Integrated research: concepts of connection
in environmental science and policy

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Abstract

The idea of integration in research has risen rapidly in both environmental science and public environmental policy since the mid-1990s, and has encouraged innovative relationships between scientists and practitioners in a range of contexts. Yet the concept of integration is broad and ambiguous, which inhibits efforts to learn from these innovations. In this paper I review the different concepts of integration that currently exist in international and Australian science and environmental policy contexts. Drawing on comprehensive examples, I identify twelve thematic categories of integration. The themes encompass integration within science, as well as integration between science and non-scientific partners. They also include integration focused on activities, and on the organisational or institutional structures that govern research activity. These groupings reflect significant differences in the ways science-policy relationships are understood, and the main problems integration is intended to overcome. They serve as a foundation for a framework that researchers, policy-makers and other partners can use to compare and learn from different integrative research approaches. This is a first step towards building a comprehensive understanding of how integration can contribute to better environmental outcomes.

Keywords: integrated research; integration; science and policy; partnerships; sustainable development
1. Introduction

The concept of integration has become a catch-phrase in environmental science over recent years. It has been used to frame research funding policies in both environmental sciences and science more generally, and has been a feature of environmental policy statements from local to national and international levels. This has resulted in the idea of integrated research taking various forms and meanings, with equally varied implementation in research practice. The range of interpretations that prevail is not merely a conversational irritant—“by integrated research do you mean…?”—but also inhibits effective learning about integration in research practice. If integration is to become a useful concept for stimulating innovation and learning in scientific practice, the different meanings need to be clarified, and their broader implications need to be understood.

In a general sense, integration suggests disparate elements being brought together into a more holistic entity. It shares the same etymology as ‘integer’, whole number, for example. There are, of course, many elements within environmental science, and between environmental science and policy that are typically separated by one boundary or another, and hence many candidates for ‘integrated’ research approaches. These include bureaucratic divisions, disciplines, methodological preferences, organisations, institutions, and physical locations. Yet the concept of integration has gone beyond a simple description. It is emerging as a formal concept—or suite of concepts—that is being used to prescribe research activity and the form and function of relationships between researchers and environmental policy-makers and managers. This emerging formalisation forms the substance of this review.
The current state of the concept of integrated research resonates with Rip’s (1997) description of ‘emergent situations’ in science. He writes:

In emergent situations, where there is not yet a shared code or paradigm, there will still be exchange, mutual adjustment, various rules of the game related to existing (local and shared) institutions and groups. From this heterogeneous situation, the elements of what will become a code or a paradigm will emerge, in the sense that some elements start to orient further behaviour of actors, and shape the packaging that is done and the expectations about what will be received. A “reversal” occurs: what were contingent products of action and interaction now start to shape action as if they were forces by themselves. (626)

The presence of multiple definitions and new typologies of integration indicates that we are in a period of ‘various rules of the game’, with a number of candidates for a ‘code’ or ‘paradigm’. In the context of environmental science, Bosch et al. (2003) have noted that there has been a shift in demand by environmental managers away from issue-oriented research inputs toward integrated strategies for natural resource management. Taken together, these points suggest that the concept of integrated research is approaching Rip’s point of ‘reversal’, and that this transition may be driven by demand.

To date there has been little attention paid to questions concerning demand for integration: who is asking for (and paying for) integrated research? How are they defining it? What is its scope, in terms of what gets integrated? How is this influencing scientific practice? Yet those calling for integration potentially play a powerful role in defining what counts as integrated research. Consequently this review focuses on policies that frame the role of research in terms of integration. In it I aim to answer the questions of: how is the concept of integration being used in policy arenas that are directly engaged with environmental science? How do these
different uses relate to each other? How might a comprehensive understanding of demand for integration help both policy-makers and the research community to engage in debates about the ‘emerging code’, and thus enhance learning about innovative, integrative research practice?

To answer these questions I review different concepts of integration that currently exist in science policy and environmental policy contexts. In examining the policies I show variations in the actual use of the terms of integration and integrated research (which I use interchangeably), and the implications of these variations on the ways the relationships between research and implementation are understood. The review is arranged according to three categories. I first discuss general science funding policy; then environment and natural resource management policy; and conclude with environmental science policy as a specific convergence of these two broad areas.

To capture the range of uses of integration, and examine their implications in detail, requires a trade-off between the breadth and depth of the review. I limited the survey first by searching only international and Australian policies, as an example of national level implementation. I chose seven examples of policy where the concept of integration is being applied in an analytical way, or in a way that substantively distinguishes integrated research from other forms of research. The sample includes instances where integration is used as a defining conceptual feature (as in a typology of research approaches, for example), or a decision-making criterion (as in science funding policies, for example). It excludes instances where integration is used as a simple descriptor for one type of research (interdisciplinary sciences, for example). Consequently this review will not list or assess all the organisations that are engaged
in (or using the rhetoric of) integrated research, or all the policies that use the term. Nor have I attempted to make any judgement regarding whether any particular program or organisation is or is not achieving integration. Rather, I have tried to draw a useful balance between breadth and depth by keeping the number of examples small, but selecting those examples that are more detailed and specific in their use of the concept.

