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The role of funding agencies in creating interdisciplinary knowledge

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The relationship between disciplines is strongly influenced by national funding agencies and a great deal of tacit knowledge about the management of interdisciplinary research programmes and projects is held by such bodies. Funders' support is critical to achieving the potential value-added of interdisciplinarity and these agencies have key roles to play especially in shaping large-scale interdisciplinary initiatives. This paper reports on an empirical study and offers some lessons for public policy aimed at promoting learning and generating benefits broadly applicable across future efforts to tackle complex, multidimensional research challenges. There are key practical organisational steps that could be taken to promote and support collaborative working and integration for large-scale interdisciplinary research initiatives. Awareness of these critical processes can benefit funders as well as practitioners if interdisciplinary research is to achieve its full potential.

1. Introduction

As complex problems of, for example, climate change, food security or healthy ageing, become more pressing, the ability of public sector research funding agencies to deliver solutions to such challenges increasingly requires integration across disciplines as well as reaching out from academia to the policy and private sectors. Research funders constitute important drivers of interdisciplinary research and play a number of essential roles. They can stimulate interdisciplinary research initiatives, for example, by identifying questions that need an interdisciplinary approach in order to be tackled effectively. This may lead to the launch of new funding schemes where they have a role in establishing the architecture of an interdisciplinary programme through, for example, the choice of leader, location, streams of funding, and mechanisms for accountability by establishing appropriate evaluation processes at various levels. Funders will often fulfill a research capacity-building function by providing additional training or infrastructure. All of these aspects may combine to facilitate the emergence of longer term impacts from the research that they have funded.

In the UK, the Research Councils (RCUK)[1] are responsible for investing public money in research to advance knowledge and generate new ideas which lead to a productive economy, healthy society and contribute to a sustainable world. As described in Lyall and Fletcher (this issue), RCUK see interdisciplinarity as a goal and currently support a number of multi-million pound interdisciplinary investments. Funders' support is critical to achieving the potential value-added of interdisciplinarity and these agencies therefore have key roles to play in shaping large-scale interdisciplinary research initiatives. However, while it is evident that the relationship between disciplines is strongly influenced by national funding agencies (Lowe and Phillipson, 2006; 2009), this presents a number of structural challenges for these public agencies. In particular, it requires them to learn how to deal with the emergence of new strategic interdisciplinary research programmes within the funding base and to embed this learning so that they are able to routinise effective systems and structures for interdisciplinary programmes (so that these do not have to be re-invented on every occasion).

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[1] www.rcuk.ac.uk, a body comprised of seven subject-based Research Councils, e.g. Natural Environment Research Council, Economic and Social Research Council, etc.

Lack of organisational memory in these bodies can be an issue when the staff involved in championing cross-council or cross-disciplinary initiatives move on to new areas. A great deal of tacit knowledge about the management of interdisciplinary programmes can be held by these officials but, unless that people-embodied knowledge is captured systematically, there can be a lack of continuity and re-discovery of already existing knowledge. Public research funders have developed effective systems to run research programmes within their core areas but may require additional assistance to capture less frequent 'idiosyncratic' experiences – such as running interdisciplinary initiatives.

Practice varies across the seven UK research councils and different funding models can lead to varying levels of integration and outputs. For example, interdisciplinary initiatives can be shorter term (ca. 5 years), single-phase funded research programmes established to answer specific research questions or they can be longer term investments (typically up to 10 years) with two or more consecutive phases of funding with the development of sustainable capacity for interdisciplinary research as a central objective. Research Councils can also influence these investments in different ways depending on whether they are single council investments or cross-council (multi-funder) collaborations.

This paper synthesises findings from a 12-month research project funded by a directed call from the UK's Natural Environment Research Council (NERC). The requirements of this commissioned study demanded an approach that lay somewhere between applied qualitative research and a summative evaluation. Our approach might best be described as a 'learning review', drawing on the judgment and expertise of the research team which comprised experienced academic social researchers and professional evaluators. This paper is therefore primarily empirical, rather than theoretical, in scope.

Key objectives of the study were:

1. to develop multiple case studies to capture learning around the management and development of large-scale interdisciplinary investments
2. to promote organisational learning by providing transferable lessons of relevance to future interdisciplinary programmes along with practical guidance to funders and leaders of such initiatives.

