CHALLENGES OF INTERDISCIPLINARY RESEARCH

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ABSTRACT

There is no single definition that encompasses the diverse range of activities that have been described under the heading of interdisciplinary research. The history of science from the time of the earliest scholarship abounds with examples of the integration of knowledge from many research fields. In recent decades, the growth of scientific and technical knowledge has prompted scientists, engineers, social scientists, and humanists to join in addressing complex problems that must be attacked simultaneously with deep knowledge from different perspectives. On an individual basis, studies show that situational factors, such as exposure to ideas outside one's own discipline, may have a positive impact on researchers in their own discipline.

This article briefly reflects upon three issues only: (i) managing an interdisciplinary career, (ii) negotiating interdisciplinary collaborations and (iii) supervising interdisciplinary students. Interdisciplinarity is something to be learned and acquired; it does not arise out of thin air, although today the concept is frequently used as a magic word.

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1. INTRODUCTION

No one can predict the issues that science and society will consider most pressing in the decades to come. But if we look at some high-priority issues of today – such as world hunger, biomedical ethics, sustainable resources, homeland security, and child development and learning – and pressing research questions such as the evolution of virulence in pathogens and the relationship between biodiversity and ecosystem functions, we can predict that those of the future will be so complex as to require insights from multiple disciplines. What research strategies are needed to address such a future? To what extent will interdisciplinary research and interdisciplinary education be among the strategies? What exactly is interdisciplinary research?

2. DEFINING INTERDISCIPLINARY RESEARCH

No single definition is likely to encompass the diverse range of activities that have been described under the heading of interdisciplinary research. Interdisciplinary research is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or filed of research practice.

Being interdisciplinary is an old virtue of OR/MS – but often forgotten (Müller-Merbach, 1984, 83f). The rationality behind the necessity of an interdisciplinary approach to problems is simply that problems in general are not ordered according to the scientific disciplines; instead, most real problems (at least the major and more complex ones) have at the same time physical, chemical, technical, economic, legal, social, ethical aspects etc., or as R. Ackoff put it: "Disciplines are categories that facilitate filing the content of science. They are nothing more that filing categories. Nature is not organized the way our knowledge of it is. Furthermore, the body of scientific knowledge can, and has been, organized in different ways. No one way has ontological priority" (Ackoff, 1973, 667). Therefore, problem solving requires the cooperation of individuals with a "wide scatter of scientific backgrounds and interests" such as Miser (1992, 633) characterized his first interdisciplinary teams have to be conducted ideally by an interdisciplinary generalist.

3. A VISION OF INTERDISCIPLINARY RESEARCH

The history of science from the time of the earliest scholarship abounds with examples of the integration of knowledge from many research fields. The pre-Socratic philosopher Anaximander brought together his knowledge of geology, paleontology, and biology to discern that living beings develop from simpler to more complex forms. In the age of the great scientific revolutions of 17th-century Europe, its towering geniuses – Isaac Newton, Robert Hooke, Edmond Halley, Robert Boyle, and others – brought their curiosity to bear not only on subjects that would lead to basic discoveries that bear their names but also on every kind of interdisciplinary challenge, including military and mining questions.¹ In the 19th century, Louis Pasteur became a model interdisciplinarian, responding to practical questions about diseases and wine spoilage with surprising answers that laid the foundations of microbiology and immunology. Today, the proliferation of new understanding about the molecular and genetic underpinnings of life demonstrates the power of combining disciplinary knowledge in interdisciplinary ways.

