the form of consultations, policy recommendations and eventually “tangible city action plans” were all cited in the proposal document as dissemination pathways for the research. By extending the research beyond academic journals and peer-reviewed quality control channels, this research reflected a Mode 2 configuration.

In the following sections, I compare the characteristics of the sustainability research project against the following five criteria differentiating Mode 1 and Mode 2 forms of knowledge production: research in an academic context versus a context of application, disciplinary versus transdisciplinary research, homogeneity versus heterogeneity, academically accountable versus socially accountable and reflexive, and peer-review quality control versus socially-situated quality control. (To reference again, see Table 2-2 in Chapter Two.) These comparisons help contextualise the configuration of the interdisciplinary research project as embodying either Mode 1 or Mode 2 research.

7.3.1 Academic interest versus context of application

The first attribute of Mode 2 knowledge production is that it is carried out in the context of its application, such that it is "intended to be useful to someone in industry, government or society more generally and this imperative is present from the beginning" (Gibbons et al., 1994, p.4). In Mode 2 forms of knowledge production, research is carried out within the "new utilitarian science regime" (Nowotny et al., 2001, p. 76), in which science must be held accountable to public 'usefulness' and demonstrate its benefit to society. Gibbons et al. (1994) argue that funding, policy and public pressures are responsible for this change, creating a desire for universities to be more accountable in their research. In the traditional Mode 1 version of knowledge production, scientific research can be carried out in the absence of a particular goal, as the pursuit of 'doing' methodologically sound science is seen as legitimate enough. The goal of Mode 1 research is "defined in relation to the cognitive and social norms that govern basic research or academic science" (Gibbons et al., 1994, p. 4). For example, the goal could be to further the application of the discipline or develop a new theory to be applied within it. The main difference between these two modes is what and who the research is for.

For the sustainability research project studied in this thesis, the larger research objective as a whole seemed to be for the case study cities and specifically for employees in Nottingham City Council to understand what actions could be taken in order to make their city more sustainable. This would make the project Mode 2 by the standard of context of application. However, upon looking further into the smaller projects undertaken within the larger project, much of that research tended to take a Mode 1 form: it was academically contextual and functioned to further disciplinary understanding.

An example of the contextual application of this research project stemmed from the anticipated engagement this research would have with Nottingham City Council. Discussions in Progress and Integration

meetings debated how the Council could use the findings from the research project and how much the researchers could realistically provide them:

> Xavier: And I think what we need to be careful with the proposals bit is where you say achievable with existing resources, I think you need to say who you had in mind, what's that resource, and they can confirm what it is they can actually deliver. Because if I was reading this in the City Council my expectation may be different to what the researcher or PhD student may be able to deliver within their project. […] That could mean two days' worth of work by whoever was doing the research, or it could be a three-month piece of consultancy work targeted to a proper economic appraisal of different types of energy generation, of pay back times and so on.
>
> If I was sitting in the city, I would want the latter, but we probably would deliver something nearer the former. I just think we need to be careful we don't promise more than realistically whoever's name is behind each of these paragraphs can realistically deliver.

In this quote, the researcher communicated apprehension about the level of engagement the group should promise to the Council. Xavier wanted to make it clear that the research could provide useful findings to the Council, but not on the level of a private consultant. Although these discussions took place prior to engaging with Nottingham City Council, the issue resolved itself because discussions with the Council started and ended with a joint workshop on campus. Further contact with the Council about additional work or how the project could contribute to their aims did not take place.

Other aspects of the project followed a Mode 1 form of disciplinary application rather than a Mode 2 form of contextual application. Some of the smaller individual projects and many of the published articles from the research project were the result of disciplinary-oriented research. For example, some of the mathematical modelling was very abstract. In one project, a natural science researcher wanted to explore the key factors of residential choice amongst city citizens; however, this 'city' was hypothetical. The focus of that paper was the methodology and equations that were utilised to reach the conclusion, rather than the conclusion itself. In this example, the problem was academically focused, providing novel research methodologies to feed back into mathematics as a discipline; in other words, it was feeding back to the disciplinary 'column' from whence it came.

In the research project, a wider objective included action plans or recommendations for Nottingham City Council to take forward and make their city more sustainable. However, these outputs did not materialise in practice. The outputs that were centrally tracked and measured across the project were mainly a list of academic publications, furthering academic knowledge. The wider goal of creating applicable research did not translate to the smaller projects within the wider project, therefore making this project Mode 1 as judged by this characteristic.

7.3.2 Disciplinary versus transdisciplinary

Another attribute of Mode 2 knowledge production is that it is transdisciplinary rather than Mode 1's characteristically mono-disciplinary research. In transdisciplinary research, the "final solution will normally be beyond that of any single contributing discipline" (Gibbons et al., 1994, p.5). Gibbons et al. (1994) outline four characteristics that define transdisciplinary knowledge production: 1) a creative, distinct framework that guides problem-solving efforts; 2) a contribution to knowledge that is not necessarily disciplinary-focused but creates research methods that are developed for the specific

project; 3) dissemination of results via non-traditional channels; and 4) discoveries existing outside of the disciplinary mode of validation and which can be applied to various contexts (Gibbons et al., 1994). Disciplinary (Mode 1) knowledge speaks back to itself, has its own methodologies to draw from and the dissemination of results takes place through traditional communication channels. Transdisciplinary (Mode 2) knowledge production operates in a two-way communication loop in which researchers from different organisational structures speak to one another and receive feedback (Gibbons et al., 1994). In this study, I focus on both the non-disciplinary configuration (interdisciplinary) and transdisciplinary (outside of disciplinary expertise) aspects of the project.

A principal objective of the sustainability project was to work outside of the disciplinary confines of research and develop new ways of working amongst members of the team. The goal was to create outputs that would go beyond the contribution of a single discipline. In order to understand the perceived degree of cross-disciplinary collaboration, this section looks at the extent to which researchers felt that they used new methods, applied new theories and worked in new ways. This section also investigates the results of interdisciplinary collaboration in the form of research output. In the research project, there was not a single output that could be credited towards the project as a whole; rather, there were multiple outputs from a variety of efforts within the project. This section looks at some of the collaborations and outputs that took place in shared spaces.

The researchers who drafted the funding proposal purposely included expertise from multiple departments across the university, spanning the natural and social sciences. The intention was that once the disciplines were brought together, ideas would flow between them, making connections between two distinct strands of work. This movement of information from one discipline to another mirrors the flow described in Gibbons et al.'s (1994) description of how information flows between

previously disconnected disciplines. Information may also flow between science experts and members of the public. This flow is facilitated by the increasingly permeable boundaries between these bodies of distributed knowledge (Gibbons et al., 1994).

However, placing the researchers together on one project and removing them from their disciplinary academic buildings was not enough to create a flow of information. Such a flow was not felt by researchers on this project. A senior academic in an interview discussed the institutional barriers to knowledge flow, despite having a co-located space (‘dancefloor’) in the form of a shared office:

> I think there’s been a success in having the research assistants all co-located so that they do learn from each other. But I think the problem is with structures, is that sometimes it doesn’t quite allow for that real free-flow. […] So, you have one post-doc in this area, one post-doc in this area. In some ways, I think if you wanted an interdisciplinary project to work, I think the funding agency needs to say, okay, we’ll just give you the money and see how things bubble up. – *Ottilie*

For Ottilie, the prescriptive nature of pulling from clear interdisciplinary boundaries confined a researcher to their “area” or theme; the structure prevented a “bubbling” or flowing of knowledge between disciplinary boundaries. Even though spaces for interdisciplinarity in the form of shared office space and Progress and Integration meetings were provided, this was not enough to create organic interdisciplinary ideas within the project. Not only does this illustrate that only providing the space (‘dancefloor’) for cross-disciplinary action was not enough to create interdisciplinarity, it also shows that the disciplinary ‘columns’ maintained their strength and clear identity throughout the project’s lifetime.

There was some feeling that the Progress and Integration meetings were not fulfilling their integrative function, so the meeting format was changed temporarily from a round table to a workshop format. In this new format, a research question or a problem was posed and researchers then broke up into smaller, disciplinary-mixed groups to brainstorm and address possible approaches. However, though knowledge was shared, researchers still perceived a lack of integration on a larger scale happening in Progress and Integration meetings:

> Genghis: I think most of the integration actually happens during [Progress and Integration] meetings. So, there are discussions raised and it's not the modelling itself that could be—
>
> Bruce: Yeah, but I think the meetings at least from my perspective are not really integrating, because the updates we get are brief and often enigmatic, unless someone makes an effort to say, what do you mean by that? […] it's like—you know, on all sides of the project, my feeling is that the integration doesn't really happen at these meetings. And changed the format, there are no longer long and technical slides, but they are shorter, enigmatic statements. And not much is coming out of that, just by putting these into the room, right?

For Bruce, the action of simply putting people together in a room to update their respective disconnected pieces of work did not function to integrate and connect them. It was not enough to superficially know what others were up to on the project, and a real engagement was lacking. Even after changing the meeting format to prevent long technical explanations, the lack of integration was still obvious.

This lack of flow between disciplines in shared spaces speaks back to the initial project organisation that recruited disciplinary experts and placed them in disciplinary themes. Though Progress and Integration meetings were changed to lessen the emphasis on disciplinary expertise, disciplinary knowledge was still produced from the project. For a project to be considered interdisciplinary, a new framework to guide problem-solving efforts needed to be established outside of disciplinary boundaries. In this study, the existing framework of producing knowledge persisted, and the project organisation did not create flow across boundaries or new frameworks of working.

Despite the lack of knowledge flow between disciplines, researchers pointed to an exceptional example of successful integration in the form of a jointly-authored paper that focused on income inequality and segregation in the UK. This paper was a collaborative effort of a mathematician, a data scientist and an urban scholar. It utilised previously unanalysed publicly available data, and it was considered an innovative collaboration. Participants in this initiative considered it to be a success in knowledge integration across the natural and social sciences because the collaboration resulted in a paper (a tangible output). However, this successful interdisciplinary collaboration and the Three Pillar Paper introduced in Chapter Five were exceptions in their integration of knowledge and skills. The project's other research streams were principally disciplinary-oriented, and integration meetings were focused on individual project updates rather than finding connections between workstreams.

In reality, as a result of the project's foundation comprising separate blocks of disciplinary expertise, researchers largely felt more comfortable working within the known boundaries of their own discipline. Therefore, many of the research strands and resulting outputs from workstreams were disciplinary contributions rather than interdisciplinary collaborations. The cross-disciplinary research organisation that so defined the project was still organised in themes

along disciplinary lines, methodologies and ways of working. Therefore, this structure determined a largely disciplinary way of working and resulted in more disciplinary-specific outputs.

This example from the sustainability project demonstrates the power of thinking in disciplinary themes and how that presents a challenge to collaborate in a more disciplinary manner. In reviewing reflections from the Relu programme, one can see mixed outcomes with regards to its interdisciplinary integration, with some researchers recognising genuine interdisciplinary integration and some not. The Relu programme had a different configuration than the urban sustainability project and was an established programme that received funding in 2004–2013 for interdisciplinary research. Scientists had to apply for this funding by fulfilling certain criteria, including interdisciplinary construction and justification (Lowe & Phillipson, 2006). The wider programme was also divided up into themes; however, these themes were organised by problem issues rather than disciplinary expertise. For example, Theme C in the Relu programme was called ‘Successful and sustainable food products and food chains’, which could potentially encompass food science, nutrition science, the social issues related to genetically modified foods and the economics of food production. Under these wider programmes, four small awards and 19 larger research projects were funded and assessed individually on their interdisciplinary merit (Lowe & Phillipson, 2006). As a result of this interdisciplinary assessment, social scientists on the project played an important role in the problem framing of projects, bringing in their participation at the very beginning of the research process (Lowe et al., 2013). This differs from the approach in the urban sustainability project. In one of the Progress and Integration meetings, a senior academic expressed the challenge of attempting to bring the research together “at the end”. At this stage, many of the research projects continued on their different disciplinary trajectories. The difference in outcomes between the two projects suggests that organising an interdisciplinary project using disciplinary

themes makes it more difficult for researchers to integrate their disciplinary knowledge and think outside of disciplinary building blocks.

Researchers at UKERC acknowledged interdisciplinary outcomes from their project. However, like the urban sustainability project, researchers recognised more separate multi-disciplinary outcomes than integrated interdisciplinary research, particularly in Phases 2 and 3 of the project (Winskel et al., 2015). More ambitious forms of interdisciplinarity were desired at UKERC, and researchers suggested that disciplinary structures and processes played a role in determining the multi-disciplinary feel of the project (Winskel et al., 2015). Like the urban sustainability project, themes were organised along disciplinary lines, and interdisciplinary integration was encouraged through 'soft' measures such as Centre meetings and thematic workshops (Winskel et al., 2015). Without hard metrics or incentives to engage in interdisciplinary activity, individual motivation to do interdisciplinarity was the only way interdisciplinary collaborations took place.

This mirrors the experience of researchers on the urban sustainability project, where individuals chose their engagement level in shared office spaces and Progress and Integration meetings. Particularly towards the end of the project, when impending deadlines focused researchers towards disciplinary-oriented publications, engagement in project-wide meetings and office spaces visibly reduced. Researchers provided their own individual updates in Progress and Integration meetings and then tuned out or turned their attention towards their open laptops whilst others gave updates. Not all researchers exhibited this behaviour, but finding connections to other research projects was no longer a priority. The focus towards disciplinary outcomes that comes at the end of a project poses a conflicting priority with waiting to connect disciplinary parts 'at the end' to achieve interdisciplinarity. Waiting until 'the end' of the project, when academics need to focus on published work for their individual careers, ensures interdisciplinary integration will not happen as individual motivation disappears.

Another aspect of Mode 2 research is its transdisciplinary nature, in which dissemination and engagement of the research include members of the public and other external actors. To realise a project's transdisciplinary nature, this engagement has to be two-way, with external actors speaking to the research and influencing its direction and conclusions. In this research project, plans were made to encourage knowledge sharing with a transport organisation and engage with Nottingham City Council to ensure the relevance of the project workstreams. The transport organisation specialises in 'intelligent mobility' and aims to connect the needs of the transport industry with research being undertaken in the university as consultants. Nottingham City Council is a district council responsible for local planning and building control.

At the beginning of the project, a natural scientist, Reese, was seconded the transport organisation that focuses on innovative research and development projects to support market opportunities in the UK's transport sector. This secondment aimed to encourage knowledge sharing between the university and transport organisation to help select and build models relevant to the project. Given the breadth of resources at the transport organisation, Reese hoped he would learn some best practices to apply to transport modelling. During the three months that he was away, his objective was to scope different modelling software and methodologies that were appropriate for the project. Reese felt he did find a good modelling software that could be useful. However, some senior academics on the project selected a different modelling software to be used instead for the transport modelling projects. From Reese's perspective, knowledge from the industry was not utilised in the project: "I was sent to the [transport organisation] to scope models, I came back with answers and they were […] rejected."

