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Exploring Interactions among the Sustainable Development Goals: Case Studies from Three Continents

Collaboration, creativity, conflict and chaos: doing interdisciplinary sustainability research

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Abstract

How do the social dynamics within interdisciplinary research teams shape sustainability research? This paper presents a case study of interdisciplinary research projects at the University of Sussex, as part of a programme aimed at encouraging collaborative work to address intersections between the Sustainability Development Goals. Using data gathered during a series of participatory workshops at the start and end of the projects, combined with non-participant observation and analysis of project discussions during the lifetime of the projects, we examine the diverse ways in which research teams configure themselves to navigate the terrain of interdisciplinary sustainability research and the kinds of social and discursive dynamics that shape projects. In particular, we relate the emergence of distinct project team configurations to diverse problem framings, and aspirations for collaboration within these teams. We examine some of the challenges facing researchers attempting to work in these ways, and explore implications of these dynamics for knowledge production for sustainability. We conclude by drawing out and addressing some of the challenges for institutions funding and supporting interdisciplinary sustainability research.

Keywords Interdisciplinarity · SDGs · Collaboration · Integration · Higher education

Introduction

Interdisciplinarity has become a powerful ‘buzzword’ in contemporary academia and science policy (Cairns and Krzywoszynska 2016; Cornwall and Brock 2005), a term that is often accepted as a ‘good thing’ and which acts as a password to securing funding and influence; meanwhile, it often remains somewhat opaque what is actually done under its auspices. The intractability of complex sustainability challenges, and, in recent decades a narrative of ‘grand challenges’ (Kaldewey 2018) such as climate change, global poverty, and biodiversity loss, have been important drivers of increasing interest in interdisciplinarity, to the extent that contemporary usage of the term is sometimes synonymous with ‘problem solving’ (Goyette 2016), and it is now

common to see interdisciplinarity stated as prerequisite for research funding (Buller 2009). More broadly, the prominence of discourses of interdisciplinarity can be understood as part of a longstanding debate about the need for greater accountability in publicly funded science (Nowotny et al. 2002), and an awareness of the role that scientific knowledge and technological innovation can have in driving problems as well as helping to solve them (Owen et al. 2012). Implicit in calls for more interdisciplinary science for sustainability is the belief (or hope) that better, more integrated, or more socially embedded knowledge production can help steer society toward desirable futures. However, simultaneously there is pervasive unease about the role of ‘the expert’ in addressing the kinds of complex, far reaching, ‘post-normal’ (Funtowicz and Ravetz 1994) challenges that characterise the sustainability domain. Calls for more interdisciplinary science have co-evolved with calls for a re-conceptualisation the role of experts, practitioners and citizens in the production and use of scientific knowledge (Ludwig 2009; Popa et al. 2015) as evidenced in the growth of related concepts such as community-based, interactive, or participatory research (Lang et al. 2012).

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Despite its discursive prominence, interdisciplinary working remains the exception rather than the norm in academic practice. In part, this is because of an ongoing trend within academia toward increasingly narrow specialisation and disciplinary fragmentation (Becher and Trowler 2001; Weingart 2000); in part, it is due to the well-recognized complexities and challenges to carrying out work of this kind (Lowe and Phillipson 2009). There is thus an acknowledged difference between ‘the level of interest in interdisciplinarity and sustainability at the level of discourse and rhetoric, and manifestations in practice as regards policy and programmes’ (Blake et al. 2013). Reflecting these challenges, one of the recommendations of a recent report by the British Academy was the protection of ‘seedcorn funding’ for interdisciplinary projects, provided directly by universities (Soskice 2016, p 12). We observed seven such projects, funded by the University of Sussex between 2016 and 2018, to carry out research on the intersections, synergies and trade-off between the Sustainable Development Goals.

The disjuncture between the ‘state of the art’ in academic writing on interdisciplinarity, and the realities of project work on the ground is caught by Donaldson and colleagues: ‘the ways in which we talk about interdisciplinary research are not straightforwardly connected to the doing of it’ (Donaldson et al. 2010, p 1521). Work is needed to reconcile ‘conceptual ideals and expectations with researchers’ realities’ (Wuelser and Pohl 2016, p 789). In light of this, and recognising the plurality of ways in which interdisciplinarity is operationalized in practice, we set out to explore the ‘messy realities’ (cf. Donaldson et al. 2010) and examine the implications for knowledge production for sustainability and for the funding and institutional support of this kind of work.

Why interdisciplinarity?

