Mess among disciplines: interdisciplinarity in environmental research

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Abstract. This paper discusses interdisciplinary collaboration between social and natural scientists from the perspective of 'mess'. The literature on interdisciplinarity has generated a series of conventions about what it means to conduct interdisciplinary research. Building on the experience of a research project that brought social and natural scientists together with local residents to study flooding, we argue that interdisciplinarity can be understood as a response to mess, to the irreducibly complex problems of the world. Mess can be dealt with as an epistemological or ontological problem. We argue that discursive conventions focus on the epistemological dimensions of mess and thus have their limits. By considering the ontological dimensions of mess the whole range of objects that are involved in interdisciplinary research is brought into focus.

1 Introduction
This paper presents an analysis of interdisciplinary research, and specifically of collaborations between social and natural scientists in the field of environmental research. As recent writing suggests, interdisciplinarity is currently a prominent issue for the social sciences (Barry et al, 2008) as well as being a "master steering mechanism in government science policy" (Lowe and Phillipson, 2006, page 167). In the UK the Treasury has argued that "over the next decade many of the grand challenges in research will occupy the interfaces between the separate research disciplines developed in the 19th and 20th centuries" (HM Treasury, 2004, page 22) and emphasises the increasing need for research to transcend disciplinary boundaries. Strathern (2004) argues that, as both an explicit objective of research funding and a means by which new science policy is generated, demands for interdisciplinary research have become 'hyperformalised'. Such demands are keenly felt in research on environmental issues. Although the idea of disciplines still has strength and merit, and each discipline still has its champions, there are many social scientists working on environmental issues for whom interdisciplinary work is either an important aspiration or a simple fact of life. Equally, there are those who are suspicious of political demands for greater interdisciplinary collaboration to solve 'real-world' problems. Our aim is to try to move discussion of interdisciplinarity beyond the well-worn ruts it has created in recent years. In the paper we will argue that the ways in which we talk about interdisciplinary research are not straightforwardly connected to the doing of it. We draw on recent work that has juxtaposed the ordering practices of method with the mess of the world (Law, 2003; 2004), as mess and interdisciplinarity have been connected previously (Ackoff, 1974a; 1974b).

This paper is based on our experience of the design and conduct of a research project—*Understanding Environmental Knowledge Controversies*—funded under the UK

Research Council's Rural Economy and Land Use (RELU) Programme in the UK. The RELU Programme is a collaborative strategic research effort between the UK's Biotechnology and Biological Sciences Research Council, Natural Environment Research Council, and Economic and Social Research Council, with the last acting as the lead council. All of the projects it funds must include both natural and social scientists. The empirical focus of the Knowledge Controversies project is flooding but, more broadly, the project has explored the production and circulation of knowledge technologies (in the form of hydrological models) and experimented with producing environmental science in new collaborative ways involving academic researchers and local residents (see Whatmore, 2009). A fundamental principle in developing the project was that environmental issues are not easily categorised as either 'social' or 'natural' problems. Instead, they are seen as an inseparable mixture of the two—a 'hybrid problem'—and this should be the starting point for thinking about them. The project aimed for a mode of interdisciplinary working that would require participating social and natural scientists to engage constructively with the working assumptions and methods that underpin each others' research practices and, in so doing, to reevaluate their own. Working through ideas of disciplines and interdisciplinarity in a critical manner was an implicit part of working in this way.

In the development phase of the project, an idea was formulated whereby the first author of this paper would document and analyse—through interviews with researchers, observation, and other means—the 'dynamics of interdisciplinarity' within the project team. There was not, however, at that time much of an idea of what the 'dynamics of interdisciplinarity' might entail. One possibility might have been that individual researchers from specific disciplinary backgrounds would, through their engagement with others, develop into 'interdisciplinarians'. What kind of metric or other form of accounting could trace such a transition? What was encountered instead was a situation in which 'disciplines' were hardly in play and ideas of interdisciplinarity competed with the technologies of knowledge production and practices of expediency and collaborative working, a situation where objects became more interdisciplinary than people.

The fact that fixed disciplines did not seem to play a great role in shaping the project led us to question the very term 'interdisciplinarity' as an adequate description of collaboration between social and natural scientists. However, we cannot get rid of the terminology, so we propose to reframe it. Disciplines are only one of a number of things in circulation in messy research situations. Most of our ideas about interdisciplinarity are drawn from an understanding of the term as meaning 'between disciplines'. This presents a simplified picture of a dialectical relationship that ends with synthesis. In such a relationship, interdisciplinarity could be seen as an outcome of successful research (Strathern, 2004), but this ignores the process that leads to the outcome. However, the prefix 'inter' can also mean 'among'. What would it mean to be 'among disciplines', and so for the disciplines involved in any instance of interdisciplinary research to be among the many resources that can be applied to any problematic situation? For us this term 'among disciplines' acts more effectively as a heuristic device that draws attention away from interdisciplinary research as something that occurs at the interface of disciplines, and directs it towards a wider terrain of exploration.

