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Main Article:

Integration Initiatives at CSIRO: Reflections of an Insider

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Abstract

These days CSIRO is focusing on providing holistic solutions to Australia's major problems. For example, the organisation hopes to address significant natural resource management problems of Australia by combining the wisdom of a wide array of disciplines. A number of recent measures have been initiated towards this end, which are described in this paper. Implicitly, CSIRO has recognised that cultural change is needed if the organisation is to contribute to the resolution of long-standing "wicked" problems. Innovations to achieve a more integrated approach are described and assessed in terms of their ability to meet recommendations derived from a formal review of past attempts to conduct multidisciplinary or interdisciplinary research. Much of the interpretation however is personal, reflecting changes observed in thirty years of service within CSIRO. The discussion concentrates on the pragmatics of the creation and performance of teams with differing disciplinary backgrounds in natural resource management. In addition the paper discusses the wider ongoing changes to the roles of scientists as society evolves. It outlines the issues of defining the appropriate questions for research and the changing interaction between scientific and community knowledge. The potential contribution of complex systems theory to assist in creating productive integrated research is discussed. It is concluded that the CSIRO case study provides compatible findings with other analyses of integrated research performance and also other descriptions of the evolving role of scientists within wider society.

Keywords: integration; natural resource management; interdisciplinary; community; research

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1. Introduction

This paper has two parts: a discussion of the organisational challenges involved in *integration research* with particular reference to the CSIRO experience, and a short discussion of the role of scientists in solving natural resource management problems and whether that can be enhanced by the development of the integration research perspective.

CSIRO is an Australian government research agency. It has existed in one guise or another since 1916 when it began as the Advisory Council of Science and Industry. The acronym CSIRO is now formally the name of the organisation but originally it stood for the Commonwealth Scientific and Industrial Research Organisation. Currently it is a statutory body with approximately 6,700 staff; about 4,300 of these staff are research scientists or staff related specifically to research projects. The organisational structure is shown in Figure 1. CSIRO currently has 21 divisions, which are regarded as separate business units. Traditionally these divisions have tended to be organised along disciplinary lines and focused on particular issues (e.g., atmosphere, oceans, human nutrition, or forestry). This structure is however constantly under review as the organisation responds to the requirements of relevance to contemporary issues. As part of this response there has been a tendency towards more multidisciplinary and integrated research.

It can be seen that CSIRO deals with a wide gamut of Australia's problems from health through ecosystems and land management to industry. Its research is conducted in both urban and rural settings. For this reason, CSIRO has professional scientists with different disciplinary backgrounds, representing natural science, engineering, and social science. The current ethos of CSIRO is well expressed as its purpose in its Annual Report for 2003-2004:

> People are at the centre of everything we do. We work to create the right environment to amplify our talent. We take a 'Team Australia' approach.

It is not enough just to have a great idea; we must have impact, solve problems and make a difference.

We take a triple -bottom -line focus in our activities, balancing between commerce and the public good.

Great science is our foundation. Getting it out there is our aim. (CSIRO, 2004, p. 1)

Figure 1. Organisational Structure of CSIRO

As may be imagined this is a difficult task and there are many opinions as to how well CSIRO is succeeding in meeting its goal. Nevertheless the preferred direction of progress is clearly expressed.

To achieve our purpose in operational terms one of the central tenets of CSIRO these days is the "one CSIRO" approach to problem solving. The organisation hopes to address significant research problems for Australia by combining the wisdom of a wide array of disciplines. A number of measures have been initiated to ensure that this happens. As to whether this integration can be achieved by the creation of truly interdisciplinary research approaches or simply by assembling multi-disciplinary teams is still a moot point. But it is evident that the approach that CSIRO will take is likely to vary from problem to problem and will be largely influenced by the background of the senior researcher(s) in the team.