From Reese's perspective, the others thought using his model scoped from the organisation would be too resource-heavy to implement.

However, Reese stated that the industry partner would be able to provide assistance on that front. For Reese, this potential collaboration and knowledge from the industry went unused on this aspect of the project. Though Reese did engage with knowledge and different ways of working with an external collaborator, it fell short of impacting the methodology or research trajectory of the project and, therefore, fell short of a two-way transdisciplinary collaboration.

The researchers also engaged with Nottingham City Council in a half-day workshop that took place with members of the project and employees of Nottingham City Council who specialised in issues relating to transport, management, environmental management and housing development. There were a number of motivations to engage with the Council. Researchers wanted to build relationships with Council members who had access to key data sources about the city that would help build more accurate models. Another motivation was to ensure that the research being conducted made sense to those working at the Council and matched their priorities on key issues. By inviting relevant Council members to the workshop, sustainability researchers hoped that further engagement in the form of data sharing and access to relevant contacts for interviews and other useful information would be obtained.

Though researchers on the project reported interesting round table discussions that took place on the day and fruitful connections made with Council members to be contacted later, evidence is lacking that this workshop significantly directed the project's research orientation. In other words, communication in the direction from academics to Council members occurred, but impactful feedback or input in the other direction from Council members to academics was lacking. This engagement was not reciprocal because the research project did not engage with the City Council from the beginning; therefore, many of the project workstreams were already determined and underway, meaning the City Council's priorities could not realistically influence the project's research

trajectories. A comment by a senior researcher indicated that reaching out to Council members later in the game was preferable; once the project had reached adequate maturity, they would have some research findings and models to showcase, rather than receive input on how the research would be developed. This statement revealed the researcher's underlying thinking that, as a scientific expert, his role was to communicate science to the public rather than receive input on how it should be built. Working on the project did not change this researcher's way of thinking, and he continued to operate in a 'Mode 1' manner by maintaining a separate research role for the university. Though follow-up engagement and meetings were anticipated after the workshop, no other meetings or requests for work from the project materialised, and the engagement reached an end. The large engagement effort started and ended with this workshop.

Transdisciplinarity in the form of public engagement and industry partnership were opportunities that researchers on the project tried to pursue. However, from Reese's standpoint, this engagement was not two-directional enough (coming from the outside into the project) to merit a genuine transdisciplinary effort.

7.3.3 Homogeneity versus heterogeneity (Hierarchy versus heterarchy)

Gibbons et al. (1994) describe Mode 2 research as planned and organised outside of a centralised institution, instead being knowledge production "heterogeneous in terms of the skills and experience people bring to it." (Gibbons et al., 1994, p. 6). An example is the appearance of new knowledge organisations such as think tanks, management consultancies and activist groups. With additional sites for knowledge production, new and instantaneous forms of communication are more prolific, such as 'virtual communities' and communication to coordinate knowledge efforts. This multiplicity of decentralised institutions is also organised temporarily. Characteristics of these temporary structures include their flexibility and rapid response times to changing research direction, as well as their heterarchical structure (Gibbons et al. 1994).

According to the authors, “Mode 2 research groups are less firmly institutionalised; people come together in temporary work teams and networks which dissolve when a problem is solved or redefined.” (Gibbons et al., 1994, p. 6). Inherent in this description is its contrast: the centralised institution of Mode 1 research configuration and the traditional institution of the university, one of the oldest sites of knowledge production. Implicit in the homogenous and centralised university institution is its hierarchical structure.

The heterogeneous nature of the sustainability project was closely related to its interdisciplinary quality. In bringing together disciplines spanning the natural and social sciences, the project brought together researchers with heterogeneous skill sets. As this project was funded for a set period of years and worked towards the specific aim to understand urban sustainability, it also had a temporary configuration. Once the project was finished, the researchers would go on to work on other jobs or research projects. However, in one aspect of the project, its heterogeneous intention actually brought to light some underlying hierarchical structures. In order to integrate these heterogeneous skills, the modelling (‘Lego blocks’) part of the project intended to amalgamate all of the skill sets together to create different predictive urban models. However, as described in Chapter Six, an interesting, though not new, disciplinary hierarchy was perceived by the social scientists in the project. The natural scientists perceived the role of the social scientists was to contribute to the modelling that served as the site for integration. Many social scientists understood this collaboration as a *subordination-service* mode of interdisciplinarity, where one discipline takes a subordinate role to other disciplines in a collaboration (Barry & Born, 2013). They did not recognise the modelling as representing an *integrative-synthesis* mode of interdisciplinarity, because they understood the models to have a positivist approach to research. The social scientists perceived they would be reifying that approach if their role was to only provide indicators for the models. Though the *subordination-service* mode is documented in the literature as a

recognised form of interdisciplinary collaboration, the social scientists on this project expected a more equal and heterarchical research organisation.

Despite these hierarchical structures, the project was imagined to be heterogeneous in that it was a temporary configuration of researchers for the purpose of exploring urban sustainability. It was also heterogeneous in that it pooled together a range of skills and expertise across the sciences. After the project's end date, researchers returned to their departments and previous work commitments. More junior researchers moved on to new job contracts within academia and other research institutions. Some researchers from outside of the UK returned to their home countries or moved elsewhere to pursue their personal lives and careers. The temporary nature of this project ticks the Mode 2 research configuration box.

This temporary configuration of the project was made possible by the external funding source, the Leverhulme Trust. Not only did it encourage the heterogeneous nature of the disciplines involved in the research, but it did so from a location external to the university. By being unaffiliated with a university or research council and, therefore, those disciplinary structures, this outside funding agency represented a different configuration of institutions enabling research to take place. It did not specify how the funds were to be distributed amongst the disciplines, and over the course of the project the Trust was flexible when some funds were requested to be redistributed from one academic administration budget (the School of Engineering, for example) to another (the School of Sociology).

Altogether, this project was heterogeneous only to an extent. Although a diverse group of disciplines were brought under this project's umbrella, the disciplinary-oriented thematic structure drove the research focus into separate disciplines. The natural scientists and the social scientists on the project did not agree on the nature of the collaboration surrounding modelling. Whilst natural scientists recognised modelling

as a way of working together, the social scientists viewed this as a service to the natural scientists rather than a symmetrical exchange of research ideas. Also, although the Trust did not have a disciplinary orientation and provided the funds to the project, accounting for research and funds still took place within the budgeting processes of the separate university departments. An attempt at a novel project configuration and a funder that encouraged cross-disciplinary research was not enough to change the strong disciplinary 'columns' that existed at the university. This tension between the priorities of the funding body and the inflexible nature of the university proved to be an ongoing presence throughout the project. Ultimately, the strength of the university structure and disciplinary cultures reinforced a Mode 1 configuration of knowledge hierarchy within a centralised university institution.

7.3.4 Academically accountable versus socially accountable

According to Gibbons et al. (1994), "a growing public concern about issues to do with the environment, health, communications, privacy and procreation, and so forth, have had the effect of stimulating the growth of knowledge production in Mode 2." (p. 7). Due to such public concerns, research and scientific knowledge in these areas have become a priority, and the public not only influences the research priorities but also the outcome and composition of the research process itself. As a result of working according to public priorities and in the context of application, participants in research are made more reflexive, according to Gibbons et al. (1994). To accommodate the additional perspectives that are now included in a Mode 2 research configuration, individuals are required to reflect throughout the research process and try "to operate from the standpoint of […] all the actors involved." (Gibbons et al., 1994, p. 7). This reflexive stance has the impact of influencing the research structure itself. Mode 1 knowledge production research has very limited accountability by contrast and is only

accountable to the disciplinary practices, methodologies and standards of rigour collectively agreed upon by disciplinary peers.

This section revisits the engagement with Nottingham City Council to assess the project by this characteristic of accountability. The Council could be considered a stakeholder in the research, as theoretically it would benefit from the research findings and recommendations about how to make Nottingham a more sustainable city. All of the other actors in this project were academic researchers, and therefore it did not inherently follow that they would adhere to any standard of accountability outside of their disciplines. As outlined earlier, there was engagement with Nottingham City Council regarding the work the project was doing. However, this interaction seemed to have more of the quality of science communication than a two-way dialogue. For example, at the beginning of the workshop, presentations were given to the audience to inform them of the work to date on the research project. And although a *world café* format of round table discussions ensued at the end of the workshop, there was little evidence that these discussions were fed back or utilised within the project as research inputs. A follow up with the Council did not result in any continued engagement or communication. This meeting with Nottingham City Council cannot be considered an engagement that resulted in outside stakeholders evaluating the work or the project findings' applicability.

The decision by the Principal Investigator to engage with the City Council once the project reached adequate maturity illustrates the one-directional knowledge sharing that he imagined would take place. In discussions at Progress and Integration meetings, he proposed when the Nottingham City Council workshop would take place after he deemed there to be enough work on the project to show them and the project had reached a level of maturity to share with others. Allowing a project to reach this level of maturity prevents any meaningful expert input outside of the academics involved in the research. Engagement

should happen sooner with stakeholders for their input to have some impact on the trajectory of a project.

Researchers working in a Mode 2 configuration are expected to have a more reflexive way of working as a result of conducting research that is more connected to societal priorities. Reflexive in this sense means that researchers work with other individuals from different standpoints and must try “to operate from the standpoint of all the actors involved.” (Gibbons et al., 1994, p. 7). For Gibbons et al. (1994) “reflexivity appears to demand an ontological insecurity, an institutionalisation of doubt, […] All givens must be mistrusted because they represent the treacherous reassurances of tradition which inhibit reflexivity.” (p. 103). Because research questions span across a range of disciplines, disciplinary scientific methods and technical terms cannot be taken for granted (Gibbons et al., 1994). To be reflexive is to embrace the uncertainty that comes with working outside of known disciplinary practices and boundaries. It means questioning existing frameworks and seeing the roles that other frameworks could have in knowledge production. It also requires that researchers acknowledge that disciplinary standards and norms are not universal and cannot be applied to all research problems.

To understand how this project operated against this dimension, this section explores disciplinary reflexivity and reflexivity about interdisciplinarity as a concept itself. There is evidence that working in an interdisciplinary manner led to reflections amongst the team members about their language use and their discipline’s methodological choices. There was some evidence that, as a result of my presence as an interdisciplinary practitioner, researchers reflected on doing interdisciplinarity and the value of conducting research in this way.

Researchers reflected on their own disciplinary approaches and assumptions, particularly when confronted with conflicting or different uses of language by other researchers. Participants commented that using certain vocabulary either did not translate to others in a different

discipline or went over their heads completely. Particularly when a specific word was shared but the meaning was not, it created an opportunity for reflection on how the word was used in one discipline and how it could be used otherwise. For example, Oscar, a computer science postdoctoral researcher, shared in an interview his reflection on the unanticipated difficulties defining the word 'sustainability' in the larger project's research questions. He said that he was "naive in thinking" that it would be a "simple" question to construct and agree upon. When other social science disciplines began to unpick what they meant by sustainable, for him the task to define the question became surprisingly much more complicated. It had not initially occurred to him that there would be so many different ways to define and conceive of sustainability.

Reflecting on language use across different disciplines also led researchers to consider methodological differences and reflect on their own methodological choices. There were reflective moments in the project when researchers were forced to re-evaluate their approaches when questioned about them by those from another discipline. As opposed to speaking to individuals within their own discipline where these methods were taken as a given, researchers found that a lack of familiarity with presented methods and terms sparked reflexive moments. For example, returning to the discussion about the term case study in Chapter Six, the geographer who discussed the geographers' difficultly using (and then not using) the phrase 'case study' in project meetings reflected on the effects of being questioned on that methodology. When asked if those conversations affected the way the geographers proposed to conduct case study research, she replied:

> Isolde: It didn't, it was helpful because it really made us think about how we were going to justify it, not the same way you would do it to a social scientist anyway.

> Moderator: And when you say ‘to justify’, at what level were you justifying it, justify to what *they* thought as legitimate means? Or not?
>
> Isolde: A bit of both really, the justification helped in that it helped us write a more robust methodology section in the paper that came out of this […]

In this sense, a reflection occurred that encouraged the researcher to “think about how we were going to justify it.” However, her reflection stopped there, as her understanding of ‘case study’ did not change and she did not alter this methodological choice in the project as a result of reflection. In fact, disciplinary methods were further reinforced by providing a more robust explanation and rationale for the methodology in subsequent papers (which were submitted to geography-relevant journals). In future meetings with natural scientists, geographers omitted the term ‘case study’ from their dialogue, deliberately preventing any further engagement on the subject. So, although the reflexive thoughts and challenging discussions did affect their thinking and methods, it ultimately served to reinforce them within their peer group and discipline. The disciplinary divide, it seems, was maintained, and the disciplinary ‘columns’ were made stronger.

Being watched in the interdisciplinary practitioner’s ‘diary room’ encouraged researchers to think about an objective to the research besides its disciplinary rigour, which was to make sure the research was done in an interdisciplinary way. In one instance, after a presentation I gave about my research approach to the group, Stella, a social science PhD student commented that she would not be thinking so much about interdisciplinarity had I not joined the group. My presence and feedback of my observations and findings functioned to make researchers reflect upon their interdisciplinary efforts.

As a result of reflecting often on their (inter)disciplinary efforts, researchers wondered if they were doing enough interdisciplinary collaboration. This had the effect of making researchers try to do more interdisciplinary work with others, especially at the beginning of the project, therefore influencing the research process. This was particularly the case with the Policy to Model to Output project, an initiative created with a principal objective of getting social science researchers to understand the modelling process and therefore potentially contribute more effectively to the modelling aspect of the project.

Whilst the research project as a whole had clear points of reflexivity, reflexivity as a concept in and of itself was not actively pursued or systematically included as part of the research process. This *ad hoc* approach to reflexivity contrasts with the much more active approach in the Relu programme (Lowe & Phillipson, 2006). In their aptly named publication, "Reflexive Interdisciplinary Research: The Making of a Research Programme on the Rural Economy and Land Use", the research leads observed the reflexive practice as an inevitable part of the interdisciplinary process. For Lowe and Phillipson, interdisciplinary projects are unusual in that they focus "on the research and problem-framing process and call for (self-) reflection on one's own disciplinary perspective and that of other disciplines." In the Relu programme, participants explicitly engaged with research framings and the way these were shaped by broader or narrower research interests (Lowe & Phillipson, 2006). This acknowledgement of research interests helped the participants trace the origins of research questions and framings, therefore implicitly recognising that there are diverse approaches rather than one right way to conduct research to reach a universal truth.