In recent decades, the growth of scientific and technical knowledge has prompted scientists, engineers, social scientists, and humanists to join in addressing complex problems that must be attacked simultaneously with deep knowledge from different perspectives. Students show increasing enthusiasm about problems of global importance that have practical consequences, such as disease prevention, economic development, social inequality, and global climate change–all of which can best be addressed through interdisciplinary research. A glance across the research landscape reveals how many of today's "hot topics" are interdisciplinary: nanotechnology, genomics and proteomics,² bioinformatics, neuroscience, conflict, and terrorism. All those invite and even demand interdisciplinary participation. Similarly, many of the great research triumphs are product of interdisciplinary inquiry and collaboration: discovery of the structure of DNA, magnetic resonance imaging, laser eye surgery, radar, human genome sequencing, the "green revolution" and manned space flight. There can be no question about the productivity and effectiveness of research teams formed of partners with diverse expertise.³

4. PROMOTING INTERDISCIPLINARY RESEARCH

On an individual basis, various studies (e.g. Feist, & Gorman, 1998) show that situational factors, such as exposure to ideas outside one's own discipline, may have

¹ Robert K. Merton's classic *Science, Technology and Society in Seventeenth Century England* describes the work of the remarkable "natural philosophers" whose reach spanned many of today's disciplines.

² Study of all the proteins encoded by an organism's DNA.

³ A recent editorial in *Science* notes: "The time is upon us to recognize that the new frontier is the interface, wherever it remains unexplored.... In the years to come, innovators will need to jettison the security of familiar tools, ideas, and specialties as they forge new partnerships." (Kafatos & Eisner, 2004, 1257).

a positive impact on researchers in their own discipline. Prolific and influential researchers are more likely to keep up with developments outside their own domains, and this interdisciplinary curiosity can lead to major breakthroughs on their own projects. For example, it was Charles Darwin's reading of Malthus's "*An Essay on the Principle of Population*" that led to this theory of natural selection.

The academic community has responded to the burgeoning specialization of knowledge and increased cross-fertilization by creating new hybrid research fields – such as bioengineering, biogeochemistry, and paleoseismology-and innumerable courses of study that explore the interstices between traditional disciplines. The administrations of many campuses have begun to respond vigorously with renewed energy and innovative organizational structures. After several decades of experimentation, interdisciplinary centers, institutes, programs, and other structural mechanisms have proliferated on and adjacent to university campuses; indeed, these research units often outnumber traditional departments. Despite frequent tensions over budgets, space, and intellectual turf, many of these centers and institutes are vibrant research and training environments. They do not supersede the departments but complement them, often generating new kinds of excitement.

5. PROFILE OF AN INTERDISCIPLINARY GENERALIST

According to Müller-Merbach (2008, 495-496), an interdisciplinary generalist we have mentioned before should (i) be familiar with the basic *content* of the single disciplines, (ii) be able to *apply* his knowledge and (iii) have some *passion* for the disciplines, such as:

- *mathematics*: ease with symbolic abstraction and familiarity with mathematical structures of cause-effect as well as means-end- networks; the ability to design mathematical models of reality and to draw insight into the reality through the results of mathematical manipulations of the model; delight with abstraction and value-free logic;
- *sciences:* knowledge of the static states and the dynamic processes of the living and the inanimate nature; the ability and the will to apply this knowledge to technical realizations; respect for creation, administration of nature in its eternal harmony;
- *engineering:* knowledge of technological laws and understanding of technical processes; the ability to design, shape and evaluate technical systems;

pleasure with design activities and functionality; admiration for technical masterpieces.

- *computer science:* familiarity with programming languages and practical experience with information technology; the capability to design information systems; fascination by the division of intelligence between man and computeras well as their cooperation.
- *economics:* familiarity with economic theories and-based upon theories-insight into economic realities; the ability to analyze and interpret economic structures and processes; pleasure to take responsibility for economic action;
- *business administration:* knowledge of structures of and processes within as well as between enterprises and micro-economic institutions; the qualification to understand the micro-economic structures and processes as well as to design and operate man-machine systems; delight to play a responsible role within a micro-economic institution.;
- *social sciences:* knowledge of sociological theories and understanding of social structures and processes; acceptance of the value load of any human information processing; consciousness of the manifold criteria of judgment of social systems; enthusiasm to cooperate with other people and willingness for responsible leadership.
- *judicature:* knowledge of the legal system and the judicial processes; the aptitude to judge structures and processes from the legal point of view; satisfaction with finding decisions within the legal limits;
- *fine arts:* sensitivity for harmony and tension, aesthetics and beauty; the talent to integrate aesthetic aspects in processes of judgment; satisfaction with aesthetic beauty.
- *philosophy:* foundations for insight how and why which powers, ideals, values, and convictions hold the world together; sensitivity for the interdependence between causality, finality, ethics, and aesthetics; pleasure in studying the roots of philosophy.

