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Main Article:

Integrative Research in the University Context: Centre for Resource and Environmental Studies, The Australian National University

Robert J. Wasson
Charles Darwin University, Darwin 0909, AUSTRALIA
robert.wasson@cdu.edu.au

Stephen Dovers
Centre for Resource and Environmental Studies, The Australian National University, Canberra 0200, AUSTRALIA
dovers@cres.anu.edu.au

Abstract

At a time of increasing interest and advocacy in integrated and policy-oriented research, this paper offers an empirically-based view of the intellectual and practical challenges of undertaking such research. It analyses the experience of a long-standing university research and postgraduate training centre from 1973-2004: the Centre for Resource and Environmental Studies at The Australian National University. The paper discusses staff development issues, cross-disciplinary understanding, organisational requirements for collaborative research, postgraduate and early career considerations, a range of integrative frameworks, and the tensions that arise for interdisciplinary research in the political and economic operating environments of modern universities.

Keywords: interdisciplinarity; environment; research; policy; universities

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1. Introduction

It is often claimed that resource depletion and environmental degradation are recent problems, and that the widespread call for integrated knowledge, as part of the solution to these problems, is also recent. Yet the modern idea of sustainability, often seen as a product of the 1990s, has deep historical roots in classical economics, renewable resource management, and elsewhere, which began to be clearly stated as a policy imperative from the late 1960s. The modern agenda of sustainability demands integration of environmental, social, and economic considerations over the long term, because contemporary sustainability problems are understood as products of interdependent biophysical, ecological, economic, political, and cultural systems. Thus sustainability and its significant subsidiary issues require some degree of interaction between the specialisations into which knowledge has been increasingly organised. Such interactions are most commonly termed interdisciplinary or *integrative research*. Moreover, the perceived magnitude and urgency of sustainability problems call for a policy-orientation in environmental research.

This paper tracks interdisciplinary and policy-oriented research and postgraduate training at the Centre for Resource and Environmental Studies (CRES), which is part of The Australian National University, covering the period from 1973 to 2004. It distils observations and lessons relevant to the rising levels of interest and activity in interdisciplinary research. The paper is an empirical one, focusing on integration and interdisciplinarity as these notions have been dealt with at the Centre, but situates itself within the broader evolving literature concerning environment and sustainability (e.g., Becker & Jahn, 1999; Klein, 1990; McNeill, 1999; Nowotny, Scott, & Gibbons, 2001; Pezzey, 1992; Turner, 2002).

2. Organising Integration and Interdisciplinarity: Establishment and Mandate of CRES

From the 1970s university curricula began including “environmental studies” and “environmental science,” reflecting growing public and policy concern. In 1960, the Australian government proposed a Faculty of Agricultural Science at the newly amalgamated Australian National University and Canberra University College. The Australian National University responded in 1973 by establishing the Centre for Resource and Environmental Studies (CRES), on the basis of a Statement of Intent prepared by the University in 1969:

> The ANU sees a need in Australia to ensure that the natural resources of the country are at the same time husbanded, developed and conserved in the general interest and in a wise and informed way. There is an urgent and continuing need for the conservation and improvement in the quality of existing assets and for their regeneration; for their development, where appropriate, in the national benefit; and an evaluation in economic terms of the renewable resources of the country. (Quoted in Fenner, 1979, p. 2)

That mission statement is still relevant today. Between 1969 and 1982, when a formal mandate was proposed, there is abundant evidence in Fenner (1979) and Harris (1994) for the philosophy that guided CRES:

- resource development and environment should not be divorced (hence the title Resource *and* Environmental Studies);
- CRES should be concerned with policy issues relating to natural resources and environment to a much greater degree than universities usually have been; and
- because the problems of concern are complex, involving relationships between the human and non-human worlds, research should be inter-disciplinary but rooted in strong training and understanding of disciplines.