The intention of this research was to capture, analyse and distil insights in such a way that others funding, facilitating, leading or pursuing interdisciplinarity in the future might benefit from this shared learning. The empirical work examined the experiences and the lessons learned from five case studies representing long term, multi-million pound, multi-discipline, multi-centre, and multi-national interdisciplinary research investments.

Evaluation at the end of individual programmes tends to focus on measuring outputs. This leaves (i) gaps in understanding the practices and processes occurring *during* an interdisciplinary research initiative and (ii) no opportunity to revise, modify or improve effectiveness and integration during the lifetime of the investment. In contrast, we sought to bring together learning from across several past and current programmes to contribute to the effectiveness and integration of future interdisciplinary investments.

The challenges of conducting interdisciplinary research at the project level are well-documented (e.g. Bracken and Oughton, 2006; Lau and Pasquini, 2008; Lyall et al.,

2011c) but the literature on the strategic management of interdisciplinarity at the national, programme level is more sparse. Our work contributes to a growing body of critical comparative studies (e.g. Barry et al., 2008) and analyses of the dynamics of interdisciplinarity at the level of programmes in Europe (e.g. Bruce et al., 2004), the UK (e.g. Meagher and Lyall, 2005; 2007; 2009) and the US (e.g. National Academies, 2004; Lattuca, 2001; Klein, 2010). Inevitably, the UK orientation of our study reflects the distinctiveness of the UK Research Council system[2]. This paper builds on existing literature on the institutional and research funding structures that shape interdisciplinary programmes by providing evidence-based lessons for funders of future interdisciplinary programmes (as well as the academic leaders of such research programmes). Some of these lessons may, in turn, be applicable to those managing or conducting smaller-scale interdisciplinary projects[3].

2. Contributing case studies

Our case study methodology used a mixed portfolio of data capture techniques which were primarily qualitative but supplemented with additional quantitative indicators[4]. The case study approach was used to provide rounded, detailed illustrations of the four interdisciplinary programmes, focusing on the nature of interdisciplinarity within each programme, how it has developed, obstacles faced and value added. This method allowed the subject matter to be examined in depth in a particular place, time and specific circumstance in a way that recognises interactions and complexity (Punch, 2009; Thomas, 1998).

The empirical research was structured around four interdisciplinary environmental initiatives: Quantifying and Understanding the Earth System, Rural Economy and Land Use, the Tyndall Centre for Climate Change, and the UK Energy Research Centre, which are summarised in Table 1. A fifth case study complemented these four main UK case studies by providing some international perspectives[5].

As this study took the form of a learning review rather than a more open-ended, hypothesis-driven research project, the objectives of the directed call for this project underpinned our research design and informed the development of the framework of analysis. Accordingly, we sought information about specific experiences of interdisciplinarity across the four comparator initiatives. This included any expectations of interdisciplinarity on the part of stakeholders; whether there were any interrelationships between the nature of the research and interdisciplinarity; and the identification of relevant affiliations, networks and community-building. We sought to identify any influences that the initiatives had had on the careers of next generation researchers; any particular challenges of interdisciplinarity; and any additional value

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[2] For an explanation of the key features of the funding system for UK university research see BIS (2010).
[3] The intention with this paper is not to report in detail on the individual findings from the component cases within our study; these are presented in Lyall et al. (2011a, b).
[4] Data collection included: six learning visits, with at least one to each of the UK initiatives; 63 semi-structured interviews either face-to-face or by telephone using purposive sampling to ensure a range of perspectives (from funders, directors, research leaders, senior researchers, research fellows and PhD students); an online survey; 12 Q sorts; and four focus groups. Analysis included: document analysis of both academic and grey literature; comparative analysis of case studies based on the analytic framework; factor analysis of the Q sort; bibliometric analysis of publications; and analysis of the survey results. Full results, including the detailed case studies, are included in Lyall et al. (2011a,b).
[5] Three comparative overviews from the Integrated History and Future of People on Earth (IHOPE) and the US National Science Foundation's Dynamics of Coupled Natural and Human Systems (CNH) and Integrative Graduate Education and Research Traineeship (IGERT).

that research leadership brought to the programmes. Finally, we sought information about the implications that this might have for research funders.