Interdisciplinarity requires high competence in one's own discipline. It does not mean that one should become a bit of a specialist in another area; rather, it means that one is open-minded and poses new questions to another field of study. This is the only way to arrive at a hypothesis that the other discipline could not develop on its own, since its representatives lack the necessary distance from their own frame of thinking.

In formulating such hypotheses we need to differentiate between two most frequent varieties of interdisciplinarity: top-down interdisciplinarity and bottom-up interdisciplinarity (Folkers, 2010, 33). In the former, there is a central protagonist who formulates a hypothesis and brings together co-operation partners in order to test the hypothesis from a different standpoint. In the latter case, representatives of a wide variety of disciplines come together in order to develop a common hypothesis and to decide on adequate procedures to test it.

The second approach required by the networked research in disciplines could be denoted as transdisciplinarity. In this case, the concepts of one's own discipline are modified, or sometimes the concepts of other disciplines are adopted. How does this take place? First, researchers develop tolerance for methods and procedures of other disciplines in order to examine the common hypothesis, and then synergies are developed.

There is something that both approaches have in common; namely, they are exposed to a process which does not work automatically or through its structure alone. Interdisciplinarity is something to be learned and acquired; it does not arise out of thin air, although today the concept is frequently used as a magic word. Inter- and transdisciplinary processes and structures need to be continuously challenged and questioned, especially with regard to unavoidable frictional losses that arise from translation between disciplines, languages and cultures. Just like with two particles dissolved in water, which first have to change, strip off and rebuild their protective hydrate membrane in order to blend with each other, there are interferences in the interdisciplinary processes by administrative structures, academic customs and personal prejudices before protagonists come into play.

There will certainly be barriers to overcome along the way and there are several import issues likely to arise from interdisciplinary research that may require careful management or "troubleshooting" (Lyall & Meagher, 2008). Here we reflect briefly on just three: managing an interdisciplinary career, negotiating interdisciplinary collaborations and supervising interdisciplinary students.

I. Managing an interdisciplinary research career

An effective interdisciplinary manager needs to be aware that will not always be straightforward for team members to develop careers based continuous interdisciplinary research. Organizational cultures may not favour interdisciplinary research which often cuts across the traditional discipline–based academic structures and systems of reward and resource allocation found in most university.

People working in academia often regard interdisciplinary research as a risky career move. Interdisciplinary researchers may be considered less productive because good interdisciplinary research often takes a long time. Also, finding high status outlets for interdisciplinary publications can be a challenge as interdisciplinary papers may be perceived as having a lower "value" (e.g. as a result of publication in lower impact journals).

A permanent, tenured university position (and subsequent promotion) still usually depends on a track record in a single discipline. Interdisciplinary researchers often have a shifting peer group over time, depending on the current focus of their research. Furthermore, reviewers of publications, grant applications and promotions boards may lack interdisciplinary expertise themselves.⁴

II. Negotiating interdisciplinary collaborations

Research managers, like all good interdisciplinary collaborators, are likely to be open-minded, willing to learn from other disciplines, and have a broad appreciation for the languages, research methods and cultures of different disciplines. It is often said that personality can be a more significant factor than discipline base and interdisciplinary collaborations need to be based on trust and knowledge of collaborating partners.