The systematic reflexivity exhibited by the Relu programme was closely linked to societal accountability, whereas reflexivity that occurred in this ethnography was linked to other academic research priorities. In the Relu programme, their reflections "explore the decisions and processes that have shaped the programme and their receptiveness to non-

academic influences and priorities" (Lowe & Phillipson, 2006, p. 181). "Non-academic influences" in the Relu programme refers to the stakeholder consultations and engagement activities undertaken by the programme. This focus on non-academic influences reflects the link made between social accountability and reflexivity outlined by the Mode 2 thesis. This type of reflection and responsiveness to stakeholders represents the type of reflexivity outlined in Mode 2 more clearly than the reflections about academic disciplinary practices and norms that took place in this research project.

Overall, researchers reflected on their own practices and ways of working as a result of working with other disciplinary practitioners. They learned that terms and concepts can not be taken for granted and that researchers use different methodologies to focus on different research questions. My role as an interdisciplinary practitioner encouraged researchers to reflect on their research process and question if it was interdisciplinary enough. Even if they were unsure how to do interdisciplinarity, efforts were made to distribute disciplinary understanding outside of disciplinary peer groups in order to encourage future collaborative efforts. But, although these reflections occurred, the effect on changing existing research practices was limited, as researchers in the project sought to avoid potential challenges or confusion over terms or methods as long as they felt comfortable pursuing them in their own discipline.

7.3.5 Peer-review quality control versus socially distributed quality controls

In fitting with the contextual nature of the organisation of Mode 2 forms of knowledge production, evaluation of the new knowledge produced is meant to be flexible and adjust to a project's needs. In addition to its fluid nature, Mode 2 research is meant to include a wider range of judgement criteria in its evaluation. The evaluation of Mode 2 research "now incorporates a diverse range of intellectual interests as well as other social, economic or political ones." (Gibbons et al., 1994, p.8).

Rather than the research only needing to be of good quality standard, it also needs to be recognised as efficient or useful to society (Gibbons et al., 1994). This standard of evaluation rejects the notion of science for science's sake and wants research and knowledge to be safe, applicable, politically feasible and helpful to society. This expanded standard of criteria for how knowledge should be produced speaks to the supposed bi-directional communication model of transdisciplinary interactions. Policymakers, interested stakeholders and members of the public could all be included in the evaluation process in the Mode 2 form of knowledge production.

Conversely, quality control in Mode 1 goes through a process of consensus among peers in a research domain. Control is maintained by "careful selection of those judged competent to act as peers which are in part determined by their previous contributions to their discipline." (Gibbons et al., 1994, p. 8). This important social practice maintains control over what becomes knowledge and what does not and maintains autonomy in research (Gibbons et al., 1994). This means that only those who are qualified in a field may ascertain the value and rigour of any new research that comes to the field, creating a circular reinforcement. In addition to this narrow range of qualified practitioners evaluating research work, the merit of new research has a narrow judgement criterion as well: it need only demonstrate disciplinary excellence (Gibbons et al., 1994).

In this project, academic peer-reviewed quality controls strongly determined the research trajectories and resulting outputs. This was reflected in the pressure on PhD students to conform to a disciplinary structure and the difficulty of collaborating on co-authored publications. There was no evidence that the interdisciplinary funder or encouragement by Co-Investigators developed or enforced any alternative quality controls to assess the research outside of the usual disciplinary norms.

As outlined in Chapter Five, PhD students experienced considerable pressure to approach their research and work in a way that would contribute to and reflect a disciplinary orientation. To revisit the experience of the computer scientist, he felt that he needed to choose to make a contribution to knowledge in computer science, as this was deemed acceptable for a PhD. In his interpretation of the School of Computer Science's requirements, using existing computer science methods as an 'application' for the wider urban sustainability project was not a sufficient intellectual contribution:

> […] often the requirements of the project will not align neatly with the requirements for a computer science PhD. Project objectives are likely to focus more on results of a simulation than the simulation method or development process, with some pressure to conform to and apply standard methods used in the domain rather than building on or replacing them with new tools. – *Hanson*

For Hanson, a contribution to the computer science discipline required that he build or create new tools in simulation methods and develop simulation processes. After demonstrating this contribution, he would then be awarded a PhD. His examiners in the School of Computer Science made this clear after his first-year review, when his work, thinking and ideas were reviewed by computer science specialists. As his principal goal was to receive a PhD, that became the primary objective and contributing to the project was secondary.

In the example of the Three Pillar Paper authored by three PhD students, time constraints were much of the reason why the work did not continue. The focus turned from collaboration to submitting work for their PhD qualifications. This incident illustrates that the interdisciplinary goal of the paper and the disciplinary objective of getting a PhD did not necessarily feed into each other, nor was this the case for the majority

of PhD students. It was considered something extra that they would get to when they had more time.

Although mixed interdisciplinary groups of supervisors were collected to guide students' PhD journey and a walled space was created for interdisciplinarity to happen in supervisory meetings, this structure was not enough to make PhD students adopt other disciplinary theories, techniques or ways of working. This structure did not translate as an incentive to encourage interdisciplinary working, and therefore interdisciplinarity became a secondary objective. Although there was pressure from the Principal Investigator to ensure that projects contributed to the wider project, this pressure did not override the incentive of being awarded a PhD. This dynamic illustrates the strength of the established university structure and reward system. There was no other real structural incentive or mechanism to reward research by PhD students that contributed to the wider project in cases where the project and the PhD research were not one and the same.

This, too, appeared to be the case for researchers attempting to publish work. Publishing work that is recognised by peers in one's home discipline is how careers in academia are built and maintained. Aside from the implicit and explicit encouragement to do interdisciplinarity coming from the Principal Investigator and my presence as an interdisciplinary practitioner, these pressures did not translate to a clear incentive to conduct interdisciplinary work.

While publishing disciplinary work was a priority, quality controls to evaluate interdisciplinary work when it did arise were hard to come by. In the project, this difficulty was illustrated by an income inequality and segregation paper written by a PhD mathematician, a postdoctoral urban scholar and a postdoctoral data scientist. Another senior academic who was a mathematician outside of the project also contributed to the paper. It utilised a public data source on income within the city of Nottingham and used that information to understand the effect of income inequality and segregation in the city. The group

managed to successfully collaborate, draft a paper and submit it to several journals for publication. However, they faced difficulties getting it past the first stage at the editor's desk.

The urban scholar who worked on the project, Elisa, experienced frustration and surprise at the number of 'desk rejections' that this paper experienced at the submission stage. Though anecdotal, her conclusion from these rejections was that assessing this new piece of work on data was considered risky by the journal. Also, her junior status as a researcher resulted in some discriminatory assumptions, and the journals did not have the review skills or capacity to evaluate all the disciplinary aspects of this cross-disciplinary research effort. With regards to this last point, it seems that interdisciplinarity in academic quality control circles continues to go unrecognised and therefore not incentivised.

Outside of academic disciplinary quality controls, there were no socially-distributed quality controls or additional criteria to measure the project. The only potential additional research criterion outside of academic peer review was my role as an interdisciplinary researcher, charged with observing interdisciplinary collaborations in the group. My presence had the unintended effect of making researchers feel evaluated on their interdisciplinary efforts, which encouraged some researchers to try to do more interdisciplinarity and caused them to reflect on how much interdisciplinary collaboration was occurring. However, my interest in interdisciplinary collaborations was not to judge the quality or presence of interdisciplinarity but rather to understand its perceptions, processes and impacts as the researchers understood them. Although there was no clear evaluator to assess the interdisciplinary quality of the project, it was generally agreed by the project members that it did not have enough interdisciplinarity, as illustrated by the frustrated sentiments described in Chapter Six. There was no clear mechanism to evaluate this interdisciplinary objective, potentially because it assumed that since the constructed building was in place, it would just happen.

The project's main judgement criterion was ultimately that research was academically rigorous; there was little emphasis on its impact outside of academic published work and conference presentations. There was no formal investigation or evaluation of how interdisciplinary the project was, nor any mechanism for outside stakeholders (Nottingham City Council) or industry experts (transport organisation) to provide feedback to the project regarding its relevance or efficacy. The potential to provide an alternative assessment of work outside of mono-disciplinary knowledge in the form of interdisciplinary supervisory teams or project members was not enough of an incentive to do interdisciplinary work or develop evaluation criteria outside of disciplinary homes. Interdisciplinary co-authored papers lacked a multi-disciplinary evaluation process, as it was hypothesised that a lack of relevant expertise in the journal editorial boards contributed to the inequality paper being desk rejected multiple times. The result of conducting this work within a university environment meant that the academic peer-review process remained supreme.

The institutional and disciplinary boundaries within an academic research project also proved to be a challenge for previous interdisciplinary research projects in sustainability. At UKERC, researchers reflected the understanding that to advance in an academic career, publishing in disciplinary-oriented journals is necessary. Researchers discussed the REF as a "fundamental barrier" to interdisciplinarity (Winskel et al., 2015, p. 31). At the PhD level, one researcher pointed out that there were increasingly more interdisciplinary PhD programmes; however, this researcher found this problematic, as the diverse knowledge and experiences of the PhD student are not recognised when they try to progress in discipline-oriented academia (Winskel et al., 2015). From the perspective of UKERC researchers, there was a clear lack of additional quality control measures outside of the academic publishing institution.

Speaking from his position as the director of the Tyndall Centre for Climate Change Research, Hulme discussed the limited avenues for recognising different project successes and outcomes outside of the traditional academic peer-review system. Hulme stated that conventional quality control measures in academic research are inherently biased against interdisciplinary research approaches (2006). To remedy this issue, Hulme suggested an increased focus on policy-impact measures to recognise interdisciplinary research and for less weight to be given to disciplinary-oriented journal publications (2006).

Taking the experience of the sustainability project into account, discipline-oriented publishing practices were indeed a priority. However, measuring impact in policy and the real world has its difficulties. Policy impact is very difficult to attribute to a project and simultaneously difficult to measure. In addition, long term impacts can take years to manifest, thereby compounding the difficulty to trace an impact back to a clear interdisciplinary initiative. The tendency to fall back on academic standards of quality control to measure success is not surprising given the immediate feedback it provides; for example, it is easy to count the number of articles published over a project's lifetime. Without clear and measurable quality controls for interdisciplinary research endeavours, it is easy to fall back on established disciplinary research criteria.

7.4 Disentangling Mode 1 and Mode 2

From its beginning, the project was built to encourage collaboration between different disciplines and establish a programme of work that could be used by the local Nottingham City Council. On the surface, these aspects embody Mode 2 knowledge production. However, as this thesis illustrates, providing an intention for interdisciplinary working, structuring the project to facilitate it and building a heterogeneous disciplinary foundation may not be enough to cause Mode 2 knowledge production. Despite an interdisciplinary supportive external funding source and an initial desire for interdisciplinary working, the established academic reward structure persisted.

Hessels and van Lente (2010) provide insight into how an intention for interdisciplinary working and an external funder in favour of interdisciplinarity can fail to translate to a Mode 2 knowledge configuration. Hessels and van Lente state that the Mode 2 thesis creates confusion due to Gibbons et al. “conflating interrelated yet independent trends” in research (p. 65). This means that though two trends are interrelated, such as increases in transdisciplinarity and reflexivity among research scientists, they can still operate independently. Although stated in passing as an introduction to more concrete criticisms about the theory (namely, the lack of empirical evidence in the thesis), this statement is an important one as it helps to question the arbitrary demarcation between the two modes of research implied by Gibbons et al. Although the continued existence of Mode 1 alongside Mode 2 is acknowledged, Mode 2 “constitutes a distinct mode with its own set of cognitive and social norms” (Gibbons, 1994, p. 14). This distinction fails to account for or describe a research mode that combines or amalgamates characteristics of both modes.

This thesis interprets Hessels and van Lente’s (2010) statement to mean that the five characteristics describing Mode 2 research are not necessarily as closely related to each other as the NPK thesis implies. For example, just because researchers are working in the context of application, it may not follow that research scientists will therefore become more reflexive in their research practices. Gibbons et al. (1994) state that “working in the context of application increases the sensitivity of scientists and technologists to the broader implication of what they are doing. Operating in Mode 2 makes all participants more reflexive” (p. 7). However, as we have seen in this project, one characteristic of Mode 2 may be introduced into a project but not necessarily translate throughout; two Mode 2 characteristics can operate completely independently.

In this project, the temporary and heterogeneous nature of the project did not encourage cross-disciplinary working. This was an example of

characteristics operating independently of each other. Although researchers were exposed to other methodologies and ways of working, the project's temporary nature did not provide a lasting incentive to create shared outputs or work that was not academic in nature. Merely meeting and being exposed to other disciplinary ways of working did not encourage researchers to incorporate them into their own practices. As researchers were focused on the longer-term goal of building their careers, disciplinary contributions were favoured over interdisciplinary collaborations.

Once it is recognised that Mode 2 research characteristics can operate independently from one another, it is easier to see how a project can display characteristics from both Mode 1 and Mode 2 research configurations. For example, it is possible for a research project to be simultaneously hierarchical along one dimension and heterarchical in another. This example manifested itself in this project as different disciplines were brought together in a temporary configuration to work on the project (heterarchy), but historical disciplinary hierarchies still managed to manifest themselves in which the natural sciences occupied a higher position than the social sciences. The diversity of participants involved in a project does not prevent a hierarchical structure from forming. In fact, in this research project, the hierarchical structures amongst the sciences were further highlighted when different disciplinary practitioners were placed on a project together. While Gibbons et al. (1994) used the examples of increasing numbers of diverse authors on scientific papers and additional actors participating in national research and development initiatives as evidence that research was evolving to a Mode 2 structure, they failed to investigate this trend further to understand underlying hierarchical power dynamics at play. Here, this was illustrated in the reification of the hierarchy of the disciplines; social science researchers on the project perceived their intellectual contribution to the project as secondary to the natural science disciplines with a positivist approach to research. In this case,

the project simultaneously had a diverse heterarchical organisation and a clear hierarchical dynamic.

In light of the above examples used to illustrate each of the corresponding characteristics of Mode 1 and Mode 2 research, it is clear that a hard line cannot be drawn between the two modes as the theory implies. Although the university institution appears to be responding to external demands for greater accountability and more interdisciplinary research, it can maintain its internal evaluation practices. The traditional university departmental structures and disciplinary cultural arrangements are stronger than the NPK theory appreciates, maintaining traditional structures of quality control in this instance.

This interdisciplinary project illustrates empirically that Mode 1 and Mode 2 research are not clearly demarcated. Analysing the research within this framework also shows that the characteristics of each Mode did not necessarily correlate or follow each other but were a mixture of the two. Navigating a project that attempted to be interdisciplinary and conducting it within a disciplinary university environment created a scenario where, ultimately, expectations of transcendent transdisciplinary research were not met. The inevitable strength of incentive structures made it easier to retreat to the ways of a disciplinary home rather than pushing against the grain to produce knowledge in a new way.