In the paper we first build on the claim that interdisciplinarity is becoming a master steering mechanism to suggest that it is also becoming a relatively fixed and conventional object in the academic literature—some of the things interdisciplinary research interfaces with are the discourses of interdisciplinarity themselves. We then suggest that calls for interdisciplinarity can be seen as a response to messy realities. We go on to give an account of how, in our project, the conventional ideas of interdisciplinarity rubbed up against this, illustrating that conventions can be useful in

practice but that they have their limits. We then examine the practical ways in which the project handled complexity. We conclude that thinking of interdisciplinarity as being a response to mess helps focus attention on the role of objects and argue that analysis of the experience of interdisciplinary working to date has paid insufficient attention to the objects through which it is conducted.

2 Interdisciplinarity is becoming conventional

Within the academic literature, research projects that involve researchers from different disciplines are variously referred to as multidisciplinary, pluridisciplinary, or inter-disciplinary (Nowotny, 2003). These different terms are often used interchangeably, or sometimes considered as 'modes' of interdisciplinary engagement. Many analyses of interdisciplinarity in practice (eg Barry et al, 2008; Evans and Marvin, 2006) make the assumption that there are different degrees of depth to interdisciplinary working. The Knowledge Controversies project proposal developed a threefold typology. First, multi-disciplinary research involves scientists from different disciplines working in discrete disciplinary work packages that are subsequently stitched together with little meaningful cross-disciplinary engagement. Second, functional interdisciplinarity involves data exchanges and common epistemological approaches linking different disciplines and framing integrated research projects, but with little or no reevaluation or develop-ment of research practice. Barry et al (2008) suggest a mode of 'integrative synthesis' which parallels this category but can be further divided into two subcategories. The subordination-service mode involves one or more disciplines being seen as subordinate to or serving other disciplines, while the agonistic–antagonistic mode involves ways of working that are oppositional to conventional forms of disciplinary practice. The project's third type, radical interdisciplinarity, involves the sustained interrogation of, and engagement with, the different research approaches and practices of collaborating researchers to generate new collective modes of working. Here, implicit philosophical assumptions and methodological conventions are subject to scrutiny, along with the taken-for-granted scientific cultures and working practices of different disciplines. Barry et al (2008) refer to the extreme form of this mode of working as transdisciplinarity, implying a transgression or transcendence of disciplinary norms. This might be in order to fuse disciplines together, to address complexity, to solve real-world problems, or to overcome the divide between academic researchers and others (Lawrence and Despres, 2004; Strathern, 2004).

Another way to cut interdisciplinarity is by characterising the forces driving it. For example, the increasing emphasis on interdisciplinary working within strategic research can be understood as part of a wider shift from what has been termed mode-1 to mode-2 knowledge production (Gibbons et al, 1994; Nowotny et al, 2001). Mode-2 has been proposed as a new form of knowledge production that emerged in the 20th century in which the 'context of application' is crucial to knowledge production. Tradi-tional research (or mode-1 knowledge production) is internally initiated by academic researchers and is based within disciplines. In contrast, mode-2 knowledge production is context driven, and involves multidisciplinary teams brought together to respond to 'real-world problems' and challenges. This simple model has been influential in discussions of the changing nature of university research in the context of wider socioeconomic changes such as the rise of the so-called 'knowledge economy.' A key characteristic of the mode-2 model is that a much wider range of actors become involved in shaping research agendas, setting funding priorities, and participating in the management and evaluation of on-going research (Nowotny et al, 2001). These include government, business interests and nongovernmental organisations and stake-holder groups. The idea of mode-2 research highlights a singular feature of current

discourses of interdisciplinarity: it is presented as inseparable from contemporary interests in widening political participation and democratising science.

This connection appears as one of three distinctive *logics* of interdisciplinarity identified by Barry et al (2008). These logics encapsulate key rationales, principles, and ethics that have guided the recent development of interdisciplinary thought and practice. First, the 'logic of accountability' is evident when interdisciplinarity is guided by the idea that the opening up of science to a wider range of public and stakeholders will improve its relevance and accountability. Thus social scientists might come to 'stand for' society in an interdisciplinary project, making scientific institutions more responsive to nonscientists. Often social scientists will be used as a barrier to potentially more destabilising intervention by wider social interests while allowing projects to meet minimum requirements for public consultation and engagement. At the opposite extreme, social science can form the bridge that leads to the production of science to support civic protest. Second, the 'logic of innovation' is rooted in the idea that interdisciplinary research generates novel instruments, practices, policies, or products. Bringing together different people with different perspectives fosters innovation. Third, the 'logic of ontology' sees interdisciplinary research as driven by the desire to challenge the assumed nature of the objects and practices of research. This logic is concerned with attempts to reconceptualise the basis for research towards producing new types of knowledge. As such, it can act as an irritant alongside the other logics, introducing insights that are not easily incorporated into ongoing research and development.

Much social science literature dealing with questions of collaboration with natural sciences has tended to focus on the barriers to successful interdisciplinary engagement, leaving aside any questions of what would actually constitute such a successful engagement. A key argument is that the knowledge practices within disciplines present fundamental obstacles to mutual understanding between disciplines. Language and communication have often been cited as barriers to interdisciplinary research (Bracken and Oughton, 2006; Schoenberg, 2001) as have "cultures of practice" (Bracken and Oughton, 2009, page 371). Different ways of talking and thinking require time and openness to overcome, an observation paralleled by Buller's (2007; 2009) assertion that interdisciplinary collaboration "requires great friendship" (2009, page 396). Emerging practical prescriptions for improved interdisciplinarity include: longer start-up phases for projects; sensitive management of interdisciplinary teams; the need for flexibility and openness of individual researchers; and the need to understand the ways of thought and language of others.