I then use the examples as an inductive base from which I build a typology of integration, which in turn forms the basis for an analytical framework. By building the framework inductively, the range of integrated research that is covered is more comprehensive than drawing solely on my own disciplinary background, perceptions or experience of integration. Yet it is also more targeted than a deductive approach might be, as the relevance of the categories can be traced back to actual instances in use.

In the following discussion section of the paper I then make a brief comparison with research approaches that also use integration as a key concept, and apply the framework to some specific examples. This illustrates academic contributions to the formalisation of integrated research, and shows that the framework can be used to compare different integrative methodologies. I conclude with a discussion of whether and how the concept of integration can enhance learning about innovative research practice and effective engagement with environmental policy-makers and managers.

First, though, I will briefly introduce the broader academic debates that are attempting to contextualise the emergence of integrated modes of research.
2. Integration in science: an academic overview

Over the last decade several authors have argued that a range of forces have converged to produce a major shift in science at large. While the terminology varies, one of the key features of this shift is a move away from individualistic, discipline-driven science to utility-focused research that connects research activity across a number of boundaries.

In one of the first major analyses of recent trends in science, Gibbons et al. (1994) delineated the now well-known distinction between Mode-1 (conventional) and Mode-2 (integrative) science. In Mode-2 science, research is not decided within the academic domain alone, but in negotiation with other actors who have various intellectual and social backgrounds, interests and demands. Mode-2 is characterised by transdisciplinarity; heterogeneity and organisational diversity; greater social accountability and reflexivity than Mode-1; and a broader set of criteria for quality control. Gibbons et al. (1994) described the forces underlying the emergence of Mode-2 as increasing capacity for competent research outside academia, combined with information and communications technologies. They argue that together these two forces create increasing demand and supply of specialised knowledge, which in turn fosters closer, more interactive relationships between researchers and those who apply research.

A similar team published a follow-up book (Nowotny et al., 2001) in which they explicitly distinguished between ‘integrated’ and ‘segregated’ modes of knowledge production. Under the ‘integrated’ scenario, the boundaries between science and
society become more permeable. As they write: “Under the new rules of engagement scientists are no longer expected to interact almost exclusively with other scientists; nor does wider interaction with members of other social groups occur only along predetermined and prescribed lines.” (102-3). The integration implied or explicit in these publications encompasses integration across the disciplines, as well as integration between research and practical application, and new organisational forms to accommodate these rules.

Ziman (2000) makes a similar argument about the changing nature of science. He describes the emergence of ‘post-academic’ science, a cultural shift that does not repudiate the goals of conventional science, but rather emerges from it bearing new practical and epistemic perspectives. The trends Ziman notes as driving this “undramatic revolution” (68) largely resonate with the trends identified by Nowotny et al. (2001) in the shift from segregated to integrated research. Ziman’s trends include collectivisation (the need for researchers to confront complex problems entails teams); limits to growth (the financial cost of research is slowing the growth of science); exploiting knowledge (pressure to show value for money increases emphasis on utility of research); and industrialisation (privatisation of research agencies and increased pressure for public-private partnerships). He also includes bureaucratisation of science (more formal organisation, regulation and accountability); and the emergence of science policy.

These accounts of new modes of science have been criticised for the lack of empirical evidence to support their sweeping claims. The most extreme end of this critique is scepticism that there is anything new or different going on at all (Weingart, 1997),
and the view that the Mode-1 Mode-2 distinction may be more a social platform than a “serious, systematic framework for scholarly inquiry” (Shinn, 2002:604). However, most authors appear to concur that there has been a shift in contemporary research, albeit perhaps not as profound or for quite the same reasons. For example, Martin (2003) argues that Mode-2 represents a shift back from an anomalous period of scientific independence post-World War II, to a more typical relationship where research agenda are strongly influenced by ‘users’. He argues that this is a result of increasing market competition, constraints on public expenditure, and increasing importance of scientific and technological competencies. Callon (2003), in the same volume, attributes the rise of ‘hybrid forums’ (which encompass integrated research) to the increasing prevalence of socio-technical controversies and the emergence of concerned groups that build strategic alliances with public researchers.