Another critique of the NPK theory is that it fails to substantiate the claim that these trends occur universally across multiple research configurations, social contexts and organisations. As Hansen (2009) argues, the NPK theory fails to take into account the diversity of ways that a Mode 2 research configuration could manifest. In terms of different interdisciplinary configurations specifically, Barry and Born (2103) suggest that “interdisciplinarity enacts an array of interrelations between disciplines, with distinctive effects—a diversity that the discourse of Mode 2, with its focus on an epochal shift in the forms of

knowledge production, tends to overlook." (p. 13). Shinn (2002) calls Gibbons et al.'s approach "anti-differentiationist" in that "it seeks to minimize or to deny demarcations between academic, technical, industrial, political and social institutions." (p. 604). A weakness of the Mode 2 thesis is that it "neglects to examine how these changes [from Mode 1 to Mode 2 research] operate in different settings" (Hansen, 2009, p. 69). Although this alleged universal experience of Mode 2 can account for the popularity of the NPK thesis, it also is one of its main criticisms.

Related to this critique questioning the universality of this theory, critics also note its lack of empirical evidence. Shinn (2002) states that "almost no concrete evidence is given for the assertions advanced" (p. 603). Hansen asserts that Gibbons et al. (1994), in writing the diagnosis of the shift from Mode 1 to Mode 2 research, "seem to be writing about everywhere and nowhere, in particular, giving no indication of the scope or validity of their analysis." (Hansen, 2009, p. 72). Therefore, the NPK thesis reads more as an aspirational manifesto, illustrating where the authors would like the research landscape to go, rather than a report of where current research is actually going.

In this case, the research project did not provide empirical evidence of a Mode 2 research project. Without an established reward system for interdisciplinary working or a new research configuration, researchers were less committed and incentivised to adopt new ways of working, and they continued to engage in established ways of doing research. Though the Mode 2 thesis implies a disappearing boundary between disciplines as well as between scientific disciplines and other forms of external expertise, educational and cultural systems continued to provide important, distinct guidance for action within their specific contexts. These norms persisted despite 'pressures' from funding agencies and government initiatives to create platforms for interdisciplinary research in the context of application, as would be expected following the Mode 2 thesis.

This study supports the critiques claiming that the NPK thesis's five characteristics are incorrectly conflated and that it lacks an empirical foundation. However, as a conceptual framework, NPK has provided useful parameters to investigate and compare the characteristics of interdisciplinary sustainability projects. Due to hierarchical university structures and disciplinary-oriented peer-review channels, an interdisciplinary group of researchers based within a university environment lacked external evaluation measures and alternative accountability structures that could facilitate interdisciplinary working. The NPK thesis also (unintentionally) shows how characteristics of Mode 1 and Mode 2 research can coexist within one project, therefore understandably creating an expectation that interdisciplinarity would happen on the project if it was correctly constructed. Where an undisciplined funding source recognises the merit of a interdisciplinary project and multiple disciplinary experts are recruited to work together, these qualities reflect a Mode 2 project configuration that could potentially lead to interdisciplinary research and outputs.

7.5 A Mode 2 university?

In describing a "Mode 2 university", Nowotny et al. (2011) discuss the changing nature of this institution as the principal site for knowledge production. As universities evolve, research will become more contextualised research to account for the demands of the society and funding agencies that give universities power and legitimacy. Some examples of this manifestation include wider dissemination requirements, impact assessments and trainings for researchers to give them skills marketable outside of academia (Nowotny et al., 2001).

Gibbons et al. (1994) outline what universities must do in order to maintain relevance in light of the increasing presence of Mode 2 research. They must create the capacity to work externally with other partners. They must also update their incentive system and create university work environments that reflect expanded and temporary configurations of quality control (Jansen, 2002).

However these were not characteristics of the existing university structure on this project. For example, while researchers attempted interdisciplinary collaborative papers and PhD contributions to the wider project, existing academic departments and disciplinary-oriented academic journals proved too strong and established to budge from their existing ways of working. Therefore, the majority of outputs from this project resembled single-discipline academic articles for disciplinary-oriented journals.

To address the challenge of working with external partners, researchers initiated collaborations with industry and policymakers, but these collaborations were inconsequential to the research outcomes. The distributed knowledge configurations and alternative dissemination pathways seemed to be superficial rather than transformative to the project. Knowledge about potential models from the transport placement went unused in the actual project. In addition, discussions from the City Council meeting were not referred to in any of the research outputs or utilised to influence the project's trajectory.

The initial ambitions to engage with other sectors in the research and disseminate findings more widely were most present during the funding application stage. In the grant application, engagement with the private sector and local council organisations were considered important. In the implementation stage, the researchers' priority was to establish their academic careers by focusing on what Gibbons et al. would describe as 'Mode 1' outputs such as journal articles, book chapters and academic conference presentations.

The strength of the disciplinary-oriented university institution is highlighted in Lyall's (2013) assessment of the academic landscape in the face of growing interest in interdisciplinary research. She points to the "lack of organisational memory" (2013, p. 336) in universities as preventing interdisciplinary lessons and collaborative experiences from being shared beyond a project's lifetime. Without these lessons to pass on to other areas of a university, it prevents the lasting change and

fundamental restructuring of university systems required to reward interdisciplinary research. In this research project, two well-documented challenges to prioritising interdisciplinarity within the university environment (recognising challenges in cross-disciplinary publishing and a commitment to existing disciplinary modes of quality control) were largely unanticipated by the researchers. Training was not given to prepare researchers for the challenges of working in an interdisciplinary manner, and no strong commitment was made to research previous experiences of interdisciplinary researchers. Conflicts around authorship when publishing across disciplines came as a surprise to the researchers and ultimately went unresolved in the project, preventing any institutional change in the present or the future.

Overall, the findings from this project suggest that a new ‘Mode 2 University’ with interdisciplinary research configurations and priorities is not the reality of how research is conducted at present. Despite funding priorities and existing collaborations with outside institutions and public bodies, the university has maintained its relevance in producing knowledge without changing its quality control systems, hierarchical configurations or practices of engagement with outside institutions. Though this project was funded by an interdisciplinary-oriented funder and had communicated with a transport organisation and the local City Council, these factors did not significantly influence or change the disciplinary research trajectory or how research findings were valued or evaluated.

7.6 Conclusion

This chapter analysed the findings of this thesis’s research against Gibbons et al.’s (1994) NPK theory. The project conducted research that was contextual and tried to operate across interdisciplinary boundaries by collecting a heterogeneous group of disciplinary experts. These factors all look like characteristics of Mode 2 forms of knowledge production. But although the aspirations were present and the building constructed to facilitate interdisciplinarity, the academic structures and

incentives that underlined this building meant that aspects of Mode 1 knowledge production were clearly present. These factors came in the form of projects that furthered discipline-specific knowledge, hierarchical dynamics and the lack of an alternative quality control mechanism to evaluate interdisciplinary research.

Although different strategies to build interdisciplinarity were employed (disciplinary columns, dry-walling and dancefloors for space; a diary room for reflection; and Lego blocks for integration), the disciplinary columns were the most visible determinates of how the research was prioritised, carried out and assessed at the end of this project. Producing discipline-oriented knowledge for PhD projects and journal articles was prioritised over the more difficult and undefined objective of collaborating on an interdisciplinary level.

The NPK theory helps to categorise characteristics of the project as resembling knowledge production in Mode 1. This reveals that a heterogeneous group of actors brought together to conduct research can still create disciplinary outcomes due to the wider structures in place. This Mode 1 research configuration helps to explain why interdisciplinarity was not perceived as successful by researchers in this instance.

This thesis concludes that even with explicit attempts to develop different configurations of knowledge production, the structure and institution of the university did not allow for a Mode 2 research project to exist alongside its Mode 1 way of doing things. The NPK theory helps to highlight the existence of university structures and processes. In this case, the university structures did not provide incentives for researchers to do more interdisciplinary work, hence the sense of ‘failed’ interdisciplinary attempts.

Chapter 8: Discussion

The previous chapter analysed empirical data from the sustainability project against Gibbons et al.'s NPK thesis. The NPK thesis provided a theoretical framework to interpret the various relationships and dynamics on the project. The previous chapter discussed how, despite the desire to work in an interdisciplinary way, existing university structures and disciplinary norms produced disciplinary-focused project outcomes.

This chapter discusses the overall findings from the thesis in reference to its contributions to methodology and interdisciplinary studies. The interdisciplinary studies' contribution is framed in reference to the thematic table (Table 2-1) outlined in Chapter Two. This chapter does not go through all of the themes, instead reviewing the themes this thesis significantly contributes to, either with new interpretations of existing themes (time, communication/language and university environment) or by adding altogether new themes (expectation and emotional affect). The chapter also discusses my methodological contribution as an embedded researcher of interdisciplinarity and the comparison of the NPK thesis against the empirical data of the sustainability project.

8.1 Contribution to research methods – The embedded interdisciplinary researcher

This research was conducted from my unusual standpoint as an embedded researcher who was written in at the start of the project. I

also simultaneously analysed conclusions as an outsider who did not collaborate on the project's main outputs. In navigating the insider-outsider continuum, I had a unique perspective on how narratives and understandings of interdisciplinarity were implicated in its making and doing.

Most analyses of interdisciplinary projects have not been done by dedicated researchers of interdisciplinarity. In previous interdisciplinary reflections, research has been led by project coordinators (Winskel et al., 2015), research directors of interdisciplinary projects (Hulme, 2006), multiple members of the research group (Lowe et al., 2013), the STS researcher on the project (Goulden et al., 2017), and social scientists who also had another research role in the project (Callard et al., 2015). All of these studies resulted in articles analysing their project's interdisciplinary nature and provide a useful comparison for the sustainability case study. However, this thesis provides the unique perspective of a dedicated ethnographer of interdisciplinary throughout a project's lifetime. This dedicated perspective is important because such a researcher can focus solely on the interdisciplinary process, exploring the different ways that interdisciplinarity is understood and the effects these various understandings have on collaborative efforts. Using the ethnographic method provides concrete observations that bring an abstract concept like interdisciplinarity into tangible actions and descriptions.

In the sustainability research project, my role as an investigator of interdisciplinary collaboration was my primary focus. This is unusual in that I worked with both social and natural scientists on the project but was not necessarily collaborating with them on the main research outputs. Comments made to me about being a spy on the project revealed an insecurity among researchers that not enough interdisciplinarity was happening. This insecurity implied two things: 1) that interdisciplinarity was desirable and *should* be happening, and 2) that researchers perceived that I was evaluating their interdisciplinarity

efforts. It was not only the case that I perceived their insecurity, but my very presence on the project as an interdisciplinarity researcher created the insecurity in the first place. By creating a position that looked solely at interdisciplinary collaboration, senior academics elevated interdisciplinarity to a primary concern. I was in a unique position to observe these concerns, and my position created these very concerns. In recognising this active role of positionality, navigating the insider-outsider continuum could be reimagined as leveraging positionality to understand interdisciplinary dynamics. For example, how could I receive these ‘spy’ comments about my work and analyse them for what interdisciplinarity meant to that researcher?

This complex and multi-layered account of my positionality illustrates the dynamic nature of the insider-outsider in ethnography. Eyben (2009) and Freeth and Vilsmaier’s (2019) both leverage their positionality in research along this insider-outsider continuum but take different approaches. Eyben (2009) describes the “threshold” as a balancing act between the role of an outsider observer and that of an insider who is a full participant (p. 72). From her perspective, ethnographers “hover” in this space in order to get a vantage point on power dynamics not visible from other positions. Hovering, from my perspective, does not capture my experience of moving along the continuum between the two extremes. Freeth and Vilsmaier’s (2019) proposed method to actively move between and mediate within opposing stances (complicit insider versus isolated outsider) better captures the negotiation I undertook, walking further inside at certain times of the project and backing further outside at other times in order to get critical distance. This thesis further develops the insider-outsider concept beyond hovering and active, to show how ethnographers appear to paradoxically exist in multiple places on the continuum at once. For example, during project board meetings, I was allowed inside the inner workings of the project forbidden to other research participants at my level. However, as an observer of the process instead of an active contributor, I was still an outsider in those meetings. I was an inside member of the group of PhD

students on the project and welcomed in small working group meetings, but comments about my job as a ‘spy’ revealed that some perceived me as an outsider who would inform the senior academics.

I also revisited emotions and feelings of uncertainty, using them as data to help me understand interdisciplinary approaches and attempts on the project. For example, while listening to Ingmar say he tried to “look” for where interdisciplinarity was happening to prevent disappointment, I understood that he felt more interdisciplinarity should be happening but was unable to recognise any occurrences on the project. While much of the literature views difficult emotions around interdisciplinary work as an inevitable side effect (Boix Mansilla et al., 2016; Cairns et al., 2020; Strober, 2011), Callard and Fitzgerald (2015) provide deeper reflections about the role of emotions in interdisciplinary collaborations. Callard and Fitzgerald not only acknowledge the “emotionally exhausting” aspects of interdisciplinarity but also encourage its emotional quality to be investigated as a data point and not just “a situation to be managed” (2015, p. 128). I found that statement particularly helpful and appreciated the explicit use of emotion and affective tensions as data within that interdisciplinary study. I combined this approach with Hillersdal et al.’s (2020) concept of affective tension to guide my own ethical obstacle course when navigating my insider and outsider positions. These sources also served as a guide on worried days, as I tried to tell a story whilst respecting the trust of my research participants.

This ethnography combines the auto-ethnography approach of the above studies with emotional data (both from the research participants and my own experience) to reveal the underlying expectations of and approaches to interdisciplinary collaboration. For example, my study highlights how a personal sense of fairness can bring collaborators closer together or drive them further apart. Feelings of suspicion and of being treated unfairly caused senior academics to want to withdraw guidance and help on future writing projects to PhD students. The PhD

students were less open about sharing future work for fear that supervisors would want credited authorship. The result was that the Three Pillar paper, which would have been an approved indicator of successful interdisciplinary working, went by the wayside.

In another example, I turned my feelings of insecurity regarding what was considered good research into a reflection on how methods and ethical standards differ across the natural and social sciences. When a natural scientist suggested that we put recording devices into the shared offices to ensure we capture the 'seeds' of interdisciplinary collaborations, the School of Sociology reacted with shock and surprise at the suggestion. These differing perspectives highlight different epistemological assumptions in the natural and social sciences. From a positivist perspective, capturing a large amount of recorded data would allow a representative sample to be chosen from the data to provide 'generalisable' conclusions. However, an ethnographic methodology does not subscribe to this positivist definition of generalisable, as outlined in the methods in Chapter Three. These divergent opinions uncovered different perspectives of what my ethnographic project was for and expectations around what conclusions it would reach. It revealed that the natural scientists wanted to find a starting point of interdisciplinary collaboration that could be traced forward to a successful outcome. This perspective took an uncritical stance towards interdisciplinarity, assuming that it would lead to positive collaborative experiences. However, to conduct research that would earn me a PhD from the School of Sociology, a more critical perspective was required, and I also needed to abide by the ethical standards of the School to move forward.