Understanding interdisciplinarity (and its promotion in response to various problems) requires a brief exploration of the notion of an academic discipline. Contemporary disciplines are neither fixed nor static structures, and in their current form (as institutionalised in contemporary universities worldwide), are relatively recent historical phenomena (Weingart 2012). Furthermore, they are often internally heterogeneous or divided. Commitment to a discipline ensures ‘that certain disciplinary methods and concepts are used rigorously and that undisciplined and undisciplinary objects, methods and concepts are ruled out’ (Barry et al. 2008, p 21). Despite pervasive geographical metaphors such as Snow’s influential characterisation of physical scientists and ‘literary intellectuals’ being at opposite poles (Snow 1959), or even the aspirations of interdisciplinarity itself to ‘bridge’ disciplines, disciplines are not fixed, unchanging features or locations in the knowledge landscape, but are

much more fluid, sometimes highly porous constructions, varying across geographical space and evolving over time (as the proliferation of disciplines in recent years illustrates (Becher and Trowler 2001; Clark 1996)). The concept of ‘boundary work’ draws attention to this constructed nature of disciplinary differences, describing the ways in which the boundaries between the scientific and non-scientific, and between different disciplines ‘are drawn and redrawn in flexible, historically changing and sometimes ambiguous ways’ (Gieryn 1983), and require active ideological work by members of different groups. Disciplinary boundaries can be understood therefore as ‘relational and in formation’ (Barry et al. 2008, p 27). An important part of what defines disciplines is their institutionalisation in the basic organisational components of the HE system (university departments, degree programs etc.). But there are also important cultural dimensions to the obduracy of these knowledge communities (Geertz 1983), including adherence to particular traditions, transmitted knowledge, rules of conduct, and linguistic and symbolic forms of communication (Becher and Trowler 2001, p 47). Importantly, disciplines are not only intellectual but also social structures, made of people with ‘vested interests based on time investments, acquired reputations, and established social networks that shape and bias their views on the relative importance of their knowledge’ (Weingart and Stehr 2000, p 11). Disciplines—and their disciplining of work practices—matter because they not only reflect but also act to ‘structure the production and distribution of knowledge’ and as such ‘have the function of mediating and directing social change’ (Weingart 2012, p 4).

Calls for researchers to work beyond their disciplines are not new, and debates around the need for interdisciplinarity were taking place in the late 1960s and early 1970s (Apostel et al. 1972), with some tracing the roots of the discourse back further to the ‘unity of science’ movement of the 1930s (Weingart 2012, p 11). The US National Academy of Sciences defines interdisciplinary research as: ‘a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice’ (National Academy of Sciences 2005, p 2). However, diverse definitions of interdisciplinarity exist, and there are a number of fault lines in the discourse. For example, many authors distinguish between multi, inter and transdisciplinary research according to the profundity of engagement between disciplines (Harris and Lyon 2014), with multidisciplinary defined as research involving juxtapositions of disciplinary approaches, interdisciplinarity as involving more robust integrations and collaborations (Klein 2008), and transdisciplinarity as involving the incorporation of knowledge

from stakeholders outside academia (Stirling 2015). Some distinguish between ‘instrumental interdisciplinarity’ aimed at problem solving, and ‘critical interdisciplinarity’ which ‘interrogates the dominant structures of knowledge and education with the aim of transforming them, raising questions of value and purpose’ (Klein 2008, p 23) and ‘unsettling’ established assumptions’ (Popa et al. 2015, p 47).

Integration has been called the ‘crux of interdisciplinarity’ (Klein 2008), and is key to many definitions (including the NAS definition above). However, this focus on integration has also been the subject of critique, with some highlighting a lack of clarity around what the term means (O’Rourke et al. 2016). Popa and colleagues suggest there has been a shift in the discourse of interdisciplinarity from an integrative ideal in which the contributions of different disciplines are articulated ‘into a coherent framework’ (Popa et al. 2015) toward contemporary ideals of ‘coproduction’¹ and ‘co-design’ (cf. Moser 2016) involving ‘the intentional act of engaging extra-scientific actors in the process of scientific knowledge production’ (van der Hel 2016). Barry and colleagues argue that the integrative/synthesis mode is just one *mode* of interdisciplinarity, which can also take other forms, including what they describe as subordination/service mode, in which one (service) discipline is understood as filling in for a lack in another (master) discipline, as well as what they call an agonistic/antagonistic mode, in which creative tensions are brought to the fore, and neither synthesis nor service are the expected outcomes (Barry et al. 2008). Others have cautioned against viewing integration of disciplines as an unproblematic ‘good’, pointing to the ways in which integration may act to obscure the political nature of claims to ‘holistic expertise’ in global systems at the macro level (Sarewitz 2010), as well as the politics of knowledge at the more micro level (Stirling 2015). As MacMynowski summarises, different ‘knowledge claims have differential power associated with them: within the sciences, between social and biophysical science, and between science and society... [which] can manifest in many ways, e.g., individual scientific status, the most accepted account of an environmental problem, inclusion or exclusion of researchers, or perceived relevance of research to policy decisions’ (MacMynowski 2007, p 1). Indeed Sarewitz argues that claims to holistic expertise about a complex system are necessarily political, because ‘they reflect a choice process—about how to define the system, about what system functions and outcomes are important, about what is to be done to

make things better, about what ‘better’ means’ (Sarewitz 2010, p 73).