Further discussion of barriers to interdisciplinary working comes from the analysis of a series of cross-council research initiatives in the 1990s examining cities and sustainability (Evans and Marvin, 2006). The case for interdisciplinary research on the urban environment was, they argued, "deceptively simple": "Sustainability is a complex problem that transcends conventional disciplines and requires social, engineering, and natural sciences each to contribute their relevant expertise" (2006, page 1012). Thus, including more disciplines means producing more "complete knowledge" (page 1012). Evans and Marvin argue that the prevailing disciplinary paradigms in the social, environmental, and physical sciences proved to be obstacles. This was more than just a question of different technical languages, but of distinct "outlook, beliefs and identities" (Lowe and Phillipson, 2009, page 1172). According to Evans and Marvin, in the urban programmes of the 1990s, the questioning of fundamental disciplinary assumptions proved too much and there was a retreat from radical interdisciplinary ambitions to the safer ground of more limited collaboration between cognate disciplines. Notably, Lowe and Phillipson (2009) challenged Evans and Marvin's implied assumption that

disciplines are fixed, homogenous, and strongly bounded units that produce clear, distinct, and unitary identities in disciplinary specialists.

On any brief tour through the recent literature, we can see interdisciplinarity dissected by 'mode' and by 'logic'; we can catalogue the barriers to the enterprise, and prescriptions for how to overcome these. On the one hand, we might view the topic as ill defined, leading to repetition and confusion. On the other hand, a stronger sense emerges of just how much common ground is covered by recent discussions of interdisciplinarity. Clear parallels can be drawn between the various classifications and discussions. In a much earlier round of discussions on interdisciplinarity, Rip (1985) suggested that a lack of definition in the field actually led to snap judgments becoming entrenched. The creation of these schemata hints that interdisciplinarity 'in the wild' is a complex beast that researchers feel the need to tame with helpful, well-ordered classificatory systems and advice. This jars somewhat with the taken-for-granted universal good of interdisciplinary research promoted in science policy. Nevertheless, both forms evidence a conventionalisation of interdisciplinarity discourse, a set of common tropes that aim to define the practice. The 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. This has particular consequences. When talking with colleagues on our project and elsewhere, the most commonly encountered response to the literature on interdisciplinarity is that interdisciplinarity is becoming 'conventional' in more than one sense of the word. Not only does the literature channel thought down the types of scheme outlined in this section, it also—and this is surely a related point—offers little in the way of novelty or inspiration to those experimenting with interdisciplinary work.

3 Interdisciplinary research and mess

As we have seen, the literature provides us with orderly justifications and typologies for interdisciplinary research alongside prescriptions for overcoming barriers. We want to find another starting point because we think that mess is the very stuff of interdisciplinarity. What we mean to emphasise by this is not that doing interdisciplinary research is messy (although it is at least as messy as any other form of practice), but rather that interdisciplinary research is meant to deal with messy problems that overflow disciplinary boundaries. It has been argued by government, research councils, and academic researchers that research will increasingly need to be interdisciplinary in order to meet the new challenges of the age. Accounts of the rising interest in, and need for, interdisciplinary research often point to the emergence of new forms of 'hybrid' problems (Callon et al, 2002; Latour, 1993; 2004), especially associated with environment and life sciences. Significantly, Rip (1985) has previously noted that 'interdisciplinarity' is often understood as synonymous with 'problem solving' by those who espouse it as a practical management tool. While the notion of a 'real-world problem' that often seems to underlie calls for interdisciplinary research always carries the whiff of a problem already framed by someone else, Ackoff (1974a; 1974b) used the term 'mess' to describe the kind of 'problem complexes' encountered by professional managers and decision makers who had frequently been trained in academic disciplines and then found themselves subject to very different demands and rules.

From Ackoff's perspective, a mess is a situation from which a number of problems, each requiring a seemingly different solution, can be abstracted. The term 'abstracted' is important—a mess is not inherently divided into problems but can be framed in such a way by researchers. Therefore, those problems cannot be treated in isolation, solved individually, and their solutions then reintegrated. For Ackoff a mess is an irreducibly

complex situation which demands at least some attempt to get to know it for what it is, not what it can be reduced to by a series of different disciplinary perspectives. Mess is how we often experience the complexity of a world made up from multiple overlapping and interacting processes and practices. (In all the literature noted here, the terms and concepts of 'mess' and 'complexity' tend to be used interchangeably. Although mess is inherently about complexity, framing it as such—especially to an audience accustomed to the advances that computational technologies have brought to the understanding of complexity—can be to suggest a misleadingly simple solution.) Ackoff considered interdisciplinary research a necessary response to dealing with the problem complexes of messy realities. Interdisciplinary research is a means by which mess can be ordered, simplified, and made manageable—though perhaps this simplification is not as overly reductive as it is when a problem is approached from a single disciplinary perspective.