The 1982 mandate codified this evolving philosophy, repeating the emphasis on policy relevance, interdisciplinarity, and the nexus between resource use and environmental change, observing that:

> CRES should concentrate on issues which tend to be too broad to be undertaken effectively by specialist sections of the university and which require the range of disciplines which CRES can command. In addition, the research should be excellent, published in both the standard academic mode, and made available to a wider public, focus on the development of concepts and methodologies rather than being based on the collection of primary data, identify key issues and programs of research but also carry out short-term projects as necessary, and staff should pursue the Centre's programs rather than their individual research interests. (CRES Internal Document, 1982)

The mandate did not mention postgraduate students. The sentiments and prescriptions of the 1982 mandate not only grew from the ideas that set up the Centre but also continued in the CRES mission and vision statements designed to guide activities from 1999-2004. The "hand of continuity" noted by Mobbs and Crabb (2002) is clearly evident, but only from 1999 was postgraduate training explicitly part of the mandate.

The Australian National University context, and that of its research and postgraduate focused and statute-defined Institute of Advanced Studies of which CRES is a part, must be recognised. CRES is a small, interdisciplinary unit comprising 11-15 core staff within an Institute of Advanced Studies dominated by much larger and mostly discipline-defined research schools. As Australia's most research intensive university, the focus of activities, and the manner of promotion and selection of staff is different from those of most universities. "Research excellence"--in a formal sense and oriented toward the international sphere--dominates, and therefore individual disciplinary standing is emphasised. Integrative ventures in new domains, where established literature does not exist or is only just emerging, are not easy in such an environment.

3. Organisation and Disciplines

The 1982 mandate and early organisational structure of CRES were programmatic, involving an internally planned set of activities that could be funded and staffed. In the early years, three programs were formed: Natural Resources, Applied Systems, and Human Ecology. The 1978 review of CRES criticised this structure and led to more interaction between the programs. The review also urged more short-term projects, which the then director resisted because of the need, in his view, for research to be carried out "within the framework of logical, connected, and systematic programs of research, which are more than mere collections of projects" (Fenner, 1979, p. 19).

But the programs did not survive. Some large projects were established (e.g., in the Hunter Valley in New South Wales, focusing on major resource developments, and the East Kimberley in Northern Australia, on indigenous development) to explore the multifaceted nature of resource use and human well-being. Long-term ecosystem monitoring and analysis of dynamics and programmatic work on catchment hydrology and integrated catchment management have developed without formal structures; although much of the latter work is now institutionalised in a new centre called Integrated Catchment Assessment and Management, a joint initiative of CRES and the Faculty of Science.

Programs were considered divisive as they created separate groups. Projects are problem- or issue-focussed, and most current research is carried out by individuals or small collaborative groups rather than larger teams. This shift from programs to projects and individuals is the result of managerial compulsions, i.e., ever-present pressures to meet disciplinary strictures

for professional development and the growing proportion of the budget that is externally sourced. When a large fraction of funds (about 50%) comes from outside, programs designed from inside are difficult to maintain. Although ongoing research themes can be maintained, such as forest ecosystems dynamics and conservation, spatial and temporal dynamics, environmental history and catchment management, to name a few, they are fed by external project-based funds that provide operating money, PhD scholarships, post-doctoral fellowships and equipment. Salary costs are mainly funded from a block grant from the federal government to the Institute of Advanced Studies, but discretionary expenditures must be separately sourced. This is the result of a deliberate policy, under tightening budgets, to maintain adequate number of academic positions and thus disciplinary spread and supervisory capacity rather than provide discretionary budgets for fewer staff.

In order that CRES did not degenerate into a mere collection of projects, to echo Fenner (1979), the 1999-2004 Strategic Plan gave heightened emphasis to policy relevance, interdisciplinarity, and the larger sustainability domain, rather than specific environmental issues. Interviews of CRES staff by Mobbs and Crabb (2002) clearly showed that policy relevance presents few problems, although connecting research and policy remains a challenge. The injunction to be interdisciplinary does present challenges to staff and students, despite a history of rhetoric and some achievements. The broader focus of sustainability, even as a general domain within which to contextualise more specific research, remains problematic for some.

Interdisciplinarity is seen as unattainable, fashionable, and therefore suspect and dangerous, given that rewards in academia are tied to disciplines. It is also seen as an obvious requirement because it flows directly from the nature of the problems. The idea that the problem determines both the range of disciplines and the degree of their integration is attractive to many staff, but this can result in staff tackling problems that require fewer disciplines, based on voluntary behaviour in a world where the disciplines still define the structure within which careers are fashioned. Informing some researchers' aversion to interdisciplinary endeavours may also be the view that such work may exist outside an adequate peer review and quality control system, although the increase in academic societies and quality interdisciplinary journals has changed this situation.

