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Debate

Interdisciplinary research: putting the methods under the microscope

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Abstract

Background: While the *desirability* of interdisciplinary inquiry has been widely acknowledged, indeed has become 'the mantra of science policy', the *methods* of interdisciplinary collaboration are opaque to outsiders and generally remain undescribed.

Discussion: Many have analysed interdisciplinarity, especially in relation to the creation of new disciplines and institutions. These analyses are briefly outlined. Still, there currently persists a silence about the *methods* of interdisciplinary collaboration itself, and the core of this paper proposes a template for such methods.

Summary: Breaking this silence – by making the methods of interdisciplinary projects transparent – could further invigorate interdisciplinary research.

Background

"Herein lies one of the major crises of modern knowledge. It is what I have called the Humpty Dumpty problem. To understand the world it has seemed necessary to analyze it by breaking it into many pieces (i.e., the disciplines and their own divisions). But to act in the world, to try to address the issues for the understanding of which highly specialized knowledge was presumably sought, we need to somehow reassemble all the pieces. Here is the rub. Try as we may, we are no more able than all the king's horses and all the king's men to put our knowledge together again for coping with the whole real problems of the world."[1]

Approaching research questions from the perspective of more than one discipline simultaneously, and thereby bridging disciplines, appears to be old hat. When, in the 1810s, Magendie brought together organic chemists and physiologists to investigate the importance of nitrogen in animal nutrition, he helped catalyse the birth of biochemistry [2]. Nernst similarly forged physical chemistry through his basic research in electrochemistry and thermodynamics during the early 20th century, and Delbrück's and Szilard's application of physics to cell reproduction proved instrumental in the eventual discovery of the DNA double helix. Moreover, many interdisciplinary institutions such as Rockefeller University, California Institute of Technology, Harvard's Bauer Center for Genomics

Research have been established to foster interdisciplinary research.

Nonetheless, while the *desirability* of interdisciplinary inquiry has been widely acknowledged, indeed has become 'the mantra of science policy'[3], the *methods* of interdisciplinary collaboration are opaque to outsiders and generally remain undescribed. Many have analysed interdisciplinarity, especially in relation to the creation of new disciplines and institutions. These analyses are briefly outlined immediately below. Still, there currently persists a silence about the *methods* of interdisciplinary collaboration itself, and the core of this paper proposes a template for such methods and explains how breaking this silence – by making the methods of interdisciplinary projects transparent – could further invigorate interdisciplinary research.

Discussion

Disciplines

Disciplines are defined by their conceptual specificity; the encounter between different conceptual structures is the core of interdisciplinarity [4]. One perspective on interdisciplinarity is therefore to assess sharing and merging between disciplines. Patricia Rosenfield's investigation of collaborative projects involving several disciplines in the life sciences finds that disciplinary boundaries are most thoroughly transcended when members of disparate fields develop a common language that facilitates a shared conceptual framework [5]. She concludes that this level of collaboration has the most potential for originality, but occurs least often because developing a common language is difficult.

Peter Galison[6] goes further in his study of the interaction between different sub-cultures within twentieth-century microphysics. He analyses the competing traditions of researchers who collected microphysical data by imaging high-energy phenomena, and those who collected them by electronically counting subatomic events. Galison argues that fruitful collaboration between these groups occurred only when they began to share not only language but practices – methods – thus creating a 'trading zone' in which commerce of ideas and methods could occur.

A multitude of examples, spanning over 200 years, can be marshalled to illustrate Galison's and Rosenfield's conclusions that common language and methods are the currency of meaningful interdisciplinarity. One of the major challenges of 18th- and 19th-century life science was to explain how organisms obtain and use energy. Lavoisier, a physicist and chemist, used to thinking in terms of experimental machines, in 1789 put forward the notion that animals' bodies are combustion machines for carbon and hydrogen. The notion was wrong; nevertheless, Lavoisier's and his followers' insistence that chemistry be brought to bear on biology, forced physiologists of the age to *do* chemistry, if only to refute him. The results gave rise to our understanding of respiration, and formed the cornerstone for biochemistry [7].