An argument made by Law is that while there are "provisionally stable realities" that can be presented as "clear and definite", there are also "complex, diffuse and messy" things that are only made more messy by attempts to simplify them (2004, page 2). All research, whether disciplinary or interdisciplinary in its focus, can encounter such messy things at one time or another and dealing with mess is not as simple as tidying things up. Dealing with mess can convince researchers that something has gone wrong. In research this can mean that a method has been incorrectly applied, that the researcher is at fault. It can also mean (following Law, 2003; 2004; Law and Singleton, 2005) that the object, situation, or issue being researched is, quite simply, messy. It is too complex to be adequately explained by methods that look for, or seek to impose, a single order. As all attempts to order involve exclusions and losses (Law, 2004), interdisciplinary approaches could be seen as a way to minimise these. However, further problems can be encountered with the interactions of methods viewed as tools of ordering. Law and Mol (2002) discuss the problems of handling complexity and highlight the possibility of interference between different methods. Each simplifies and orders mess in its own way, but when those simplified orders interfere with one another, they generate new complexities. The interaction of different orders is one of the ways in which we end up with more mess.

Law and Singleton (2005) have suggested that we can take two different approaches to dealing with messy objects: epistemological or ontological. An epistemological approach presumes that an object looks messy because there are different perspectives on it, and so it means different things to different people. Law and Singleton suggest that the methodological solution to mess, in this case, is to describe and interpret the different perspectives and discover the 'real' object behind them. The literature on interdisciplinarity, as we have described it, can be seen as just such a response—different schema and typologies have been generated to pin down the reality of interdisciplinarity. Whether there is any such underlying reality is another question. The ontological approach suggested by Law and Singleton presumes that there is not always a stable underlying reality and that objects are multiple: rather than different perspectives there are various sets of practices which articulate different, though interrelated, objects. If we look at practice rather than opinions, objects appear clearly as fluid and multiple, brought into being in multiple sets of differing practices, yet linked together (Law and Singleton, 2005; following Mol, 2002).

Mess is a feature of interdisciplinary research both because it is a feature of all research and because the objects around which interdisciplinary research is oriented are constructed and articulated through multiple research practices. Conducting successful interdisciplinary research is not just a matter of bringing the right disciplines together and overcoming barriers to collaboration. Bringing together different ways of doing the ordering work of research may only add to the complexity of the problem,

making it messer. We have suggested that thinking of interdisciplinarity as being 'among disciplines' rather than between them might be a way of focusing on the object—ie the research topic—rather than the interface between disciplines. Both epistemological and ontological articulations of mess were at work in our project, though expressed to different extents, and the following two sections deal with each in turn, considering the role that conventions play in relation to a messy problem and the different types of objects involved in interdisciplinary research.

4 Working with conventions

The specific knowledge controversy that our project engaged with was flooding (Whatmore, 2009). The very fact that flooding is controversial suggests that there are differing views on the issue. However, there may be more to it than just differing views. A flood event can come about for a number of reasons, but ultimately it means that water ends up in places where it is not usually found. Computer models can be used to calculate where floodwaters are likely to go, given certain inputs, but they are only partially connected, through data translated and transferred from the field (Latour, 1999), to the physical landscape where a flood event might happen. The risk of flooding occurring in specific places over time can be calculated, but this process entails uncertainty. Flood events are not one-offs—localities have histories of flooding. These can be at least partly captured by hydrologists and their collaborators. Yet histories of flooding are also biographies of people. The movement of water around a landscape becomes the stuff of professional careers. It gets entangled in the quotidian details of lives, interfering with joy, tragedy, and boredom. Flooding enters into experience and knowledge in many different ways, yet particular types of knowledge become privileged in the making of policy concerned with flooding. Very specific technologies, which often involve a series of opaque decisions about which knowledge to apply, become hard-wired into further decision-making processes within government and the insurance industry. Ideas change, strategies change, new questions get raised: How should land be managed to reduce the risk and impact of flooding (both in terms of flood-plain building and upstream land management)? How should risk be communicated? Should people at risk of flooding be included in management and decision-making processes? This complex of issues (and more besides) is the stuff that the project started with. It casts flooding as an interdisciplinary object of research that reflects exactly the kind of mess that Ackoff (1974a; 1974b) was concerned about.

We stated that disciplines barely seemed to be in play at all in the project, and this needs some elaboration. Different ways of working and institutional divisions certainly mapped onto dissatisfactions or disagreements among the project team. Many team members expressed concern with how their collaboration was progressing, about whether their expectations were being met, about the ways in which they themselves or others were working as part of the project. These concerns were 'among disciplines'; disciplinary perspectives got a mention, but the lines of disjunction were more local, and based around the way that the project framed the mess. This framing was built into the structure of the project, the way in which it parcelled up work on different aspects of the problem complex. The project was divided into three work packages. Work package 1 would examine the production and circulation of environmental knowledge, especially the production of flood models and the processes by which particular knowledge becomes hard-wired into decision-making processes. Work package 2 would develop a new computer model for understanding the effects of land management on flood risk. Work package 3 would focus on the public engagement and interdisciplinary aspects of the project, facilitating groups in which academic and nonacademic knowledges were applied to the problems of flooding, and to the development of the flood

model, by local residents working with the project team. The three work packages had no overlapping team members, but they were not divided along disciplinary lines. Although work package 2 was the 'natural science' element, the leaders of all three work packages had a background in geography that included interdisciplinary training and close association with their natural/social science counterparts in geography departments. This is perhaps one reason why 'disciplines' were not big players.