‘Science for the SDGs’

In 2016, the University of Sussex launched the Sussex Sustainability Research Programme (SSRP), a £3 million investment in ‘integrated research’ with the tagline ‘Science for the Sustainable Development Goals’. The programme aims to encourage interdisciplinary collaboration (between natural sciences, social sciences, and the humanities) across campus (and including the Institute of Development Studies), with a focus on supporting research into ‘possible trade-offs among SDGs, and solutions that avoid these trade-offs, enabling many SDGs to be accomplished at the same time (University of Sussex 2018). The SSRP programme does not apply a strict definition of interdisciplinarity to the projects it funds, hence in the present paper we also eschew a strict definition (to avoid possibly excluding some projects). We use interdisciplinarity in this context as an umbrella term to refer to a ‘family resemblance’ (Soskice 2016) between kinds of research in which groups or individuals aspire to work beyond the confines of a single discipline in a variety of ways. This approach is not without risks. It has been argued, for example that ‘where concepts or ideas are not properly defined the risk is that a rather shallow interpretation prevails’ (Jahn et al. 2012, p 1). However, Donaldson and colleagues have cautioned against attempting ‘pin down the essential reality of interdisciplinarity’, claiming that accepting a looser definition is part and parcel of living with the ‘mess’ which is a fundamental and irreducible element of interdisciplinary work on ‘messy problems’ that overflow disciplinary boundaries (Donaldson et al. 2010; Law 2007). Counter to suggestions that interdisciplinarity needs to ‘be disciplined’ (Bammer 2013), they suggest that ‘[t]he way in which interdisciplinarity is written about is effectively a method which irons out the mess of actually working together, in much the same way that considering disciplines as static irons out the mess of their evolution and multiplicities’ (Donaldson et al. 2010, p 1525). There is, they argue, ‘no reality to interdisciplinary research other than that which is made in practice’ (Donaldson et al. 2010). Our current focus is on the dynamic processes of interdisciplinarity (Buller 2009), leaving as an empirical question whether—and in what ways—integration is imagined as the desired end point. Keeping the analytical focus on dynamics allows us to interrogate interdisciplinarity as a messy, political process of negotiation, taking place in temporary, relational spaces in which disciplinary affiliations are only one important factor. Exploring process opens up to critical scrutiny the ways in which closure occurs (e.g. around particular problem framings, aspirations for collaboration, understandings of validity, and notions of success). Mindful

¹ Here, the term ‘co-production’, has taken on a meaning distinct from its use within social studies of science (where it refers to the ways in which ‘knowledge and its material embodiments are at once produces of social work and constitutive of forms of social life’ (Jasanoff 2004, p 2).

of the fact that, in interdisciplinary research as in research in general, there are strong pressures toward simplification and the artificial ‘neatening’ of social realities, which Stirling cautions ‘are most vulnerable to political manipulation’ (Stirling 2010), we do not aspire to write out the ‘mess’ of interdisciplinary working, but on the contrary to provide empirical descriptions of the messy realities of these kinds of project.

Data collection

We worked with seven interdisciplinary project teams, funded by the Sussex Sustainability Research Programme between June 2017 and October 2018. The work described here was also funded as part of this programme to provide a space for reflexivity within the programme and to contribute to SDG17 (strengthening global partnerships to support the SDGs). Reflexivity in this context is understood as a process of making explicit, and reflecting upon, the assumptions, framings and politics shaping the processes and outcomes of research. Our project team was itself interdisciplinary in nature, involving co-investigators from the Science Policy Research Unit and the School of Engineering and Informatics.

The projects we worked with were all mandated to focus upon ‘possible trade-offs among SDGs, and solutions that avoid these trade-offs’ (University of Sussex 2018). All projects faced similar funding and institutional constraints, including a funding model that funded the time of research associates but not that of the principal investigators or co-investigators of projects. Data collection comprised a series of participatory workshops, and non-participant observation of project meetings. Participatory workshops took place with seven groups at the start of the projects’ lifetime (June 2017) and had two main aims: to explore the disciplinary commitments of the participants (for which a modified ‘rivers of life’ exercise was used Moussa 2009), and to map the kinds of interactions and project structures that teams envisaged might arise as the projects unfolded, as a way of probing ideas of collaboration. Participants took part in a creative group exercise in which they represented in 3D (using a range of modelling materials including string, paper, and pasta shapes), their imagined collaboration over the course of the project (see Light and Boys 2017). This latter exercise involved the creation of an object ‘for thinking with’ (Turkle 2007) at the start of the project, which could be returned to at the end of the project, in the form of photos, to facilitate reflection on the collaboration. Over the following year, a researcher attended project meetings of five of the groups as a non-participant observer to witness interdisciplinary collaborations in action. In addition, two of these projects were followed in more depth, with the researcher observing regular project meetings. Towards the end of the projects,

follow-up workshops were carried out with four of the seven groups. These meetings were designed as a series of exercises encouraging teams and individuals to reflect upon what had worked or been challenging or unexpected in their projects, and to re-visit (and where necessary revise) their initial expectations of interdisciplinary working. Invitation to participate was open to all SSRP projects, and the final corpus of projects studied were those who self-selected to be involved. All workshops and meetings were recorded with participant consent and selectively transcribed, and coded thematically using Nvivo 10 qualitative data analysis software (QSR International Pty Ltd 2012).