A more recent development illustrating the point is the field of biophysics, in which physicists, computer programmers, chemists, and biochemists have learned each other's conceptual vocabulary and methods in order to collaborate in exploring problems such as biomolecular processes coupled to mechanical force, bioelectronic metabolism, and the function and mechanism of membrane proteins. Contemporary cognitive neuroscience provides a final illustration. By the 1960s, clinical neuropsychologists, who studied the consequences of brain lesions for cognition and behaviour, realized that their field was thwarted by a lack of models of normal cognitive function. They therefore looked to cognitive psychology, which had developed such models – albeit at a purely functional, not physiological or anatomical, level. As a result, the clinical neuropsychologists began to speak the language and use the methods of cognitive psychology, and to do cognitive psychology at the same time as neuropsychology. The result was the new field of cognitive neuroscience [8]. All these examples bear out the notion that a commonly understood language and set of methods are key to overcoming the ontological and epistemological challenges of interdisciplinary research.

Institutions

After analyses of how disciplines merge, the next most prominent body of research into interdisciplinarity addresses the importance of institutions. Perhaps the most important environmental condition favouring interdisciplinarity is the building of an institutional 'platform' for collaboration: an infrastructure of research organizations, academic journals, funding committees and informal networks of researchers that actively foster interdisciplinary research. Several research institutions have organized themselves expressly to promote interdisciplinarity. The Rockefeller Institute during the 1950s brought together researchers from a broad spectrum of sciences, minimized the divisional structure of the organization, and revolved socially around communal meals, all of which contributed to a matrix for the Institute's biomedical breakthroughs [9]. In our own era, Caltech has developed a programme in computation and the neural sciences in which collaboration among neurobiologists, electrical engineers, computer scientists and physicists is common rather than exceptional. The Pasteur Institute was recently reorganized around cross-disciplinary research programs intended to maximize links between scholars from disparate fields. Harvard University's Bauer

Center for the Study of Genomics "aims to reap a post-genomic harvest by uniting physicists, mathematicians, chemists and computer scientists with a spectrum of biologists."[10]

Research funding institutions have typically endorsed disciplinary structures [2]. However, there are important exceptions such as the MacArthur Foundation which has facilitated grants to interdisciplinary networks organized around research problems; the outcomes have included seminal discoveries in surgery, psychiatry, and neurology [11].

Methods

The disciplinary and institutional perspectives on interdisciplinary research reviewed above have already proved to be useful: neither is a new idea. In contrast, this paper's concluding section addresses a notion that has hitherto been virtually neglected, and which we propose could improve interdisciplinary research's rigour, accountability, and productivity. We propose that the single most valuable step forward in interdisciplinary research would be to render transparent the methods of interdisciplinary research projects.

Researchers have an obligation to make their procedures transparent, but interdisciplinary teams – while they report methods of data collection and analysis – seldom report the methods they employ in the process of achieving interdisciplinary collaboration itself. We could identify only one group, which is still very early in its work, focussed on examining the methods of interdisciplinary collaboration [12]. Because the process of collaboration itself determines the premises of a research project (namely, how a phenomenon is conceived of and the ways it is to be apprehended) not reporting the methods of collaboration can make it difficult for others to assess the validity, reliability or trustworthiness of data collection and inferences, and to build on the methods of earlier groups. Other researchers should be able to follow the process of collaboration and the decisions made during inquiry; this allows them to think out how they might attempt to replicate findings, or choose to carry out collaboration differently. Making it possible thus to evaluate collaboration could open up debate around decisions until now always implicit in the process of interdisciplinary research.

For example, in developing a large-scale collaboration on genomics policy among scholars from philosophy, law, management, medicine, public health sciences, social sciences, and molecular biology, we developed a research methods template shown in Figure 1, which represents a new approach to bioethics research [13]. The process begins with identifying the problem to be studied. Then, case studies are conducted to understand the context. Ethical and legal analyses of relevant concepts are conducted. The case studies and ethical and legal analyses are considered by a consensus panel of representatives from academia, industry, NGOs, and government that then produces guidelines. Public consultation is sought on the draft guidelines before finalizing them. The guidelines are disseminated and their impact evaluated.