8.2 Contribution to the field of interdisciplinarity studies

In this section, I return to the interdisciplinary thematic table (Table 2-1) created in Chapter Two as a basis for discussion. I describe my contribution of two additional themes to the literature: expectation and emotional affect. Then, I explain this thesis's contribution to knowledge

on existing themes from the literature. I end by explaining my contribution of combining STS theory with empirical interdisciplinary experience as a way to understand the sustainability project's characteristics.

8.2.1 New interdisciplinary themes

This thesis sheds light on how individual *expectations* of what interdisciplinarity should look like affected researchers' approach to interdisciplinarity and collaborations. 'Expectations' as a theme is not explored in this way in the literature. There are only mentions of different expectations for valuing knowledge across disciplines (Ozkan et al., 2019), different career expectations for academics at different levels (Gibson et al., 2019), and expectations of researchers' own work goals within an interdisciplinary collaboration (Kaygan & Aydınoğlu, 2018). *Expectation* focuses on researchers' expectations of the interdisciplinarity that they hoped to find on the research project.

In this case study, researchers adjusted their approach to collaboration to maintain their sense of fairness and symmetry in academic research exchanges. Researchers expected that interdisciplinarity would have an equal exchange of skills or disciplinary expertise. For example, when a social science researcher felt that a proposed collaboration did not utilise their research skills, either by providing demographic data for a model or acting as a science communicator with local city councils, they declined to collaborate. This feeling of unfairness was rooted in a lack of understanding of one another's research approaches and expectations. While a natural scientist felt that asking a social scientist to provide 'indicators' for a modelling project was a collaboration, the social scientist perceived this exchange to be unequal and a service. Ingmar's protest that he was not a "repository of data" illustrates that these indicators were not readily available. To conduct the research and create these indicators from scratch would have required a lot of work by the social scientists, a fact that the natural scientists failed to appreciate. To produce this work for the natural scientists also did not

address the social scientists' research questions and thus was not seen as a priority. Therefore, social scientists on this project understood their interdisciplinary contribution as envisioned by the natural scientists as a *subordination-service* mode, rather than the more symmetrical *integrative-synthesis* mode (Barry & Born, 2013). This particular dynamic of social scientists feeling subordinate reinforced existing disciplinary hierarchies, in which the natural sciences sit at the top due to their perceived homogeneity in approach (Cole, 1983) and the research value of positivist epistemological frameworks (MacMynowski, 2007). This mismatch in expectations of what interdisciplinarity should look like affected potential team collaborations.

Diverse disciplinary cultures and practices also resulted in different expectations of what it would look like to collaborate on a practical level. The main example illustrating this point is the Three Pillar Paper. Different disciplinary practices in the natural and social sciences around authorship of academic work resulted in conflict, as researchers from both sides of the disciplinary spectrum felt that the practice of the other side was unfair. The unmet expectations and strong emotions of 'fairness' were important because these impacted collaborative efforts moving forward. In efforts to restore feelings of fairness and work within their own expectations of authorship, social science researchers were reluctant to share work for fear of demands for unwarranted authorship credit. Natural science researchers were also reluctant to offer help in the conceptual development of papers out of fear they would be uncredited on a paper when they felt credit was due. When initial expectations around ways of working were not met, new shared expectations were not established, halting progress on interdisciplinary collaboration.

Diverse disciplinary cultures also resulted in different expectations of my role as an interdisciplinary researcher. As outlined in section 8.1 above, different expectations, largely determined by disciplinary backgrounds, existed regarding my role as the interdisciplinary

researcher. Natural scientists on the project tended to view my role as practical in nature, desiring that I find the ingredients of interdisciplinarity or provide specific actions to help them collaborate better. On the other hand, social scientists on the project tended to understand the research value of exploring what different researchers meant by interdisciplinarity and accepted my direction towards a more critical approach to the research.

Underlying all these expectations was the ultimate assumption that if the foundations were laid to facilitate interdisciplinarity, then interdisciplinarity would occur. The ‘Lego blocks’ building metaphor illustrates how the models were imagined to integrate the disciplines. The models were meant to both facilitate interdisciplinarity and provide evidence that interdisciplinarity had occurred. However, instead of integrating disciplinary knowledge, the model highlighted the disciplinary divide between the natural and the social scientists, as the social scientists did not participate in their development. No alternative integrative function was developed, so much of the social science and natural science work remained separate. The expectation of interdisciplinarity, compared with the perception that interdisciplinarity did not take place because of the lack of outputs to evidence it, led to disappointment.

To further explore these feelings of disappointment and uncertainty, this thesis engaged with organisational dynamics literature to understand the role of emotional affect in interdisciplinary collaborations—an aspect less documented in the literature on interdisciplinarity (Callard et al., 2015; Hillersdal et al., 2020). In seeing researcher silence as a conflict avoidance tool (Verouden et al., 2016), this ethnography also connects how silence led to feelings of suspicion of other academic researchers (Morrison & Milliken, 2000), particularly around the Three Pillar Paper. These feelings of distrust ultimately discouraged academics from collaborating with others in the future for fear of being side-lined during the author recognition process. Given that cross-disciplinary joint

authorship is considered a key indicator for interdisciplinary collaborations, more investigations around researcher feelings are warranted to understand the ways in which they can help or hinder team trust and dynamics. This study brings those emotional feelings to the forefront, repositioning the role that feelings play in general and interdisciplinary collaborations.

These observations of feeling and affect capture the mundane dynamics that characterise an interdisciplinary collaboration. The feelings of uncertainty, frustration and reservation to collaborate all play a significant role in either bringing collaborators together or pushing them apart. These everyday affects were the reality of interdisciplinary collaboration; there were none of the epiphany or 'Aha' moments of clarity that researchers expected. Interdisciplinarity remained uncomfortable and confusing throughout the project.

Emotion and affect differ from the mundane activities emphasised by other STS research ethnographies, which focus on the "mundane material actions of scientists in the laboratory that produces new objects" (Sismondo, 2009, p. 1670). For Latour and Woolgar (1979), mundane practices include writing up the laboratory notes, conducting meetings, and collecting data to create orderly facts out of disorderly data. For Goulden et al. (2017), installing the "digital plumbing" (p. 142) in the form of Internet services to an underserved population represents the mundane preparation of setting up a research experiment 'in the wild'. For Lyall et al. (2011), it is the active management skills of senior leadership that facilitate research collaboration and integration in an interdisciplinary context that is considered "mundane" (p. 44). Observing the mundanity of participants' day-to-day feelings adds an additional layer to these research activities and skills. In fact, they underlie the decision-making processes and choices made in scientific activity, and therefore, merit further investigation by future research.

8.2.2 Stretching existing themes

In addition to introducing new themes, this thesis expands some of the existing themes found in the literature on interdisciplinarity. The understanding of time is expanded to include the difficulty of finding the right time for interdisciplinarity. The analysis also expands the concept of language/communication to encompass the metaphorical meaning of language in interdisciplinarity, namely as the incommensurability between different disciplines. Finally, this section examines how the interdisciplinary outcomes of the sustainably project were largely tied with the disciplinary structures of the university.

While the literature discusses the need for more time for interdisciplinary projects in general (Goulden et al., 2017; Lotrecchiano et al., 2016; McBee & Leahey, 2017), what is clear from this sustainability project is *when* those feelings of being time-pressed were most salient for the research participants. At the start of the project, more effort and reflection on the interdisciplinary process occurred because there was a perception that there was 'time' for interdisciplinarity. However, towards the end of the project, a sense of urgency emerged amongst the researchers, and there was a feeling that they needed to just get on with things such as publishing in disciplinary journals and focusing on next career moves. Interdisciplinary integration tools such as the Progress and Integration meetings became unproductive uses of time that interfered with researchers progressing with their work. Paradoxically, senior academics thought that the integration of disciplinary knowledge should take place "at the end", as Sebastian said—at a point when the researchers thought there was no longer time to spend on interdisciplinarity.

One of the most common themes documented in the literature on interdisciplinarity is the challenge to speak another discipline's 'language' (Looney et al., 2015), i.e., to communicate with others on an interdisciplinary team. Consistent with this literature, researchers on the

project overwhelmingly cited language as a key challenge in collaboration. However, this study also identifies ‘language’ as a euphemism for discussing the incommensurability between different disciplinary paradigms (Kuhn, 1970). In the sustainability study, understanding that researchers were sometimes actually referring to different research paradigms when they mentioned ‘language’ reveals an uncertainty around research rigour. For some researchers such as Oscar, it was not enough to simply understand different disciplinary terminology. He saw a full understanding of other research approaches as necessary to maintain researcher integrity. For him, understanding the language meant more than being able to understand definitions; it was also about understanding the underlying methods and principles of other disciplines. Researchers wanted to actually understand different research approaches enough to be able to confidently incorporate different disciplinary aspects into their own work. As researchers’ credibility is important in academia, overcoming this language barrier was viewed as necessary to sufficiently engage with other disciplines.

Discussion around different disciplinary languages appeared in the other sustainability projects compared in this thesis and is closely tied to the theme of time in interdisciplinary collaboration. In the Transition Pathways Project, engineers also commonly referenced language as a challenge to interdisciplinary working and attributed communication difficulties as a key reason for the extended time needed to conduct interdisciplinary research (Hargreaves & Burgess, 2009). The research respondents in the UKERC also discussed the importance of the “language barrier” in relation to the extra time requirements needed for interdisciplinary working (Winskel et al., 2015). Allocating the time up-front to facilitate these exchanges was deemed essential for the interdisciplinary process (Winskel et al., 2015).

While participants from these studies described different languages as a barrier to interdisciplinary collaboration and more time as the potential solution, it is not clear whether more time could address underlying

problems of incommensurably between disciplines. For example, while the engineers on the Transition Pathways Project desired more time to communicate with other disciplines, this perspective differed from the project's social scientists who perceived the challenge to run much deeper to include differences in problem framing and the conceptualisation of worldviews (Hargreaves & Burgess, 2009). The view of the social scientists was more aligned with the position that disciplines are fundamentally incommensurable. Similarly, the Relu programme's reflections on language barriers focused less on the extra time commitments and centred on the epistemological divide that language highlighted between the natural and social sciences (Lowe et al., 2013). For example, social and natural scientists came together in specific instances not because they had more time but because social scientists who approached their research quantitatively, particularly economists, were able to communicate in numbers and data sets (Lowe et al., 2013).

While the sustainability project is a case study showing the university's resilience, the findings also emphasise the influence of university disciplinary structures in determining (inter)disciplinary project outcomes. The disciplinary-oriented research themes in the sustainability project were structured around different Schools within the university. Consequently, senior academics, postdoctoral researchers and PhD students were each affiliated with a specific School and adhered to their respective disciplinary research practices, ethical standards and authorship norms. Particularly at the lower end of the hierarchy, PhD students on the project were pushed back into their disciplinary cultures by the university administration when they appeared to deviate from disciplinary norms. For example, Stella, a sociology PhD student, was encouraged in her first-year meeting to spend more time in the School of Sociology instead of the shared project office in order to get more grounding in her home discipline. "Interdisciplinary ravines were uttered as a warning," according to Hanson, a computer science PhD student. As a result, project

outcomes were overwhelmingly disciplinary-focused academic journal articles and PhD theses approved according to disciplinary standards.

Lyall (2013) picks up on this conflicting trend in interdisciplinary academic collaborations.This theme was particularly salient within the sustainability research project, as illustrated by the challenges the PhD students experienced along their journey to earn a discipline-specific PhD. To a lesser extent, this challenge also applied to postdoctoral researchers, whose temporary contracts relied on a record of good publications in reputable journals, which tend to be organised along disciplinary lines. While the literature documents the difficulty of conducting interdisciplinary work in academia, this research goes further to question whether it is possible to do interdisciplinary research in a university setting at all, given the lack of incentives to collaborate across disciplines and the strong hierarchical structures that reward disciplinary knowledge contribution.

Due to the wider university environment, the project studied in this ethnography was organised into disciplinary project themes, similar to organisation of the UKERC (Winskel et al., 2015). Feedback from both of these projects was that there was a lack of natural and social science knowledge integration throughout the project, especially toward the latter stages when researchers became more focused on developing disciplinary outputs. In contrast, Relu's programme was organised by problem issues that could encompass a range of disciplinary expertise (Lowe & Phillipson, 2006). Although the assessment of interdisciplinary integration was mixed among the researchers, there was an overall feeling that social scientists played a role in the formation of the project's research questions and approaches. This approach seemed to facilitate the inclusion of the social sciences throughout the research project, giving Relu a more interdisciplinary than multi-disciplinary feel. Although these examples are few, these findings suggest that organising an interdisciplinary project along disciplinary lines plays a

large role in determining researchers' ability to make the leap to collaborating with different disciplines on a project theme.

8.2.3 Theoretical contribution

While the above comparison of research projects provides a useful reference point for the study's sustainability, the conclusions are empirical in nature. A theoretical explanation of interdisciplinary project outcomes is missing from the literature. This thesis's contribution to STS theoretical knowledge is to use the NPK theory (Gibbons et al., 1994) as a framework to analyse the sustainability project. In doing so, this ethnography reveals the difficulty in disentangling characteristics of Mode 1 and Mode 2 research, indicating that other forms of modern research could also exhibit both modal characteristics. It also illustrates that although there were attempts to construct the research project into a Mode 2, cross-disciplinary, heterogeneous and socially accountable research project, the disciplinary-oriented Mode 1 university strongly determined the research approach. The university structures created a hierarchical dynamic (both regarding academic status and between the sciences) and prioritised academically-oriented research outputs. By showcasing the strength of the academic institution, this study highlights the reciprocal relationship between external research pressure and the university, a bimodal direction that is neglected in Gibbons et al.'s theory of NPK.

This study engages with Nowotny et al.'s (2001) predictions and description of the role of the university within the 'new' knowledge production paradigm. This study demonstrates that the university has yet to reflect the transgressive power of Mode 2 research configurations to challenge the epistemological core of established disciplines (Nowotny et al., 2001). In analysing the NPK thesis against the research configurations documented in this study, this thesis recognises the widening role of funding agencies in incentivising an interdisciplinary research approach. However, there was no evidence to support that the university was changing their disciplinary orientation as a result. This

study describes how the university and its disciplinary experts reified and maintained their epistemological and methodological norms and practices in the face of difference instead of bending to accommodate different ways of doing research. These challenges that Mode 2 knowledge production poses to the university proved to be superficial rather than transformative in this case.