However, pains were taken in the project planning to avoid conventional pitfalls of interdisciplinarity, such as unfamiliarity with terminology and working practices. Two week-long training events for the whole team were arranged before the empirical research got fully underway. These involved training in the use and underlying science of flood models, as well as discussion of the social science underlying knowledge controversies and the different traditions in approaching the subject. The training culminated in collective work on defining principles for designing and running the public engagement group element of the project. The first such group—the 'Ryedale Flood Research Group'—became what several team members described as the "crucible" for interdisciplinarity within the project, although having that single focal point was not always seen as desirable. In fact, at the end of the second training week one team member remarked:

"I think there is a serious danger that the [groups] will now happen and they will take over our interaction. That will become our interdisciplinary focus, and we will actually miss all the other elements of the project."

Despite the general agreement reached over the training weeks, individuals and work packages did diverge once the first local participatory research group began. The different views on interdisciplinary collaboration within the project were split along the lines of these work packages.

In discussions with the lead author (whose role was to document and analyse the 'dynamics of interdisciplinarity' of the team), researchers began to give differing accounts of the process and history of the project. They commented on the varying levels of input of the researchers into the local group and some questioned whether it had come to be dominated by the modelling. Others noted that the local members had driven this change, and others still that the social science was providing (subtle) input, but these were not just disagreements. The researchers in the different work packages had different degrees of contact with nonacademic members outside of the group meetings, which led to different positions within the team on what were important issues to tackle and, more significantly, differently nuanced framings of the problem of flooding. They differed in their attachment to the collectively defined principles along which the groups were being run. They also accorded different degrees of importance to particular documents circulating within the team, relating to the running of the groups, with different work packages holding to different sets of, more and less explicit, guidelines and aspirations for the conduct of the groups. In short, the objects—the foci of attention—of the three work packages were differently constructed.

In documenting this process, the lead author began to doubt whether it would be possible to provide a single account of interdisciplinary interaction in the project that everyone involved could agree with: the multiplicity of the objects at the centre of the project led to a perception of mess. Despite this, everybody considered the local flood research group to be a success. The connections between the grumblings and differing accounts and the apparently functioning flood research group were not at all obvious. And the waters would only get murkier before they began to clear.

One of the approaches used to document and analyse the experience of interdisciplinary working in the project was Q methodology, which employs both qualitative and quantitative techniques to identify the ways of talking about a particular subject that exist within a sample population (Eden et al, 2004; McKeown and Thomas, 1988).

Q methodology was chosen in order to determine if shared positions on interdisciplinarity existed amongst the team members. None of the team members other than the lead author had previous experience of the approach and its novelty caused the team to focus and organise their thoughts in a way that would not have occurred purely through interviews. A number of statements are collected based on existing views about a given topic. Respondents are asked to sort a set of statements into a pyramid-shaped grid according to a specific instruction. The columns of the grid are numbered left to right from negative to positive, passing through zero. Statements can be given a degree of positive or negative value or left in an ambivalent position (closer to or at zero) depending on how the respondent feels they relate to the question at hand. Each sort then has a numerical value for each statement, enabling factor analysis to be undertaken. Once factors have been determined, an ideal sort (positions of statements on the grid) can be reconstructed for each factor and interpreted back into words, based on which statements most strongly define the sort. Also, a measure is determined of how strongly each individual sort agrees with the ideal factor sort.

Each of the six researchers on the team was given a set of statements about interdisciplinarity derived from literature reviews, observation, and interviews. The statements reflected a range of positive and negative attitudes towards interdisciplinarity, reflecting the conventional range of positions already described above. The following is a selection of statements used, to illustrate what the researchers were working with.

"Interdisciplinary research is a solution to real world problems."
"Interdisciplinarity is about working together to find things out."
"Problems are more important than disciplines."
"Some disciplines are rife with internal divisions anyway."
"Interdisciplinarity promotes innovation."
"I don't privilege any particular way of framing a problem."

The researchers were asked to complete the exercise twice: first, to rank the statements on how well they described their own experience of interdisciplinarity; and, second, to rank the statements on how well they described the general or 'received' view of interdisciplinarity. The team members completed this exercise together, in a room they used for meetings in their field site.

The results were the production of two very distinct discursive positions with respect to interdisciplinarity. The first position was defined solely by sorts representing the researchers' own experiences of interdisciplinarity. There was a very high level of agreement between almost all of the researchers' own sorts with this factor, which can be described by the following text, generated from the statements that were most important in defining the factor:

The most important feature of interdisciplinary research is that it opens up the framing of problems. Different disciplines provide more than just different perspectives and working with people from different disciplines is a way to improve my own research. Any problems we encounter in working together are more likely to arise from different philosophies than from our different disciplines. I don't especially see interdisciplinary research as being necessarily more applied or about tackling real world problems and I strongly disagree with anybody who suggests that it is less cutting-edge than pure discipline-based research.