In the early years, CRES had few social scientists other than economists and very few from the humanities. Among the natural sciences, the physical, earth, biological, and

mathematical sciences have been represented. Psychology, human ecology (arguably an "interdiscipline"), economics and geography have all found a place. At the time of writing, the 15 core staff included individuals with backgrounds in ecology, mathematics, economics, public policy, geomorphology, anthropology, history, and hydrology. (Note that this paper does not explore *intra*-disciplinary issues and differences, even though these are a fascinating and under-explored dimension of interdisicplinarity.) Environmental history was practised until recently by one scholar on a part-time basis, but later also by a historian of science and a geomorphologist. The recent broadening of the disciplinary base to include the humanities, in the form of history and anthropology, has seen the development of the "ecological humanities" in CRES, which emphasises culture and human values. Finally, policy and institutional analysis by one researcher (plus a substantial cohort of PhD students) has had considerable impact inside and outside the Centre.

With a few staff and many relevant disciplines, there have always been gaps. (For a list of the formal disciplines relevant to sustainability policy, see Dovers, 2003.) For example, CRES has never included a lawyer on staff, despite law being key to resource and environmental management. While there were times when some missing disciplines may not have been warmly welcomed in CRES, their absence now is simply a reflection of budgetary constraints. In such cases, linkages with other disciplines have been achieved through collaboration with other research organisations and individuals.

The number of staff in each discipline has always been small--in some cases only one. This is problematic when postgraduate demand outstrips supervisory capacity. It is also a limit because one institutional analyst, for example, cannot cover the whole field, represent its heterogeneity, or provide the flexibility to respond to pressing policy issues or externally commissioned research. Visitors fill some of the gaps but long-term visitors cannot be expected to fully act as staff members and short-term visitors have a tightly prescribed purpose. In times of contraction (e.g., the mid-late 1990s), losing or discontinuing one position could equal loss of an entire disciplinary area.

4. Postgraduate Education

Although until recently education and training of students was not explicitly part of the mandate, a long-standing view in CRES is that universities must be involved in those activities and that students bring a vibrancy and heterodoxy to a research establishment.

They also expand the amount of research carried out. In fact, postgraduate students have been at the forefront of interdisciplinarity at CRES.

A coursework Masters was delivered at CRES during the first decade. More recently, a few research Masters students have been educated, but by far the bulk of postgraduates have been PhD candidates, varying in number between 9 (in 1987) and 55 (in 2004).

Until 2002 when the Institute of Advanced Studies was brought into the Australian Government's main funding schemes, there were no financial incentives to the Australian National University for the education of PhD students. CRES nonetheless had a respectable number of PhD students (nearly 40, following a change of director and thus policy from the late 1980s), although this actually cost the Centre money from its block funding. This supervisory workload, although high by Institute of Advanced Studies standards, was viewed as a worthwhile and there was little resistance from staff. However, in 1997 the number was deliberately reduced because of the strain on resources and lack of internal structures within the university to reward postgraduate training.

That situation has changed now and CRES has again increased its student numbers. This has not required any great effort, and the demand from highly qualified prospective students still exceeds supervisory resources and availability of scholarships. Most PhD students are not the fresh Honours graduate that is the target of the standard Australian Postgraduate Award scholarship process, but older individuals with professional experience and an interest in interdisciplinarity and/or policy. One of the chief legacies of the Centre is its students, most of whom have been actively involved in the intellectual life of the Centre and then have gone on to positions of influence elsewhere (Mobbs & Crabb, 2002). Completion and employment rates are very high, and destinations in government, the private sector and non-university research organisations exceed academic careers for graduates.

Approximately 25% of PhD research projects over the past decade can be defined as deeply interdisciplinary in that various disciplinary perspectives are challenged and/or altered during their integration, through re-assessment of assumptions and theory. Another 25% are multidisciplinary, combining differing perspectives such as economics and social network analysis, but without challenging the disciplines' theories or methodological assumptions. The remainder are largely disciplinary, notwithstanding forays into other fields to contextualise the research or for supplementary techniques or data. This mix has varied over

time, but has remained reasonably constant over the history of CRES (although total student number has risen sharply since the late 1980s).