Results and discussion

The projects we worked with were diverse in terms of their empirical and geographical focus, and the researchers involved self-identified with a broad range of disciplinary affiliations (see Table 1). Noteworthy is that many of the participants identified with relatively new and ‘interdisciplinary’ disciplines, such as sustainability science (Komiya and Takeuchi 2006) or conservation biology (Soule 1985), and many had both natural and social science degrees. As one collaborator described the team’s backgrounds “*both of us have been working anyway on divides of different disciplines so we were trained in thinking through the cracks of different disciplines*” (Co-I, Debt). This appears contra to the idea that what is required as the basis for encouraging interdisciplinary engagement is the existence of robust disciplines (Soskice 2016), or at least to suggest that the skills and experiences gained by having worked across boundaries make people more suited to, and more attracted to, the specific challenges of working this way.

We observed several differences in how the various teams approached the challenge of interdisciplinary working, which we describe below with regard to two central ‘axes’: firstly the degree to which research problems were open to negotiation through the collaborative research process; and, second, the particular ideas of integration (for example of concepts, data or methods) underpinning the projects, including aspirations for the collaboration itself. Both these factors shaped how success or failure in the projects was conceptualised and shaped the knowledge that was produced. In the descriptions that follow, the projects are referred to using their abbreviated title in italics (see Table 1).

Problem fields or problems?

A formative difference between projects was the degree to which ‘the problem’ being researched was fixed at the outset of the research process or left more open to negotiation

Table 1 Interdisciplinary projects followed and (self-assigned) disciplinary affiliations of collaborators

Project title (abbreviated title in bold)	Project summary	Disciplinary affiliations of collaborators
A. People, pollinators and pesticides in peri-urban agriculture*	Using citizen science to collect data on pollinators, crop yields and pesticide use to understand more about peri-urban food production, in Brighton, UK, and Kolkata, India	Conservation ecology; science policy; law
B. Managing large herbivores for biodiversity, food security and broader sustainability*	Exploring the role of large herbivores in community connected agriculture, conservation and rewilding, in southeast England	Ecology; conservation biology; science policy
C. Adaptive Capacity and collective action in Marginal Mountainous Areas of India	Analysing how external intervention is shaping collective action and adaptive capacity among rural households in Uttarakhand, India	Sustainability science; geography; sustainable entrepreneurship; development studies
D. Building global surveillance with local data: towards a sustainable global response to antimicrobial resistance	Applying a bio-social approach to examine antimicrobial resistance, in Cairo, Egypt	Development studies; microbiology, international relations
E. Assessing the impact of debt on forest cover, air pollution and resource efficiency	Producing a systematic account of how global and local debt dynamics impact environmental indicators of forest cover, air pollution and resource efficiency	International relations; environmental sciences; economics
F. Understanding trade-offs between SDGs in urbanising contexts: Novel methods of mapping rural–urban interactions in food systems to analyse risks and opportunities for environmental and human health	Developing novel transdisciplinary methodology for mapping and analysing the impact of different development trajectories and urban planning decisions; considering health and wellbeing across time, space and social groups	Ecology; environmental science; science policy; informatics; development studies
G. Determining the impact of migration , remittances and food security for rural households	Exploring the interaction between food security, cash and in-kind remittances, and migration for rural households in Zimbabwe	Economics; geography

An asterisk (*) indicates a project that was followed more intensively over the year

through the collaboration. While, at one level, all projects were framed by the funding mandate to elucidate ‘SDG interactions’, the extent to which this framing was operationalized within projects varied considerably. In the academic literature on interdisciplinarity, problem framing—which refers to the processes of identifying and bounding the research area—is often considered an important stage of the interdisciplinary research process (Wuelser and Pohl 2016). In contrast, in disciplinary research this process of framing the research is not usually explicitly defined, because ‘it is accepted, or habitual, within a school of thinking which shares an ontology and epistemology’ (Oughton and Bracken 2009, p 386). Lang et al. provide detailed guidance on this stage of research in the form of a set of ‘design principles’. They suggest that all team members should be involved in creating a ‘joint understanding and definition of the sustainability problem to be addressed’ (Lang et al. 2012, p 29) and specify this should be done so as to integrate and balance ‘contradicting normative scientific and political claims of importance and relevance’ (Bergmann and Jahn 2008, p 92). Others have described this stage in terms of a dynamic process establishing and reframing the ‘purpose to guide learning’ (Mansilla 2012, p 299). Oughton and Bracken suggest that, rather than a discrete stage, ongoing, reflexive negotiation of the research framing is key: ‘[s]uccessful projects are able to identify and support the processes that allow the communication and negotiation that is necessary not just for the initial framing of a research funding proposal but to be able to maintain negotiation. Self-awareness and continual reflexivity and a willingness to be questioned by others are essential to this process’ (Oughton and Bracken 2009, p 392).