The second position was defined solely by sorts representing the researchers' understanding of the general idea of interdisciplinarity, the wider view driving towards interdisciplinarity in the research policy community. There was less strong consensus amongst the individual researchers, but most were in some degree of agreement with this factor. The following text is derived from the statements that were most important in defining the factor:

Interdisciplinary research leads to science that better serves the needs of society and the economy. It provides results that are more easily put to use by policy-makers and practitioners. Interdisciplinary science tends to be closer to the concerns of citizens and more accountable to them.

These two clearly differentiated positions articulate agreement around some of the key conventions identified in the literature on interdisciplinarity in section 2. But what they say is less significant than the fact that they define a clear boundary between the group's own experiences of interdisciplinarity and how they consider it to be articulated within the political–economic domains outside their project. (The general position imagined by the team members was, after a group discussion with the lead author, based on their understandings of the views of those who steer state research policy and funding.) The project had been running for eighteen months and had reached the end of its first case study when this exercise was undertaken. Clearly, in that time, a particular collective position on the discourses of interdisciplinarity had developed. That the expressions of individual experience matched so well is an indication of this. How then might this agreement be reconciled with the feelings of discontent and disconnection outlined earlier? If the Q methodology seems to reveal a general level of agreement about what interdisciplinarity was about, why did some of the team members think this was not being realised within the project, while others thought that it was? A partial explanation lies in the nature of what is revealed/constructed by Q methodology.

Q methodology was developed specifically to structure subjective positions, to emphasise sameness and difference. A key reason for the particular stepped pyramid shape of the sorting grid is to permit fewer statements to occupy extreme positions, to force the sorter to be discriminating. The output of a Q methodology study is effectively one or more *ideal types* and there are two possibilities for how to utilise these. First, an ideal type as conceived of by Weber (1949 [1904]) is a deliberately skewed construct, a synthesis of features not actually representative of any real object, which gives order to mess and facilitates comparative research. The ideal types produced in a Q methodology study can be used in such a way, providing the researcher with a basis for classification and interpretation. In this study the first factor describes a position that fits with Ackoff's (1974a; 1974b) understanding of interdisciplinarity being based on abstracting problems, and with Barry et al's (2008) promotion of interdisciplinarity as a space for invention. The second factor mirrors the type of statements made in science policy. These are comparable with Barry et al's (2008) logics of 'innovation' and 'accountability', respectively. Second, an ideal type is one kind of *boundary object* identified by Star and Greisemer (1989). A boundary object is something that maintains its identity across a range of different communities of practice, providing a commonality that allows them to work together. As a kind of boundary object, an ideal type parallels Weber's coinage if not his application. It is a form of description, which does not adequately describe any real object, and is vague enough to facilitate communication across a range of situations, and between individuals with differing positionalities. This use of ideal type has quite different connotations. It is not to be used as a means of rigorous research, but rather as a means for researchers to navigate a messy terrain.

We can consider the agreement that manifested, as being around an ideal type. The researchers are agreeing on something that will never exist in quite the way they frame it. The ideal type that emerged from the group's experiences was a discursive construct based around how the project was initially framed and the values ascribed to it. These values and ideas were revisited during the training weeks and in presentations to other researchers outside the project (a period termed the project's "ripening" by an

external advisor). They were contrasted with the presumed values of those who fund interdisciplinary research. Any tension between the ideal position and the actual practice of the research opened up space for dissatisfaction and perceived failings, as well as potentially constructive debate. The researchers on our project could very clearly express in principle what they meant by interdisciplinarity, by using the conventional language of the field. Mapping those clear ideas onto practice is more difficult, because they are ideal types and interdisciplinary practice, as we have stated, is inherently about dealing with mess.

By using a method aimed at ordering a topic, the lead author documented a key point of order within the project. The articulation of interdisciplinarity, in principle, could be described by conventionalised discourse understood as ideal types around which consensus emerged. The epistemological approach to dealing with the mess of interdisciplinarity *does* help to deal with what interdisciplinarity *in general* is about. The team were more-or-less united in their understanding of the 'why' of interdisciplinarity, but 'what' they were doing remained a messier business. On reflection, it would have been possible to use the Q methodology approach to tackle this too, by asking the researchers to sort statements based on articulations of the problem of flooding, or on the way in which they were experimenting with that problem. This may have been a case of using the right tool on the wrong target. That is to say, using Q methodology to explore discourses of interdisciplinarity itself might not be as revealing as using it to explore a research team's framings of their research topic would be. The following section deals with the ways in which the problem of flooding was articulated and suggests an alternative model for understanding interdisciplinary collaboration.

5 The objects and practices of interdisciplinarity
The local case study of flooding in the project ended with a report, a half-day public exhibition with poster presentations, speeches, and a digital resource for the local library. The report and exhibition prompted regional agencies and the national government to select the local catchment for further research and investment to experiment with reducing flood risk (Defra, 2009; Ryedale Flood Research Group, 2008). The researchers viewed this set of circumstances as successful, and certainly it dealt with a lot of the problem complex, the mess, in some way. However, it did not reduce the mess to a simple order. So what sort of thing was going on to tackle the mess? To go into this we need to move from the epistemological approach, that sees mess as a result of different perspectives on a singular object, to the ontological approach, which sees mess as a result of the multiplicity of objects.

