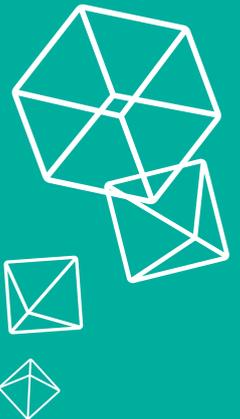


Creating value across boundaries

Maximising the return from
interdisciplinary innovation

Alan Blackwell, Lee Wilson, Charles Boulton and John Knell



NESTA is the National Endowment for Science, Technology and the Arts.
Our aim is to transform the UK's capacity for innovation. We invest in early-stage companies, inform innovation policy and encourage a culture that helps innovation to flourish.

Executive summary

The effective use of professional or academic teams from several different disciplines can help develop new solutions to complex problems or research questions, a process that can lead to interdisciplinary innovation. UK policymakers are keen on both interdisciplinary teamwork and innovation, yet there is too little clarity about how interdisciplinary innovation works in practice or about the optimum conditions for its development. This report seeks to fill that gap. The report draws on interviews with over 500 people who have been involved in interdisciplinary teams, many of them among the most innovative leaders in their field.

Guiding concepts

There are two guiding concepts that appear to be vital to the practice of interdisciplinary innovation.

Knowledge boundaries: Knowledge is often held within defined communities or organisations, with their own language and ways of working. These disciplines can be self-sustaining, and the source of insights into particular questions. Innovations require the right structures and attitudes to allow intellectual interests to develop across disciplines.

Boundary crossing: Whilst small innovations might optimise an existing structure or process, scientific breakthroughs or completely new business models usually involve crossing organisational boundaries, creating new processes or defining new organisational structures.

Practitioners structure much of their thinking through disciplinary ‘frames of reference’ that we use to make sense of the world as professional practitioners. Different sectors do not simply have different languages to express ideas; they have different *kinds* of knowledge not always mutually recognised. This presents a major team-building challenge requiring leaders with unusual personal qualities and skills.

The value of interdisciplinary innovation

There are four key targets for innovative activity across different sectors:

- **Commercial exploitation** of new ideas, technologies and processes to create, develop, implement and sell products or services.
- **The creation of social value** through improved health or social cohesion.
- **Curiosity-driven blue-sky research** most often found in the academic sector.
- **Problem-solving activity or applied research** directed toward identifying some new approach that solves a recognised problem.

Unexpected outcomes

The key paradox of interdisciplinary innovation is that one must plan for something one is not expecting. Radical innovations arise in ways that *cannot be anticipated* at the outset.

The most valuable innovations arising from interdisciplinary research are those that had not initially been anticipated. Yet it is only after significant periods of time or with specific attention and focus that collaborators from different disciplines can adopt each other's values to an extent that problems can be reformulated in radically different ways. An effective interdisciplinary innovation, designed to deliver maximum possible value, is in effect an 'organised surprise.'

The most significant benefits from innovative interdisciplinary initiatives are likely:

- To be different from those that were expected.
- Not to be expressible in terms of the discipline that originated the initiative.
- To involve new questions, or reformulation of objectives.
- To be in the form of capacity to respond to future events, not past ones.
- To arise after a long time – perhaps long after the initiative has formally ended.

These kinds of benefit are not easy to manage. Developing capacity to identify and exploit unanticipated outcomes relies on entrepreneurial alertness to unexpected opportunities.

Ways of working

There are a number of important ways in which interdisciplinary innovation works most effectively.

Effective vehicles: *Interdisciplinary enterprises* are generally collaborative teams, directed and coordinated by a *leader*. The enterprise will require resources, often from a *sponsor*. The enterprise will have some *outcomes*, many of which will be unanticipated. The different knowledge and values of different disciplines mean that there will be room for debate over what constitutes success, and how it should be *evaluated*. It is important to 'sell' the enterprise both to participants and to external sponsors, investors or beneficiaries. This can be achieved with a shared 'brand' identity.

Essential Enablers: Allowing the possibility for 'organised surprises' to emerge requires leaders

who can draw together a disparate team around a common goal, with the expectation that the most valuable outcome will be an unexpected one. This was defined as the ability to maintain a '*pole-star*' vision, in which a team works together toward a shared goal without it blinding the team to opportunities on the way to that goal.

Trust is another crucial enabler. All stakeholders must have confidence in the likelihood of an outcome, in the processes being followed and in the competence of team members. Trust also requires individual openness and institutional funding flexibility. Freedom to innovate results from such generosity and trust. Interdisciplinary innovation also takes *time*. Enterprises often fail or are less successful where they have insufficient time for trust and social capital to develop. Time is also required to understand other team members' different ways of thinking and acting.

Radical innovation entails taking *risks*. These risks can be managed, and the potential returns often far outweigh the cost of doing nothing or progressing incrementally. The more dangerous risks lie at the boundaries between systems, knowledge or disciplines. So, a team that merely identifies each discipline's own risks can both miss hidden dangers and have less chance of scoring big wins. Conventional risk management tools, such as project portfolios or prototypes can easily be adopted for these purposes. Programme sponsors must be able to accommodate risk through long-term and diverse investment, a readiness for unexpected outcomes and trust in the leader's vision.

Team building and creativity often occurs in *workshops*, as well as '*sandpits*' (meetings spread over several days) and brainstorming (shorter focused periods). Workshops need to be well facilitated. They should also adapt to their audiences. Novel approaches, such as facilitated design workshops, can prove particularly valuable.

The interdisciplinary practitioner

Our findings have identified the skills that appear to be particularly valuable for interdisciplinary innovation. The personal stories of innovators suggest that their *disciplinary styles* often reflect their first professional experiences or their undergraduate training in higher education. Many felt that their formal academic training had

left permanent traces that influenced their intellectual style, regardless of their later careers. If individuals have fixed disciplinary styles and approaches, a diverse team should include a range of such styles to achieve different approaches to a problem.

The most relevant skills appear to arise from personal attributes – including being competent and persuasive communicators, offering both collegiality and charisma – and good leaders. Although charisma and passion are important, leaders must be able to recognise, accept and celebrate successes that do not arise directly from their own work or vision. Some expert witnesses described this as *feminisation* and the personality and styles of collaboration that we found are more stereotypically feminine than those normally found in organisational contexts.

Barriers and obstacles

Interdisciplinary innovators face three main barriers or obstacles:

Career problems: The difficulty of forging a career is the most important ‘hidden’ barrier to embedding and growing interdisciplinary innovation within the UK. Interdisciplinary work can be bad for academic career advancement, making it less attractive to younger researchers. It is thus often the domain of more established senior academics whose status is already established.

Intellectual property: IP contracts prevent fluid recombination of ideas. Good interdisciplinary innovators try to focus on more meaningful mechanisms than patents to capture progress and commercialisation potential, including value narratives or personal contact with industrial stakeholders, for whom ‘early wins’ matter more than major research advances or IP exploitation strategies.

Silos: Interdisciplinary activity necessitates working across silos. The very real barriers they impose are widely recognised by interdisciplinary practitioners – particularly the silos that can form around new interdisciplinary enterprises. Yet, where an enterprise is successful, it can create its own silo. While innovators are aware of the dangers, many do end up leading institutes that build on their leadership of interdisciplinary teams.

The ecology of interdisciplinary innovation

The extent to which a project’s objectives are tightly defined from the outset may affect the potential for innovation. Radical innovations tend to require freedom for the unexpected to occur. To understand the potential value of interdisciplinary innovation, we have developed a spectrum to illustrate its ecology (see Part 2). The spectrum ranges from curiosity-driven to outcome-driven research, and the extent to which projects are knowledge-based or applied, disciplinary or functional, as a way of illustrating key aspects of interdisciplinary innovation.

Groupings from different sectors may be found across the spectrum. Skilled interdisciplinary practitioners rarely allow an interdisciplinary innovation project to sit rigidly at one end of our spectrum. Good practice may include a portfolio incorporating both ends of the spectrum in a single project. However, business and academic audiences may appreciate the spectrum more than those from the public sector. New disciplines are more likely with curiosity-driven research.

Recommendations for supporting interdisciplinary innovation

Support innovative leaders: Interdisciplinary innovation, bringing completely new ideas, relies on people changing their minds. But demand for quick returns, short-term planning cycles and conventional managerial styles can easily destroy this essential dynamic. To enable and protect this kind of innovation, we need to find policy mechanisms that recognise and support pole-star leadership.

