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Interdisciplinarity - Transport and the Environment

Introduction

There is very widespread recognition that many environmental problems cannot be addressed separately within the confines of individual disciplines as these have developed over the last half-century. Indeed, the importance of interdisciplinary research is formally acknowledged by the research councils and major non-government research funding agencies. Yet our experience is that today much environmental research is not interdisciplinary, and such interdisciplinary research as does take place tends to occur more within the natural or social sciences, than between the natural and social sciences. Since most environmental problems have anthropogenic causes this is surprising and disappointing.

The Environment Committee of the Royal Society decided to hold a one-day conference in order to explore the reasons why this is so - in terms of both the scientific (methodological and conceptual) barriers to interdisciplinarity and the structural and funding barriers. The meeting was also designed to use examples of interdisciplinary research undertaken in case studies to illustrate not only the pitfalls and difficulties it poses, but also the benefits to both science and policy. The central theme of transport was selected to focus the meeting because of its topicality, and because of the numerous disciplines that had to be taken into account when addressing transport issues.

This article summarizes the conference held at the Royal Society on 19 February, 1996 which was jointly sponsored by the Royal Society, EPSRC, ESRC and NERC.

Multidisciplinary and interdisciplinary research

It is important to clarify the difference between multidisciplinary and interdisciplinary research, as there is often confusion about these terms. Pulling together a group of experts from different disciplines to contribute to a single project does not constitute interdisciplinarity. Indeed, in most cases the resulting research is multidisciplinary in nature.

Multidisciplinary research involves people from different fields cooperating: working together towards a common goal but staying within the boundaries of their own fields. They may reach a point where, because of the restrictions and limitations of their disciplines, they cannot make further progress. They may then be forced to work at the fringes of their fields, and forge new ones. At this point the research becomes interdisciplinary. An example of this is the relatively new field of ecological economics. It was born of the need to integrate the scientific aspects of ecological events with their social consequences, and to make objective assessments of ecological impacts. In this case, traditional subject boundaries limited enquiry into the new questions, so the new discipline came into being.

Interdisciplinarity has some advantages over multidisciplinarity, and these will be examined later on; but there is still an important role for multidisciplinary research, and it is needed in different circumstances.

It is sometimes oversimplistic to categorize research as being either multidisciplinary or interdisciplinary. In reality there is a whole spectrum of work which falls between the two extremes, from multidisciplinary work with sharp boundaries between the disciplines at one end to the holistic approach of interdisciplinarity at the other. What is the most helpful mode for any given problem depends on the character of the problem and the state of development of interdisciplinarity for this type of research. It is not usually possible to go straight to a completely holistic approach without undergoing an evolution through different stages, gradually becoming more integrated as the problem becomes better defined. Where an attempt has been made to go straight to a holistic approach (e.g. in the case of 'World models' which try to incorporate input from both the natural and social sciences in determining the response of a system such as the climate system) without evolving from a more multidisciplinary approach, the research was found to lack rigour.

Interdisciplinary approaches have been adopted in the treatment of a number of environmental problems where multidisciplinary approaches have failed. Examples include the analysis of climate change and biodiversity loss. The results are a genuinely novel set of research questions, and a research agenda which puts the multiple feedbacks between natural and social systems at centre stage. The marriage of ecology and economics, in the case of biodiversity, has allowed the emergence of properties that had failed to appear in twenty five years of collaborative multidisciplinary research in the area.

Sir John Houghton, formerly Chief Executive of the Meteorological Office and Chairman of the Royal Commission on Environmental Pollution, opened the meeting. Interdisciplinary research is vital, he said, for understanding environmental problems and how people and ecologies respond to them. There are however problems which this sort of research has to overcome: the nature of trust; competence and understanding between different disciplines; the ethos of funding which is parcelled up according to disciplinary boundaries; and the fact that interdisciplinary projects may appear less focussed than others and thus less attractive to grant-givers. The meeting would use transport as a convenient topic to address these and other issues in interdisciplinarity.

Section 1 of this document gives a very brief description of the research each talk presented. Section 2 takes up the interdisciplinary issues the contributions raised.

1: The Presentations

Professor Roy Harrison of the University of Birmingham focussed on the scientific and human aspects of urban air quality management. He described how air quality models are constructed and how they can be used in air quality management in London requiring experts in physics, meteorology and atmospheric chemistry, and for technological questions mechanical engineers to deal with vehicle emission controls; civil and highway engineers for traffic management; economists for road pricing. He emphasised that attempts to improve air quality through traffic management must take human behaviour into account.