The first step in our qualitative data analysis was one of data reduction and pattern identification (Caudle, 2004). In order to do this, transcripts from the interviews and focus groups were thematically coded using NVivo software. This initial coding, based on the themes identified in the framework of analysis, allowed us to interrogate the text, exploring and comparing data across the case studies. This enabled us to identify issues relevant to the analytical questions and to develop both a structure and an analytical narrative. This method allowed for a degree of flexibility beyond the confines of a fixed set of evaluation questions and permitted exploration of some broader themes around the concept of interdisciplinarity which may not have been envisaged in the call for proposals.

We analysed our findings across the five case studies and identified a number of success factors ("sub-factors") in interdisciplinary capacity- and community-building. We then used a form of strategic mapping using Banxia Decision Explorer® which allowed us to develop a synthetic, visual representation of these sub-factors (identified by boxed text numbered 1 to 5 in **Figure 1**). This data visualisation technique allowed us to manage the complexity of the findings by drawing perspectives together into one representation and to explore links between findings.

These five success factors rely on sub-factors identified in our analysis of the case studies (Lyall et al., 2011a) and which are summarised as simple summary statements[6]. For example, active management (4) involves mechanisms to foster collaboration (17), integration (27), addressing issues of timing (25), encouraging the engagement of stakeholders (18), focus on policy relevance (26), building interdisciplinary capacity (19), recognising the value-added through management (28) and understanding the appropriate locus of responsibility (29). Similarly, catalysis of interdisciplinary research (2) can rely on interdisciplinary capacity being available (19), the use of mechanisms to foster collaboration (17) and opportunities arising where research domains are not well defined (15). Mechanisms to foster collaboration within these cases studies (17) in turn are influenced by encouraging self reflection (16), incorporating social sciences (14) and examining examples of effective interdisciplinarity (13).

Analysis of this simplified map of the success factors we had identified, using the Banxia Decision Explorer® software, suggests that building interdisciplinary capacity and active management are particularly core issues. Both are linked to more factors than others considered (eight factors for each) and both are more central to all factors (both directly and indirectly) than others considered.

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[6] Numbers at the front of the statements are added to aid navigation and are indicated in parenthesis in the following description (they do not imply any hierarchy of importance). Lines linking summary statements imply causal links between the statements, and arrows indicate direction of causality.
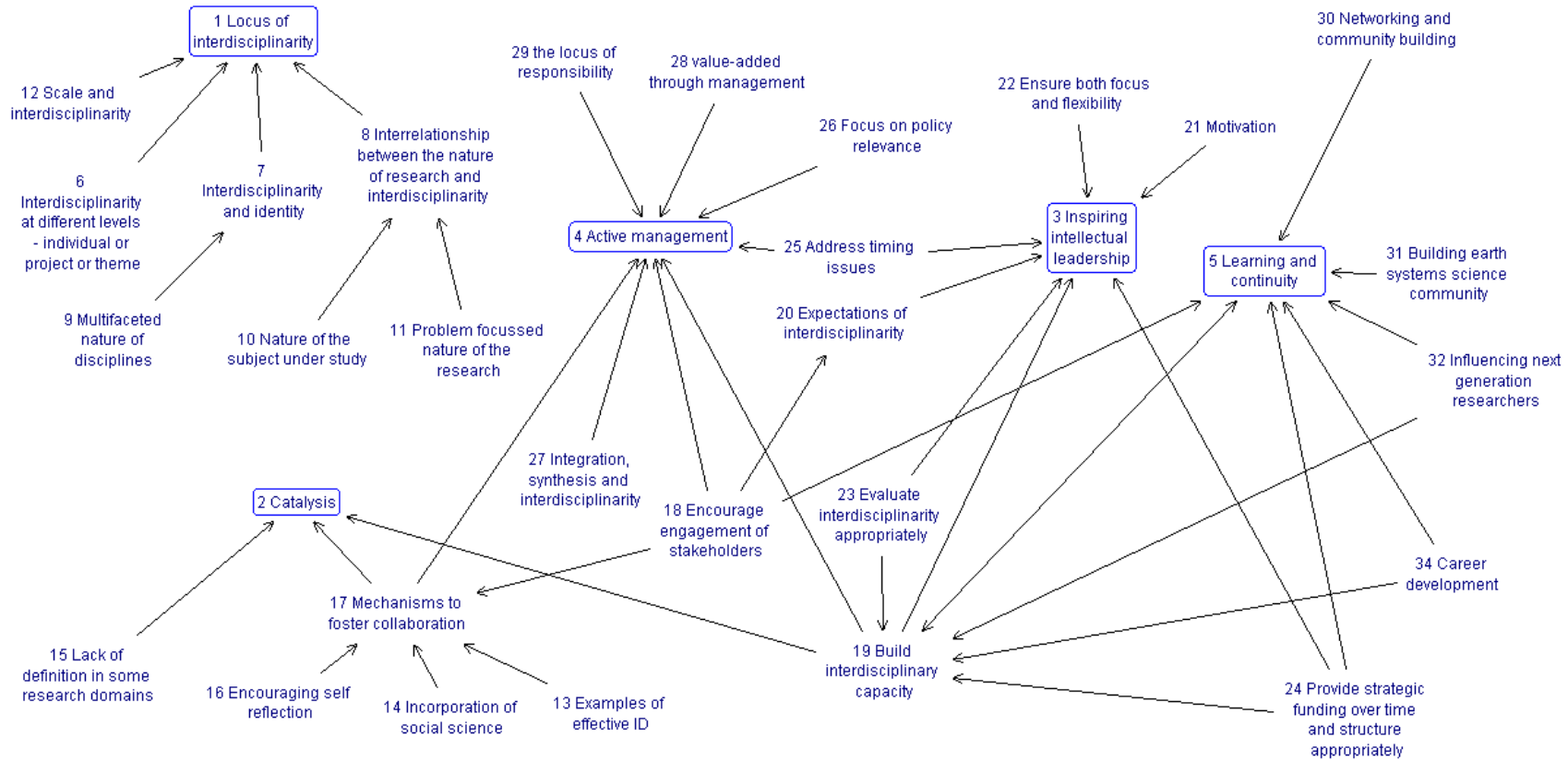
TABLE 1: Description of contributing case studies