Measure impacts more openly: Existing processes for setting investment targets and evaluating outcomes bring disciplinary assumptions with them and reflect arbitrary budgetary cycles. Because it can seem foolish to set targets for creativity, curiosity, collegiality or serendipity, policy makers focus on what can be measured. Even patents resulting from academic research can be anti-innovative. Recognition of new insights and intellectual capacity requires a portfolio of benchmarking and descriptive approaches instead of existing metrics.

Provide the right resources: For the value of interdisciplinary innovation to be

maximised, interdisciplinary approaches must be used to frame the problem. The most innovative outcomes arise when the problem statement itself is open to challenge from new perspectives. Investment in resources must emphasise process and capacity for sustained innovation, not simply drawing together diverse skills. Developing the spaces in which interdisciplinary innovation can occur, and nurturing the processes and personal skills that enable it, is an essential contribution of public policy and public funding.

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Introduction

1. Our main priority in this project was to understand and interpret the experiences of people who actually do interdisciplinary innovation, rather than to validate any prior theoretical principle or hypothesis about what this might involve. This approach does represent good practice in interdisciplinary research, to the extent that convening the project around a particular disciplinary orientation might cause us to neglect important factors, as well as making it difficult for our own interdisciplinary team to collaborate effectively.
2. Please see Appendix 1 for a more detailed account of the methodology deployed in this study.
3. See Blackwell, A., Wilson, L., Street, A., Boulton, C. and Knell, J. (2009) 'Radical Innovation: Crossing Knowledge Boundaries with Interdisciplinary Teams.' University of Cambridge Computer Laboratory Technical Report UCAM-CL-TR-760. Available at: <http://www.cl.cam.ac.uk/techreports/UCAM-CL-TR-760.html>

Interdisciplinary innovation represents the successful exploitation of new ideas that are the result of people bringing together knowledge drawn from different research disciplines. The findings summarised here are the result of an in-depth study focusing on the personal experiences of those innovators. This report aims to offer a gritty account of the drama and dynamics of the phenomenon – identifying what drives successful interdisciplinary innovation.¹

Our findings suggest new ways of conceiving and defining interdisciplinary innovation, and general factors which commonly contribute to its success.

Appropriately, given the subject matter, this report has been developed by a team that itself brings together different disciplines, with a particular focus on anthropology, design research and strategic policy. We have based our findings on a large-scale survey and detailed discussions with many of the UK's most successful interdisciplinary innovators, and on reports from expert witnesses and invited commentators in many other fields.²

Our purpose throughout has been to illuminate how best to enable and facilitate the process of interdisciplinary innovation. To do this, we push the concept of 'innovation' beyond that which is conventionally found in management textbooks, where 'innovation' is assumed to describe the processes by which businesses successfully create new products and services (or combinations of product and service like the iPod).

We have reviewed the practice of interdisciplinary innovation not just in

businesses and academia, but also within the broader public sector.

Our aim has been not only to consider the creation, transfer, application and exploitation of knowledge as a linear process (the main focus of government policy in science and technology), but also to understand better the whole ecology by which people, understanding and skills move between different professional contexts. We have sought to discern where value is created within interdisciplinary innovation, and the key to maximising that value.

This report is a condensed version of a more detailed analysis of the research material upon which this narrative is based.³

Part 1: All together now – defining interdisciplinary innovation

1.1 Distinguishing interdisciplinarity

Interdisciplinarity is associated with teamwork, where team members each bring different specialist expertise to solving a problem. But such work, though valuable, is often routine. Our concern is more with the kind of interdisciplinarity that leads to new kinds of knowledge, and that crosses the boundaries by which knowledge is structured. Some writers call this *transdisciplinarity*, to distinguish it from *multidisciplinary* situations such as the medical team where people with different skills work together to save a patient, or more routine collaboration on problems that, although they cross disciplinary boundaries, have no further consequences for the disciplines involved.⁴ We believe that the word interdisciplinarity is sufficient, and have found subtle and important features that the simple tripartite classification does not capture.

1.2 Interdisciplinary innovation – much talked about but poorly understood

So much for interdisciplinarity – what about interdisciplinary innovation?

Sometimes, two words become attached to imply something desirable and beneficial – even when what is meant by them remains distinctly unclear. For example, policymakers use the phrase ‘sustainable communities’ to mesh the modern concept of environmental sustainability with the tradition of people working together for the greater good. Or, ‘progressive consensus’ is used to suggest that change – which has often implied radicalism – can be married with the widespread acceptability of ‘consensus’ more often linked

to conservative values. ‘Interdisciplinary innovation’ is not dissimilar in that it merges the idea of cross-discipline cooperation with innovation (in its various senses), linking two desirable policy inputs with little clear idea of what it actually means. Here, we seek to give the phrase meaning.

When we began this research, references to both innovation and interdisciplinarity were ubiquitous in UK research and economic development policy. Across government, think tanks and academic papers, the notion of interdisciplinarity had achieved heightened significance due to a more general association of innovation with processes of boundary crossing, collaboration and the integration of different kinds of knowledge.

A typical example is the statement on ‘Impact, Innovation and Interdisciplinary Expectations’ currently advertised by the Economic and Social Research Council (ESRC):

“Innovation – The Council is keen to support research which is ambitious (but clearly specified) and has the potential for high scientific impact and/or high user impact. ... Interdisciplinarity – As part of its portfolio, the ESRC also expects to support new and exciting research which combines approaches from more than one discipline.”⁵

In many analyses,⁶ interdisciplinarity has become associated with the creation of new boundary-crossing ideas, and innovation with the economic consequences of such ideas. Thus there has been a demand to identify uniform dynamics across the knowledge economy, so that interdisciplinary and ‘innovative’ academic research and education could become the basis of more competitive business activity.

4. For example Klein 1996, Latucca 2001, Miller 1982, Rossini and Porter 1985; Tress, Barbel, and Fry 2004; Wickson, Carew, and Russell 2006

5. For example Economic and Social Research Council (2009) ‘Impact, Innovation and Interdisciplinary Expectations.’ Available at: www.esrcsocietytoday.ac.uk/ESRCInfoCentre/Support/esrcexpectations/index.aspx

6. See Cox, G. (2005) ‘Cox Review of Creativity in Business: Building on the UK’s Strengths.’ London: HM Treasury. Available at: www.hm-treasury.gov.uk/independent_reviews_index.cfm

However, while the rhetoric is strong, we identified a lack of empirical research into how interdisciplinary research might lead to innovation in practice. In some academic fields, ‘interdisciplinary’ can be shorthand for applied research; in others it is more cutting-edge. Moreover, the relationship between interdisciplinarity and innovation is often taken for granted by policymakers, to the extent that the terms are used interchangeably.⁷

In this project, we therefore set out to do further research into what interdisciplinarity might mean for those involved in interdisciplinary research and innovation, as well as how knowledge is shared and what such innovative research achieves.

Rather than seeking to develop more precise definitions, we investigated the experiences of those individuals who have been identified by their peers, within the current policy climate, as being the exemplars of successful ‘interdisciplinary innovation’.⁸

1.3 Towards some key guiding concepts for interdisciplinary innovation

Our approach has proved very effective in developing new insights about interdisciplinary innovation. Our findings suggest that there are two guiding concepts that are vital to both the practice, and defining essence, of interdisciplinary innovation. If we were beginning our study again, we could use the concepts of ‘knowledge boundaries’ and ‘boundary crossing’ to frame our enquiries.

1.3.1 Knowledge boundaries

Disciplinary boundaries should be regarded less as ‘barriers’ to interdisciplinary innovation than as essential and beneficial aspects of the practice of interdisciplinary innovation. That said, two challenges remain: finding a home for the resulting innovations, and a career for multidisciplinary young researchers.

The truth is that knowledge is often maintained within defined communities or organisations. It is the crossing of boundaries between communities and organisations that is the central defining characteristic of interdisciplinary activity.

In our analysis, we have considered many different kinds of boundaries – those that separate individual institutions, government departments, companies, departments within

a company, or local and national government, branch offices from corporate headquarters, and research and development from manufacturing.

In each case, knowledge is held within a ‘discipline’. These common bodies of knowledge sustain organisations and communities, which in turn rely on them. That knowledge is codified and developed by leading experts at the ‘centre’ around which the boundary has been drawn.

So, for example, social science and medicine claim different insights into the lives of the elderly within a given social context. Social scientists may be concerned with living conditions and welfare while medical researchers may be more concerned with general health issues. The way in which boundaries are arranged around the knowledge, goals and values that constitute each discipline provide a stable starting point to explore combined perspectives or to generate new perspectives.