In this paper I have attempted to evaluate ongoing effort towards the achievement of integration in CSIRO. This evaluation is by no means definitive. It reflects largely my own views based on participation and discussion with others over a 30-year period as a social scientist. During this time I have been a research group leader and more recently a Research Director within one division, CSIRO Land and Water. I have had a managerial and/or participative role in each of the initiatives described here. (Elsewhere in this issue, Roughley and Salt provide a description of my role in relation to the introduction of social science in natural resource management in Australia.) In addition, this discourse does rely heavily on a formal review of socio-economic integration which was conducted by a new staff member who did not have a personal interest in the studies examined, although she was supervised by me (Kington, 2003). The paper concentrates mostly on socio-economic integration because of my own experience. But I think some of the lessons are common to those in other biophysical arenas which are attempting to pursue the path of integrated research.

As noted above, this is also a time of rapid change within the organisation and so definitive conclusions as to the "correct" philosophical or implementation approach would be unwise. There are, for example, significant organisational changes that have occurred between the writing of the first draft of this manuscript and its revision some six months later.

The major purpose of this paper therefore is not to argue for or against any particular philosophy of science or problem solving nor is it to create definitional discussion on the differences between multidisciplinary, interdisciplinary, and transdisciplinary research. This has been discussed by others (e.g., Ramadier, 2004). The intent is to describe how CSIRO has responded so far to creating holistic problem solving given its traditional management structure based on a combination of biophysical science disciplines, and its aspiration to produce "great science." The interpretations made are mine but from some years of

discussions with a wide range of researchers within and outside the organisation. I use the CSIRO case study to advance my thoughts on the possible future role of problem-led (as opposed to theory-led) research in developing a productive role for science and scientists in natural resource management. The possible development of their role is briefly discussed in the light of complex systems theory.

2. Current CSIRO Initiatives to Achieve Integrated Research

In CSIRO, as in universities, individual scientists' career prospects have depended on publications in internationally respected journals. These journals usually have a disciplinary focus. Involvement with multidisciplinary efforts therefore holds personal risks for the individual researcher: transaction costs can be high, negotiations with other researchers uneasy, and publication rates in traditionally high prestige journals impeded.

Implicitly, CSIRO has recognised this issue and that cultural change is needed if the organisation is to contribute to the resolution of long-standing and often "wicked" problems (e.g., Achapelle, McCool, & Patterson, 2003; Gilmore & Camillus, 1996). A number of corporate- and scientist-driven initiatives have been undertaken in this direction. Some of these are described below.

Currently CSIRO has a comprehensive suite of initiatives to encourage the formation of problem-focused research groupings in the natural resource and other sectoral areas. These have arisen from a history over the past 10 to 15 years of attempts to create a matrix approach to research. This approach has taken time to evolve and the latest formulations are described below.

2.1. Flagship Programs: Water for a Healthy Country

The Flagship programs have been a logical development from the initiative of the former Chief Executive Officer, Malcolm McIntosh, who introduced a matrix structure in the 1990s. That is, problem areas have been identified and business unit (divisional) responses have been mapped against problems. For example, the theme areas CSIRO was involved with were defined and divided into sectors. These sectors in turn were divided into components. The Land and Water Sector comprised eight components varying from National Water Reform to Restoring Contaminated Environments. Divisional activities were mapped against each component. For example, CSIRO Land and Water could account for its

outputs by plotting staff allocations against each component in the land and water sector and other sectors (e.g., biodiversity) to which it was contributing.

Theoretically this represented an important advance in terms of potential multidisciplinary research in that the "problem" became the focus for divisional effort rather than the interests of the business units (large or small) that often consisted of disciplinary groups or like-minded individuals. Unfortunately internal funding arrangements and the dependence of many groups on winning external funds, and therefore being driven by others' priorities, meant that this early initiative had limited impact. The sectoral committees established to oversee sectoral development have, however, remained.

With the appointment of a new Chief Executive Officer, Geoff Garrett, the sector approach has evolved into a Flagship program initiative in which key areas from the wide range of national and CSIRO interests have been identified. Unlike the earlier attempts at a matrix structure, this initiative has been funded by significant reallocation of resources from business units. In the natural resources area an early investment has been the "Water for a Healthy Country" Flagship. The key challenges for CSIRO researchers in meeting the requirements for the Flagship are the formation of multi-disciplinary problem-focused teams, often across divisions, and the recognition that effective external partnerships are required. CSIRO acknowledges that it has neither all the expertise required for holistic problem solving nor the firsthand experience of the problems, which is available in industry or responsible government agencies.