Programme title	Quantifying and Understanding the Earth System	Rural Economy and Land Use	Tyndall Centre for Climate Change	UK Energy Research Centre
Acronym	QUEST	Relu	Tyndall	UKERC
Duration	2003-2011	2004-2011 (extended to 2013)	2000-2010 (now extended)	2004-2014
Location(s)	Directorate at University of Bristol, projects located across >UK 40 institutions	Directorate at Newcastle University, projects located across >50 UK institutions	Consortium led by University of East Anglia with Cambridge, Manchester, Newcastle, Oxford, Sussex, and Southampton	Headquarters in London; research and networking activities spread across >30 UK institutions
Funder(s)	NERC	BBSRC, ESRC, NERC	EPSRC, ESRC, NERC	EPSRC, ESRC, NERC
Budget	£23m	£24m	£18m	£34.5m
Main themes	The contemporary carbon cycle and its interactions with climate and atmospheric chemistry The natural regulation of atmospheric composition on glacial-interglacial and longer time scales The implications of global environmental changes for the sustainable use of resources	Land and Water Sustainable Food Chains Animal and Plant Disease Adapting to Environmental Change Interdisciplinarity	Mitigation Adaptation Energy Futures Resilience International Development Cities and Coasts Community Integrated Assessment System Governance Water and Land Use	Energy demand Energy supply Energy systems Energy and environment Technology and policy assessment
Published objectives relative to ID	QUEST's primary objective is a better qualitative and quantitative understanding of large-scale processes and interactions in the Earth system, especially the interactions among biological, physical and chemical processes in the atmosphere, ocean and land, and their implications for human activities	To deliver integrative, interdisciplinary research of high quality that will advance understanding of the social, economic, environmental and technological challenges faced by rural areas and the relationship between them To enhance capabilities for interdisciplinary research on rural issues, between social, natural and biological sciences To enhance the impact of research on rural policy and practice by involving stakeholders in all stages of Relu, including programme development, research activities and communication of outcomes	To seek, evaluate and facilitate sustainable responses to climate change that will minimise its adverse effects and stimulate policy To develop, demonstrate and apply new methods for integrating climate change related knowledge To promote informed and effective dialogue across society about the options to manage our future climate	The UKERC research programme takes a whole-systems approach, explicitly drawing on physical, environmental and social sciences UKERC promotes interdisciplinarity across the Research Council Energy Programme and acts as a bridge between the UK research community and the wider world

| **Website** | http://quest.bris.ac.uk/ | www.relu.ac.uk | www.tyndall.ac.uk | www.ukerc.ac.uk |