Our findings suggest that innovations require the structural and attitudinal support to allow intellectual interests to develop across disciplines.

1.3.2 Boundary crossing

So, interdisciplinary innovation arises from the positive effects that result when stepping across knowledge.

But our study has underlined that effective interdisciplinary innovation also crosses other boundaries. Whilst small innovations might optimise an existing structure or process, larger-scale innovations – scientific breakthroughs, or completely new business models – usually involve crossing organisational boundaries, creating new processes or defining new organisational structures. And the constitution of these boundaries varies in different professional sectors.

All those who have contributed to our research have a disciplinary training themselves, whether within higher education or in a professional context. Without exception, they saw themselves as coming from a particular discipline, sometimes describing it as a ‘home’ or ‘native’ discipline. Early educational and professional experiences clearly shape individual values and intellectual styles, in a way that is preserved even as a person moves between sectors, organisations or disciplines (as most of them did).

7. For a more complete treatment of the relevant literature please see the longer report, Blackwell *et al.*, (2009) and the section entitled ‘Review of literature on interdisciplinarity and innovation’.

8. In fact, our team did not agree at the outset on the definitions either of ‘interdisciplinarity’ or ‘innovation’. We therefore agreed to ‘bracket’ the definition of ‘interdisciplinary innovation’, treating it as a term representing some phenomenon that we did not yet understand. This is a common strategy in phenomenological research, where researchers wish to understand the experience of individuals, but allowing people to express that experience in their own terms. The bracketed terms are expected to be meaningful to the people whose experiences is being studied, and may also be personally meaningful to the researchers themselves, but care is taken to allow all those involved to describe their own experiences in terms that are meaningful to them.

Our findings suggest that the ways in which disciplinary practices shape our thinking are much underestimated. It is through these particular 'frames of reference'⁹ that we structure and make sense of the world as professional practitioners.

Moreover, it is important to recognise that these different sectors do not simply have different pieces of knowledge, or even different languages to express ideas (a common cliché of interdisciplinary misunderstanding). Rather, they have different kinds of knowledge – that which is valued in one sector may not even be recognised as being knowledge by another.

As we shall see later, this observation underlines one of the key challenges in interdisciplinary innovation: how to develop shared values and culture across an interdisciplinary team? This is often presented as a mere 'translation challenge' – developing a common language between different disciplines. It is more accurately conceived as a team-forging challenge – building new teams and intellectual environments within which innovation can occur.

Managing such teams is extremely challenging. It requires unusual personal qualities and skills. It is also inherently risky because the very opportunities created by combining perspectives mean that the outcomes cannot be predicted. The experience can, for example, lead to a greater capacity to respond to future events beyond the scope of the project. If the result of an innovation is a new body of knowledge or insight, the new grouping may even become a new discipline, organised around its own shared values and knowledge.

Surprising discoveries may arise even within a project, but further developments are unlikely to conform to today's disciplinary boundaries. This is why it is so important to have the right interdisciplinary investments that make it easier to respond flexibly to new problems.

9. Goodman, N. (1978) 'Ways of worldmaking.' *Harvester studies in philosophy*. Brighton: Harvester Press. pp.2-3.

Part 2: Expecting the unexpected – the value of interdisciplinary innovation

Interdisciplinary innovation is in vogue because it is perceived as having the potential to solve entrenched social and economic problems and to develop new insights. This reflects a growing understanding about the nature of the knowledge economy – the ideas needed to solve a problem are often in a different place from the problem itself, making interdisciplinary innovation an essential tool. Complex questions like reducing obesity or tackling terrorism need complex responses. Research and public policy, therefore, need to cross the boundaries of established disciplines, in a way that is similarly innovative.

2.1 Interdisciplinarity in business, government and academia

Our study has revealed that there are many targets for innovative activity across different sectors, including the following:

- **Commercial exploitation of new ideas, technologies and processes** is a primary concern of innovation, enshrined in UK government definitions. The objective is to create, develop, implement and sell products or services. To this end, commercial innovation is likely to be purposeful and managed. The result may be an incremental development of an existing product, service or process – such as improved fuel efficiency in a car using a differently shaped roof for better aerodynamics or something more radical, perhaps with a capacity to disrupt previous business, such as the Apple iPod.
- **The creation of social value** is another outcome of innovation, whether in improved health (perhaps through improving diet to

reduce obesity) or the social cohesiveness of a community (such as creating new community meeting places). Here the development may lie in a new intervention – such as an overhaul of school dinners – or it may lie in the process by which change was exercised, as when a local council works with an arts organisation to re-engage with community aspirations.

- **Curiosity-driven blue-sky research** is most often found in the academic sector, for example when a palaeontologist works to understand the anatomy of a dinosaur or a mathematician explores an abstract theorem. It seeks knowledge and new insights, creating new explanations of phenomena we see around us. Those phenomena might be equally in the domains of the sciences, humanities, arts, or social and political sciences. The aim is insight, not necessarily with the intention of action or intervention.
- **Problem-solving activity or applied research** is directed toward identifying some new approach that solves a recognised problem. Investigating how to reduce CO₂ emissions, design a low-cost medical diagnostic device or stabilising a pedestrian bridge across the Thames, are examples in which such innovation occurs. The objective is an explicit intervention to solve or ameliorate a problem. In this context, success is reflected in the extent to which the problem is resolved.

So, how valuable is interdisciplinarity in these examples?

With problem-solving or commercial exploitation, the objectives may be tightly defined. Here interdisciplinarity is explicitly

intended to use different skills or analytic perspectives to frame the problem, using different knowledge sources and the insights gained to achieve a better solution. There is also a growing belief that interdisciplinarity increases the likelihood of more radical solutions.

Such work requires more than the simple combination of professional skills to carry out routine business (such as when a nurse, an anaesthetist and a surgeon work together in an operating theatre). Radical innovations combine people and skills in unexpected ways, leading to results that are different from those that might be achieved through the familiar patterns of a single professional discipline.

In academic, curiosity-driven research there may be new insights created by the new conjunction of differing knowledge bases and perspectives. In such cases the different disciplines combine in ways that stimulate unexpected breakthroughs not anticipated in existing disciplinary descriptions.

2.1.1 Understanding the spectrum of interdisciplinary innovation

One way to understand the potential value of interdisciplinary innovation is to think of a spectrum of interdisciplinary innovation activity, with curiosity-driven interdisciplinary innovation at one end, and 'directed' (problem-

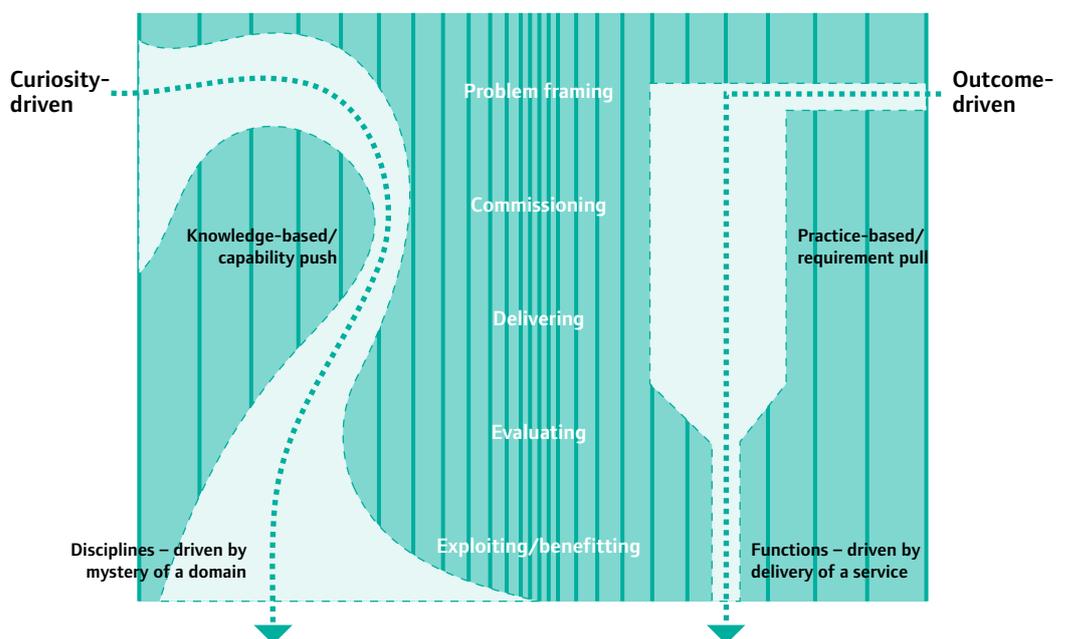
solving) or 'outcome-driven' interdisciplinary innovation at the other (see Figure 1).