The Water for a Healthy Country Flagship therefore creates new teams and new partners as well as new internal funding mechanisms. The Flagship also requires new models for delivering research. CSIRO researchers are in a stage of learning how to deliver in this new world despite many of the organisational characteristics of the old, some of which (e.g., differing divisional procedures) may initially create high transaction costs.

2.2. Emerging Science Areas: Complex Systems Science, and Social and Economic Integration

In addition to focusing CSIRO's efforts on major Australian problems, there has been recognition that there is a need to invest specifically in "new science." For this reason an Emerging Science program has been developed. While this is still in its evolving stage, two areas of particular significance to integration have been created. These are Complex Systems

Science and Social and Economic Integration. The research that has begun to emerge from both has a significant natural resource management focus and requires inputs from a variety of disciplines, both in the biophysical and socio-economic areas. Projects from both initiatives require integration between the social sciences (including economics) and the wider context of science in society. Research is currently in its early stage and the organisation of both Complex Systems Science and Social and Economic Integration is still fluid.

Additional initiatives have included a retrospective review of the lessons to be learned from earlier multidisciplinary research within CSIRO (Kington, 2003) and an ongoing action research based "learning by doing" project sponsored by the Social and Economic Integration program. The Social and Economic Integration, and Complex Systems Science programs also sponsor a Science Forum that, among other things, encourages ongoing debate on both integration research and emerging theoretical and methodological issues of relevance to CSIRO. Finally, an Ethics Forum has been initiated to examine the ethical issues involved with research in the context of public policy, especially with integration research.

2.3. Informal Team Building in Response to Demand

With the culture of attempting to achieve a "one CSIRO" approach to specific problems, there is an emerging flexibility between groups to assemble one-off teams to tackle major research or consulting projects. These are particularly evident in natural resource management areas. Thus, for example, a major research proposal has been negotiated between the community, air monitoring specialists from CSIRO Atmospheric Research, social researchers from CSIRO Land and Water, and a variety of government stakeholders. This proposal deals with a chronic controversy relating to outputs from a smelter.

In this case, there was considerable investment in designing the question to be addressed from different disciplinary perspectives from inside CSIRO, but also in scientific and engineering inputs from outside. Most importantly there has been an attempt to design the study incorporating local knowledge from the community. The research process itself has been negotiated with the community to ensure procedural justice. While the proposal was not implemented in full, it became a powerful vehicle for ongoing information and exchange between the community, industry and the government. It is an example of a number of

significant attempts to develop an integrated approach to research within the organisation (CSIRO, 2003).

2.4. Incorporating Integration within the Research Management Structure

Perhaps the most obvious means of integrating social and economic research with biophysical research is to incorporate the expertise of differing disciplines within the same research or business unit. This has tended to be the approach of one division, CSIRO Sustainable Ecosystems, for example in their Rangelands and Savannas, and Resource Futures programs. On the other hand, another division, CSIRO Land and Water, has tended to assemble their socio-economic scientists within two larger groups, the Australian Research Centre for Water in Society, and the Policy and Economics Research Unit. Even between these "specialist" groups there have been two approaches. The Australian Research Centre for Water in Society preferred to nest itself within a wider Directorate incorporating a variety of disciplines and the Policy and Economics Research Unit opted to stand as an independent unit. Both groups aim to serve CSIRO and outside clients. Most recently it has been decided to incorporate both groups as separate "streams" within an integrated research theme entitled Society, Economy, and Policy. It is interesting that within the two divisions CSIRO has tried four models for integration within the last decade. There has been no formal evaluation of the strengths and weaknesses of the four models in terms of providing integrated solutions to priority problems for their divisions, flagships, or CSIRO as a whole. Nor has there been an assessment of the issues involved for the professional development of staff both inside and outside the socio-economic sciences.

3. Evaluation of CSIRO's Integration Initiatives

All these developments reflect an extensive and recent change in the way CSIRO "does business" and are intended to be the foundation for ongoing change. They are, however, not novel. As indicated above, there have been attempts to create interdisciplinary, multidisciplinary, and transdisciplinary work in CSIRO in the past. There were more than 70 substantial initiatives identified by Kington (2003).