8.3 Conclusion

This discussion chapter examined some aspects of Chapters Four, Five, Six and Seven with a view to analyse overall findings and their implications for ethnographic research methods and the literature on interdisciplinarity. This chapter also explained the thesis's contribution to the field of STS.

This chapter discussed the personal challenges in navigating the 'insider-outsider' positionality and emotional anxiety experienced during the project. I discussed how I reframed the emotional anxieties of myself and others into sites where conclusions about interdisciplinarity could be made. This strategy also doubled as a contribution to the STS literature as well, as ethnographic studies of scientific projects are an important part of understanding how science is done. This strategy of reframing emotional discomfort as critical incident sites for key interdisciplinary findings introduces another tool in the STS researcher toolbox, one I refer to as 'leveraging positionality'.

This chapter contributed to the literature on interdisciplinarity by providing additional interpretations of the themes: time, communication/language and the university environment. Not only did interdisciplinary projects require more time to get the research underway, but it was unclear *when* the interdisciplinarity could start to take place. On some accounts, interdisciplinarity could not happen until researchers got acquainted with their collaborators, yet equally, interdisciplinarity came too late in a project if individual researchers already had their own research trajectories underway. This thesis

unpicks the concept of miscommunication across disciplines to reach a different interpretation from the generally accepted one, arguing that researchers recognised the incommensurability between different research approaches and used the word ‘language’ as a euphemism to describe this phenomenon. Finally, this thesis recognises the power of the disciplinary academic structure in determining work priorities. Though Nowotny et al. (2001) predicted the changing university structure within the wider research landscape would become more collaborative and interdisciplinary in nature, the evidence from this case study did not support this.

In addition to adding to the themes above, the thesis also introduces two additional interdisciplinary themes that featured in this project: expectations and emotional affect. Diverse expectations about interdisciplinarity and the role of other disciplines played a significant role in determining how researchers interacted with each other and how they approached collaboration. A gap in expectations of and experiences with interdisciplinarity was also the principal cause for researchers’ feeling disappointed that interdisciplinarity did not take place. Participant emotions were also significant because researchers made collaborative decisions based on whether they felt an exchange was ‘fair’. Researchers were more likely to withdraw from working with another discipline if they felt their skills were not utilised or if they did not feel adequately recognised for their contribution.

Finally, to bridge the fields of interdisciplinarity and STS, this thesis uses Gibbon’s et al. (1994) NPK theory as a framework to analyse the themes identified in the empirical case study. As most studies have focused only on the empirical data in interdisciplinary projects, this comparison provides a theoretical understanding of interdisciplinary project configuration. Although this empirical case study does not support the predictions of the changing university environment proposed by NPK, applying the NPK theory to the empirical data

reinforces the importance of university structures in reifying disciplinary boundaries.

Chapter 9: Conclusions

The sustainability research project examined in this thesis brought together natural and social scientists from a range of disciplines to work together at a university in the UK. In addition to finding solutions to modern sustainability challenges in the urban environment, the project aimed to reach these goals through interdisciplinarity. This case study provided an opportunity to study interdisciplinary collaborations as they unfolded and to investigate the various expectations, collaborative processes and outcomes.

The research was a challenging endeavour for multiple reasons. Firstly, navigating the ethical challenges as an embedded researcher trying to write about my participants whilst maintaining trust was a principal source of anxiety. I tried to bring this tension to the surface in this thesis rather than shy away from its difficult reality. Secondly, writing about interdisciplinarity, which in and of itself has various meanings depending on the audience, was difficult. It was unsurprising that the research participants in the case study also found interdisciplinarity to be a difficult concept to define and implement in practice. This challenge is one explanation for why interdisciplinarity was expected yet not reached by the project's conclusion. Lastly, this thesis documents challenges to committing to interdisciplinary project goals in the face of competing disciplinary administrative and academic requirements. I also experienced this in my own research, feeling the pressure to prioritise one goal over the other. These challenges were not only personal challenges to conducting my research but also significant sources of insight regarding challenges to interdisciplinary collaboration in general.

This concluding chapter revisits these challenges and brings together the analysis from the previous chapters to understand gaps between expectations and experiences of interdisciplinary working in a university environment. This chapter recaps the research questions introduced in Chapter One and summarises the answers from data Chapters Four,

Five and Six. I also incorporate the theoretical analysis from Chapter Seven and weave in the main discussion points from Chapter Eight throughout. I conclude this chapter with specific implications and suggestions for future interdisciplinary projects and outline ideas for possible directions of future research in this topic.

9.1 Summary of findings

Creating an expectation around ‘interdisciplinary working’ when its definition and objectives are unclear creates uncertainty in a project, and expectations are inevitably unmet. These feelings have the potential to distract from the other genuine research efforts and outputs created by a research project that does not reflect ‘good’ interdisciplinary collaboration. Working in an academic environment is output-driven, with clear, established criteria for success. Appreciating the process of an interdisciplinary project is more difficult, as alternative evaluation measures do not exist.

These feelings of uncertainty were pronounced when a postdoctoral researcher, Reese, repeatedly referred to me as the ‘spy’ as I entered the room or when participants shouted “don’t record that!” in the middle of a meeting. This outward display of self-consciousness indicated that researchers were reflecting on the project’s interdisciplinarity. However, it did not necessarily bring them closer to a united definition of interdisciplinarity.

Uncertainty gave way to feelings of mistrust and injustice when three PhD students drafted the Three Pillar Paper. Unforeseen complications arose when it became clear that authorship practices differed across the natural and social sciences, as did the definition of a ‘significant contribution’. In the social sciences, supervisors were added to PhD student articles only when they wrote a significant portion of the paper. When supervisors in the natural sciences wanted authorship credit for the Three Pillar Paper because they believed they had provided a significant contribution to its ideas and guidance in meetings, the

students went silent about its progress, and the supervisors grew suspicious that the paper might be submitted without their knowledge. This incident brings to light the different disciplinary cultures across the natural and social sciences, illustrating that the complications around interdisciplinary working are not limited to epistemological or methodological differences. It also illustrates the role that emotions play in determining collaborative practices. Without trust to bring collaborators closer together, Sebastian, a natural science PhD supervisor, was tempted to withdraw help for articles to restore a sense of fairness with regards to providing advice and funding opportunities. The social science PhD students, Stella and Ingmar, were therefore tempted to keep future papers to themselves out of fear that supervisors might unfairly demand credited authorship on their work. Withdrawing from sharing went against the spirit of collaboration, as stated by one of the senior academics. Within the disciplinary-positioned university structure, it was easier and became a priority to focus on disciplinary-oriented journals rather than navigate the uncertain territory of interdisciplinary collaboration and co-authorship. As a result, interdisciplinarity became a separate and secondary objective for the researchers.

With the withdrawal from collaborative efforts and the missing Three Pillar Paper, researchers on the team were disappointed that the interdisciplinary aspect of the project was a failure. As outlined in Chapter Four, this disappointment was tied to the *expectation* that interdisciplinarity should have happened because it was built into the project. This disappointment also arose because researchers superimposed existing university indicators of success, such as publications, onto the interdisciplinary project due to the lack of existing interdisciplinary-specific indicators. Interdisciplinary efforts and meetings took place, such as the Policy to Model to Output initiative. However, the perception was that nothing ever came of those interactions, meaning that no outputs resembling new models or published work resulted from the exchanges. Lottie, a researcher,

described the collaboration as interesting but not useful, illustrating the expectation that interdisciplinary work would provide clear outcomes to indicate success.

In the following sections, I recap and summarise the answers to the research questions from Chapter Four, Five, Six and Seven. I also revisit the interdisciplinary themes from the literature review outlined in Chapter Two.

9.1.1 Research Question 1: How did the researchers on the project understand interdisciplinary working? What did researchers see as important aspects to include in an interdisciplinary project?'

Chapter Four documents an interpretive account of the researchers' understandings of interdisciplinarity and their expectations regarding the results of interdisciplinary collaboration. A dominant narrative was apparent, aligning with notions that interdisciplinarity is more holistic and suited to sustainability projects (Frank, 2017), as stated in Chapter Two. In this narrative, interdisciplinarity is a desirable research approach that is necessary to adequately grasp and understand the complex dynamics associated with urban sustainability and its components (Holling, 2001; Rafols & Meyer, 2010; Schoolman et al., 2012).

Adhering to this dominant narrative, researchers applied for funding from a trust that supported interdisciplinary approaches. In building the project in an interdisciplinary way, they imagined an *integrative-synthesis* form (Barry & Born, 2013) of interdisciplinarity was imagined. Towards this form of interdisciplinary working, researchers built the project by collecting expertise from different disciplines across the university and bringing them together to collaborate on one project. Researchers assumed that they would then integrate their knowledge to reach conclusions that would not have been possible using mono-disciplinary research.

In order to facilitate interdisciplinary working, academics designed the project at the application phase to provide the right environment and framework for interdisciplinarity, within which it was expected to happen. To explain how researchers understood this set-up, I developed architectural and geographical metaphors to describe interdisciplinary working and provide a framework for analysis.

In constructing the interdisciplinary project, experts from individual disciplinary fields were recruited to provide their disciplinary knowledge and expertise. I have illustrated these disciplinary experts as ‘columns’ to signify the strength of disciplinary practices and norms that exist in research fields. Supervisory meetings provided one ‘space’ where supervisors from different disciplines input their different knowledge and approaches into one research effort—the PhD thesis. I have described this space as a separate ‘dry-walled’ room for interdisciplinarity, along with the Progress and Integration meetings. In these meetings and in the shared office space, disciplinary experts interacted and tried to integrate their knowledge. I have used the term ‘dancefloor’ to metaphorically describe the space where different actors were imagined to meet, find synergies and collaborate. Two ‘location’ themes (Callard et al., 2015; Guimarães et al., 2019; Lyall, 2019; Lyle, 2016; McBee & Leahey, 2017; Santamaría, 2015; Trussell et al., 2017) from Chapter Two feature heavily in Chapter Four: the *university environment* theme played a big role in determining the disciplines brought onto the project and the creation of *shared spaces* were thought to facilitate interdisciplinarity.

According to the literature, shared spaces for meeting and collaboration are an important prerequisite for interdisciplinary working (Callard et al., 2015; Freeth & Caniglia, 2020; Lyle, 2016; Oughton & Bracken, 2009; Santamaría, 2015; Trussell et al., 2017). Formal meetings are important for allowing the researchers to collaborate academically, but informal spaces are just as important to facilitate social engagement between interdisciplinary researchers (Callard et al., 2015; Freeth & Caniglia,

2020). It is in these informal social engagements that *trust*, another prerequisite for interdisciplinary collaboration, is fostered (Balmer et al., 2015; Castán Broto et al., 2009; Harris & Lyon, 2013). In this project, the formal spaces of the Progress and Integration meetings were emphasised by senior management as the main vectors of interdisciplinary sharing. In the literature, shared offices provide important informal space for conversations to bubble up and turn into future collaborations (Lyle, 2016; Oughton & Bracken, 2009); these spaces played a secondary role in disciplinary integration in the sustainability project.

Spaces can also hinder or constrict interdisciplinary collaboration—specifically, the particular environment of the academic university (Frickel et al., 2017; Lyall, 2013). In this project, the disciplinary structures of the university provided the basis for the disciplinary themes. Although these disciplinary 'columns' were brought together, they determined how the participants approached one another on the project. Because the sustainability project created disciplinary frames, it was difficult for participants to think outside of their disciplinary identity; they automatically viewed others as representatives of their disciplines and approached them with their own assumptions of what they thought those specialists should do.

My own position as the interdisciplinary expert on the team served as the project 'diary room' because researchers thought my position was omniscient. Senior academics gave me access to closed project board meetings, and I rotated between the PhD and postdoctoral offices to gain more visibility of the inner workings of the project. Like other researchers studying the interdisciplinary process (Callard et al., 2015; Freeth & Vilsmaier, 2019; Hillersdal et al., 2020), I did a lot of emotional work, navigating feelings of uncertainty and anxiety whilst travelling along the insider-outsider continuum. Sharing offices with both natural and social scientists meant different *expectations* were imposed on my role according to their respective disciplinary understandings. While the

natural scientists tended to view my role as instrumental in nature and about facilitating interdisciplinarity, the social scientists accepted my more critical approach to questioning the interdisciplinary process itself. Establishing my own research amongst the divergent expectations of my collaborators was an exercise in uncertainty that continued throughout the project.

Finally, the computer modelling aspect of the project served as the principal strategy to integrate the knowledge of the social sciences together with the natural sciences. The ‘Lego blocks’ metaphor for this modelling illustrates the integration strategy that researchers had in mind to facilitate interdisciplinarity. It also embodies the model as a finished product, and therefore evidence of the interdisciplinary collaboration taking place.

Although the dominant narrative was positive regarding interdisciplinary working, there was variation in the specific meanings attached to the notion of interdisciplinarity. Some researchers referenced academic disciplines as a starting point. For example, Richard stated that “perhaps other people would define it more by academic, well previous academic, perhaps more to do with departmental disciplines.” Other researchers defined interdisciplinarity as what results from collaboration. For example, Tristan stated interdisciplinarity was a “new product […] that embeds all the different components.” From Elisa’s perspective, interdisciplinarity was about the working process of collaboration: “You work with people whose understanding of the world, their understanding of epistemologies and that, are different to yours.” These diverse viewpoints on interdisciplinarity coupled with the divergent narrative that interdisciplinarity is risky for an academic career meant that there was not an overall agreed definition for interdisciplinarity or how it should work. Despite this diversity, the construction of the interdisciplinary project created the *expectation* that interdisciplinarity would take place.

9.1.2 Research Question 2: How was interdisciplinarity experienced by researchers on the project?

The combination of a positive dominant narrative, a desire for researchers to collaborate and a project built for interdisciplinarity to take place made researchers expect productive collaborations to happen across the disciplines. As outlined in Chapter Two, a desire to do interdisciplinarity can be largely based on *personal motivations* to conduct research in a new way. However, once the project started, researchers experienced tensions around time commitments, difficulty aligning departmental PhD requirements with project contributions and clashing publishing cultures across the natural and social sciences. Personal motivations for many then shifted towards their own disciplinary publications and qualifications.

In line with the literature, the theme of *time* in interdisciplinary collaborations featured heavily, as Chapter Five describes. Time challenges are common in interdisciplinary projects, and project researchers commented on the lack of adequate time to really conduct the interdisciplinary project. In one example, for Genghis, it meant that much of the interesting group collaborations fell by the wayside: “Things are very much delayed already and that caused a problem that all the interesting things that I’m interested in, I was promised actually, might be crossed out.” Specifically, the researchers commented that more time up-front should be dedicated to understanding the project and different research approaches and perspectives.