This spectrum is useful in explaining key aspects of interdisciplinary innovation:

- Interdisciplinary groupings from different sectors (commercial, academic, governmental) can be found along the whole spectrum. So, curiosity-driven interdisciplinary innovation is no more exclusively academic than directed innovation is exclusively commercial.¹⁰
- Good interdisciplinary innovation practice often includes a portfolio incorporating both ends of the spectrum within a given project.
- An activity's purpose is the best way to differentiate it. As Figure 1 makes clear, curiosity- and outcome-driven innovations often share a common interdisciplinary process in their cycle of problem framing, commissioning, delivering, evaluating and exploitation.
- There is a stronger understanding of the value-creating possibilities of this spectrum amongst business and academic audiences than amongst the broader public sector.
- Not all interdisciplinary work leads to the formation of a new discipline (as

10. The detailed report of this study (Blackwell et al. (2009)) outlines in considerable detail the characteristics of different sectors as sites for interdisciplinary innovation, describing the common boundary distinctions and strategies deployed to navigate boundaries and barriers, and successfully run a portfolio type approach to the management of interdisciplinary innovation.

Figure 1: The ecology of interdisciplinary innovation



when chemistry and biology combined in biochemistry), but all new disciplines must start with new knowledge. Using the proposed ecology for interdisciplinary innovation we can say that the formation of a new discipline is likely to be an outcome at the curiosity-driven end of the spectrum.

2.2 Interdisciplinary innovation and unexpected outcomes

The key paradox of interdisciplinary innovation is that one must plan for something one is not expecting. In both problem-solving and curiosity-driven approaches, radical innovations arise in ways that cannot be anticipated at the outset of a new interdisciplinary enterprise, whether a commercial team or a research project.

This is a central finding of our research, and one that has not been emphasised sufficiently in previous research.

Most professional or academic disciplines have their own ways of approaching a problem. This often involves restating the problem in a way that is compatible with the knowledge of the discipline. The problem of obesity might be described by a physicist as being essentially one of 'energy balance,' the result of people consuming more calories than they expend in exercise. Obesity might alternatively be described by the anthropologist as a problem of social structure, to be addressed by investigating the fact that it is the wealthy and powerful who are obese in some cultures, but the poor and excluded in others. Neither formulation of the problem offers any direct assistance to the other; the definition of a problem in disciplinary terms immediately excludes insights of other disciplines.

In the research workshops from which our findings are drawn, we repeatedly heard that the most valuable innovations arising from interdisciplinary research were those that had not initially been anticipated. This is not a sign of fatalism or laziness on the part of researchers: successful interdisciplinary outcomes cannot be anticipated, because they involve not only new answers, but also new questions.

These new questions arise from the particular values of different disciplines (i.e. in the obesity example, physicists are primarily interested in closed systems, while

anthropologists are primarily interested in societies). It is only after significant periods of time or with mutual sensitivity that collaborators from different disciplines can adopt each other's values to an extent that problems can be reformulated in radically different ways. Once this has been achieved, the ecology of interdisciplinary knowledge provides the context in which newly discovered problem formulations can be developed and exploited. Many examples can be found among approaches to complex social problems, such as poverty, obesity or security.

It is in this sense that we can think of effective interdisciplinary innovation, designed to deliver maximum possible value, as an 'organised surprise.' This is because interdisciplinary innovations are always partly serendipitous,¹¹ so it is necessary to mobilise resources toward a particular goal, while always allowing new knowledge to arise from the exercise of individual curiosity and enquiry.

2.3 Designing for value means entrepreneurial alertness

Perhaps by definition, the results of a creative process cannot be anticipated from the outset. This is certainly true of interdisciplinary innovation. For a start, a planned innovation is not likely to be a radical one – it is simply a process of implementation or delivery. Furthermore – and more significantly for our project – if it were possible to specify the final result at the start of an interdisciplinary enterprise, then the knowledge necessary to achieve the result would be expected to come from within the discipline that supplied the specification. Although an external 'real-world' problem might often form the motivation for an interdisciplinary enterprise, the problem is rarely straightforward. Collaborators are more likely to conclude that the real problem was not that which had initially been assumed. They redefine the question.

To summarise the findings reported by many of our expert witnesses, the most significant benefits from innovative interdisciplinary initiatives are likely:

- To be different from those that were expected.
- Not to be expressible in terms of the discipline that originated the initiative.

11. In this sense, the word 'serendipity' does not mean by chance, but the skilled ability to benefit from unexpected events.

- To involve new questions, or reformulation of objectives.
- To be in the form of capacity to respond to future events, not past ones.
- To arise after a long time – perhaps long after the initiative has formally ended.

These kinds of benefit are not easy to manage. Developing capacity to identify and exploit unanticipated outcomes relies on entrepreneurial alertness to unexpected opportunities. In the face of the risk associated with the unexpected, this capacity and alertness provide the pay-off through creative outcomes from a project. Furthermore, interdisciplinary teams provide longer-term capacity for innovative responses to future challenges beyond the life of the project itself.

In the following sections of this report we describe the consequences and strategies in terms of how such teams are constructed and managed.

Part 3: The practice of interdisciplinary innovation – from enterprises to ‘pole-star’ visions

In this section, we describe particular ways of working that we have found to be characteristic of successful interdisciplinary enterprises: at the outset of an enterprise, in its conduct, and in how its outcomes are evaluated.

In each case, the creation and facilitation of collaborative work in teams is central to interdisciplinary innovation. We therefore place special emphasis on that team dynamic, and on how to lead, build and manage it. Our findings have also highlighted a range of barriers and obstacles to the practice of effective interdisciplinary innovation, which we also detail below.

We have split the presentation of this material into three key themes:

- Effective vehicles.
- Essential enablers.
- Barriers and obstacles.

3.1 Effective vehicles

3.1.1 The interdisciplinary enterprise

This study has investigated interdisciplinary innovation at a range of different scales: the activity of a single individual; short-term project teams; longer strategic investments; campaigns; and in programmes or initiatives composed of many individual projects.

We use the term *interdisciplinary enterprise* to describe a particular attempt to do interdisciplinary innovation, in different time scales and with variable resources. Our research

suggests that interdisciplinary enterprises have the following characteristics:

- These are generally collaborative enterprises, in which a *team* has been brought together.
- The collective work of the team will be directed and coordinated (to some extent) by a *leader*.
- The enterprise will require resources, some of which come from a *sponsor*.
- The enterprise lasts for a defined period of time, during which it has a formal structure.
- Outside that defined period, some work will have started earlier and will continue afterwards.
- The enterprise will have some *outcomes*, many of which will be unanticipated and challenge conventional approaches to project risk management.
- The enterprise is likely to have some official *goals*. All stakeholders will have varying motivation for their engagement in the enterprise, but all have some expectation of success in their own terms.
- The different knowledge and values of different disciplines mean that there will be room for debate over what constitutes success, and how it should be *evaluated*.

The issue of shared goals merits some additional elaboration. An interdisciplinary enterprise needs to have some defined goals, in most cases derived from the requirements of sponsors, although often influenced by the

motivation of the team and other stakeholders too.

The leader must be able to present those goals to the team and other stakeholders as a vision or desirable outcome, including a narrative of its value. He or she must be able to simplify the project's complexity with an inspiring phrase or shared visual representation. However, these shared project goals must also allow for the unanticipated outcomes that occur in innovative interdisciplinary projects. Teams must also be able to take account of non-commercial benefits, such as the innovative delivery of public services.

3.1.2 Branding and selling the interdisciplinary enterprise

Our findings also underline the importance of 'selling' an interdisciplinary enterprise both to participants and to external stakeholders (whether sponsors, investors or beneficiaries). This can be achieved with a shared 'brand' identity. If an interdisciplinary enterprise is successful early on, its brand grows in importance, and is defended by those who would like to see it become the basis for new institutionalised resources and boundaries. Many of those who testified at our workshops said that an element of proselytising for a new interdisciplinary brand could be both innovative and a valid area of knowledge.

Box 1: The Equator IRC

Equator was one of five interdisciplinary research consortia (IRCs) funded by the Engineering and Physical Sciences Research Council (EPSRC) to run between 2001 and 2007. The director of Equator, Professor Tom Rodden from the University of Nottingham, was one of our expert witnesses. He described Equator as 'the wacky one' of the five IRCs that were funded in that period, representing the greatest risk in the combined or total investment of £40 million public funds. Equator investigated an area described as 'ubiquitous computing', exploring and anticipating the effects of having computer hardware distributed throughout the physical context of human life. Involving sociologists, computer scientists, philosophers, engineers and artists, Equator researchers undertook not only laboratory research and experimental studies, but also created 'experiences' where members of the public engaged directly with new technologies 'in the wild' as a way of challenging technical limitations and preconceptions.