A subset of six of these initiatives from across differing divisions was evaluated in detail as an initial activity of the Socio-Economic Integration program. Five of these could be said to have fitted loosely within the natural resource management ambit. From this analysis, eight major recommendations emerged (Exhibit 1). The first recommendation related particularly

to the development of the Socio-Economic Integration program itself. The remaining seven recommendations related to socio-economic issues but since they are organisational and functional in nature they are probably equally applicable when integration is being considered among the biophysical sciences.

Exhibit 1. Summary of Recommendations from the Review of Contemporary Social and Economic Integration Best Practice in CSIRO (adapted from Kington, 2003).

1. Cultural change
Communication and staff training is likely to be required following the clarification of CSIRO's strategic direction in social and economic integration. The training should include familiarisation with methods of knowledge generation beyond the traditional hypothetico-deductive approach, new approaches to interfacing between technology and people, and knowledge of policy evaluation, and the role of research in policy formulation.

2. Project management skills
Project management skills were vital within most of the social and economic integration research reviewed and a significant investment in training would be required to support an expansion of effort in this field.

3. Gaining the best from existing Social and Economic Integration groups
It has been noted that there have been some interdisciplinary groups formed within CSIRO, particularly in CSIRO Sustainable Ecosystems and CSIRO Land and Water. These are recent initiatives but the experience gained by the groups would be of great assistance in developing this emerging science area. It is recommended that a formal evaluation of the issues relating to promotion of integration be conducted in the next three to five years.

4. Rewarding integration
Clear reward systems for participation in multidisciplinary teams and other social and economic integration endeavours need to be developed to encourage participation in social and economic integration research. This may encompass inclusion of specific integration categories in the Annual Performance Appraisal pro forma and promotion cases. Team rewards should also be systematically developed.

5. Minimising transaction costs
The transaction costs for social and economic integration are currently high in all research organisations. It is recommended that a systematic investigation as to how to minimise these costs needs to be conducted. This investigation should include improved coordination of Divisional financial and administrative systems and maintenance, evaluation and succession planning for more established social and economic integration groups. The widespread uptake and commitment to the philosophy underlying "One CSIRO" is of crucial importance in this area.

6. Addressing the "right" problems
Recognition of the importance of precise problem definition in social and economic integration projects needs to be supported through planning and budgeting of well organised scoping phases of research projects for at least twelve months. Techniques such as action learning and scenario scoping techniques may assist in this regard.

7. Succession planning for projects
In cases in which social and economic integration projects have a change role (e.g., those involved with community partnerships or organisational change), provision should be made for the hand over of processes or knowledge. This would maximise the project's on-going influence.

It can be seen that apart from the cultural change recommendation (which is a basic reason why the Social and Economic Integration was instituted in the first place), most address organisational and implementation issues. This finding is compatible with other evaluations of integrated research in other settings (e.g., Bruce, Lyall, Tait, & Williams, 2004; Stokols, Harvey, Gress, Fuqua, & Phillips, 2005). It is understandable that organisational and cultural change will take time but until some progress is made in responding to these recommendations, the development of integration research perspective may be hampered by implementation deficiencies.

These recommendations are also suggestive that new roles may be required at strategic levels in CSIRO in terms of group management and fostering career development. This change will also need to flow to the project level where project coordination and operations management should become key and rewarded roles within research teams.

But perhaps the major challenge to individual researchers and groups within CSIRO will be the determination of whether or not the project is addressing the "right" problems and their critical questions (Item 6, Exhibit 1). This recommendation suggests that action learning may be involved as well as incorporation of local knowledge. This may require a partnership approach in which the research agency provides special skills towards solving the "problem" and is just one of many participants. While this may enhance adoption of output, it can be challenging to professional scientists who often see the role of "expert" as equivalent to the role of "leader."

In the remainder of the paper, I use the CSIRO experience as a backdrop to examine the generic issues they expose for the development of the role of scientists in addressing significant societal questions and what this may mean for the contribution of theory in this enterprise.