Figure 1:   **Synthesis of project findings**

3. Key success factors for interdisciplinary programmes

Analysis of the evidence captured across the case studies led to the identification of five key success factors for interdisciplinary programmes (**Figure 2**) and the development of recommendations for how research funders can achieve interdisciplinary success with such investments which we now discuss in the remainder of the paper.
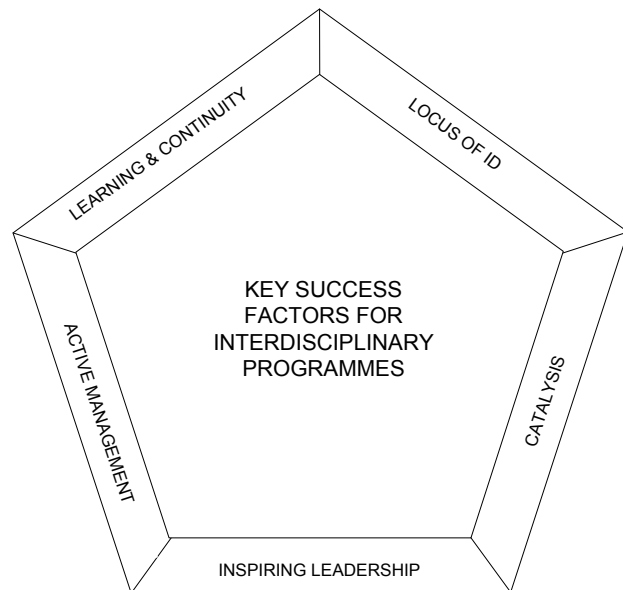

Figure 2: Key success factors for interdisciplinary programmes

3.1 Locus of interdisciplinarity
The way in which interdisciplinarity is situated within a research programme may have various ramifications. Evidence from the case studies, which each exhibited different organisational structures, indicated that interdisciplinary work might occur at different levels. This could be at programme level (for larger-scale initiatives); at theme level (i.e. a sub-programme level) where certain topics might be integrated across projects; or at project level, within a project team or individual project members.

In designing such a programme, it is important to identify the appropriate locus (or, indeed, loci) of interdisciplinarity and to think through the implications of which level(s) are to be the chief platform for interdisciplinarity. The links *between* levels may be especially important. This requires an examination of the foundational and existing knowledge involved, focusing on where individuals within the programme draw their assumptions from, and how this will impact on the locus of interdisciplinarity. For example, in the case of environmental research, there may be particular tensions between universal and contextualised knowledge, between

global and local scale, and between cultural differences where research is conducted on an international level or with non-academic stakeholders.

3.2 Catalysis

Interdisciplinarity takes place over time and proceeds through different stages. It is highly unlikely that integration will occur spontaneously if it has been left to the end of a project or programme. Our research found that successful programmes had taken deliberate steps throughout to achieve integration and coherence. In particular, they had considered how best to tailor the design and implementation of such activities at the start of their particular programme through, for example, seed-corn funding for small starter projects, early workshops and/or other activities that might help to build and consolidate collaborations.

The strategy for achieving interdisciplinarity may evolve as a programme develops. So, in the early years, the focus might be on running events organised by the programme directorate then, as the programme matures, shifting the focus to stimulating others in the project teams to run such events. Those tasked with interdisciplinary integration need to put effort in to encouraging project teams to develop other forms of cross-cutting activities, not just events, in order to pull together different projects or themes across the wider programme. This helps to build linkages across projects and make a programme 'more than the sum of the parts'. The key implication of this for funders is that they will need to recognise the validity of any additional time and expense spent on tailored 'catalytic' activities at various stages throughout a programme's lifetime.

3.3 Inspiring leadership

Researchers need to be motivated, supported and engaged if they are to give of their best in what is, by definition, an unconventional, risk-taking endeavour. Leadership is required to inspire diverse individuals on a continuing basis so that their motivations align with a common goal while simultaneously managing expectations to match feasible interdisciplinary outcomes. Careful consideration needs to be given to the source of interdisciplinary leadership, whether it is provided by funders or by the programme director, or by a team of individuals in charge of component projects, and also how to use external advisory boards to best effect. When considering potential leaders for challenging interdisciplinary programmes, leadership capacity and integrative vision will often need to be weighted more heavily than a conventional academic track record within a discipline although the two are not necessarily mutually exclusive.