To take a concrete example: We had identified nutrigenomics as a problem and its importance was ratified through a set of consultations with experts and attendance at the First International Nutrigenomics Meeting in Amsterdam in 2001. We conducted a case study of the first company providing nutrigenomics services on the internet. We analyzed ethical and legal issues such as consent, privacy, and consumer choice in the context of the case study. We formed a consensus panel to develop nutrigenomics guidelines. The draft guidelines will be released for public consultation at a range of meetings. The finalized guidelines will then be disseminated to relevant agencies. We will continue to evaluate the model above and refine it through use.

What are the characteristics of this approach that are crucial to its interdisciplinarity and its success? This interdisciplinary approach is developed to address important issues not yet addressed through traditional disciplinary approaches (e.g. the ethical, environmental, legal and social implications of advances in genomics). The broad range of disciplines represented by the research participants (philosophy, law, management, medicine, public health, social sciences, and molecular biology) was achieved in two ways: some participants are selected because their disciplinary expertise is obviously necessary to address the research issues, and some participants self-select because of their own interest in the issues. The participants are made aware from the start that this is a unique interdisciplinary research effort that would be guided by the research template (Fig. 1) and that each participant's contribution would occur within that interdisciplinary framework. Moreover, each participant agreed that only through this type of interdisciplinary approach, could the research issues be adequately addressed. Anticipating potential communication issues between participants from disparate disciplines, frequent electronic communications and face-to-face meetings occur to enhance opportunities for dialogue and information exchange. A key feature of the actual research is the combining of empirical and theoretical methodologies. In particular, the use of qualitative research methods (e.g. qualitative case studies) facilitated the identification and analysis of key ethical, environmental, legal and social concepts. The empirical and theoretical analyses then feed into explicit consensus building methods (e.g. Delphi