Professor David Pearce, from the Centre for Social and Economic Research on the Global Environment at University College, London, examined integrating economics and epidemiology in air pollution policy. He described how the costs to the UK of mortality and morbidity due to air pollution were huge and explained how environmental economists could contribute to air pollution policy by valuing the damage from pollution. The health effects of pollution could be valued by using the 'willingness to pay' or 'willingness to accept compensation'concepts to find out how much people will pay for changes in risks of morbidity and mortality. These sorts of calculations need inputs from specialist areas including epidemiology, corrosion science and global circulation models.

Professor B.O. Jansson, from the Stockholm Centre for Marine Research, described the Baltic system and the interactions between its morphology, pollution, water quality, fish stocks and tourism. He predicted that the building of the Oresund Bridge between Sweden and Denmark will affect the land through increased traffic emissions and road-building; and both land run-off and tourism will degrade the resources in the coastal zone, including cod populations.

Professor Kerry Turner from the University of East Anglia described a recent interdisciplinary project which tried to identify the environmental pressures building up in the Baltic, and the damage they were causing. Its aim was to see whether government policies could be changed in response to the damage, and how to judge the efficacy of such changes. The project, which used marine biologists, ecologists and social scientists (economists and geographers), concentrated on eutrophication. Its goal was to examine the measures that could be taken to reduce it; estimate which of these would be most cost-effective; and discover whether the societies around the Baltic would think it worthwhile spending the money in that way. The study concluded that reducing nitrogen and phosphorous input into the Baltic by 50% would bring benefits that the surrounding populations wanted and were willing to pay for.

Dr David Carson from the Meteorological Office's Hadley Centre talked about the role and value of interdisciplinary research in understanding global environmental change. Many physical, chemical and biological disciplines are required to contribute to modelling and interpreting the complex interactions of the global climate system.

Professor Martin Parry of University College, London, put forward a bottom-up approach to climate research: identifying critical sensitivities in climate systems so that the danger of breaching them can be avoided. He stressed the need for comprehensive policy responses **not** bounded by traditional disciplines in order to address the impact of climate change that will be felt on many sectors including transport, finance, construction, soil, water, geography, flora/fauna/landscape, insurance and banking.

Dr Gary Acres from Johnson Matthey argued that progress to date on reducing vehicle emissions has resulted from legislation-driven technology. Many disciplines are involved, from environmental research to decision-making to policy-making to legislation, solutions and applications. This is not real interdisciplinarity because it has not developed in a collaborative way; but collaborative programmes on transport and the environment are being developed at the European level, and these are the way of the future.

Dr Amanda Root, from the Environmental Change Unit at the University of Oxford, considered organisational issues in interdisciplinary work on energy, transport and the environment. She works with a group of experts in cultural studies, anthropology, statistical modelling, architecture, energy and industrial design. She valued the interaction and exchange of knowledge that this allowed but was concerned at the possible isolation of individuals in interdisciplinary groups from their own disciplines.

Professor David Banister from University College, London, outlined the difficulties of interdisciplinary research in the Economic and Social Research Council's programme on Transport and the Environment, which he is directing.

The Research Councils were represented by:

* Dr Nick Lawrence from the Engineering and Physical Sciences Research Council, who agreed there were problems but pointed to the Inland Surface Project and the Project on Sustainable Cities as pointers for future interdisciplinary research.
* Mrs Christine McCulloch from the Economic and Social Research Council, who contrasted the characteristics of disciplinary and interdisciplinary research. She gave examples of the interdisciplinary research the ESRC supports and suggestions for making it less cosmetic and more real.
* Dr Michael Schultz from the Natural Environment Research Council, who mentioned some of NERCís interdisciplinary projects and asked questions about ways in which this sort of research could be made more effective.

2: Interdisciplinary Issues

The meeting raised many questions about the nature of interdisciplinary research and the problems it faces. Both speakers and audience were enthusiastic about interdisciplinarity, but also very aware of the difficulties it involves. The issues raised can be grouped under the following headings:

Advantages of interdisciplinary research

In much existing multidisciplinary research the various disciplines are inter-dependent as each uses the output of another to do its work. Interdisciplinary research offers scope for progressing far beyond this.

There is general agreement that the outcome of good interdisciplinary research is greater than the sum of its parts. It can create modes of thinking and new techniques of developing knowledge which translate across other boundaries. Unlike disciplinary research, which formulates the problems it tackles to match its methodologies, it is more issue-driven and therefore more holistic. It is not self-referential; it is open to new ideas. It may develop a new language to cope with new concepts.

Interdisciplinary research also develops different approaches and theoretical models. Examples of new theoretical models include those which integrate the behaviour of economic agents and the behaviour of the communities of organisations on which those agents depend.