3.4 Active management

There is often a tendency to assume that networking, community- and capacity-building will automatically occur as a result of participating in a research programme, in contrast to a more deliberative and reflective approach to achieving these ends. However, there are key practical organisational steps that large scale interdisciplinary research initiatives can take to promote and support collaborative working and integration. Pro-active management is crucial throughout an interdisciplinary initiative in order to achieve genuine interdisciplinary integration. Focusing on network- and community-building in the early stages of a research initiative greatly contributes to the degree and extent of integration and thus the synergy achieved. This adds value to the research investment and develops long-term capacity for interdisciplinary research but these aspects of a research programme are often overlooked or assumed to emerge spontaneously.

It is therefore important for funders and research leaders to recognise the demands posed by the process of achieving genuine interdisciplinary integration, and to identify responsibilities for various aspects of active management so that this is developed and maintained throughout the life of the grant. Management skills are not routinely taught to academics: while this issue may seem mundane in a monodisciplinary context, this skills deficit is exacerbated when faced with the challenges of an interdisciplinary programme. The nature of this active management will vary depending on the locus of interdisciplinarity. Other questions to consider include whether one person or a team will manage the integration, and who (at what level of seniority) plays these roles at which points in the programme's development. Funders' support for active management is critical to achieving the potential added-value of interdisciplinarity.

3.5 Learning and continuity

This study found that the initiatives examined had two different approaches to doing interdisciplinarity. One depended on the structuring of the scientific research to underpin its integration; the other worked to establish networks and community from the outset. The first used the science as a mechanism for integration that predetermined who needed to work with whom, in what way, and to achieve specific goals or outputs in order to synthesise the research. This produced boundaries around groups, projects and themes that were not easy, or even necessary, to bridge. Conversely, other initiatives had topic areas, or phases of funding, that oriented the scientific research but were much more flexible in allowing people to organise themselves and their work in a way that contributed to a common goal such as an overarching research theme. One approach is not necessarily better than another; and in certain instances one might be more appropriate to a particular research issue than the other, depending on what outcome is desired. However, we found these different approaches produced different intensities of interdisciplinarity, networking, community and capacity building. Significantly, those programmes that dispersed funding in successive funding rounds had more opportunities to review performance and adjust research foci and funding priorities accordingly.

Capacity-building – including the development of knowledge and strengthening of skills, competencies and abilities of people, networks and the research community – is critical to the growth and longevity of interdisciplinary research in the UK. This poses challenges for funders and research leaders to ensure that learning from past experiences of interdisciplinary investments becomes embedded within collective organisational memory. This requires greater continuity – of research networks and communities but also of research careers so that future career options are available for interdisciplinary Early Career Researchers and their expertise is not lost at the end of a programme.

4. Key aspects of funding for interdisciplinarity

Decisions that funders make and the intention behind funding calls have a major impact on how interdisciplinary research is shaped, the extent of integration, and ultimately its effectiveness. Funding mechanisms, questions and research agendas, and relationships between co-funders, can all influence interdisciplinary research initiatives in different ways. Research funders clearly have a role to play in framing calls for interdisciplinary proposals and developing rigorous evaluation processes (for both interdisciplinary proposals and, later, funded projects). Even more can be achieved when different funding bodies collaborate but this can present them with difficult choices. For example, whether and how research resources are pooled; what governance structures are put in place to shape an interdisciplinary programme; how to address interdisciplinary data management and

archiving; and the means though which social and natural sciences can make a balanced, rather than an asymmetric contribution, to programmes and projects.

With such critical roles to play, funders' own structures and procedures should reflect good practice in the support of interdisciplinarity, especially when interdisciplinary programmes require cross-council collaboration. Multiple funders investing in the same interdisciplinary programme should model good interdisciplinary collaborative practice among themselves, with good communication, shared ownership and gradual development of a collective vision. For example, in the UK, shadowing the performance of Relu was a team of officers from each of the three research councils which used to meet, at least initially, on a regular basis, ensuring that each council's interests were represented within the programme. Similarly, in the US, the National Science Foundation's Dynamics of Coupled Natural and Human Systems has a specific programme manager from each of the three funding directorates working as a team, rotating leadership annually so that each directorate has equal ownership. Over time, this cross-Directorate group has evolved, achieving a collective vision and CNH has been cited by NSF as transformative in the way it has pushed research beyond normal disciplinary boundaries.