Two challenges specific to conducting interdisciplinary research within the academic environment occurred: 1) the tension between doing work that was required to earn a PhD versus doing interdisciplinarity and 2) the pressure to do work that would earn researchers recognition within their disciplines versus participating in project collaborations. Again, the theme of conducting interdisciplinarity in a *university environment* was influential in how participants chose to spend their time on the project. As the project went on, it became clear that the interdisciplinary

objective and PhD research goals were not the same and, in some cases, contradicted each other. Interdisciplinarity then became a separate objective, secondary to conducting disciplinary research as personal motivation and incentive to do interdisciplinary work waned.

Therefore, time spent trying to do interdisciplinary work was sometimes considered unproductive, as researchers found it difficult to turn their efforts into much needed outputs that would justify their time commitments and provide evidence of their efforts. For example, 'dancefloor' spaces such as the Progress and Integration meetings were viewed as unproductive time-suckers rather than an opportunity to find synergies where research approaches could be integrated. For Elisa, her least favourite part about the project at the time of her interview was the unintelligible conversations in the Progress and Integration meetings: "When there are lots of long technical conversations, you have to listen to that and can't contribute to it. That is also time-consuming. And time is limited."

Affective tensions arose around the clash of publishing cultures, highlighting the divide between the natural and social sciences. As illustrated in the Three Pillar Paper critical incident, different *expectations* around authorship resulted in uncomfortable confrontations between researchers and manifested as feelings of frustration over perceived unfairness. Researchers then adjusted their approaches to collaborative publishing in order to regain a sense of fairness. These adjustments resulted in sharing work less often and not volunteering to help others, which by some researchers' standards went against the spirit of interdisciplinary collaboration.

Despite a project set-up that was meant to facilitate interdisciplinarity, engrained practices within the university environment and different approaches across the natural and social science disciplinary divide remained. This created a differentiation between interdisciplinary collaborations and disciplinary work: they became mutually exclusive

objectives. This differentiation resulted in disciplinary objectives becoming the priority over interdisciplinary collaborations.

9.1.3 Research Question 3: How did researchers assess the interdisciplinary element of the project? How did they come to those conclusions?

As a result of these largely unanticipated tensions that positioned interdisciplinarity as a separate and secondary objective, less interdisciplinarity occurred than researchers expected and desired. Researchers largely felt disappointed in this result, and many discussed the project in terms of being a 'failed' interdisciplinary endeavour.

The theme of *communication/language*, common in other interdisciplinary projects as outlined in Chapter Two, played a large role in assessing the success of interdisciplinarity on this project. From the researchers' perspectives, they thought they had 'failed' at interdisciplinarity because they could not understand each other due to different languages being spoken. As doing interdisciplinarity was often synonymous with speaking across disciplines and being understood, researchers used this as an indicator of successful interdisciplinary collaboration. A desire to converge on and create shared definitions of terms led the way to suggestions to develop shared glossaries to facilitate cross-disciplinary communication. However, these initiatives did not materialise and were therefore deemed unsuccessful.

Efforts to do interdisciplinary work were considered interdisciplinary *attempts* by researchers because no final outputs were produced to evidence the collaborations. In Stella's reflection on Reese's attempt to work together in Chapter Six, she indicated that although he tried, he was not successful in integrating the social and natural sciences through modelling:

> Reese really tried yeah […] It is a pity. I think it still looks really difficult, but I found it really interesting to see how he would build a model.

> But [I] don't know if there is potential to tackle any social justice issue with that. -*Stella*

Interestingly, the concept of outputs in the form of academic articles and books came from the university incentive structure that mostly recognises published work as achievements. However, as the university departments and journals are largely organised along disciplinary lines, there were tensions regarding how to write and where to publish interdisciplinary work. This tension reveals that applying universally-defined outputs to interdisciplinary efforts is a poor fit.

There was not enough evidence of interdisciplinarity in the form of outputs or published work, and social scientists on the project perceived their role in the collaboration as not embodying the ideal *integrative-synthesis* model (Barry & Born, 2013) of interdisciplinary working. This applied especially to the modelling ('Lego blocks') and prompted resistance from some social scientists to providing data or information to the natural scientists. Though this contribution was seen as needed and legitimate from the natural scientists' points of view, it was considered a service and did not constitute a real intellectual contribution from the social scientists' perspectives. This highlighted another dimension in which the natural and the social sciences were divided: they did not agree on what an interdisciplinary collaboration would look like. This reinforced that a *diversity of project goals* was not made visible until later in the project, a common challenge to interdisciplinary collaboration as outlined in Chapter Two.

Overall, these findings illustrate that the interdisciplinary nature of this project was uncomfortable for the researchers involved, as researchers found it difficult to *trust* in the methodologies or practices of other disciplines. As outlined in Chapter Two, trust is a necessary prerequisite to collaboration when communication is difficult and researchers are wading into new methodological territory. Interdisciplinarity within an academic incentive structure lacks clear evaluation measures and roadmaps to success. In their attempt to use the limited time to balance

project commitments with academic incentives to produce disciplinary outputs, researchers found they ultimately had to choose between these two objectives rather than balance both. Although 'walled off' and 'dancefloor' spaces were built for interdisciplinarity in supervisory and Progress and Integration meetings, exposure to other disciplines eventually became a distraction from getting a PhD or writing academic papers. Adopting a different language and changing ways of working to service other disciplines was more uncomfortable than retreating to one's disciplinary 'home'. Overall, this thesis speaks to a lack of evaluative measures for interdisciplinarity, making it difficult to deem the project 'successful'. And there was a rift between the *expectation* of interdisciplinarity set up by the project configuration described in Chapter Four and the reality of the experience as discussed in Chapters Five and Six.

9.1.4 Research Question 4: How can we understand the research in light of theoretical frameworks?

Chapter Seven addresses the lack of theoretical frameworks in the literature on interdisciplinarity to understand interdisciplinary research project outcomes. To address this gap, Chapter Two analyses multiple STS theories and takes Gibbons et al.'s (1994) NPK theory forward as a theoretical framework. The NPK theory outlines a Mode 2 research configuration which describes how knowledge is produced in a more public, socially accountable and reflexive manner. This is contrasted with the Mode 1 way of producing knowledge characterised by disciplinary researchers doing science to further scientific knowledge. In Mode 2 research, conducting research across disciplinary boundaries is key to contextualising it for real-world applications, thereby making this research more accountable and 'useful' from a social perspective.

As this research project was interdisciplinary, based on real-world case study cities and included a reflexive element in the form of a resident interdisciplinary researcher, the NPK theory provided the most relevant framework to understand the nature of this project. This thesis

investigated if the theory could help understand why researchers did not consider interdisciplinarity to have occurred in this instance, despite their initial desire to collaborate.

In comparing elements of this project with each of the five contrasting characteristics of Mode 1 and Mode 2 research, it is clear that this research project had Mode 1 foundations. In their attempt to create knowledge that crossed disciplinary boundaries, researchers tried to build an interdisciplinary project. This interdisciplinary organisation funded by an external supportive trust resembled some Mode 2 characteristics; however, in its disciplinary organisation, its hierarchical university structure and its strong traditional forms of disciplinary quality control, the project actually produced knowledge in a Mode 1 formation.

Grouping multiple disciplines together on a project can still maintain create hierarchical structures within a project and even highlight them further. As the research took place within the walls of the academic university, grouping several disciplinary expert ‘columns’ together did not necessarily produce interdisciplinary working. In addition, though the ‘dancefloor’ and ‘drywall’ provided spaces for interdisciplinary exploration, researchers could choose to opt-out of these potentially uncomfortable situations by retreating to their disciplinary ‘homes’ with their academic credentials intact. Although the importance of interdisciplinarity was communicated in funding reports and through the existence of a ‘diary room’, the researchers did not agree on how they could contribute to the project’s models (‘Lego blocks’). This disagreement around integration reinforced a disciplinary divide between the natural and social scientists regarding what was considered ‘good’ research. Although the building blocks established in the project’s foundations attempted to create an alternative research configuration outside of disciplinary confines, the existing disciplinary and university structures remained intact.

9.2 Future implications

The findings above provide guidance for what other researchers can expect in their own interdisciplinary endeavours. By anticipating some of these challenges, future researchers could think through how to address them, whereas on this project much time was spent trying to understand why conflict arose in the first place. Some specific suggestions for future research projects are given below.

9.2.1 Create separate, dedicated time to reflect explicitly on definitions and perceptions of interdisciplinarity.

Scheduling time to deliberate on what researchers expect from and understand of ‘interdisciplinarity’ creates the opportunity for inevitable variations to be identified early on. Bringing invisible assumptions to light puts researchers in a better position to either converge their thoughts on interdisciplinarity or consider and appreciate different perspectives.

This recommendation is related to the commonly repeated theme that time, or lack thereof, is a challenge to interdisciplinary collaboration (Goulden et al., 2017; Lotrecchiano et al., 2016; McBee & Leahey, 2017). Participants in this ethnography desired more time for interdiscilpinarity. Although they expressed that more time would have been useful to understand their fellow collaborators from different disciplines, I argue that time for explicit reflection on interdisciplinarity could have contributed towards mutual understanding.

This recommendation is also based on the research finding that definitions of interdiscipinarity varied widely amongst the researchers on the project. These definitions undoubtedly contributed to their individual interdiscipilinary attempts. Creating a mutual understanding of these defintions could be a first step towards coordinating interdiscipliary efforts.

9.2.2 Organise exercises that allow researchers to reflect on their own assumptions about research to facilitate reflexivity.

In addition to understanding what their colleagues think of interdisciplinarity, researchers will benefit from thinking about what good research means to themselves and others. Before researchers can come together in meetings and recognise potential connections with other research approaches, they must first understand why they perceive these connections and whether other researchers agree. Preparing a workshop that requires researchers to reflect on ontology and epistemology in their own research could be a helpful starting exercise.

Reflexivity amongst participants did occur on this project and was cited as an interesting by-product of working with others from different disciplines, particularly when discovering other definitions of research methods (case studies were a particular example referenced in Chapters Six and Seven). Researchers on the project credited these self-reflections as an avenue towards more robust research because they were put in the unusual circumstance in which assumptions about research methods were not automatically shared. I recommend that reflexivity extend beyond being a by-product of interdisciplinarity (Nowotny et al., 1994), making it a more deliberate exercise integrated into the start of interdisciplinary collaborations.

9.2.3 Create an environment of experimentation by recognising collaboration efforts despite their outcomes.

In an academic culture where researchers are measured by their outputs and funding proposals are evaluated on impact statements, experimental approaches can be positioned as risky rather than desirable. However, as interdisciplinarity can describe a multitude of component disciplines, modes of working and research approaches, many things in interdisciplinary work will be something that has not been attempted before, meaning there will not be a blueprint for

success. In recognising efforts and attempts as doing interdisciplinarity, the process itself can be appreciated, potentially preventing feelings of failure.

Recognising interdisciplinary attempts is hard to prioritise in an academic environment that uses disciplinary-oriented publications as measures for academic success (Boon et al., 2014; Castán Broto et al., 2009). Therefore, the incentives for interdisciplinary efforts could be built in by funders of interdisciplinary projects. Much like impact statements are required in funding applications and reports, interdisciplinary plans and coordination efforts could be given their own space and priority in applications and reports. Requiring researchers to explicitly think through and write how they plan to implement interdisciplinarity would prevent projects from expecting interdisciplinarity to just happen if they include enough members from different disciplinary backgrounds.

This project imagined that integration and interdisciplinary collaborations would coalesce around the models. However, it became clear during the course of the project that not all of the researchers, namely the social scientists, understood modelling to be a site of interdisciplinary collaboration. Due to perceived time constraints and a lack of incentives to find alternative meeting points, other avenues for interdisciplinarity were not seriously considered. A space to experiment or brainstorm alternative ways to ‘integrate’ disciplinary knowledge may have led to different outcomes.

9.2.4 Recruit experienced interdisciplinary researchers.

Interdisciplinary research can take many forms and approaches, but previous experience in an interdisciplinary project has the potential to inform other projects that are not necessarily similar in scope or form. Even just translating one’s experiences of a past project to anticipate what might occur in a new project has the potential to foster more thinking and reflexivity around expectations of interdisciplinarity by other

researchers. Returning to the researcher from Chapter Five who “knew it would be hard, just not this hard,” many of the principal collaboration challenges in this project—publishing across disciplinary cultures and the extra time needed—were unanticipated by the participants.

Researchers who have spent years focusing on a single-discipline career tend to find it more difficult to accept and implement new methods into their research and, therefore, have more difficulty collaborating with other disciplines and respecting the interdisciplinary process (Siedlok & Hibbert, 2014). Ensuring that documenting interdisciplinary research experience is included as a factor in the funding proposal would ensure that interdisciplinary experience can be passed on and appreciated.

9.2.5 View conflict as a source of learning.

As this study recognises, interdisciplinarity is as an exercise in being uncomfortable. Events that were characterised by conflict in this case study indicate a lesson to be learned in interdisciplinary working. Rather than view conflict as a negative experience to be avoided, encourage a culture where conflict is explored as a source of learning and reflection.

Recognising conflict as an inevitable and necessary aspect of interdisciplinary collaboration can help prevent it from being avoided. In this project, avoiding conflict and giving the impression of complicity through silence prevented any meaningful discussion about dissenting attitudes. In addition, it created a breeding ground for mistrust between the senior and junior researchers. Trust, a key theme outlined in Chapter Two, is often cited as a prerequisite for cross-disciplinary collaboration. Creating a dedicated safe space for conflict and recognising it as an opportunity for learning (Freeth & Caniglia, 2019) can help bring issues to the surface, even if there is no ‘resolution’ at the end. In order for real negotiation to take place, grievances and opinions need to be made visible.

9.2.6 Work with funding agencies to ensure that interdisciplinary learnings are passed on.

The reappearing themes of time constraints (Goulden et al., 2017; Lotrecchiano et al., 2016; McBee & Leahey, 2017), disciplinary preference in academia (Boon et al., 2014; Castán Broto et al., 2009; Guimarães et al., 2019; Lyall et al., 2015) and a lack of experienced interdisciplinarians on projects imply a lack of learning and knowledge sharing in interdisciplinary collaboration. As funding agencies drive interdisciplinary research, they should work directly with universities and consider what they can do to ensure that interdisciplinary projects are adequately resourced. Additional resources could include a required gestation time at the start of interdisciplinary research projects and funding for interdisciplinary training and workshops.

9.2.7 Appoint observers of interdisciplinarity to document the lived experience of collaboration.

A key resource that funding agencies can recommend at the application phase of interdisciplinary research projects is to appoint an interdisciplinary observer. This can be a dedicated role that resembles my position as the ethnographic researcher of interdisciplinarity. It could also resemble the roles that Fitzgerald (Callard & Fitzgerald, 2015) and Goulden (Goulden et al., 2017) played in their respective projects as research collaborators who reflected on the interdisciplinary process. The idea is that dedicated time is spent reflecting on and writing up the interdisciplinary experience in order to share key learnings about interdisciplinary collaboration.