Equator's results were considered to be very successful. The consortium produced opportunities for substantial breakthroughs as a result of investing significant public funds in a single managed enterprise (drawn from multiple projects and institutions). It also attracted a great deal of public and international attention, with valuable benefit to the EPSRC 'brand'. It resulted in some significant changes, not only in academic attitudes to ubiquitous

computing, but among leading commercial design practices – for example, in the use of 'cultural probes' (introduced by Equator member Bill Gaver while at the Royal College of Art) to engage with potential users of technology in a less deterministic and constrained manner.

The results of Equator were achieved largely through the kind of management practices described in this report. It took several years before the members of the consortium understood and trusted each other sufficiently to invest their effort in scientific work that had not been initially recognised by their respective disciplines. Rodden convened and insisted on attendance at regular 'all-hands' meetings, including not only project managers and leaders, but all staff and students funded at all the universities. He consciously maintained a rhythm of intellectual divergence and convergence, and made use of EPSRC willingness to grant researchers autonomy in management of funds to reallocate resources between projects, and to keep funds in reserve for support of unexpected opportunities appearing later in the IRC period. The result was a wide range of radical innovations – from city-wide GPS-enabled mobile games to furniture that integrated digital worlds into the home – outcomes that had not been anticipated at the time the IRC was funded. At the same time, Equator engaged directly with the public who were ultimately funding this enterprise.

3.2 Essential enablers

3.2.1 The pole-star leader sustaining a pole-star vision

One of our central findings is that radical innovations arise in ways that cannot be anticipated at the outset of a new interdisciplinary enterprise – whether that enterprise is the assembly of a commercial team or the start of a research project. But, allowing the possibility for ‘organised surprises’ to emerge requires a very particular role for leaders of interdisciplinary enterprises. These leaders must be able to draw together a disparate team around a common goal, with the expectation that the most valuable outcome will be an unexpected one.

The essential attribute was defined as the ability to maintain a ‘pole-star’ vision, in which a team works together toward a shared interest in a goal that motivates the general direction of their work, but without it blinding the team to opportunities on the way to achieving the goal. The leader must be able to recognise opportunities for other outcomes, and to harness excitement among team members as those opportunities arise. This approach to innovation presents a number of challenges and paradoxes for managers and research sponsors. Few organisational structures can accommodate radical changes in the goals of a project, and it is hard for investment decisions to be made without articulating explicit expected outcomes that can be evaluated.

The expert witnesses in our workshops included many pole-star leaders, and our recommendations draw together their experiences and insights. The pole-star metaphor itself developed in one workshop, over the course of a day’s discussion, but was originally introduced by Professor Jeremy Baumberg, the director of an interdisciplinary research centre for nanophotonics at the University of Cambridge.¹² Baumberg had managed highly skilled teams of scientists in both commercial and academic research settings, and had consistently found that the most exciting discoveries from his well-funded research were not those expected at the start of a project. He believes in the value of giving researchers the freedom to pursue questions that interest them, and also emphasises the importance of motivating a team through shared purpose. The tension between leadership ‘from behind’ that enables skilled individuals – and leadership through vision and example, led him to describe his management style as ‘sideways management’.

Other witnesses recognised and had shared these experiences, prompting the notion of the pole-star.

The pole-star analogy strikes a balance between the desire to guarantee value and outcomes and the need to remain open to curiosity and serendipity. The pole-star vision creates commitment to a long term and overarching goal for the interdisciplinary enterprise, within which subsidiary and contributory goals (and programmes) can be formulated that allow realistic resource allocation, control of risk and evidence of progress.

The pole-star approach also enables parallel innovation programmes, offering interdisciplinary outcomes shared between competing and collaborating teams. Some important factors include: the balance between focus and serendipity; working strategically to achieve capacity rather than specific goals (just-in-case rather than just-in-time); linking short-term goals with long-term vision; and coordinating team goals versus each collaborator’s individual goals.

3.2.2 Trust underpinning individual and institutional generosity

Because the outcomes of an interdisciplinary enterprise are uncertain, all stakeholders must have confidence in the likelihood of an outcome; in the processes being followed; and in the competence of team members. Each of these facets involves different trust relationships, providing ways of bonding within the enterprise:

- Sponsors must have trust in the value of the research (its vision).
- Members of the team must have confidence in management of the process.
- Members of the team must respect each other’s skills and disciplines.

Trust should noticeably increase as the enterprise advances. Lack of trust might be related to concern over outcomes (resolved through open expectation, negotiating diverse outcomes and risk management) or doubts that others are collaborating in good faith (that they are devoting effort, commitment and loyalty to the joint enterprise). Lack of familiarity with the working methods of other disciplines can also weaken trust.

Because of the tension between time spent crossing boundaries and developing trust

12. See <http://np.phy.cam.ac.uk/> [Accessed 22/03/2009].

inside them, openness is important both within the team and across the organisation. This requires individual and institutional generosity. Institutions and funding bodies need to provide funding and structural flexibility. Individuals must be ready, openly and playfully, to explore new ideas rather than impose their own disciplinary skills, methods or theories on the team. Freedom to innovate results from such generosity and trust.

3.2.3 Time

Interdisciplinary innovation takes time. This was a repeated message from all those we interviewed. Enterprises often failed or proved less valuable where they had insufficient time for trust and social capital to develop. Existing reserves of social capital tend to reside within disciplines (or at least within inter-disciplines). When those boundaries are crossed, new reserves of social capital must be developed, though it is sometimes possible to use local networks to do so.

We noted earlier in this report that it is not 'different languages' that most obstruct communication between disciplines, but lack of recognition of the nature of knowledge in other disciplines. Time is required to move from simply learning the words that others use to understanding how those words represent different ways of thinking and acting.

3.2.4 Interdisciplinary innovation and the management of risk

Radical innovation entails taking risks. But these risks can be managed, and the potential returns often far outweigh the cost of doing nothing or progressing incrementally. So, how does interdisciplinarity affect these truisms and how can effective risk management enable interdisciplinary innovation?

Our findings suggest that the very nature of risk management in interdisciplinary radical innovation is profoundly different from that in a well-specified incremental innovation. Nonetheless, and counter-intuitively perhaps, interdisciplinary enterprises can be very effective risk-bearing vehicles.

Interdisciplinary teams have the potential to manage a wider range of risks where each team member identifies the risks within his or her own discipline and suggests ways of managing those risks.

But, especially with complex systems, the more dangerous risks lie at the boundaries between systems, knowledge or disciplines. So,

a team that merely identifies each discipline's risks can both miss hidden dangers and have less chance of scoring 'big wins'. Using an interdisciplinary team to span the boundaries, assess the interactions and build insights into the potential for complex systems to unfold in unexpected ways, allows the identification of the risks of interaction. Working effectively, an interdisciplinary team may offer a breadth of insights that would not otherwise be available. In this context, innovation in risk management goes hand in hand with innovation.

All the conventional risk management tools are easily adopted for interdisciplinary innovation. Examples include:

- Portfolios of a range of projects and initiatives allow diversity to control the volatility of outcomes – multiple radical interdisciplinary options can be explored or radical interdisciplinary innovation can be used as the high-risk part of a portfolio of otherwise conventional innovations.
- Agility and the use of parallel development routes, often used to prevent business innovation being stopped by a dead-end, is just as applicable for interdisciplinary innovation.
- Staging or phasing the project to evaluate progress before committing to larger scale development provides the same degree of assurance within interdisciplinary innovation, but must be configured for agility and adaption within the pole-star framework we have described.
- Prototypes and demonstrators can reassure sponsors and other stakeholders that outcomes are being achieved, whilst also acting as 'boundary objects' that allow different disciplines to respond to the objective in their own terms.

These insights have a number of practical implications for risk management within interdisciplinary exercises. Sponsors of programmes of interdisciplinary innovation must be able to accommodate risk through:

- Long-term investment, waiting for returns on capacity building.
- Spread investment across a portfolio of diverse activities.
- Encouraging awareness and reflection on the collaborative process.

- Readiness to accept unexpected outcomes.
- Trust in the leader's vision.