Interdisciplinary research, at its best, is innovative, flexible and inclusive. It can respond to the need for work that engages the public and is of practical use in tackling environmental issues. Sometimes it is the only way of avoiding the unrealistic appearance of rigour which results from isolating one factor from its natural setting and measuring it to an unwarranted level of precision.

Research on environmental problems is particularly suited to an interdisciplinary approach. Questions of public policy, such as what societies should do about global warming or the depletion of the ozone layer, demand a holistic approach. They need to build on a wide range of traditional subjects, including physics, chemistry, geography, biology, oceanography, economics, medicine, epidemiology, technology, sociology and psychology. Modelling the global climate system means representing the atmosphere, oceans, cryosphere (ice and snow), land and biospheres, with all their different processes and interactions over many different time-scales: how the atmosphere interacts with the land surface and with the oceans; how the atmosphere and ocean respond to the input of greenhouse gases; how vegetation cover changes during the year; how the full carbon cycle can be represented; and how sulphate aerosols will affect models. This example illustrates the importance of interdisciplinarity within the natural sciences; this can be complemented by appropriate interaction across the natural and social science divide which can facilitate an interchange between those who produce scenarios of change and those who model their human impacts.

Policy responses to environmental problems must be suited to the variety of effects they need to address and therefore should not be constrained by traditional boundaries. The wide-ranging impact of environmental change on many sectors is another reason why interdisciplinary research is particularly suited to environmental questions.

The government's refocussing of its research priorities, for example in the Technology Foresight programme, will probably increase interdisciplinary research in other areas in the future.

Approaches to interdisciplinary research

Disciplinary range: The range of disciplines needed to tackle effectively any given problem depends on the nature of the problem. Air quality management research involves experts in medical practice, epidemiology, aerosols, meteorology and atmospheric chemistry; but it is still carried out within the natural science area. Other projects cross the natural/social sciences boundary: e.g. climate change, or catchment pollution. These demand the integration of disciplines developed to deal with hydrological, ecological, socio-economic and political systems, often at an international level. For example, the impact of a change in the transport infrastructure in the Baltic region (the construction of the Denmark-Sweden bridge) is expected to have very general, although indirect, impacts on the whole of the Baltic ecosystem. It is more difficult to cross the natural/social sciences boundary than to remain on one side, for reasons that are expanded later; and it may be that the demands of policy-making provide the incentive for much of this work.

Monitoring air quality means setting up and validating models which predict airborne concentrations of pollution and how they will change with emissions. This requires experts in physics, meteorology and atmospheric chemistry.

Management also means estimating the effectiveness of control strategies. Here, technological questions demand a range of expertise: mechanical engineers to deal with vehicle emission controls; civil and highway engineers for traffic management; economists for road pricing. Social scientists and psychologists are needed to contribute data on people's responses to control strategies. Medical and epidemiological expertise is also necessary for understanding the medical impact of pollution on human beings.

Model of Collaboration: Two main models of collaboration were discussed. First, a linear model: multidisciplinary research in which the information from one discipline is passed to the next set of researchers, who use it in their work. Against this is a more preferred model which could be characterized as circular or spherical because it involves multiple feedbacks between cooperating researchers. It can be used for multidisciplinary or interdisciplinary research, but it is essential for interdisciplinary research. All disciplines are involved in the research from the very beginning and cooperate in setting the terms of the questions to be asked, as well as the way they are to be answered. Spherical models of climate impact assessment may construct a scenario and consider its impact on plants, enterprises and regions, as well as an appropriate policy response. This 'top-down' approach is currently the most popular one, but it may be replaced by an adjoint or bottom-up method which asks what types of sensitivities to current climate exist, where the critical infrastructural and ecosystem vulnerabilities are, what are the magnitude of those vulnerabilities which, if exceeded, could cause dangerous impacts, and how changes of climate can be described in terms that will estimate likely impacts. In both approaches, all disciplines must be involved from the start.

Spatial scales: These vary from the local to the regional and global. This is one of the difficulties facing research which crosses the natural/social sciences boundary. As the spatial and temporal scales increase, so does the complexity of the problem and the number of disciplines involved. Dealing with the interactive effects between the components of the very complex global system is the main challenge confronting interdisciplinary research in the future.

Logistical and organizational requirements

Rigour in interdisciplinary research requires a foundation of sound basic knowledge in the contributing disciplines. That all disciplines should contribute to shape the research and its goals from the beginning, is generally held to be a precondition of good interdisciplinary research. Each group will then understand how its input relates to others' contributions. Clear leadership and coordination is necessary. Each participant must understand the philosophy, methodology and language of the others, and be willing to share and discuss data and ideas within the group or network. Information must also be disseminated effectively.