4. Letting "the Right Question" Lead Research

There is significant intuitive appeal to developing "the right question" to lead research. Care should be taken to assure precision in objectives. In the past, particularly in disciplinary research, the "right question" has emerged from existing theory or from peer review from other scientists. But in CSIRO's new age of problem solving for Australia's benefit, the

question will only be seen as "right" if the community or stakeholders are involved in its definition.

If one defines the right question purely from the researchers' viewpoint, even if multi-disciplinary or interdisciplinary approaches are involved, the influence of the resultant research is likely to be limited. This can be attested by the poor uptake of computer based decision making aids despite increasingly wide disciplinary input into them. There are, of course, successful models, but these have usually been accompanied by a systematically thought-out interaction with stakeholders (e.g., McCown, 2001).

The achievement of the right question therefore must involve "local values," and ongoing participation of stakeholders and/or the wider community in the research process itself. This will involve some ethical issues as recognised by the Social and Economic Integration program and foreshadowed by others. Nowotny and colleagues (Nowotny, Scott, & Gibbons, 2001) label such changes as a Mode 2 knowledge approach, reflecting changes in science itself, as also in society.

There are wider and more personally challenging issues. Viewing the researcher as simply having a specialist, but largely equal, role in problem solving can create acute challenges to perceptions of self-worth. The skills and wisdom of the trained researcher may appear less valuable to society. For example, the following two quotations from Nancarrow and Syme (2001) show that despite the authors considering that their justice and fairness research must naturally fill a central role in water allocation decisions, this did not occur. Both in terms of influence on decision makers and even choice of method by the community, the researchers were cast in supporting rather than starring roles. It transpired that the most sophisticated methods, often forming the bases of internationally published works in the area of social justice research (and recommended by Nancarrow and Syme [2001]), were considered by the community to be inappropriately complicated. At the time this was much to the researchers' chagrin. Two quotations from the Nancarrow and Syme (2001) paper follow. The first relates to researchers' roles in decision making. The second relates to choosing appropriate methodologies to fit with community decision making processes.

On the decision making role:

> [W]e began our research confident that justice and fairness issues were all important for decision makers. We were particularly pleased with our development of existing fairness theory as we felt that the ethic of a "fair go"

> for all had been a central tenet for Australia's development almost since federation, even though it had been overlooked in recent years... It came as a shock therefore, that when serving on an expert panel and having created a fairness "solution" it was largely ignored. But more ignominiously a procedure we were asked to design to sequentially adopt the fairness solution was noted but never discussed. (Nancarrow & Syme, 2001, pp. 446-447)

On the method:

> Social and community psychology measurement has increasingly moved on the one hand towards sophisticated techniques such as quantitative latent variable modelling and on the other towards qualitative post-modernist approaches to data analysis. Both have their good points. We found, however, that results of such analyses fed back to farmers--with the researchers' interpretation can often be inadequate. It is the community's interpretation of the data that will lead to accepted solutions. Regression weights and in-depth qualitative discourse analyses may often seem to be excessive by the community. All may not understand the jargon, or the analysis--and to present recommendations from these analyses is likely to cause resentment. Certainly, not providing information that is understandable, and more importantly useful for all, is in defiance of the need for procedural or interactive justice. (Nancarrow & Syme, 2001, pp. 443-444)

The major dilemma is that without an agreed question being answered in an acceptable way, integrated research will have problems in influencing outcomes. The fact that the research team plays a supporting role in the process can be uncomfortable for the researchers. The question arises: How do we minimise transaction costs and provide the incentives for researchers to persist with the vagaries of wider decision making processes as well as ensuring CSIRO adheres to the other recommendations suggested from the Kington (2003) review?

There is also the "politically incorrect" view advanced by many a frustrated scientist that in fact too much involvement in environmental or risk issues by stakeholders and the community will lead to "game playing" within the community for selfish reasons. This poses a fundamental problem for integration research. "The issue is larger than the discrepancies between expert and general public views of environmental risks. Public perceptions of risk have altered, and in some instances stopped, policy decisions by the now familiar NIMBY ("not in my backyard") context" (Fort, Rosenman, & Budd, 1993, p. 185).

So should researchers therefore cut the transaction costs by providing a new form of leadership through starting at the theory end first and influence through brilliance rather than negotiation or persuasion?