Student discussions in recent years have revealed a range of attitudes to interdisciplinary research. Roughly a quarter of students have come to CRES deliberately to do interdisciplinary research, while a greater proportion have been attracted by a clearly multidisciplinary research environment. Amongst the latter group of those initially less committed to interdisciplinarity are those who have been changed by the experience of being at CRES, have adopted a strong policy focus, and are alert to other disciplines to a degree unlikely to be achieved in a disciplinary unit. Others remain within the confines of their disciplines and take little notice of other perspectives, and some have been threatened by the constant reference to interdisciplinarity and policy orientation.

The often isolationist nature of research driven by external funding and the simultaneous requirement to maintain both policy focus and interdisciplinarity have triggered Centre-wide discussions to limit the danger of isolationism. These have provided opportunities for student participation. These discussion have been mostly unstructured and discursive rather than prescriptive or outcome-oriented.

Fenner (1979) identified a problem faced by CRES when he observed that collaboration cannot be forced from above. Discussion and debate therefore must be commonplace so that an “air of interdisciplinarity” is pervasive, and staff can develop collaborations knowing that their endeavours will be supported. For students whose tenure is only 3-4 years, this slow collegial process can be frustrating. Some see the need for more explicit training in integrated research for sustainability, or at least an introduction to other key disciplines.

There is a case for such formal instruction and for more of a “guiding hand” from above to maximise interdisciplinary understanding and the likelihood of interdisciplinary research being attempted. However, the danger is that many disciplinary students would not thereby be attracted to CRES, which would be disastrous given the importance of student number and completion rates to the finances and culture of the Centre, as well as the value of more disciplinary PhDs. So the debate has been inconclusive and the changes incremental.

Challenges to interdisciplinary postgraduate research include finding appropriate disciplinary as well as interdisciplinary skills for inclusion on supervisory panels. This is even more of an issue as the incentive structure created by government funding formula

works against cooperation across and even within universities. In many universities students attempting interdisciplinary work lack formal supervision in key relevant areas, and even have only a single, disciplinary supervisor. This inhibits integrative research. Students at the Australian National University must have a panel of three supervisors, and CRES students commonly have more, with co-supervisors providing support in methods, multiple bodies of theory, and applications. There is a shortage of appropriate examiners for interdisciplinary theses--some CRES staff are in constant demand as examiners, as are similar academics elsewhere, and there is a limited supply of examiners for our own theses. (Australian doctoral theses are independently assessed by 2-3 external examiners, with oral examinations held only to resolve serious issues.) Many fine disciplinary researchers struggle to comprehend and assess interdisciplinary work. Until the recent increase in early career interdisciplinary researchers translates into a larger body of eligible examiners, this problem will continue.

5. Staff Responsibilities

In a place like CRES, there is a responsibility on staff to learn about other disciplines, comprehend the sustainability domain, and understand the policy process. A deliberate step has been taken recently to broaden understanding of disciplines, accepting that interdisciplinarity requires such understanding. One explicit strategy to address this has been a book written largely by CRES staff and students about the foundational concepts of key relevant disciplines (Grafton, Robin, & Wasson, 2005). The chapters have been presented in workshops and peer reviewed, leading to a deeper understanding of the disciplines. While not universally acclaimed, this process has helped many look beyond their narrow horizons. The book is aimed at undergraduates.

Given the Centre’s long-standing focus on policy, the general lack of understanding of the policy process among many disciplinary researchers in CRES is rather paradoxical. It seems that many studies in CRES have aided policy formulation without this understanding, especially in soil, catchment, forest, and biodiversity management, and also in areas concerning indigenous Australians. But greater impact is likely to be achieved if policy formulation were better understood. Currently, there is no explicit process in CRES to bring this about--the handbook by Dovers (2005) may help fill this gap.

The integrative and policy-oriented focus of CRES can be an advantage now because the academy is seen to have at least in part denied "the social world" (Bourdieu, 1993), i.e., ignored the power relations between academics, politics, and funding, and because the social contract between knowledge producers and the state has shifted toward results that are immediately and economically useful (Nelkin, 1996). But this requires that staff and students of CRES take up the challenge of policy relevance of their work.