4.1 Shaping interdisciplinary research initiatives
Within and between funding agencies, expectations of interdisciplinary research might vary depending on perceptions of what interdisciplinary work is and what it can do and who or what interdisciplinary researchers are. Our case studies have demonstrated that the extent of integration in interdisciplinary research might vary according to the many researchers and various combinations of different disciplinary backgrounds, the range of topics addressed, and the type of research questions being asked. The degree to which interdisciplinarity is effective is influenced by the setting up, focus and agenda of an interdisciplinary investment. It is also influenced by the underlying institutional contexts, leadership style and management support, the type of interdisciplinarity that is being sought, and an awareness of its potential disciplinary and conceptual foundations.

In practical terms, funding streams dedicated to interdisciplinary research can help to ensure that interdisciplinary work does not fall at the first review hurdle. Cross-funder programmes can provide incentives for multiple research communities to participate. Such participation can be encouraged by the provision of funds for: the type of catalytic, seed-corn support, and "warm-up" activities highlighted above; development of tools and visualisation for policymakers and other users; follow-on grants to fund projects and support for emerging collaborations. Incorporating flexibility into a programme's budget allows not only evolution but also an opportunity for research leaders to develop new ways to facilitate genuine interdisciplinarity and encourage organisational and cross-institutional learning.

4.2 Reviewing and evaluating interdisciplinary research appropriately
Even as the needs and opportunities for interdisciplinary research grow, the view persists that evaluation of interdisciplinary research urgently needs to be tailored more appropriately. Peer review processes are cited repeatedly as a critical issue for interdisciplinary proposals and are regarded as a serious hindrance for interdisciplinary research: the lack of agreed indicators of quality may be one reason why a question mark often hangs over the academic value of interdisciplinarity (e.g. Oberg, 2009; Feller, 2006; Boix Mansilla, 2006; Defila and Di Giulio, 1999). Individuals do not want to be penalised for proposing interdisciplinary approaches which, by definition, are unconventional to individual reviewers ensconced firmly in disciplines; the system is seen to work against the inclusion of even the most rigorous interdisciplinary work. By the same token, it can be harmful to standards of genuine interdisciplinarity if researchers receive interdisciplinary funding for projects that are in fact

only multi-disciplinary, or if simplistic assumptions are made: for example, the inclusion of social science in a scientific research proposal does not automatically mean outputs will be policy relevant. It is important for funders and their referees and review panels to distinguish between the genuinely interdisciplinary and the use of interdisciplinarity as a blanket term to describe complex or multi-disciplinary research.

The composition and management of review processes needs care. Funding agencies have a duty to ensure adequate training for their staff so that they are more able to distinguish genuine interdisciplinarity and effectively deal with issues that arise. When managing review processes, funders should ensure that their instructions for reviewers and panels are aligned with the goals and criteria as stated in calls for proposals, and that external review panel members are selected for their experience in interdisciplinarity. Taking time at the beginning of a panel meeting to develop a common understanding of the programme and criteria by which interdisciplinary bids are to be judged can ensure more satisfactory and equitable outcomes.

Both summative, end-of-award evaluation and any formative evaluations of interdisciplinary large-scale investments also need to be appropriate. While strong publications will be sought as measures of academic rigour, other less tangible indicators might suggest that added value from the interdisciplinarity is (or is not) being achieved.

4.3 Building interdisciplinary capacity
Career paths are uncertain for interdisciplinary research and need to be addressed if capacity is to be grown (Lyall et al., 2011c chapter 6). Researchers with the potential to work across disciplines may need extra encouragement and resource to play an integrative role within an interdisciplinary team. Providing training and additional support to bring people together physically can be especially important when they are from different traditions and disciplines. Funders therefore have a crucial role in building interdisciplinary capacity if they are to meet the challenges and demands of complex, multi-dimensional, policy-related problems.

Developing next-generation researchers is a key area in capacity building (Lyall and Meagher, 2012). Interdisciplinary PhD training is affected by, for example, breadth of PhD topic, relationship to interdisciplinary centres or schools, and exposure to different research methods, along with considerations as to context such as interdisciplinary programmatic teams or standalone studies. Interdisciplinary PhD students typically have to train in methods from more than one discipline, so this requires money to be available for training at intervals throughout a PhD. Beyond the training stage, the issue of career progression is vital if funders are serious about building capacity in a more long-lasting and substantive way than 'simple' production of interdisciplinary PhDs. When considering such academic careers, funders need to be aware of the constraints imposed by universities and national research assessments; research funders (and universities) could provide more recognition for early career researchers who do interdisciplinary work, ensuring that interdisciplinary researchers are never considered 'second tier', for example, with respect to career progression.