To describe all of the concerns around flooding as merely being perspectives is problematic. Certainly, some of the framings presented at the start of the previous section could be taken as different disciplinary perspectives. However, the researchers themselves agreed that "Different disciplines provide more than just different perspectives." Disciplines are not just different ways of looking at a problem. They each have their own types of problems, practices, and objects. So the various researchers each brought their own way of 'objectifying' flooding to the research, some more fully realised than others (there was considerable difference between the project's three lead investigators in their previous experience of flooding and water-related issues and an even greater imbalance of previous experience among the three researchers in the work packages). This situation was further complicated by the inclusion of several local residents within the group, meeting with the researchers on a regular basis to collectively shape the research into problems of flooding in the case-study area. In considering the interdisciplinary nature of this group, the question arises: was there a

way to integrate all of the objects and problems brought to the group? Certainly no particular means of doing so was specified or designed in advance.

If we return briefly to the epistemological approach to mess, we can consider boundary objects a little further. Boundary objects have received attention from researchers analysing interdisciplinary research (Buller, 2009; Hinrichs, 2008; Wesselink, 2008; 2009). The argument is that many interdisciplinary objects can be boundary objects and that the selection of an appropriate boundary object facilitates interaction. One problem with this perspective is, of course, that not all objects of interdisciplinary research are boundary objects. A boundary object, by definition, is essentially singular—it retains its form across different fields. To state that the objects of interdisciplinary research are boundary objects, and that selecting an appropriate boundary object facilitates interdisciplinary research, as Wesselink (2009) does, suggests that the epistemological standpoint on mess is the only possibility—that there is really an underlying object about which different perspectives exist. In fact, thinking of boundary objects in this way does not necessarily mitigate other problems, as Wesselink (2009) notes that researchers still face the problem of communication across boundaries even with an appropriate boundary object in place. Despite their current prominence, we would argue that boundary objects offer a false sense of security. The ontological standpoint suggests that when the situation to be addressed by interdisciplinary research is controversial, that may be because the different sides of the controversy are presenting not differing perspectives, but different, partially connected objects. The essence of a multiple object is that its identity is not robust enough to be maintained uncontroversially across domains of practice without additional strategies of support (Mol, 2002). Multiplicitous objects make poor boundary objects as they require some form of coordination to hold together. Another problem is the looseness with which the concept of 'boundary object' is used. Often it is taken as anything that can make sense in different contexts, whereas Star and Greisemer (1989) are very specific about the types and forms of boundary objects. Although they state that boundary objects can be conceptual, the examples they give are mostly material or practical and they serve facilitating roles rather than posing problems. Buller (2009) does begin to develop a more nuanced sensibility to objects that draws on an extension of the boundary object literature by Vinck (2003). Buller focuses on objects that have an undeniable materiality (sheep and grasslands) that manifests differently to different researchers. He emphasises the importance that these objects have for facilitating creative discussions, for developing an atmosphere of invention, rather than as key integrative components of research. With this in mind, might boundary objects exist alongside multiple objects in interdisciplinary research? In other words, the actual objects of interdisciplinary research are often messy and multiplicitous, but can researchers introduce their own boundary objects as a means to navigate the mess?

It does indeed seem that this was the case in our project. One major boundary object can be identified: the location of the research. The case study had well-defined geographical boundaries around the catchment for the flood-prone rivers. Maps of the area were used to facilitate communication between researchers and local residents. Information such as memories, anecdotes, photographs, accounts of intervention and lack of intervention by various authorities, and gauge measurements could all be located with reference to the maps, alongside more speculative discussion of what might be done in the area. Computer models of the catchment also related to the map. This did nothing to lessen the multiplicity of the flooding problem, but provided a focus for some of the overlaps. Maps present a space of possibility in which elements of research can be collected and connected in many different ways.

If the spatial boundary and the map gave some commonality to ease the messiness of the objects in the research process, then how did the successful final report and event tackle the mess? The final report (Ryedale Flood Research Group, 2008) did not seek to offer an overarching conclusion or a set of cause-and-effect relations. It just gathered together some of the versions of flooding (the policy and the hydrological in particular) worked with in the research. In discussing strategies for dealing with complexity, Law and Mol (2002) propose the use of lists. A list is not like a classification, it does not have to have boundaries, it does not have to rigidly identify and categorise all that it contains and exclude that which does not fit a category. A list is never really closed by anything other than choice or contingency and could always have something else added to it. This suggests that one explanation for the report's success was its list-like gathering together of materials without classification. Similarly, the presentation of posters created a list-like narrative that led visitors through the problems extracted from flooding and placed them within their local context. It did not create a single chain of cause and effect, but did relate together the various aspects of the mess. In both the report and the exhibition, flooding retained its multiplicity; it was not synthesised into a single, underlying problem.

Reports and posters, forms of texts, are ubiquitous in academic research and beyond. They are 'nondisciplinary objects', things which do not belong to any particular disciplinary way of working, but are involved in all sorts of organisational and coordinating activities. There were other such objects involved which facilitated interaction: meeting agendas drawn up by researchers, sometimes based on notes and questions collected from local resident members, sets of action points drawn up on train journeys—mundane items that help to organise any research endeavour. Their importance was not argued over by any team member and they played a significant role in keeping the project moving, as they do in any research project.