Academics are under scrutiny from many quarters and funding can no longer be assured. Academic freedom is now viewed as an indulgence or even a political threat, or, more modestly, as a licence to pursue arcane research at public expense. This has never been the mode of working at CRES, but it is caught up in changing societal views of the institution of university. The positive side of pressure for more "useful" research is the emergence of research funding schemes that seek to partner research with users, such as the industry "Linkage" program of the Australian Research Council and the industry-university Cooperative Research Centre system. However, policy-oriented and public good research (i.e., research relevant to issues lacking a near-term client or economic justification) may be disadvantaged in some schemes due to either the difficulty of identifying or engaging industry partners or in establishing economic benefits.

6. Doing Integrated Research: Choices

CRES staff and students choose research questions derived either from users' needs or their own perceptions of those needs. Except for some consulting (defined as not involving new knowledge development), most of which connects with ongoing research themes, CRES has been able to concentrate on the production of new knowledge (i.e., research), intended to be of use to policy and management, and making contributions to disciplinary and interdisciplinary development.

This is remarkable, given the financial pressures over the years that could have turned CRES into a consultancy firm which happened to have students. Staff have always been clear-headed about their major purpose and kept consulting under control by doing only a limited amount and of an appropriate kind. Policy-oriented research has the risk of yielding to immediate political agendas, whereas more strategic development of interdisciplinary theory and method may have no "client" in the market place. Still, CRES has been able to guard against the increasing marketisation of research in Australia.

A topical example of this dilemma currently is the commercial focus of Australia's government-industry funded Cooperative Research Centre program, where public good research or even strategic research of a long-term nature have little place. The standard research funding system of the Australian Research Council (the main government funding organisation) struggles to cope with interdisciplinary proposals. Although research and development corporations and other partners are increasingly interested in such work, the research funding environment is still more suited to disciplinary or commercially attractive research.

The research questions are guided by the purpose of CRES, by policy relevance, by the need to be useful, and by the likelihood of a substantial academic contribution. Where theoretical developments need to be made--for example, in the mathematics of digital elevation models, the parameterisation of hydrologic models, or understanding institutional change--they are driven by the context of application rather than only by curiosity.

7. Organisation Revisited

We have already described the modes of integration that have existed in CRES: (a) individuals as interdisciplinary researchers, (b) small groups, some of which were formalised in the early years, (c) ongoing integrative themes, (d) project teams that dispersed when the task was finished, and (e) at least in one instance, the whole of CRES being engaged in one project--i.e., the Hunter Valley project established in 1981. The success of these formal and informal structures varied, as much related to personalities as structures. Individuals can be successful as interdisciplinary researchers, whether through their own work or by editing and interpreting collections of essays. The small groups, sometimes formalised, were able to create an identity that has persisted in the case of the new centre called Integrated Catchment Assessment and Management. But in a place the size of CRES, formal groups produce divisions and inhibit new collaborations and integrative activities. A hard-learned aversion to unwieldy mega-projects runs deep in the Centre.

Project teams continue to be a successful model, forming, dispersing, and re-forming as new research questions emerge--theoretical, methodological, and applied, or as collaborative or funding opportunities arise. Individuals maintain their disciplinary or interdisciplinary focus but learn integrative skills as they cycle through projects. But to some degree, this is an idealised description of what happens; CRES has encountered difficulties in building

expertise over time and projects. For short-term staff members, the opportunity to collaborate widely or for long is limited. Students work mostly alone--focused on their PhD topics. Early career researchers face risks with interdisciplinary work when they could consolidate their careers more safely as disciplinary researchers. The time to reflect on theory and method across and between projects is often in short supply, and there are breaks in the requisite continuity of staff and groups. Shifting individual research agendas, and the related principle of academic freedom, have meant that continuity and persistence have not always been achieved.

The Hunter Project of the 1980s is an example of design from the top. Everyone was to be involved, working as a multidisciplinary team with integration as the eventual goal. The project is not regarded as a successful example of interdisciplinary research (Mobbs & Crabb, 2002), although the approach is better judged as a product of its time and part of a progression through multi- to inter-disciplinarity. The integration did not work because of differing opinions about preferred frameworks, and also because integration was left until late in the project. Individuals worked almost independently. There was no clear way for generalising the integrative method to other places. There was also no committed user to provide an external stimulus. That said, many outcomes were very useful (for an overview, see Jakeman, Parker, Fromby, & Day, 1987). This is not an uncommon experience. Time is needed to build teams, understand epistemological differences, for leadership to evolve, and to define the research problem. In particular, interdisciplinary interaction must be present from the problem definition and research design phases, not added later (Barnett, Ellemor, & Dovers, 2003).