5. Where Should Theory Fit in?

The above discussion has emphasised the need for "useful research" with an external focus, and reminded that, in essence, science may be just one interest in determining the right question. Of course this is an over-simplification and there are differences among scientists themselves. In fact, if faced with an applied problem, scientists from differing backgrounds may not agree either on the question or on the answer. This reflects both the training and the personal values of the researcher. In this way diverse researchers resemble diverse values and interests in the community. It all depends on the problem and its interpretation through an individual's training, experience, and values.

This may not be of concern if we wish to view disciplinary scientists as similar to lawyers who present their side of the argument when defining the question on behalf of the people who have funded them (Frickel, 2004). The resolution of the issue can be left to skilled facilitators who lead the discussion towards compromise. In Australia, for example, we have science-based advocates of trees as the preferred solution for dryland salinity. We also have a coterie of supporters for drains. This may well reflect the difference in training (e.g., landscape compared with engineering) as well as the imageries this training creates in terms of the potential for technological fixes for natural environment problems. But to those who pay taxes and therefore expect some leadership (not dictatorship) from scientists, this may not be satisfactory. Should an argument be settled with the aid of good science (social or biophysical) or through sophisticated negotiation procedures? Inevitably often we will have to use both.

One way to ensure the procedural quality of natural resource management arguments is through the creation of procedurally just processes (Lind & Tyler, 1988) that give all parties voice and influence. Nevertheless, even the procedural justice literature demands that participants in negotiation need appropriate levels of information to help them make a decision. Are scientists and social scientists therefore acting ethically in the debate if they do not attempt to look at the emergent outcomes of their own debate?

An obvious way forward is to encourage interdisciplinary or transdisciplinary perspectives on the problem so that a more unified front can be obtained. Indeed for those problems that are not easily solved by a traditional discipline (e.g., hydrological or social psychological problems), the formation of an interdisciplinary viewpoint to contribute to the debate may lead to a more lasting outcome than a temporary truce developed from a well run and fair debate.

The advantages of taking an interdisciplinary approach have been discussed by many authors (e.g., Nissani, 1997). Individual disciplines can get "tired," become predictable, and then a crisis of ideas can ensue, after which, progress is difficult. The introduction of an outsider can create fresh perspectives, new energy and lateral thinking. All of these should be available to decision makers and the community. Outsiders are less prone to ignore anomalies and to resist new conceptual frameworks (Nissani, 1997).

Of course, when developing better understanding, outside perceptions and interdisciplinary thought are not always superior. Sometimes, for example, generalising by analogy from the perspectives of one discipline may result in tenuous conclusions. For instance, the value of borrowing biological theories to explain human organisational behaviour has both its critics and supporters. Nevertheless, it is hard to argue against integrated thinking, particularly when it comes to deriving sustainable solutions for interconnected environmental, social, and economic systems.

The issue is whether the scientist is using her or his role in the development, defining, and answering of questions in a way that can aid the integrated environmental management process. Are there theories relating to integration that can assist scientists in their contribution? If so, can we use theory to go beyond bringing disciplinary perspectives to the table? What does integration theory add to the wider debate beyond common sense or the idiosyncratic creativity of research team members?

One relatively new area of theoretical development that may hold promise is the application of complex systems theory, incorporating organisational theory (Stacey, Griffin, & Shaw, 2000), to assist in examining emergent properties that may occur from different styles of management. By systematically examining, discussing and understanding the interactions between biophysical and human factors through such tools as agent based modelling, surprises from planning are more likely to be avoided (e.g., see Wandersman, 2003). But perhaps just as importantly, processes such as companion modelling can be implemented on

a participative basis (e.g., Barreteau, Garin, Dumontier, Abrami, & Cernesson, 2003), as can other complex systems approaches such as social simulation or network theory (e.g., Moss, Pahl-Wostl, & Downing, 2001).

Scientists can facilitate debate on complex and interdependent problems by using agent based modelling as a tool for discussion, provided they are able to accommodate local knowledge into the model and be willing to discuss the assumptions of the model. If this is the case, the theory and practice of new modes of complex systems analysis that concentrate on the interaction between parts, agents, or nodes of the biophysical system, and within human processes such as the functioning of institutions, can significantly enhance the role of scientists in natural resource management.