Lending support to the claims that there is a gap between the state-of-the-art in academic literature and the realities of interdisciplinary working, an explicit focus on problem framing was not a discrete stage in all of the projects we observed. Projects in our cohort could be situated on a spectrum from those that started with a fairly open ‘problem field’, to those addressing a more or less fixed or definite research challenge. Exemplifying the latter category, one group (*Debt*) started from a clear conceptual frame, which was established through dialogue and negotiation between the co-investigators during the bid writing stage and in the early stages of the project. This frame determined, to a great extent, the structure of the project, and meant that questions that subsequently emerged were primarily technical and methodological: *is it possible to model this? Is it feasible, and is the interaction that we suspect, present in the data?* As Oughton and Bracken highlight, the ‘researchers affect the research question, and the research question determines who is drawn in as a researcher’, and in this case the framing of the project clearly determined the particular researchers that could be involved. Hence, in recruiting a

research associate to the project, the lead investigators had a clear sense of precisely what was required, and talked of an individual bringing the “*quantitative skills to deliver what we want him to do[...] He brings the complementary skill set that we want for the project*” (PI). In this project, the research associates were required to share the lead investigators’ understanding of the problem and, in particular, the methodological challenge. As the researchers put it, they needed to recruit someone who would “*love the idea*” and the PI refers to the RA as acting as “*a safeguard of the idea.*” In this instance ‘the frame dominates’ (Oughton and Bracken 2009), and can be seen in the way investigators described being cautious about the project moving too far from the original brief: “*We are cautious that we should not push it in one direction [...or] we may be losing something of what brought us together in terms of the originality of the idea.*” (PI).

By contrast, another group (*Large herbivores*) started from a much broader problem field, in which the specifics of the research question(s) remained open. In this project, the aim was to move from problem field to researchable problem collaboratively and, to that end, an away-day was held at an early stage in the project to discuss questions as broad as ‘*why are we doing this?*’ (RA) and ‘*What is an interdisciplinary question and how do we make it work?*’ (PI). Debates and discussions at the away-day reveal the complexities of negotiation that take place upstream in a research process when a project has been conceived of in these open terms. Vocabularies and concepts were not wholly shared and there was a to-and-fro process between team members as individuals attempted to ‘pin down’ the subject matter. While the openness of this moment was described as exciting, months later it was tempered by frustration:

RA. “Actually for me that’s a really exciting space to be in, developing methodologies and designing projects, but I think it did feel stressful and frustrating in the context I felt that we didn’t really have the time for it. So that’s what was frustrating.

PI. That’s my exact feeling as well, so I was consciously throwing it all out there and then, right, we need to bring it all back again almost immediately.

RA. Yeah, it felt like we really needed to crack on, so we were constantly trying to open it up but then rein it in.

In another project (*Pollinators*), we observed how interdisciplinary interactions between team members, as well as emerging research outcomes, have the potential to shape or re-frame the direction of the research, even where the starting point is fairly fixed. This is illustrated by an anecdote about a world café organised midway through the project, with volunteers who had engaged with the project as ‘citizen scientists’. As the research associate explained, the purpose

of this event was initially “*to get feedback on why people didn’t engage as much as we thought; and also part of that was feeding back the results to people to reward them for engaging*” (RA). Ahead of the world café, during discussions between the team, a Co-I raised the idea of taking this opportunity to ask stakeholders what questions they would like the project to ask, to build on the co-production aspects. This intervention resulted in a shaping of one strand of the project toward particular questions of interest to the volunteers, and to broadening of the conceptualisation of citizen scientists in the project, from simply collecting data for the project toward a role contributing ideas and knowledge to shape the project.

In another project (*Collective action*), the problem field was broadly defined or “*sketched out*”, as the Co-I put it, at the bid-writing stage, but left deliberately flexible to be shaped by the incoming research associate. In discussions early in the project, the collaboration was framed as an “*intellectual journey*” for the researcher and it was supposed that he would steer the project according to his strengths and interests, with support and input from the wider team. Referring to the potential tension between individual interests of the team (e.g. the need to publish) and the interdisciplinary nature of the project, one of the co-investigators talked of the need for compromise, saying, we may need “*to take some of our pet projects around the back of the shed and shoot them*” (Co-I).

Aspirations for collaboration and imagined forms of integration

Among our cohort of projects, we identified a range of different aspirations for collaboration and imagined forms of integration, which animated and shaped working configurations. Whether or not the notion of ‘co-production’ was a specific aim of the teams, and in what sense, was one axis of difference, and in some cases, shifted through interactions over the course of the project.