Other big projects did more. The Hong Kong Project was an early application of the ideas of human ecology to a city (Boyden, Millar, Newcombe, & O'Neill, 1981). It is highly regarded and widely cited, although now people are reinventing this sort of analysis without reference to its innovative conceptual foundations. In a different way, the Fundamental Questions Program contributed interdisciplinary insights about people and the biosphere (Boyden, Dovers, & Shirlow, 1990 was the major product).

So, large integrative projects can produce useful outcomes, provided the following prerequisites are ensured:

- one or more “integrators” who see the project through and provide the central organisational and intellectual resource and continuity;
- solid but flexible management, rather than a laissez faire approach;
- a “real” problem that motivates the contributors, ideally involving theoretical, methodological, and applied aspects;
- adequate resources to ensure proper completion;
- publications that target the interdisciplinary research community to pass on the experiences, the user community, and disciplinary peers so that individuals do not become invisible to their major peer group; and
- a physical setting highly conducive to group work and routine interaction; something that CRES has struggled with in an unsuitable building.

The same list applies to smaller projects, although at lesser scales of resource, management, and time. One insight from the CRES experience is that instant gratification through interdisciplinarity is unlikely, but rather that problem definition, human capacity building, and theoretical and methodological development may take many years before widely appreciated applications appear, although useful outcomes emerge en route. Over the Centre’s history, an example is the thread running from early human ecology work, through the Fundamental Questions Program and other work on sustainability in the late 1980s and early 1990s, to the Ecological Economics Program in the mid-1990s and subsequent activities. Similarly, there is growing interdisciplinarity from the earlier water resources and hydrological work to the recent developments in integrated assessment. *Integrative capacity* cannot be invented suddenly; it requires careful nurturing over a sequence of projects.

8. Frameworks

Integration of work done in the original CRES groups (Applied Systems, Natural Resources, and Human Ecology) was to be achieved by systems analysis as a shared framework. This strategy had limited success due to differing opinions about the nature and utility of a systems perspective. This experience has continued, and can be seen in widely differing approaches to integration in various disciplines and interdisciplinary clusters, with a number of frameworks for interdisciplinary research being used:

1. *Systems analysis* focuses on the connectivity between the components of a phenomenon or problem, either qualitatively or quantitatively. This approach is widely used in engineering but has a bad name among many social scientists and humanists because of its connection to the notion of control. This generated debate often not about systems analysis but about its normative content. The systems perspective still underpins a range of recent work at CRES, to varying degrees.

2. *Human ecology* deals with the interplay between human social systems and biological systems, especially between resource and energy use, bio-productivity of ecosystems, and the quality of human life. This can be considered an example of systems analysis.

3. *Ecological economics* takes into account natural systems, human psychology and history, and investigates interdependent natural and economic systems. Its proponents identify the lack of consideration of these as flaws in neoclassical economics. This area is possibly the largest and most rapidly growing of the explicit "interdisciplines" focusing on sustainability (for identification and discussion of these, see Barnett, Ellemor, & Dovers, 2003), but is seen by some economists as a normative pursuit. CRES had a formal but loose Ecological Economics Program during 1994-2000 (e.g., Common, 1995; Dovers, Stern, & Young, 2003).

4. *Environmental and resource economics* has been pursued at CRES in several phases and is currently a (relatively) major area (e.g., Grafton, Adamowicz, Dupont, Nelson, Hill, & Renzetti, 2003). It is focused on resource, environment, and sustainability issues, and to some degree on institutions and governance. It is more closely allied to standard neo-classical economics than ecological economics; however, theoretical reorientation to account for sustainability within economics is a theme (e.g., Pezzey & Toman, 2002).

5. *Environmental history* explores the ways in which people and the non-human world have interacted through time. As practised in CRES, environmental history contributes to modern priorities of natural resource and environmental management (e.g., Dovers, 2000; Robin, 2001). It has done so to explain better how current situations have occurred, how particular policies came about and which ones worked, and why some current changes in the landscape cannot be causally related only to recent changes because they have much older origins.