Perhaps complex systems approaches are not the only or even the best way of assisting integrative solutions. But the potential shown by these techniques provides a demonstration of how scientists can assist in novel ways in integrated planning environments. The philosophy and implementation of complex systems approaches are also compatible with the view of Nowotny and colleagues (Nowotny, Scott, & Gibbons, 2001) of the need to understand the self-organising capacity of science and society. The fact that there is a rapidly developing literature relating to participative agent based modelling, complete with emerging theories of stakeholder engagement (with the potential for integration with similar theory from a variety of social science disciplines), gives some promise that this may be something that can assist in real life planning.

The argument is not that integrated research is inherently “better” than disciplinary approaches. The key issue is whether we can develop integration-orientated theories that enhance the contribution of scientists to holistic and effective answering of the right question. In simple language, our question should be: How can integration theories place scientists in rewarding roles that will avoid serious mistakes in planning for the environment and managing natural resources?

6. Conclusions

While this review has focused on the case study of CSIRO, it is clear that the issues raised are similar to those in European multidisciplinary programs and the issues surrounding multidisciplinary medical research in the USA. As such, the findings reinforce the need for

organisational and implementation excellence and provide some specific suggestions to do so. In the second part of the paper the issue of where science seems to be evolving in terms of the definition of questions and the role of the scientist are addressed. The material for this section has been derived from personal experience and discussions with other social scientists and economists. It is clear that the issues raised within the confines of CSIRO are compatible with the trends identified by Nowotny and colleagues in describing Mode 2 knowledge (Nowotny, Scott, & Gibbons, 2001).

The first part of the paper shows, I believe, a genuine and concerted attempt by CSIRO to develop integrated research or a "one CSIRO" approach to problem solving although the organisation is obviously still learning how to achieve this goal given its organisational legacy. The Chief Executive Officer continually exhorts staff to "partner or perish." However, the Kington (2003) review of integrated programs and the early development of other integration initiatives within the organisation showed that there are many organisational and administrative issues that will need to be addressed. These will need to be canvassed systematically if CSIRO is to achieve an organisation with all staff members able to mix and match with differing disciplines and for differing problems. None of the changes as described in Exhibit 1 is difficult to achieve, but to do so systematically and across the organisation will require significant adaptability and commitment. CSIRO shares this challenge with many research organisations.

Perhaps the biggest issue facing CSIRO is a cultural change in engaging others, including the general community, in assisting it with designing and answering the "right' questions. This challenge will take some time and effort if it is to succeed. There is no point in having pockets of outwardly focused participative groups in the organisation and others that shun non-scientists and just want to get on with their research regardless of the effects on the wider community. Inconsistencies of this kind are readily spotted by the community and other stakeholders, and can lead to tension, if not addressed. How many integrators does CSIRO need and how many with a disciplinary focus? Not all problems will have 'integrated" solutions. Most importantly, how will integrators and non-integrators get along within a "one CSIRO" system which has overcome divisional barriers?

It is clear to me that the organisational issues are the vital ones to be solved if CSIRO is to achieve and develop theory in this area, particularly theory that will actually help someone eventually. This will take organisational cohesiveness and ongoing evaluation to assist in

improving performance. Such an observation is not new or surprising. In the European context, Bruce and colleagues (Bruce et al., 2004) have identified the importance of getting the organisational issues right if interdisciplinary research is to succeed. Finding the determination to succeed across CSIRO will be a novel outcome in itself. The evolution of initiatives such as the Emerging Science program and the Flagship programs will be followed with interest by those outside the organisation.

Despite having placed an emphasis on organisational issues in this paper, there is much to be gained by CSIRO acknowledging that the role of scientists is co-evolving with societal changes and that this evolution with its emergent properties needs constant evaluation. In my view integrated research is likely to be increasingly demanded by a society seeking sustainable and holistic solutions to environmental problems. Meeting the challenge of answering the right questions in an integrated fashion will need to be aided by the development of theory such as that arising from the complex systems area. If change is promoted in a participative fashion with key stakeholders and the wider society, this may result in scientists finding new partnerships with the community and also a more satisfying role in problem solving.

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