Aram (2004) places these analyses within longer standing debates over inter- and transdisciplinarity. His review of this complex literature discusses the various definitions of inter- and transdisciplinarity, and the various levels of ‘knowledge integration’ that are embedded in these concepts. He notes that while interdisciplinarity tends to remain an academic activity, transdisciplinary research increasingly refers to “…cooperation by diverse academic experts and practitioners to address real-world problems.” (385). His study points to the philosophical implications that are often overlooked in the typically pragmatic focus of integrated research.

These academic debates suggest multiple ways of thinking about integrated research, packaged in novel jargon and contested causality. Yet while these debates are
continuing, science policy, environmental management, and environmental science policy have been steadily operationalising the concept of integrated research in the form of definitions of funding criteria and performance criteria. The complexity of understanding and managing the environment from scientific, political and social points of view forms the backdrop for calls for integration. Berkhout, Leach and Scoones (2003) have neatly summarised why:

A focus on the environment invites a problem-focus, in which multiple disciplines are brought to bear on a given issue, encouraging a potentially fruitful blending of perspectives. It also requires an engagement with natural, biophysical processes – therefore bringing social science into engagement with natural science debates which have been recharacterising systems as uncertain, dynamic and scale and path dependent. … Issues of environmental change must increasingly address global and cross-border effects, across a diversity of localities, identities and capabilities. This means that environmental issues challenge governance across different scales in a globalizing world. Finally, ‘the environment’ has become a signifier of political consciousness, and of individual and collective reflexivity, leading to a variety of forms of political action, which disturb conventional boundaries and ways of thinking. (10)

These particular characteristics (shared to a large degree by related fields such as development and some aspects of public health) suggest that effective integration is both more necessary, and more difficult, in environmental management than in fields such as commercial product development or engineering. Consequently, there is considerable effort being made to foster integration in environmental research and policy sectors.
3. Demanding integration: science funding and environmental management policies

Demand for integrated research approaches can be readily identified in three arenas: science funding policy in general; environmental science policy in particular; and environmental management policies that incorporate research. The examples presented in this section include major research funding initiatives and environmental management policies. For each example I indicate key words or phrases that highlight what is being integrated in bold typeface, as the first step toward developing a typology of integration.

3.1 Science policy

3.1.1 The European Commission’s 6th Framework Program

The European Commission’s 6\textsuperscript{th} Framework Program is a major research funding program that runs from 2003-2006. The architects of this program have embraced the notion of integration in two ways. First, over 80\% of their €16 billion research budget is directed towards research concerned with ‘Integrating and strengthening the European Research Area’. In this context, the idea of integration is predominantly across nation-state, to build critical mass among the European Union research community and to capitalise on potential synergies across national borders (European Commission, 2002).

The second use of integration in the 6\textsuperscript{th} Framework Program is via a new funding mechanism, “integrated projects”:
The integrated project is the instrument being designed to generate the knowledge required to implement the priority themes. It will do that by integrating together the critical mass of activities and resources needed to achieve ambitious clearly defined scientific and technological objectives. (Directorate General for Research, 2003:1)

A later section offers more detail, describing five forms of integration that the funding body recognises. These are listed in Table 1.

Table 1 documents some of the diverse ways integration can be understood and implemented in a research context. Integration includes connecting the (unspecified) activities of researchers with users and others involved in the application of research results; connecting researchers across disciplines; integration of research and teaching as well as other unspecified boundaries ‘across the research spectrum’. Integration also supports organisational interaction between public academic and private industry sectors. Financial integration reiterates the slightly broader point of resource integration.

3.1.2 Australian Cooperative Research Centres

In Australia, a significant effort to apply the concept of integrated research has been made via the mechanism of Cooperative Research Centres (CRCs). CRCs are research organisations formed by formal agreements between extant organisations and the Australian Federal Government. They are ‘virtual’ centres, in the sense that they do not physically share the same location. Instead, they capitalise on the resources that already exist but are dispersed across different organisations. Some 22% (AU$ 1.82
billion) of the Australian Federal Government’s research budget over the decade 2001-2011 is dedicated to the CRC Program (Australian Government, 2004).

The partner organisations that make up a CRC may comprise a wide range of research and non-research organisations and firms. The CRC Program explicitly encourages integration among the partners through application criteria and through formal review processes. The CRC Application Guidelines highlight the importance of integration, stating that:

\[
\text{… the CRC should result in substantial integration of research activity that goes beyond the existing research efforts of the individual participants. (CRC Program, 1999:6).}
\]

and:

\[
\text{Participants should form collaborative relationships within an integrated research program. Participants should not divide the research program into discrete projects that are carried out solely by individual participants, pursuing their own separate objectives. (CRC Program, 1999:8).}
\]

Following the success of a bid, integration is reiterated through the review process. The Centres are funded for seven years, and undergo a formal review in their second year. In this review the CRCs are assessed on:

The degree to which key user groups, including industry, have been integrated into the CRC as core participants, and have made substantial commitments of resources

[and]

The degree to which the CRC has built links between the participating research groups and organisations, and integrated and enhanced their activities in research and education. (CRC Program, 2001:14).