6. *Policy and institutional analysis* has provided a vehicle for engaging different disciplines required to explain or develop elements of a particular policy problem. More significantly, this framework has allowed the exploration of the underlying attributes of policy and institutional problems in sustainability (Connor & Dovers, 2004; Dovers 2001, 2005), including temporal and spatial scales, pervasive uncertainty, systemic causes, and ill-defined property rights and responsibilities.

7. *Integrated water resources assessment and management* attempts to integrate ecological, social, and economic phenomena within a flexible modelling framework accepting both qualitative and quantitative inputs. This provides outputs of the "what if" kind; i.e., if a dam is built on a river, what might be the likely outcomes ecologically, socially, and economically (Jakeman & Letcher, 2003; see also White et al., 2003). More recently, empirical approaches using the techniques of earth science, isotope analysis, and environmental history have extended the scope of catchment assessment and management (Wasson, 2002).

8. *Spatio-temporal analysis* of natural systems is mostly directed to understanding the non-human world; however, exploring the spatial and temporal fit between natural systems and human decisions and institutions is a small but important work at CRES. The mathematical and statistical innovations of this framework have drawn international acclaim, especially in the construction of digital elevation models and analysis of space-time variability of climate (Houser, Hutchinson, Viterbo, Douville, & Running, 2004). Links to global models of climate and predictions of climate change have been made, along with analyses of agricultural planning, biodiversity assessment, and integrated catchment modelling. This framework has seen substantial theoretical, methodological, and applied developments, demonstrating that contributions to a broad range of knowledge are possible in a place such as CRES which has an applied and policy focus.

9. *Landscape ecology* is a prominent and highly productive domain at CRES, expanding the "plot" and "species" focus of much ecology and conservation biology to include multiple species and habitats, climate and landscape-scale processes (e.g., Lindenmayer & Franklin, 2002). This has provided an enhanced biophysical perspective from which to incorporate policy, institutional and participatory dimensions into biodiversity research.

10. *Ecological humanities* is a framework with roots in environmental philosophy, anthropology, and history, which has been recently added to the repertoire of CRES. It focuses on the cultural dimension of behaviour and decision making, and has a strong cross-cultural component that explores the differing world-views of indigenous and non-indigenous Australians, and other cultures (this area is being developed in part via the journal *Australian Humanities Review*).

The experience with so many interdisciplinary or integrative frameworks continues to inform ongoing development of these frameworks. The experience also brings out some of the systemic difficulties in interdisciplinary integration. One significant issue at CRES is the qualitative-quantitative divide between disciplines. Perhaps, there will never be a single "science of sustainability." Although significant advances have been made in many areas, the distances between the disciplines (and other knowledge systems) remain considerable.

This is not an issue not only for research providers like CRES, but also for research funding bodies as well. For example, the Australian government research and development corporation, Land & Water Australia, has been proactive in supporting integrative research. Individuals at CRES have been closely involved with the development of Land & Water Australia's Social and Institutional Research Program and with its integration initiatives (Dovers, 2002; Dovers & Roughley, 1999; Mobbs & Dovers, 1999).

9. Closing Comment

These emerging areas represent what might be seen as a new phase in developing the art and craft of interdisciplinarity. After decades of general theoretical and practical "experiments" in interdisciplinarity, it is now time to ensure that different and equally valid meanings and implications that different interests attached to the term are made explicit. Allied to this is the need to delve deeper into what the differences between disciplines really are, how they matter to gaining purchase on sustainability problems, and how we can connect if not reconcile them. Doing that is crucially important, but at the same time CRES and other comparable research units need to maintain disciplinary excellence and productivity, earn external income, nurture their people, attract and train postgraduates, and engage with the policy community.

On its own, with current resources and with existing linkages, CRES can carry out such tasks to some degree, but the interdisciplinary and integrative imperative would be better served by a larger cohesive effort involving many groups and centres towards a more evolved theory and practice of integrative research and development. In particular, better communication between separate interdisciplinary groups and between emerging interdisciplines (e.g., environmental history, integrated assessment, ecological economics, and ecological humanities) is needed, lest these ironically become silos. Such collaboration is not always encouraged by the imperatives and incentives of the modern competitive research environment.

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