There is no single model for success and interdisciplinary collaborations can fail because of a lack of understanding, or unrealistic over-expectations, of what an interdisciplinary approach can deliver. Interdisciplinary research is not a homogeneous approach and does not represent a single research method. Different kinds of interdisciplinarity have different goals and challenges.

In broad terms, interdisciplinary research can be geared towards advancing the knowledge base or tackling practical problem solving. These different approaches

⁴ See more in 'A Short Guide to Reviewing Interdisciplinary Research Proposals', available at http:// www.rcss.ed.ac.uk/isstiwiki/ISSTI_Interdisciplinary_Wiki (Accessed 12.03.2010.)

will vary in terms of what motivates the researchers undertaking the work and will have different intended outcomes. The former model of collaboration is driven intrinsic, knowledge creation goals (of access to particular tools, techniques and data). The inputs and outputs – and thus the benefits of collaborations – can be relatively well-defined at the outset. This kind of collaboration is intrinsically motivated in terms of immediately visible knowledge benefits (e.g.. A needs the data that will be provided by B). Similar knowledge-related motivations may be present in relation to emergence new scientific domains. However, in the case of complex (e.g. societal) problems, where the goals or outcomes may be rather more openended and involve a broadening of existing knowledge frameworks, there may be greater uncertainty about the process and the and point.

Whatever the motivations, it is important to reach a shared understanding of the purpose and goals of the research amongst the team and to identify agreed project milestones. When negotiating the collaboration, the project leader will need to conduct an honest assessment of the skills and roles with the team in order to ensure a fair division of labour: not every team member needs to contribute equally but they must be able to contribute appropriately – and accountably. The research manager will need to agree a plan for how the team will communicate and the frequency of meeting as this is crucial for an interdisciplinary team, which may well take longer to gel. As with any team, it is also helpful to explore some of the "what if" questions at any early stage, for example, what if there is a change in staff before the project is completed. At the same time it is still a good idea to build in flexibility to cope with any unexpected outcomes wherever possible (it is, after all these unpredicted outcomes that are among the potential benefits from interdisciplinary research). Depending on the nature of the research, it may be appropriate to negotiate intellectual property rights before the project commences. Even if patenting is not an issue, research managers should ensure that the team considers, at the outset, issues such as the ownership and any data and the thorny issue of authorship.

III. Supervising an interdisciplinary PhD

Interdisciplinary research mangers may well have oversight of postgraduates in their team so it is important to be aware of some of the challenges they face. By definition, interdisciplinary students will not be specialists in their subject but they should not therefore feel as if they are failing: they cannot afford to yield to the temptation of trying to become experts in all fields involved. Interdisciplinary students can often feel that they are a "jack of all trades and master of none" and may feel that they are more open to challenge than their single discipline peers. Openmindedness is critical to effective interdisciplinary studentships; students need to listen to others' perspectives, talk informally with other students, attend a variety and learn about the foundations of, and follow developments in, contributing disciplines. But, at the same time, students must for their survival stay focused, knowing what part of which disciplines they will use to answer which research questions. More planning may well be needed for interdisciplinary projects as, in many cases, undertaking an interdisciplinary PhD requires more work: the student is likely to be reading across more than one literature, possibly learning more than one methodology, and certainly grappling with how to integrate it all. Moreover, different disciplines have quite different conceptions of what constitutes a PhD thesis and students need to be given early guidance as to which approach to follow ((Lyall & Meagher, 2008).

CONCLUSION

Continuous changes in contemporary economy and society has 'forced' academic scholars from a single discipline they are named to expand their research focus to new fields coming from difference disciplines. In another words, interdisciplinarity becomes a new imperative in scientific research.

Interdisciplinarity is something to be learned and acquired; it does not arise out of thin air, although today the concept is frequently used as a magic word. Interand transdisciplinary processes and structures need to be continuously challenged and questioned, especially with regard to unavoidable frictional losses that arise from translation between disciplines, languages and cultures.

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