3.2.5 The effective use of workshop tools and other collaborative processes

Our inquiries yielded a wide range of data on particular tools and techniques deployed within interdisciplinary enterprises. Most emphasis was placed on teams engaging creatively at meetings – generally workshops, but also ‘sandpits’ (meetings spread over several days) and brainstorms (shorter focused periods). These meetings vary widely in their professionalism and effectiveness. In particular, workshops need to be structured and managed – a contribution that is often described as facilitation.

Many such events use techniques that were originally developed to stimulate creativity within a company or public service organisation, rather than a university. When these are applied directly to research contexts they may be less successful unless they take account of the importance of individual motivation, uncertain outcomes, maintaining disciplinary elites, disciplinary hierarchy, or technical languages.

Some leaders of interdisciplinary research regularly design innovative ways of working.

Others work directly with social scientists to develop and evaluate experimental facilitation methods.¹³ Design of novel visual representations is often a valuable strategy, as exemplified by Tom Inns (see Box 2).

3.3 The interdisciplinary practitioner

Our findings have helped identify the skills that appear to be particularly valuable for interdisciplinary innovation, drawing on our expert witnesses’ reflection on their own careers and how they developed those skills.

3.3.1 Personal histories become more important than personal qualifications

In conventional disciplines, an established hierarchy makes it very easy for an expert to enter a new situation with a ‘badge’ of expertise. Expert interdisciplinary innovators do not have this advantage. As a result, they are likely to present their qualifications through an account of their own personal history.

Many of our expert witnesses had been formally trained in more than one discipline, but had achieved this through conventional training in each discipline, rather than through a special interdisciplinary scheme. However,

13. Blackwell, A.F. (1996) ‘Designing knowledge: an interdisciplinary experiment in research infrastructure for shared description.’ Cambridge: University of Cambridge Computer Laboratory Technical Report UCAM-CL-TR-664.

Box 2: Theatres of thinking

Events such as workshops are commonplace, especially during early phases of interdisciplinary enterprises. However, poorly executed workshops can jeopardise an initiative from the start.

Tom Inns, Programme Director of the joint EPSRC/AHRC interdisciplinary research programme, ‘Designing for the 21st Century’, is a leading expert. His ‘theatres of thinking’ are less like conventional brainstorming meetings than facilitated design workshops, involving a wide range of physical media (drawing on his own professional background as a designer).

They have been central to his work as programme director, with phases marked by workshops at which objectives are reviewed from across the multiple disciplinary perspectives of the programme.

In a typical workshop, participants identified drivers of change for their field over the coming 15 years. They identified the new knowledge and understanding that would then be needed, modelled potential research project ideas in three dimensions on a large floor-size portfolio map, and used that map to explore criteria to evaluate and select projects for funding.

The programme has used similar techniques throughout, including summative meetings that review findings and identify future policy priorities. These novel techniques have resulted in a portfolio of projects with many practical outcomes (including design of new street furniture to help cut crime) while also breaking new intellectual ground with interdisciplinarity at the core.

www.theatresofthinking.org

rather than emphasising training in a core academic discipline, they more often described professional qualifications and experience as a base from which to launch interdisciplinary projects. Suitable professional backgrounds included engineering, design and even theatre.

In this project we did not specifically study the experience of young researchers, but many of our contributors feared that taking up early employment opportunities in interdisciplinary projects might damage future career prospects. Young academics are expected to teach 'core' topics in an established discipline. For most, it is critical that the field in which they are working should become established either as a proper discipline, or as a significant sub-discipline, to provide opportunities for career progression.

3.3.2 Imprinted disciplinary styles

Individuals often seem to become 'imprinted' with particular disciplinary styles as a result of early life experiences, especially first professional experiences (and for academics, their undergraduate training in higher education). Our literature review did not find any previous discussion of this topic. Nevertheless, in our workshops, and in subsequent testing of this observation, we found that those who often work in interdisciplinary groups, including those who have moved among many disciplines, felt that their formal academic training had left permanent traces that influenced their intellectual style, regardless of their later careers.

If individuals have fixed disciplinary styles and approaches, a diverse team should include a range of such styles¹⁴ to achieve different approaches to a problem. We use the term 'style' as an alternative to conventional categories, but mean it to encompass methodologies, terminology, epistemology, manner of discourse and personal conduct, and many other attributes.

3.3.3 Personality – factoring in feminisation

Our expert witnesses did not attribute their skills in interdisciplinary research purely to formal training. On the contrary, the skills most relevant to successful interdisciplinary innovation appear to arise from personal attributes and good leadership. In addition to being effective pole-star leaders, our expert practitioners also displayed a range of leadership traits, including being competent and persuasive communicators, offering both collegiality and charisma.

Does this mean these skills can't be taught?

In a research context, personal curiosity, passion and enthusiasm for the subject are essential attributes of intellectual leadership. Interdisciplinary innovators are enthusiasts – they are not motivated by an interest in securing a conventional career. Our witnesses spoke of their 'passion', a word that also occurs regularly in the literature.

However, these leaders also need a degree of humility and openness, if they are to recognise and adopt insights from other disciplines. Although charisma and passion are important, leaders must be able to recognise, accept and celebrate successes that do not arise directly from their own work or vision.

Some expert witnesses described this as feminisation, in direct contrast to an 'alpha male' style of leadership that would be counterproductive in these teams. The personality and styles of collaboration that we report are more stereotypically feminine than those normally found in organisational contexts. This was reported in both the government and academic sectors. It may be sufficiently rare in business contexts that we simply did not encounter it, but could have great potential.

Such team leadership should be distinguished from the roles that such leaders play within organisations, including those characterised as mavericks, brokers and boundary-spanners.¹⁵ Within a successful interdisciplinary team, a combination of wider personality types will also be needed.

3.4 Barriers and obstacles

3.4.1 Interdisciplinary innovation – a calling not a career

It might seem strange to begin a discussion of barriers with an account of the difficulty of forging a career in interdisciplinary innovation. Yet, in many respects, this is the most important 'hidden' barrier to embedding and growing interdisciplinary innovation within the UK. After all, for too many interdisciplinary innovators and pole-star leaders, it is a calling that is unlikely to advance their careers.

Normal professional careers rely on means of establishing prestige and authority through academic or professional elite structures. We must contrast this 'normal' way of pursuing a

14. We use the term 'style' to encompass methodologies, terminology, epistemology, manner of discourse and personal conduct, and many other attributes.

15. From our perspective the three are the same, although they may be perceived differently in different contexts.

career with the serious career concerns faced by interdisciplinary academics.

Many of our expert witnesses and sources repeatedly worried about their career prospects, and there is evidence that interdisciplinary work can be bad for academic career advancement. These problems are particularly pertinent to younger researchers who are yet to be strongly established in their discipline. Without a firm disciplinary base they risk being known as a jack of all trades.

In academia, reward structures and professional development are heavily skewed towards individual appraisal and accomplishment. Individuals are encouraged to publish in established, high-impact discipline specific journals. In some disciplines, there is also a degree of stigma attached to the label 'interdisciplinary', that could prove damaging to junior academics. We found that interdisciplinary engagement is often the domain of more senior academics already well placed in the hierarchy, and thus more able to manage the risk of stepping outside the boundaries of their disciplines.

3.4.2 The intellectual property elephant trap

All expert witnesses in this project have been critical of how intellectual property (IP) contracts (both research funding agreements and subsequent patent protection and licensing) effectively 'strangle' interdisciplinary innovation. IP contracts prevent fluid recombination of ideas, thereby favouring existing structures and relations within which the ideas have originated. They also anticipate the kinds of value that are expected to arise from relationships, in ways that can prevent unanticipated outcomes. The formalisation and legalisation of relations may further harm the development of trust between collaborators.

This concern is at odds with how government agencies use registration of patents or other IP as a surrogate for the societal benefits obtained from publicly funded research. Patents are often used as a measure of applied contributions from academic research. Even where patents are not generated in sufficiently large numbers for counting and comparison, the terms in such contracts can act as even more remote surrogates. Yet, all these mechanisms can inhibit interdisciplinary innovation.

Good interdisciplinary innovators are well aware of these pitfalls and try to focus on more meaningful mechanisms to capture progress

and commercialisation potential. One route is the construction of value narratives rather than nominal pricing arising from patent licences. Another is the recognition that industrial stakeholders are represented by individuals who are also potential collaborators, and whose main priorities are likely to be risk mitigation around speculative enquiry. For them, demonstrable 'early wins' can be more significant than long-term opportunities, whether through major research advances or IP exploitation strategies.

Discussions of open innovation, and creative commons models of collaboration, continue to challenge conventional valuation and protection of IP. Our findings support the general concern that current IP mechanisms do not support interdisciplinary innovation.