A number of projects aspired to involve extra-scientific actors in the research process. For example, in the *Collective Action* project there was space written into the project proposal for the involvement of an NGO partner, who, it was hoped, would be “*extremely helpful to co-construct the research questions*” (Co-I). Another group, (*Large herbivores*) also had aspirations to ‘co-produce’ knowledge on their project, to which end they were clear that a project structure with more than one researcher was required, as well as interactions with extra-scientific stakeholders. The intention was that two researchers from different disciplinary backgrounds and based in different schools would be “*constantly interacting*” (PI) and interpreting from different perspectives. Initially the aspiration for collaboration was very ambitious, and although there was debate around whether

there was a need for distinct research questions to ‘speak to’ different disciplinary interests and audiences, the plan (not fully realised in the end) was to collaborate at every stage of the research. As one researcher put it “*even if we did go down this route where we have questions that look like an ecology questions and a social one... We do the fieldwork together, we do the interviews together*” (RA).

The researchers on this project talked about the potential for ‘innovation’ in interdisciplinary work, the messiness (or, in their words, ‘chaos’ of) interdisciplinary working and the opportunity for learning this can afford: As they put it:

“PI. It feels like it’s supposed to be slightly chaotic you know? ... You need people coming from different perspectives with strongly held views to challenge each other in order to bring out the most of it and carry on. If you had a particularly dominating character in there that just said, you know, this is the way you do it, you’re losing that opportunity for development... ”

RA. For novelty or learning, yeah.”

This dynamic of embracing ‘difficult discussions’ would appear to share some of the characteristics of the agonistic/antagonistic mode of interdisciplinarity identified by Barry and colleagues (2008), in which creative tensions are brought to the fore and embraced. Within the project, the making explicit, and discussion, of different epistemological positions meant that the service mode of interdisciplinarity was rejected. But both the integrative/synthesis and agonistic/antagonistic modes seem to have existed in parallel in this project. Thus, at different moments in the lifetime of the project, interdisciplinarity was framed as both the ‘integration of methods’, and the transformative potential of the coming together of different conceptual frameworks.

The project’s aspirations for collaborative working and coproduction had fundamental consequences for notions such as validity. In particular, the close working relationship with stakeholders provided the project with what they termed ‘a license to operate’ in a broader sense than a disciplinarily grounded approach would have. As the PI put it:

“Because you’ve got multiple perspectives, multiple disciplines, by bringing ...practitioners and policy makers together and feeding back on what we’ve actually come up with, and get some reassurance that it’s actually relevant to what they’re thinking about. And actually one of the things they said was they want data with stories. A story behind the data, and ...that gave us a licence to operate in a much broader sense” (PI).

While the PI of this particular project expressed the view that he couldn’t see “*how you do interdisciplinary research with one post-doc in one school*”, two other projects in our group did opt to employ just one researcher, who was to act as the site of interdisciplinarity or integration in the project

(the ‘lynchpin’ as one was described). In one instance, having discussed whether to employ two researchers, the PI opted for one, providing that person was suitably ‘adaptable’ to deal with the challenges of interdisciplinary working. In another, the interdisciplinary background of the recruited researcher was felt to be key to their ability to synthesise diverse disciplinary approaches.

In these projects, perhaps as a result of the structural decision to employ one researcher, we observed that much of the teams’ aspiration for interdisciplinary collaboration was related to the learning of methods or techniques from other disciplines. Thus, for the natural sciences-trained research associate of one project (*Pollinators*), the aim was to learn ‘social science methods’ such as interview techniques, and how to run focus groups. In the other project employing one interdisciplinary but primarily social-science-trained researcher (*Collective Action*), this kind of dynamic was also apparent, with the RA describing his expectations of interdisciplinary working in the following terms: “*I thought I’d learn a bit more about natural sciences or physical aspects of environmental research*” and “*that I would be learning different research methods, and a way of integrating what I did with a different set of methods to understand similar kinds of phenomenon*” (RA). In the end, however, these aspirations were not fully realised, and the researcher expressed frustration toward the end of the project that time and resource constraints had not allowed him to achieve these aims. As he put it, “*I felt like I had to be interdisciplinary, but I didn’t really know how to do that... especially given the resources and the time frame. It’s a lot to learn a new discipline within that. And I want to do the project well, rather than... compromise it a bit*” (RA).

In these cases, it would appear that the reliance on a single individual to be the site of integration of diverse kinds of approaches and data may have the tendency to shift the projects toward what Barry et al. (2008) describe as a subordination/service mode of interdisciplinarity. In their example, they describe a problem defined in natural science terms in which social ‘factors’ need to be studied, and the way in which role of the social scientist in this collaboration is limited to provision of data. A researcher on one of the projects (*Large herbivores*) highlighted the pervasive potential for this dynamic to develop, asking: “*Doesn’t the notion that you just have one PI feel a bit at odds with having a project that’s a meeting of disciplines in a way? ... you still tend to have a ‘boss discipline’*” (RA).