4.4 Encouraging stakeholder engagement
If policy relevance is sought, explicit acknowledgement by funders at the beginning of an interdisciplinary investment can legitimise researchers doing things differently in terms of engaging stakeholders from the start, in order to avoid the phenomenon of 'just natural science plus communication'. Individuals who are adept at interdisciplinary research may be

particularly valuable resources for the generation of impacts, not simply because of the research problems they may choose to tackle but also because of their ability to work across diverse perspectives[7].

One could argue that the capacity to integrate across disciplines leads to a realism that is key to making a difference beyond academia, and that not only academics but other knowledge intermediaries have roles to play (Meagher and Lyall, forthcoming). This requires an approach that balances focus and flexibility and a realistic understanding of what can be achieved within the timescales of a grant-funded programme. In understanding the needs of research users, for example, funders need to recognise that negotiating and co-producing knowledge in a collaboration that encompasses many perspectives can require more time to achieve the genuine integration and mutual understanding needed to solve a problem effectively.

4.5 Sustainability of interdisciplinary research
Finally, there are issues for funders to consider about sustainability of interdisciplinary research capacity and research communities. Having invested the funding to support the time, effort and resources into building up a network, community and capacity, research funders should consider what happens when an initiative ends. All can disappear in a brief time if there is no funding to continue, as demonstrated by one of our case studies, where people reverted to mono-disciplinary silos. Research funders hoping to build interdisciplinary capacity as a significant component of a national research portfolio must be aware that interdisciplinary capacity-building is a long-term process. Interdisciplinary training and education are key components of capacity building but interdisciplinary researchers must also see genuine prospects for career progression and feel confident that there will be continuity of funding for interdisciplinarity.

Guaranteeing funding for interdisciplinary work over time would facilitate sustainability of interdisciplinary research. An increase in calls explicitly specifying interdisciplinary research would increase capacity among those who are currently established researchers. This is not to imply that individual interdisciplinary investments should be funded in perpetuity and, indeed there are compelling arguments that mobility may not always be detrimental to the livelihood of interdisciplinary centres (Rhoten, 2004). Nevertheless, funding agencies do need to develop more realistic expectations of the time frames within which major change can be achieved: a five-year interdisciplinary programme alone cannot provide the silver bullet to solving complex issues. This requires continuity of funding for multiple interdisciplinary investments – appropriately reviewed – over the long term.

5. Conclusion

There is currently uneven guidance on the conduct of interdisciplinary research. Public funding agencies have a pro-active role to play if we want to make the future academic landscape more inclusive of interdisciplinary research. Addressing this requires a broader approach than conventional treatments of research 'methods', one that raises questions about national research policy, practical organisation and management styles as well as the wider research skills needed to be an effective interdisciplinary researcher and research leader. It requires a conscious effort on the part of the entire research community, including public funding agencies, to build an interdisciplinary programme. This calls for a clear understanding of the complexities of the interdisciplinary process but also a good dose of

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[7] The issue of stakeholder involvement in interdisciplinary research is one that was explored in detail by one of our case study programmes http://relu.data-archive.ac.uk/explore-methods/engagement.

realism. It requires a strong interdisciplinary vision on the part of those who direct the programme at both funder and academic levels, combined with a clear understanding of how to bring the community along so that interdisciplinarity lies at the heart of such a programme and is not simply an add-on. Funding needs to be flexible, to allow programmes the time and space to evolve and realise their full interdisciplinary potential. This funding also needs to include investment in liaison roles and less visible processes – such as the warm-up activities, seed-corn support, team-building interactions, network- and community-building discussed above – as well as overt mechanisms for capturing organisational learning if publicly-funded interdisciplinary research investments are to achieve their true value added.

Funding interdisciplinary research through general calls for proposals is frequently seen as problematic. Channelling support explicitly to interdisciplinary work, by establishing either dedicated interdisciplinary programmes and/or a pool of money available only to highly interdisciplinary proposals can help to address this problem. This requires innovative thinking about structures and funding streams. We believe that providing strategic funding over time, structuring – and reviewing – it appropriately, and addressing the five key success factors for interdisciplinary success will help interdisciplinary research to evolve and become established as a productive, mainstream academic research activity.

Acknowledgements

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