Another important role was played by another category of 'nondisciplinary objects' in our project. Local and university members of the flood research group brought objects to discuss. These were photographs and household items that represented or symbolised experiences of flooding at the start of the project, videos and photographs taken by group members during the course of the project, policy documents and computer models provided by the academics. Discussions facilitated by these deliberately introduced physical objects, whether they are taken to be boundary objects or not, served to 'slow down' reasoning in the process of research (Whatmore, 2009). Working with—or through—the objects introduced a more level and measured dynamic amongst all group members than might have been generated if discussions had proceeded in purely abstract form. By explaining the stories, meanings, information and knowledges attached to the objects, the various elements of the mess were explored and problematised at length.

Noticing the inherent multiplicity of interdisciplinary objects leads us to consider the other objects that can sit beside the messy ones. Boundary objects can exist alongside 'nondisciplinary objects' and (interdisciplinary) multiple objects. Yet amongst these other objects, interdisciplinarity in practice is hard to locate or capture. If it is happening then surely it must be as much of an object as any of the others? Furthermore, it might not be greatly different to disciplinary research. We are so fixated on differences that we fail to realise that there are simple connections that do not need to be identified as boundary objects in order to work. If we do not think interdisciplinarity is 'happening', perhaps the question we need to ask is what would it look like if it was? What are we expecting? The assumption that some newly synthesised object has to emerge is misplaced. A focus on interdisciplinary researchers can cause us to miss the things they work with. Sometimes the best way to tackle the mess of an interdisciplinary

object is to acknowledge its multiplicity and not try to reduce that through synthesis. The objects around and through which interdisciplinary research is conducted are sidelined by the conventional view that focuses on languages, motivations, and the primacy of disciplinary discourse. As has been frequently noted (Hacking, 1983; Latour, 1987; Mol, 2002; Stengers, 2000), theory and philosophy of science often fail to capture what it is that makes science in practice particular. It is only by observing its interventions in the world that science can be properly understood. Thinking of research among disciplines moves us away from a preoccupation with an interface and evokes a 'borderland' rather than a border which we have begun to populate with objects.

6 Conclusions

There are undoubtedly transferrable lessons to be learned from interdisciplinary environmental research projects that take the shape of frameworks or formulae, but we have written from the position that there should also be lessons that take the form of problems, of questions, of stimuli to thought. Environmental problems are messy or hybrid problem complexes of a kind that is said to require interdisciplinary intervention. Interdisciplinarity, though, is not historically novel—disciplines (and, hence, interdisciplines) are always temporary stabilisations of knowledge communities and practices (Barry et al, 2008). Even the recent debates around interdisciplinarity presented here are not wholly novel (see Rip, 1985). Interdisciplinarity is not just an ongoing political demand (Barry et al, 2008); it is also driven by the intellectual developments of fields of study (Abbot, 2001). We would argue, though, that in both cases, interdisciplinarity is a response to mess.

Academic writing about interdisciplinarity is creating conventions that formalise the process in ways that do not always match the demands of state funding bodies. These conventions can be useful in practice for dealing with the 'why' questions of interdisciplinarity, but they do not admit enough of the specific mess of problems to help us understand the 'what' questions—what is interdisciplinary research working with? In fact, the focus on justifications for interdisciplinary research, and the generic barriers to conducting it, turns interdisciplinarity itself into the problem. Although Barry et al (2008) do classify interdisciplinarity, they prefer to view it less as a political or scientific unity and more as a field of differences and multiplicity characterised by inventiveness. This is akin to what we intend with our heuristic term 'among disciplines'. Academic research as we know it currently cannot escape the shadow of disciplines, but in practice it can move towards ways of working in which the disciplines are not the most important things at play.

We have argued that acknowledging the multiplicity of interdisciplinary objects is an important step in this direction. Much interdisciplinary research seems to proceed from the assumption that synthesis is desirable, that a new integrated perspective can be found on a singular object, if only the right object can be identified. This chimes with the epistemological view of objects. We have sided more with the ontological view, which holds that the objects of interdisciplinary research are, almost by definition, anything but singular. If they appear messy it is because they are multiply determined and partially connected. If they appear tidy it may be because there are strategies of coordination in place that iron out the multiplicity in habitual practice (Mol, 2002). Dealing with environmental problems that may be viewed as occurring on a large scale requires a highly localised look at the objects and practices that are being deployed to articulate those problems.

There is an emergent critical examination of objects in interdisciplinary research and we have demonstrated the many important roles that objects can play. The analysis of objects in interdisciplinary research needs to be deepened. We would argue that this

should be undertaken in the light of different approaches to dealing with mess. Mess and objects are inseparable, whereas it is too easy to iron out mess when words are all that is involved (as in the conventionalisation of interdisciplinary discourse), a focus on objects and practice places us right in the middle of the mess. If we follow through the logic of the epistemological and ontological dimensions outlined by Law and Singleton (2005) we can move away from the various justifications and conventions that seek to pin down the essential reality of interdisciplinarity and towards a position in which there is no reality to interdisciplinary research other than that which is made in practice.

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