I acknowledge feeling lost at the start of the project and stressed by the ongoing negotiations between others' expectations of my role and my own research objectives. Even so, sharing the lived experience of researchers on interdisciplinary collaborations in publications, presentations and other communications is necessary to address the literature's reoccurring challenges to cooperation. Much of the

uncertainty and ongoing (re)defining of my role within the project could be traced to my initial conflicted and divided understanding of my research. An ethnographer with a clear research objective would not avoid negotiations with collaborators all together, but they would have more conviction at the start of the project, allowing them to pursue their own research.

Future ethnographers embarking on collaborative projects as a member of the team should keep the insider-outsider paradox in mind. Managing the positionality to balance necessary critical distance and team trust is not something that can be resolved, but must be stayed with (Callard & Fitzgerald, 2015) and acknowledged throughout the project.

9.3 Future research

Further ethnographic accounts should aim to start right at the inception of interdisciplinary collaborations; this would help gauge potential changing attitudes towards interdisciplinarity. It was very telling that my involvement as an ethnographer of the interdisciplinary process began even before I arrived on the project. Tracking those conversations about including such a role in the project and what the researchers are hoping to gain could reveal perceptions about interdisciplinarity and how it can be measured or studied. By including an ethnography of interdisciplinary alongside in the initial construction of an interdisciplinary research project, more insights and understandings around researchers' imaginaries and how they translate into strategies for interdisciplinary working can be achieved.

This thesis is just one narrative account of the interdisciplinary process from my vantage point. Further reflections from other researchers on the team, either collaboratively or individually, would provide additional narratives to triangulate this research and add to the growing literature of the interdisciplinary lived experience. Other research participants from different positionalities—for instance, a senior academic or a researcher belonging to a specific project 'theme'—would provide

additional depth to the research by expressing the challenges particular to their academic status or discipline.

Given the unusual circumstances of my positionality as an insider-outsider interdisciplinary researcher, reflections on my multiple positions could translate to ideas for roles of STS collaborators on future interdisciplinary research projects. For example, should an STS collaborator intentionally enter a research project to disrupt existing processes and facilitate a change in research direction? Can STS research collaborators on interdisciplinary projects act as a research tool and producer of valuable data? This idea is inspired by other reflexive accounts of STS researchers in the field of natural sciences (Calvert, 2013; Viseu, 2015). Viewing my participation as intentional takes a step beyond viewing STS as a following science (Jensen, 2012) to viewing my STS research role as “formative accompanying research” (Freeth & Vilsmaier, 2019, p. 3), a position that actively balances observation with participation.

As indicated previously, a difficulty in measuring the impact of research projects partly lies in the time lag of its impacts (Omodei et al., 2016). For this project, revisiting some of the future outputs that result from the research, such as work that has yet to be published, could yield some insight into how researchers used this experience in their career. For example, did researchers choose to publish their work in disciplinary journals, or did they attempt to integrate some knowledge from other disciplines? Revisiting the researchers for future interviews could also reveal personal impacts of the interdisciplinary research experience. For example, speaking to the participants again after they have completed their time on the project could yield interesting insights on their lasting impressions of interdisciplinarity, and if those impressions have changed over time and why. This research would give an added dimension to how understandings of interdisciplinarity as a concept are created, co-created and employed in different research contexts.

9.4 Final thoughts

Although I felt prepared to study this interdisciplinary project given my previous experience outlined in Chapter One, I could see some of the same challenges occurring but felt powerless to do something concrete to change the outcome. For example, while I watched the PhD students try to negotiate authorship with their supervisors for the Three Pillar Paper, I could not offer a straightforward solution to the clashing disciplinary cultures around authorship practices that are established and accepted within their respective fields. Though I was initially imagined by senior management to be the interdisciplinary facilitator, it became clear over the duration that larger, established forces were at play that helped continue existing ways of working. I could not push against these forces to make way for easier interdisciplinary working, but I could identify them and make them visible to the researchers on the project and future interdisciplinary collaborators in similar environments.

9.4.1 I want to circle back to my first experience in interdisciplinary research that led me to undertake this sustainability research project PhD position. As described in Chapter One, a participant from that original project asked themselves: "How useful is this 'interdisciplinary' label anyway?" After embarking on my PhD research, my short answer is still, frustratingly: "I am not sure." The interdisciplinary label resembles the exclamatory 'gluten-free!' sticker on already gluten-free foods, now made fashionable by fad diets. On the one hand, successful collaborative projects with researchers from different expertises have always existed, but now an 'interdisciplinary' sticker provides access to large pots of funding. On the other hand, collaborators clamouring for funding attempt interdisciplinarity but are dissatisfied with the disciplinary-flavoured contents found inside the packaging. The interdisciplinary label had given them different expectations; whereas if they picked up the disciplinary-labelled projects, the same disciplinary content inside the packaging would not have disappointed. As this project illustrates, mismatched expectations can leave a bad taste in the mouth. Many researchers on the project were disappointed with the project's results, even though it managed to successfully produce numerous PhDs from multiple disciplines, allowed researchers to continue careers in academia and gave senior management the accomplishment of winning substantial funding from a private trust. Had this project been packaged as a 'lesser' form of interdisciplinarity, such as a 'collaborative' or 'sustainability' project, I presume those expectations would have been met even if the results were the same.

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Appendices

Appendix 1: Information sheet (interviews)

School of Sociology and Social Policy

The University of Nottingham

UNITED KINGDOM · CHINA · MALAYSIA

Information for Participants

Interdisciplinary approaches to assessing urban sustainability: an ethnographic study of interdisciplinarity in practice

Researcher: Ashley Lewis

This piece of research aims to:

- use ethnographic methods to investigate how the interdisciplinary LUCAS team studies urban sustainability

- to generate critical insights into the effectiveness of inter- and trans-disciplinary research that employs both quantitative and qualitative methods

- to ascertain key barriers that may hinder interdisciplinary research and key enablers for interdisciplinary research in urban sustainability

Your role as a participant:

As this is an ethnographic study – your role will principally be to conduct your research as you planned and outlined. In the attached consent form – if you so choose to sign it – outlines that you give permission for me to observe you during your work hours. This includes day-to-day office working including any meetings that will take place over the course of the research study. Only if everyone present in the office agrees - these observations will include audio recorded data that is recorded in the main offices during normal work hours only to capture everyday conversations as they happen ad hoc.

In addition to these observations – I may also ask questions regarding your methods and approaches during the course of the study to ensure I understand and accurately represent your rationale and research process.

In additional to conducting observations regarding office work and group dynamics, I may also ask to shadow you during any fieldwork or data collection stages of the research. This is a more in-depth observation where I observe how your ways of working on an individual level and ask questions regarding your research process and rationale. If I would find shadowing you individually helpful for my research, this would be agreed with you with your permission in advance during a time and place that is convenient for you so that it does not hinder your research process.

I will also ask to interview you as part of the study, most likely in a meeting room in the Lenton Hurst building. During these interviews I will ask you about your experiences in taking part in an interdisciplinary study and your perceptions of the work progress and outputs. I may ask to interview you more than once over the course of the study and the interviews are expected to last about an hour each time. The interviews will work around your schedule and will take place during normal office hours and work location to minimise any inconvenience.

In addition to the interview – I may ask you to record a 'diary entry'. This will be a self-recorded account of a meeting, an interdisciplinary interaction or even just your experience in general over a certain time period. Again – this recorded account will work around your schedule and take place during normal offices hours.

Benefits and information sharing:

Any preliminary research insights or findings that would facilitate the inter- and trans- disciplinary working in the research project will be shared with the wider group. This includes connections between groups of researchers that my not have been recognised or resources and data that one group may have that may benefit other researchers in the study. Any information sharing will have the full permission of the person or group who holds this information.

Potential risks

This project will not expose the research or the participants to any risk of physical or emotional harm. Any potential risk may include sharing information or data with the wider team that the participant does not want shared for privacy or funding competition purposes. To minimise this risk, participants and the researcher will make clear which data or feedback can be referred to publicly, remain anonymous or kept on a secure drive only (no sharing). Participants also reserve the right to refrain from discussing any information or topic if they so choose.

Consent:

Participating in this research is completely voluntary, and it is not required that you sign the consent form if you choose not to participate. Any participant can also withdraw their participation and corresponding data at any time for the duration of the research project.

Data storage:

Data collection and storage will comply with the University of Nottingham's research ethics procedures and code of conduct. The code of conduct can be accessed in full here: http://www.nottingham.ac.uk/sociology/research/research-ethics.aspx

All data will be stored in accordance with the requirements of the Data Protection Act 1998. It will also be stored in accordance with the University's Records Management Policy Statement (http://www.nottingham.ac.uk/academicservices/documents/rmpolicy.pdf#Records Management Policy) using University protected drives and hardware.

Research outputs:

The principle output of the research project will be a PhD thesis. Secondary research outputs could include a seminar presentation / talk, publication in an interdisciplinary research journal, media articles and / blog posts. Any upcoming plans or deadlines for any research outputs will be shared with the wider team closer to submission dates.

Prior to publishing any outputs that quote an individual or discuss any feedback or findings that are relevant to an individual, I will ask the respective participant to review the material first for approval.

Other participants:

Any principal and co-investigators of the project will be interviewed as part of the research process, as well as post-doctoral researchers and PhD students who are contributing to the research.

Contact details

Researcher: Ashley Lewis,
0753 031 3237
Ashley.lewis@nottingham.ac.uk

or write to address below:
B14 Lenton Hurst
University Park
Nottingham
NG7 2QL

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0115 95 15419
Reiner.Grundmann@nottingham.ac.uk

or write to address below:
Room A20 Law and Social Sciences
University Park
Nottingham
NG7 2RD

Complaint procedure

If you wish to complain about the way in which the research is being conducted or have any concerns about the research then in the first instance please contact the supervisor named above. If this does not resolve the matter to your satisfaction then please contact the principal investigator of the project, Professor Darren Robinson at tel: 0115 74 84012, email: Darren.Robinson@nottingham.ac.uk or write to address below:

B14 Lenton Hurst
University Park
Nottingham
NG7 2QL

Alternatively please contact the School's Research Ethics Officer, Dr Simon Roberts, tel. 0115 846 7767, email simon.roberts@nottingham.ac.uk

Appendix 2: Consent Form (interviews)

School of Sociology and Social Policy
University of Nottingham

Participant Consent Form

Interdisciplinary approaches to assessing urban sustainability research

In signing this consent form I confirm that:

I have read the Participant Information Sheet and the nature and purpose of the research project has been explained to me.	Yes	No
I have had the opportunity to ask questions.	Yes	No
I understand the purpose of the research project and my involvement in it.	Yes	No
I understand that my participation is voluntary and I may withdraw from the research project at any stage, without having to give any reason and withdrawing will not penalise or disadvantaged me in any way.	Yes	No
I understand that while information gained during the study may be published, no information that could lead to the identification of any individual will be disclosed in any reports on the project, or to any other party. No identifiable personal data will be published.	Yes	No
I understand that the researcher may be required to report to the authorities any significant harm to a child/young person (up to the age of 18 years) that he/she becomes aware of during the research. I agree that such harm may violate the principle of confidentiality.	Yes	No
I agree that extracts from the interview may be anonymously quoted in any report or publication arising from the research.	Yes	No
I understand the I have the opportunity to review any published work which contain extracts from my interview or observations from meetings.	Yes	No
I understand that any interview and group meetings will be recorded using audiotape/electronic voice recorder/video recorder	Yes	No
I understand that data will be securely stored	Yes	No
I understand that I may contact the researcher or supervisor if I require further information about the research, and that I may contact the Research Ethics Officer of the School of Sociology and Social Policy, University of Nottingham, if I wish to make a complaint relating to my involvement in the research.	Yes	No
I agree to take part in the above research project.	Yes	No

Participant's name (BLOCK CAPITAL)	Participant's signature	Date
Researcher's name (BLOCK CAPITAL)	Researcher's signature	Date

Appendix 3: Discussion Guide (interviews)

I am interested interdisciplinarity, how researchers make sense of it, how the researchers define it themselves and what it means in practice.

Please be as open and honest as you can, but of course if there are things you rather not talk about—we don't have to discuss them.

This session will be audio recorded and sent off to an independent transcriber to be transcribed, however in this process your identity will be anonymised and the only person who will view the transcripts is myself for analysis purposes. However, if you prefer, I can take notes instead of audio recording the interview.

Background

1. Can you tell me about your research educational background?
2. Can you tell me about your previous research roles, including any previous interdisciplinary projects that you have been a part of?

Project role

3. Tell me about your role in the project.
    a. PhD / Post-doc /PI
    b. Project 'cluster' or 'theme'
4. When did you join the project (month and year)?
    a. How long is your 'contract'?

Understanding of Interdisciplinary working

5. What does interdisciplinarity mean to you? How would you define it to someone else?
6. How do you discuss / describe your work to someone outside the project (in their own disciplines / disciplinary colleagues)?
    a. What influenced this description or understanding? Where does this come from?

Thoughts about the project

7. Tell me what you understand the project to be – how would you describe the project to someone else?
8. What were your expectations of the project?
    a. Where did these expectations / impressions come from?
    b. How does your current experience up until today compare with these expectations of the project?
9. Tell me what the best things are about the project / what do you enjoy the most? Why?
10. Tell me what are the worst things about the project / what do you least enjoy or find most frustrating? Why?

Interdisciplinary experience

11. What projects / collaborations are you working on with others? (both interdisciplinary and non-interdisciplinary)
    a. Tell me about them, how did they come about / arise?
12. (If involved in Interdisciplinary projects) Describe the type of interdisciplinary research / activities / collaborations you have done or are currently involved in at the moment.
    a. Who is also involved?
    b. How did it come about?
    c. What is interdisciplinary about it? / What makes this collaboration interdisciplinary?
    d. Tell me about your role versus the role of others in this collaboration.
13. Tell me about any other interdisciplinary collaborations that you know about that are happening within the project?
    a. Who is also involved?
    b. How did it come about?
    c. What is interdisciplinary about it? / What makes this collaboration interdisciplinary?
14. What have you learned about Interdisciplinarity since starting this project?
    a. Anything that has surprised you?
    b. Anything that reinforced your previous perceptions?

Motivations

15. What were you hoping to gain from this project?
    a. Exe. – published work, collaborations, networking etc.
    b. *Probe* – Are any of these goals related to the interdisciplinary nature of the project?
16. In your opinion, what would ‘success’ in this project overall mean?
17. What would ‘success’ for you personally mean?