3.4.3 Silos – pre- and post-interdisciplinary innovation

A common characterisation of the sort of structure that opposes interdisciplinary innovation is the 'silo'. The term implies protection – the walls of the silo are a barrier preventing knowledge, and those holding that knowledge, from encounters with the outside world. The conception of knowledge as a cumulative resource, to be added to and safeguarded, naturally leads to a silo, as the place where the knowledge will be stored and organised.

Yet, outside encounters are fundamental to innovation, which requires that an idea move into a commercial context, or that an organisation applies knowledge that it has not used before. Interdisciplinary activity necessitates working across silos. The very real barriers they impose are widely recognised by interdisciplinary practitioners – particularly the silos that can form around new interdisciplinary enterprises.

Where an interdisciplinary enterprise is successful it starts to gain recognition for its claims and achievements. This can result in a new silo around the enterprise that makes it look very similar to those disciplines from which it arose.

Reflective interdisciplinary innovators are often aware of this dynamic, and nervous of the implications that it brings for their work. One of our expert witnesses told us "*The last thing I would do is form an institute*". Nevertheless, the dynamics of organisational management structures and resource allocation mean that these individuals often end up leading

institutes that build on their leadership of interdisciplinary teams.

Box 3: The Gunpowder Park approach

The development of Gunpowder Park, a 90 hectare public park on the site of a former Royal Munitions testing facility in Essex, is an interesting example of project-based interdisciplinary engagement. Lee Valley Regional Park Authority (LVRPA) initially commissioned the creative and strategic consultancy, Haring Woods Associates (HWA) to conduct a feasibility study for the Park. After its opening in 2004, HWA were asked to manage the identity and programming of the initiative in partnership with the LVRPA, which they did by forming a not-for-profit company, Landscape and Arts Network Services (LANS) to facilitate access to additional public funding.

Traditionally, government agencies engage with the design of public realm projects in accordance with the existing remit and jurisdiction of the agency. With Gunpowder Park, HWA tried to break down barriers within local government through project-based interaction. Rather than cast themselves in the traditional consultative role – providing external expertise to a client – HWA aimed to bring about new collaborative processes by which existing department-based expertise might be better utilised. Their intervention aimed

not only to address specific project goals but also to develop the capabilities of the client (for creativity and for innovation) by exposing them to the practices of interdisciplinarity.

Over five years, the Gunpowder Park project offered a programme of experimental arts and environmental endeavours, and was a base for activities which brought together a range of artists to engage with social and environmental issues in collaboration with local government. HWA's work includes mechanisms of engagement with the public and working with artists to embed arts and culture in planning practice with the specific aim of transforming the public realm. The disciplinary transitions included those between different artistic practices, between different audiences, between local government departments, and across all of these domains. The transformation of locale was the focal point for specific interventions that brought together an array of stakeholders and the possibility for project-based collaborative relationships between policymakers, artists and members of the local community.

Part 4: Towards an ecology of interdisciplinary innovation value-creation

Interdisciplinary innovation is clearly complex – it is not easy to define or to capture its key dynamics. Many of its characteristics reflect ‘soft’ interpersonal factors – the quality of intellectual and project leadership, or the interplay between different disciplinary practitioners within a team. But other aspects of interdisciplinary innovation operate within quite ‘hard’ tangible rules and principles.

This observation is best exemplified through a fuller sketch of the ecology of interdisciplinary innovation that we introduced in Part 2. We have already observed that the key to unlocking value through interdisciplinary innovation is to support the conditions which allow an interdisciplinary enterprise to create an environment within which such exploitation can happen. This can harness the intellectual and skills capacity of highly trained people, with experience of working within other disciplinary contexts, as well as networks of contacts giving them rapid access to other disciplinary knowledge. Investment in interdisciplinary innovation can create this capacity, and in the short-term, develop entrepreneurial alertness to the unanticipated outcomes of the project itself.

The other key dynamic in value-creation is the degree of freedom granted to an interdisciplinary team to frame and re-frame the focus of the inquiry. Figure 2 offers an idealised schema of these dynamics.

If we accept that there is a spectrum of interdisciplinary innovation activity, from ‘curiosity-driven’ to ‘outcome-driven’, it is possible to sketch some broad rules about the value-creating potential of interdisciplinary innovation activity across this spectrum.

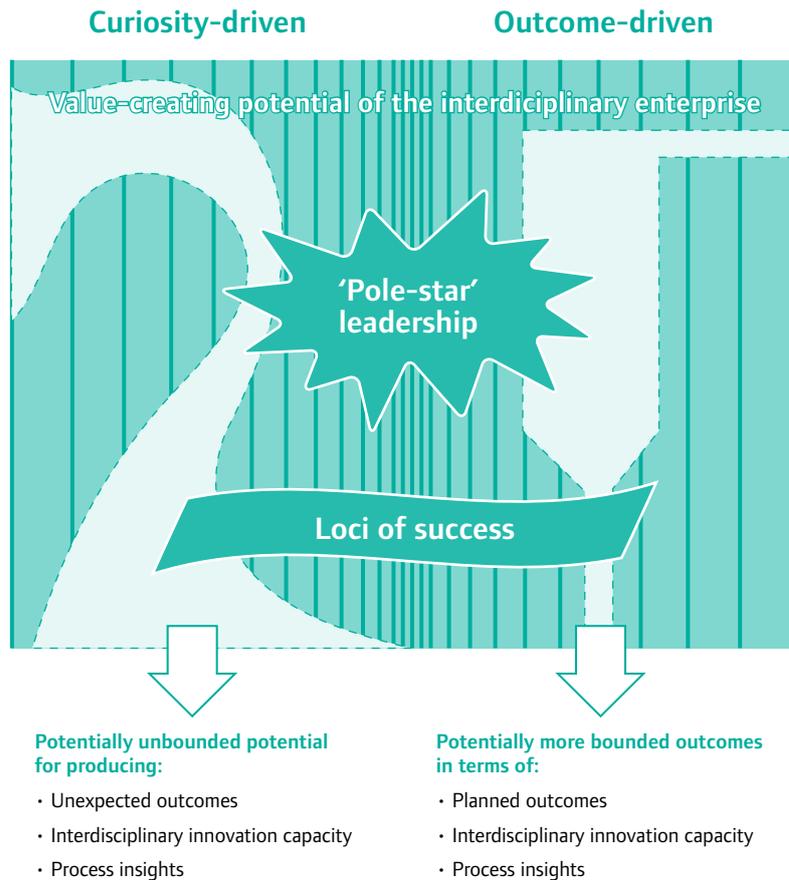
Figure 2 emphasises the fuzzy boundary areas in the centre of the spectrum. This diagrammatic relationship serves to underline the other key aspects of value-creation within interdisciplinary innovation that our study has revealed.

- The skilled interdisciplinary practitioners in our study rarely allow an interdisciplinary innovation project to sit rigidly at one end of this spectrum.
- Pole-star leaders are particularly adept at maintaining their focus on a stated outcome or problem whilst allowing for a constant reframing of that problem, and facilitating the emergence of unexpected solutions and outcomes.
- Maximising the potential value of an interdisciplinary innovation enterprise requires pole-star leaders to sit along the boundary line of the two idealised ends of this spectrum, maintaining the desired point of balance between guaranteeing value and outcomes, and remaining open to curiosity and serendipity.

The discussion leading to the pole-star metaphor suggested that more radical innovations, particularly those with the potential to be quickly commercialised, are more likely to emerge along this fuzzy boundary line than at either end of the spectrum. While this may be a hypothesis for further investigation, we believe that it is worth considering when applying findings from this report.

Whilst our interdisciplinary practitioners rarely described themselves as entrepreneurs, they frequently displayed entrepreneurial qualities

Figure 2: An ecology of interdisciplinary innovation value creation



in their ability to work across this boundary line, showing excellent instincts about how to reframe a problem or the objective of a project with a commercial end point in mind. This intriguing preliminary finding also merits further research and inquiry.

Our findings suggest that there is an urgent need to educate the sponsors and investors of interdisciplinary innovation about its essential value creating dynamics. For example, the necessary balancing act performed by pole-star leaders is poorly understood within much existing specialist literature, and certainly by sponsors and investors in interdisciplinary innovation, particularly in the public realm.

Part 5: Supporting interdisciplinary innovation: policy headache or policy opportunity?