The difficulties

There are three major obstacles to interdisciplinary research: institutional, conceptual/methodological and funding-related.

Institutional

Institutional obstacles often arise from entrenched disciplinary attitudes which come with disciplinary-based training and perceived disciplinary status. Rewards in UK universities are not based on interdisciplinary effort. Contract work from the European Community, the World Bank and governments shows far more appreciation of the need for interdisciplinarity than conventional UK universities and research councils do. Publishing in interdisciplinary journals, which are less highly regarded than specialist ones, earns fewer accolades in research-rating exercises. There are also problems with career paths. One example was cited of a computer scientist being called into a psychology department to give much-needed input into a project there. When the project was finished, there was no clear career move for the computer scientist to make, as his knowledge of psychology was not enough to secure him a lectureship in that department.

Another practical problem of interdisciplinary research is that the team needs to be kept motivated but the individuals may feel isolated, because each of them knows more about his or her area of research than the team leader and often there is only one expert in each field. Interdisciplinary research requires the capacity for flexible team building appropriate to the problem. On the other hand, the expertise gained is not recognised in the traditional university system and so the researchers' credibility may be threatened.

Peer review was another area of concern: how can interdisciplinary work be judged adequately by colleagues from traditional disciplines?

Conceptual and methodological

The conceptual and methodological difficulties were significant. The most persistent of these concerned natural and social scientists working together. Apart from natural scientists' lack of respect for the social sciences, each group finds it hard to understand the limitations of what the other has to offer. Social scientists tend to think that natural scientists can provide complete and accurate answers, and natural scientists may imagine that social scientists fully understand the complexities of human behaviour. The two areas use different methodologies, terminologies and philosophies. It can be hard for them to distil findings from one area to make them amenable to evaluation by a different discipline. These problems can be compounded by having to determine the value in cost-benefit analyses associated with environmental economics.

Social and natural sciences also often deal with different time-scales: the social sciences in short-term changes and the natural sciences in much longer-term ones. There may also be differences in spatial scales of operation. This makes for complications in constructing models which are valid for both.

There was however some optimism about the way natural and social scientists are learning to work together. In climate research, they soon began to realise that they needed each other to get to grips with the problems they were dealing with.

Another difficult problem is producing data that are significant for both natural and social scientists. Much scientific work is not producing data that can help policy-makers. As far as climate change is concerned, the Hadley Centre's move to regional-scale and time-dependent models has been encouraged by discussions with experts, who study the impact of climate change on society. This is a good beginning but there are still some on the impact side (as well as industrialists and policy-makers) to whom the data are of little value, because micro-scale data cannot be used to consider macro-scale problems; or because small-scale human decisions (e.g. what crop farmers should plant in a dry summer) cannot be built in to larger-scale climatic processes; or because the data do not deal adequately with scenarios that are only slightly different from each other. There are beginnings of more integrated models in Holland, Harvard and the Massachusetts Institute of Technology. These try to embed people's reactions to climate change into the changes themselves, as they progress, rather than modelling the changes and then handing them on to policy-makers for their decisions.

Funding

There was general agreement that funding for interdisciplinary research is easier to obtain at an international level than nationally. However, the three Research Councils represented at the meeting all fund interdisciplinary research programmes. This is a welcome development. They still face difficulties, however, funding research which crosses the boundaries between the various committees within the Councils themselves. Cross disciplinary research calls for funding across the boundaries of subjects, panels, committees, Councils and government departments. The strategy and procedure for funding such research should be transparent.

Although the Councils are providing support, it is not clear that the message is being heard by the research community. When the ESRC advertised for proposals for interdisciplinary research, its project on the social effects of transport and the environment attracted no interest at all from medical researchers or those in the natural sciences. Fears were expressed that the limited funding available within interdisciplinary programmes may reduce the effectiveness of interdisciplinary research and lead to superficiality.

Funding bodies must also realise that interdisciplinary research needs a substantial time commitment. Its complexity means that results cannot always be produced within the periods that grants currently run.

Conclusion

The meeting was in no doubt of the benefits of interdisciplinarity, especially in a policy-driven area such as environmental research. Climate change and its impact requires an understanding of interactions among a wide range of natural and social sciences; and the flexibility and conceptual novelty that interdisciplinarity offers, as well as its practical value to the public in framing environmental policy, makes it an essential tool. Although environmental research is particularly suited to interdisciplinarity, the meeting anticipated that the methodology will be taken up by other areas - and the fact that multidisciplinary research is on the increase is itself a positive signal for interdisciplinary researchers. In light of its benefits, the meeting was convinced that interdisciplinary research must be encouraged.