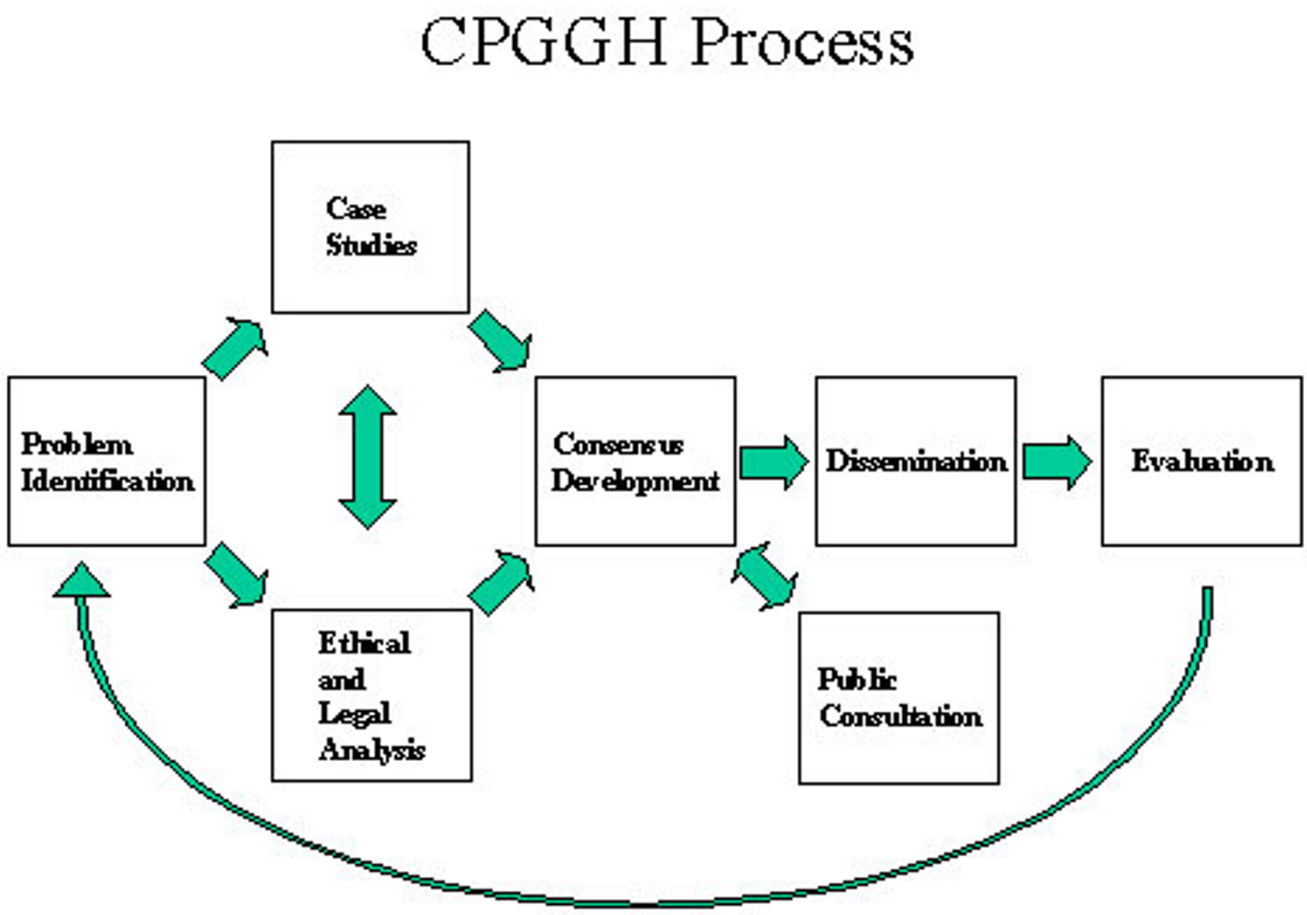

Figure 1
Example of a large scale-interdisciplinary method: The Canadian Program on Genomics and Global Health (CPGGH). The large-scale, interdisciplinary platform has been designed specifically to address the deficiencies of current approaches to the study of the ethical, environmental, legal and social implications of scientific and technological advances.

panel) that help focus the different disciplinary perspectives on a common consensus-building task. There was also a strong focus on dissemination of findings of the panel.

Of course the nature of collaboration will differ according to the research question, and the other premises of a given project. Our example merely illustrates an attempt to make interdisciplinary methods explicit. Explicitness allows others to replicate the work, make different design choices, and learn from the evaluation of the process. It will prompt researchers to more rigorous consideration of important methodological questions such as:

1. Which fields are included, or excluded, in an investigation?

2. How thoroughly did the researchers exploit the opportunity for interdisciplinary collaboration? For instance, were a new common vocabulary and new methods devised?

3. How important were institutions in facilitating or thwarting the process of interdisciplinary collaboration?

4. How key was the integration of disciplinary perspectives in fashioning a more powerful explanation of the phenomenon in question?

The methods of interdisciplinary collaboration should thus themselves become the focus of future study and debate. The actual work of interdisciplinary groups of researchers on specific projects should be observed and analysed. If this were routinely done, we would have a system for continuously improving interdisciplinary methods. Funding agencies, academic institutions and journals could promote this by requesting that interdisciplinary research teams document and reflect on their collaborations, as part of their documentation of methods and in the discussion sections of papers, respectively. They could record how it was recognized that an interdisciplinary approach was necessary, how the participating disciplines were chosen, how the disciplines' strengths were combined, and how the combination contributed to the methods, data, and results. The resulting increased awareness and understanding of interdisciplinary work would help us become more adept at reassembling the unity of knowledge and coping with problems that are too large for any discipline to tackle alone.

It is likely that understanding and improving the methods of interdisciplinary research will be necessary but not sufficient. The success of interdisciplinary research projects ultimately depends on implementation of the concepts. But without further study of method, we cannot even begin to identify what is 'good' interdisciplinary research.

Summary box

• Interdisciplinary research is much touted.

• There is confusion about what it means.

• There are at least three different meanings related to evolution of disciplines, organization of institutions, and research methods.

• Making the methods of interdisciplinary research more transparent, and sharing them among researchers, could further invigorate interdisciplinary research.

Authors contributions

DWR conducted the literature review and was the paper's primary author. DKM contributed to the paper's conception, the conceptual analysis and writing. PAS contributed to the paper's conception, the conceptual analysis and writing. All authors read and approved the final manuscript.

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Competing interests

None declared

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