Despite critique of integration as unproblematic ‘good’ (Sarewitz 2010), we observed that integrative ideals of various types are still influential in the imaginaries at work among our cohort of projects. Lending support to the critique that ‘integration’ in interdisciplinary research remains a poorly defined ideal (Dovers 2005; O’Rourke et al. 2016), the specific mechanisms through integration or synthesis

was expected to happen remained largely ‘black boxed’, with a number of researchers describing the process of interdisciplinary integration as ‘magic’. Neither were imaginaries of integration fixed, but rather more fluid and sometimes shifted over the course of the projects. Thus, for example the *Antimicrobial resistance* project initially described a process whereby data collection from distinct disciplines would occur in parallel over the course of the project, with an imagined (discrete) synthesis point taking place toward the end of the project. This shifted toward an imaginary of synthesis occurring through the interactions between researchers with different disciplinary backgrounds working alongside over the course of the project. Another project (*Large herbivores*) attempted to bring concepts into conversation across the disciplinary divide, and imagined some forms of—if not integration, then interaction and possible transformation—occurring between the researchers working in parallel, speaking of ‘genuine’ interdisciplinary research without making explicit how this might happen.

Success and failure

The question of how to assess interdisciplinary outputs or measure the success of interdisciplinary projects is the subject of ongoing debate in the academic literature (Mansilla 2006). Much academic literature on ‘barriers’ to interdisciplinary working focuses implicitly on factors aiding or hindering success (Miller et al. 2008; Morse et al. 2007). Among our participants, factors that were raised in such terms are those that are frequently cited in the literature, and included: a lack of time and money (and specific limitations of the particular funding model of the programme); disciplinary languages and vocabularies making communication difficult; different (often not explicit) epistemologies and ontologies at work; the physical layout of universities acting as a barrier to close collaboration; and cultural differences between departments about what constitutes research. However, discussing these issues in terms of ‘barriers’ to interdisciplinarity implicitly assumes a shared collective understanding of what successful interdisciplinarity looks like. Given the diversity of definitions, logics and modes of interdisciplinarity at work even in our small sample of projects, definitions of success are necessarily multiple and situated. The example of a researcher (in the *Collective Action* project) choosing to ‘do a project well’ from one disciplinary standpoint, rather than attempting to get to grips with a whole new disciplinary perspective and set of methods, which he felt might compromise the robustness of the project, illustrates the ways in which different aspirations for collaboration (and their importance relative to project goals), have implications for notions of ‘success’ within the projects.

One angle from which to examine success and failure, without needing to essentialise these concepts, is to probe the emotions generated by the collaboration. Already mentioned was the sense of frustration at expectations not being fully met. Another emotional dimension we encountered was anxiety. The idea of interdisciplinary collaboration as ‘risky’ is often mentioned in the literature on the topic, in particular we note that the brunt of this risk is primarily born by more junior researchers who have yet to establish academic track records and for whom, therefore, difficulties in publishing will be more keenly felt and hence likely to cause anxiety (cf. Stokols et al. 2008). On the other hand, various participants referred to interdisciplinary working as ‘fun’ and ‘exciting’, reflecting potential for interdisciplinary work to open up spaces for novel, unexpected or surprising findings and learning. However, it is not necessarily the case that difficult or ‘negative’ emotional responses can be mapped onto failure in any straightforward sense. Indeed, if one aspires to an agonistic/antagonistic mode of interdisciplinarity, perhaps what feels like failure (emotionally) is in fact indicative of success; it may be that interdisciplinarity is inevitably a bit uncomfortable.

In the broader terrain of collaboration, one recurring theme discussed in positive ways by participants was the importance of existing friendships and mutual respect between researchers. Clearly helpful in any research collaboration, perhaps these social dimensions are even more so in an interdisciplinary setting in which communication may be strained, and there may be potential for implicit disciplinary hierarchies, and the politics of knowledge to cause tensions. Indeed some authors have referred to the need for ‘great friendship’ to underpin interdisciplinary collaboration (Buller 2009). Perhaps related to this, several projects had explicitly non-hierarchical aspirations, as the PI of one project (*Debt*) referred to the research associate: “[he] is an equal member of the group, ..., I don’t think we ever thought of our post doc either as somebody who will just come to deliver their own project, or they would come to just assist us, or just translate among us and so on. We thought that we need somebody who would love the idea, and then they join the battle essentially as an equal.” Another project (*Large herbivores*) referred to the lack of hierarchy in decision-making: “We talked a lot about how to take decisions and about our team, the balance of the relationship and who might be boss. There is no boss” (PI). The potential for unspoken hierarchies to complicate interdisciplinary interactions is widely acknowledged in the literature, and it has been argued that dismantling these hierarchies ‘including knowledge hierarchies (whose knowledge counts (or counts more)?), is maybe some of the most difficult—and transformational—work’ (Moser 2016, p 111).