Interdisciplinary innovation – much talked about but poorly understood

Interdisciplinary innovation is a policy challenge precisely because it is associated with the creation of new boundary-crossing ideas. It is never easy to innovate ‘to order’, but here the most valuable results cannot be defined in advance. Indeed, the reframing of a problem from an interdisciplinary perspective, itself a hugely valuable step, may change stakeholders’ understanding of the main issues. Interdisciplinarity has gained currency among policymakers because of the demonstrated economic and social impacts of its innovations. But neither the necessary techniques nor the evidence of their impacts are systematically studied using methods appropriate to the phenomenon itself. This report provides evidence of how interdisciplinary innovation can be better nurtured in future.

A time and place for a new kind of leadership

Interdisciplinary innovation, bringing completely new ideas, relies on people changing their minds. But demand for quick returns, short-term planning cycles and conventional managerial styles can easily destroy this essential dynamic. It is an uncomfortable reality that most successful interdisciplinary innovation in the UK is happening despite, rather than because of, the current practices of investors and public sponsors. We have found that the role of effective pole-star leaders is crucial in protecting creativity and curiosity within a common vision shared by all partners. To enable and protect this kind of innovation, we

need to find policy mechanisms that recognise and support pole-star leadership.

Effective targets and investing for impact

Innovative interdisciplinary enterprises are not created by accident, but require determination and positive and patient investment. The policy challenge is to identify mechanisms for managing such investment without killing it at birth. This is especially difficult because existing processes for setting investment targets and evaluating outcomes bring disciplinary assumptions with them and are typically assessed within arbitrary budgetary cycles.

Because it can seem foolish to set targets for creativity, curiosity, collegiality, or serendipity, policymakers instead focus on aspects of innovation work that can be measured. Unfortunately, those measurements can prevent the very innovation that policy wishes to promote. Metrics such as peer-reviewed publications in high-impact disciplinary journals have been recognised as insufficient to capture public value. But our research found that even highly-regarded economic impact measures, such as patents resulting from academic research, can be anti-innovative. Expert witnesses, from researchers to commercial entrepreneurs and investors, regularly told us that intellectual property legislation prevents innovation, because patents have become no more than an instrument for counting and negotiating market control.

Investment in interdisciplinary innovation not only brings new insights and approaches to

entrenched problems, but builds intellectual capacity to respond to complex problems in the future. Recognition of these diverse forms of value requires a portfolio of benchmarking and descriptive approaches, to account for the valuable combination of short-term and long-term outcomes, recognising those benefits that are situated outside disciplinary structures, in interdisciplinary teams, in new capabilities, and in ecosystems and narratives of conceptual change.

personal skills that enable it, is an essential contribution of public policy and public funding.

Developing resources for interdisciplinary innovation

One of our clearest findings is that for the value of interdisciplinary innovation to be maximised, interdisciplinary approaches must be used to frame the problem. Rather than simply assembling a professional team with the skills to address a predefined goal, the most innovative outcomes arise when the problem statement itself is open to challenge from new perspectives.

In this case, investment in resources must emphasise process and capacity for sustained innovation, not simply drawing together diverse skills. Many of the instrumental goals for public investment in conventional mechanisms such as knowledge transfer are becoming normalised to disciplinary perspectives, and even anti-innovative. NESTA can continue to play an important role here with its ability to work outside of established disciplinary frameworks, for continued development of national innovation resources.

Interdisciplinary activity is more an individual calling, rather than a career choice likely to lead to easy advancement. But interdisciplinary innovators can be developed within creative public spaces, in which professional (not necessarily academic) preparation supports conversation, exploration and network exchanges in an atmosphere of trust, openness and mutual tolerance.

Competitive market environments may act as a spur to the later stages of innovation, but are more likely to damage the essential contribution of exploratory interdisciplinary work. Effective interdisciplinary innovation relies on 'interpretative spaces', such as educational institutions, geographic clusters and creative sector organisations. Developing the spaces in which interdisciplinary innovation can occur, and nurturing the processes and

Appendix 1: Methodological note: researching interdisciplinary innovation

This section describes the methodology that has been used to develop this report.

Reflective practice: Many of our expert witnesses observed that complex problems require a complex interdisciplinary response. As interdisciplinary innovation is itself a complex problem, an essential part of our methodology was to assemble an interdisciplinary team. This research was conducted by members of the Crucible network for research in interdisciplinary design, bringing varied professional qualifications, as well as academic qualifications in psychology, anthropology, engineering, economics, and philosophy, among others. Since its formation in 2001, a key contribution of the network has been its reflective practice approach, using social science techniques to understand the dynamics of interdisciplinary projects while working on them.¹⁶

Phenomenological approach: Our main priority in this project was to understand and interpret the experiences of people who actually do interdisciplinary innovation, rather than to validate any prior theoretical principle or hypothesis about what this might involve. Rather than agree at the outset on the definitions of 'interdisciplinarity' or 'innovation', we 'bracketed' them as representing a phenomenon that we did not yet understand. After reviewing existing literature on interdisciplinarity and innovation,¹⁷ we recruited a grass roots 'snowball sample' that crossed disciplinary boundaries using the networks developed by interdisciplinary innovators themselves. This was in direct contrast to previous research that has started from the perspective of conventional policy informants such as corporate

research laboratories and leading academic spokespersons.

Analytic workshops: By the end of the project, we had made contact with over 500 individuals nominated for their skills in interdisciplinary innovation. In a series of workshops spanning multiple sectors, disciplinary styles, and professional backgrounds, we then compared the personal experiences of these practitioners, using a phenomenological research approach originally developed in a Crucible project to compare professional experiences of design practice.¹⁸ Workshop conversations, together with correspondence from the snowball sample, were transcribed and analysed using a grounded theory approach (where source material is taken as the starting point for theory development, rather than as data against which to test prior hypotheses).

16. Blackwell, A.F. and Good, D.A. (2008) Languages of innovation. In: Crawford, H. (Ed.) 'Artistic Bedfellows: Histories, theories and conversations in collaborative art practices.' Lanham, MD: University Press of America. pp.127-138.

17. A complete literature review can be found in our full report: 'Radical innovation: crossing knowledge boundaries with interdisciplinary teams.' Cambridge: University of Cambridge Computer Laboratory Technical Report UCAM-CL-TR-760.

18. Blackwell, A.F., Eckert, C.M., Bucciarelli, L.L. and Earl, C.F. (2009) Witnesses to design: A phenomenology of comparative design. 'Design Issues.' 25(1), pp.36-47.

Appendix 2: NESTA Carbon Crucible

19. Pharoah, R. (2009) 'Carbon Crucible 2009 Ethnographic evaluation.' Report to NESTA by ESRO Ltd. London: ESRO.

The findings of this report can be considered in the light of NESTA's own Carbon Crucible programme, an outcome-oriented interdisciplinary initiative created in 2009 to explore potential for climate change research. An ethnographic observer from ESRO, a social and market research organisation, compared Carbon Crucible to an earlier NESTA Crucible training programme in 2008.¹⁹ The programme involved four residential workshops, in four months, for a selected group of early-career researchers. Both NESTA and sponsor UKERC saw interdisciplinarity as a specific goal of the workshops, helping researchers to develop both a network of contacts in other disciplines, and their own ambitions for an interdisciplinary career.

A distinctive feature of Carbon Crucible was that the researchers invited came with existing awareness of the broader relevance of their research. They were also competing, in a sense, to become established figures within the boundaries of the rising 'interdiscipline' (as we call it) of sustainable energy research. The ESRO researchers noted that this reduced the sense of freedom and open exploration that characterised previous Crucible programmes. A relatively short timescale, and difficulty committing to weekday meetings, emphasised the value of a longer-term series of residential events in building trust and relationships. However, despite initial resistance, the final two workshops did result in successful community-building, with participants showing willingness to collaborate on the preparation of funding proposals.

Previous Crucible programmes had demonstrated the typical dynamics of interdisciplinary engagement, with participants bringing incompatible kinds of knowledge and

different goals. In the case of Carbon Crucible, the instrumental goals of the programme both provided a shared point of reference, and also brought together researchers who had already experienced multiple kinds of knowledge and public engagement to a greater degree than usual. Nevertheless, a constant dynamic is that the young researchers who participate in Crucible are to an extent self-selecting, and the NESTA programme gives them licence and resources to pursue an otherwise risky approach to an academic career.

In the case of Carbon Crucible itself, UKERC intends to continue applying the process as a component of its own process, to maintain and develop the community of energy researchers. This demonstrates a further benefit of interdisciplinary working methods, beyond those committed to more open interdisciplinary innovation, that all new disciplines require trust, community and social capital among those coming together as colleagues. Reflective and exploratory social processes will continue to be valuable for this purpose.

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