Another factor mentioned by a number of groups as important for the success of the collaboration was the

existence of a shared normative framework underpinning research. This normative alignment was felt to transcend disciplinary divides and kept attention focused on the broader ‘why’ of coming together (i.e. the sense of the existence of a problem field of shared interest and a desire to contribute to positive change, however understood). One project team (*Pollinators*) discussed the fact that despite disciplinary differences, they shared “*similar interests and a similar ethos. We’re all interested in these big environmental problems, particularly how farming can be improved and made more ethical, minimising harm to the environment*” (PI). Another group were particularly motivated by shared sense of interest in a desire to see change locally. As one researcher put it “*we don’t want to just be the old-fashioned academics and post our knowledge into the stratosphere, and say, ‘bye bye, we’ve done our bit’, but we’re all keen to see practical difference being made in our lived worlds*” (RA, *Large herbivores*). Such activist intentions transcended ways of knowing and were cited by most teams as a motivator and means of finding connection.

Conclusion

We have analysed how research teams comprising diverse configurations of people and expertise attempt to do interdisciplinary sustainability research. We illustrate the ways in which projects are animated/underpinned by diverse ideas of integration (including distinctive aspirations for collaboration), and explore how spaces for negotiation in projects are opened up or closed down around particular problem framings during the research process. We note that these processes of negotiation are political, and emphasise the need for reflexivity to make these processes visible and transparent. We question the notion that interdisciplinarity is, or should be, synonymous with problem solving, suggesting that the creative tensions that can be generated in these collaborations may lead to more fundamental questions being asked, but not necessarily being answered. ‘Closure’ it seems might be made more difficult by the process of interdisciplinarity. Indeed, our findings support the idea that interdisciplinarity is perhaps better understood as being fundamentally explorative, ‘an emerging research praxis whose finality is more experimental, less absolute, less definitive and less objectifiably conclusive’ than other forms of research (Buller 2009, p 402).

In thinking about how interdisciplinary sustainability research happens, we have found it productive to think beyond the notion of a simple boundary or interface between fixed disciplines, but rather to broaden our attention to the wider terrain in which research develops, which is both complex and ‘messy’, and in which (more or less porous) disciplines are only one of a number of things

in circulation (Donaldson et al. 2010). In addition to the broader framing assumptions (in this case the central framing of ‘science for the SDGs’) that structure all but the most open funding calls, other elements such as life experiences, values, hopes and culture all play important roles in interdisciplinary collaboration. These provide valuable ways of knowing the world, and potential for imaginative connections and reconfigurations, and arguably are at least as important for collaboration as robust disciplines in transformative problem-solving research.

Institutions wishing to encourage and support interdisciplinary work need to recognise the plurality of modes and logics that drive such work, including, but not limited to, efforts at problem-solving. To allow potential for more novel, unexpected framings and findings to emerge through interdisciplinary processes, funders must strike a delicate balance between specific funding remits framed around particular problems, and allowing a degree of openness, time and space within which interdisciplinary teams, and partners and stakeholders outside academia, can negotiate and co-construct their problem framings.

The provision of skills and methods training to broaden the use of particular methods beyond the disciplines from which they have traditionally been associated is of crucial importance in supporting researchers and teams to work in more interdisciplinary ways, particularly in projects with shorter durations. However, this is, in itself, insufficient and there is also a need for institutions to nurture the social conditions which help to build and maintain the social relationships and communities which are so crucial to interdisciplinary working. Cultivating the expectation that there will be multiple realities operating and acknowledging the incommensurability of ideas across epistemological boundaries can allow teams to move more quickly to accommodation of different working styles.

In terms of the assessment of interdisciplinary work, there will inevitably be pressures (often most keenly felt by more junior researchers) to produce work that will be recognised as valuable and robust from within the assessment structures of particular disciplines (e.g. will result in journal articles in highly ranked disciplinary journals). However, those funding interdisciplinary work have the opportunity to use assessment criteria beyond those traditionally applied within disciplines, (including, for example, assessing the degree to which coproduction with stakeholders has been meaningfully achieved if this is the aim of the programme (Moser 2016)). We suggest that assessment of interdisciplinary work needs to be highly contextualised and tailored to the specific aims and norms of the projects in question. It may be equally important, in planning such cross-cutting work, to explore the emotional labour involved in operating without a clear reward structure. Indeed, finding a way of reassuring and rewarding

researchers who have traditionally operated in less explorative ways may be a condition of success.

Finally, accepting that ‘mess’ is a fundamental and, in many ways, irreducible part of interdisciplinary working is important. Explicit recognition of this fact by institutions funding, supporting and assessing this work, may help to mitigate the risk that such work becomes complicit in the flattening of social realities and the presentation of problems and ‘solutions’ in simplistic ways.

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