These formal requirements of the CRC Program specify integration within research both through the configurations of participants in the research projects (projects
should involve researchers from different core partner organisations) and in the sense that the project activities themselves needed to form a coordinated suite of activities rather than an ad hoc collection. The CRC Program also specifies integration as being between the research communities and ‘end users’, across public and private sectors. Recently, this rather qualitative mode of integration has given way to a more technocratic approach, as the program has shifted from supporting both public- and private goods production to a sole focus on commercialisation. While the details of this shift are still being worked through at the time of writing, the partnerships now appear to be defined on contractual specifics such as allocation of intellectual property rights. The integration criteria do not apply to new Centres formed from 2004.

3.2 Environmental and Natural Resource Management policies

3.2.1 World Summit on Sustainable Development

The World Summit on Sustainable Development, held in Johannesburg in 2002, followed on from the highly influential Earth Summit held ten years previously in Rio de Janeiro. While it can be argued that the idea of integration was a central theme at the Earth Summit in 1992, the actual term did not appear in any major statements or documents arising from it. However, at the World Summit on Sustainable Development the terminology gained some currency. The Summit Report articulated the importance of integration with respect to science in both the interdisciplinary and inter-sectoral senses. Article 109 of the Summit Report asserted the need to:

(b) Make greater use of integrated scientific **assessments**, risk assessments and **interdisciplinary** and **intersectoral** approaches;

…

(e) Establish partnerships between scientific, **public and private institutions**, including by integrating the advice of **scientists into**
decision-making bodies to ensure a greater role for science, technology
development and engineering sectors. (United Nations, 2002)

The first quotation suggests that, from the perspective of achieving sustainable
development, science needs to produce outputs that use common frameworks to
overcome the traditional divides of disciplines and issues (such as water versus land).
The second notes that decision-makers share the responsibility for ensuring that
science is brought into management or policy-making. Partnerships across public and
private sectors are suggested. The integration of scientific advice into decision-
making speaks to strengthening connections between researchers and users.

3.2.2 The Intergovernmental Oceanographic Commission: Integrated Coastal
Area Management

The United Nations Education, Scientific and Cultural Organization operates the
Intergovernmental Oceanographic Commission. This Commission promotes an
approach to coastal management called Integrated Coastal Area Management, which
has been mandated by the United Nations and endorsed by the international
community (Intergovernmental Oceanographic Commission, 2004).
The Commission draws on the work of Cicin-Sain et al. (1998) to document five
dimensions of integration that Integrated Coastal Area Management needs to address.
Four of these, **Inter-sectoral integration**, **Inter-governmental integration**, **Spatial
integration** and **International integration** are not predominantly concerned with
science. However they also include **Science-management integration**. Science –
management integration is described as integration among the different **disciplines**
important in coastal and ocean management (the natural sciences, the social sciences,
and engineering) and the **management** entities (Intergovernmental Oceanographic
Commission, 2004).
Thus the Intergovernmental Oceanographic Commission’s conception of integration within the framework of integrated coastal area management covers a broad range. It is primarily concerned with integrating across governance institutions, both vertically (local, provincial, national, international) and horizontally (across departments or functional units concerned with different aspects of coastal management). However it also brings science firmly into that framework, noting both the need for disciplinary integration within science and better integration of science with coastal management.

3.2.3 Integrated Catchment Management and the Murray-Darling Basin Commission

Integrated Catchment Management attempts to bring together all the relevant players with an interest in managing a catchment (or watershed) to develop a more holistic management approach. This includes scientists, community groups, landholders and government agencies at all levels (Hinchcliffe, et al., 1999). In Australia, Integrated Catchment Management emerged as an approach to environmental management in the late 1970s. By the mid-1990s the concept of Integrated Catchment Management had been implemented in policy or legislation by every Australian State government (Bellamy et al., 2002).

The concept of integration in Integrated Catchment Management can be illustrated by the Murray-Darling Basin Initiative, supported by the Murray-Darling Basin Commission. The Murray-Darling Basin is a watershed that covers over a million square kilometres of area, and as such the Initiative is the largest integrated catchment management program in the world (MDBC, 2004a). Significantly, this area crosses
five state and territory boundaries. Tensions and contradictions in management across these jurisdictions, and a related lack of coordination in research, were influential in the Commission seeking a more integrated approach. They describe integrated catchment management as:

… a process through which people can develop a **vision**, agree on shared **values and behaviours**, make **informed decisions** and **act** together to manage the natural resources of their catchment. (MDBC, 2004b)

The reference to visions and values, brings a normative dimension to integration, the need to reconcile different worldviews. While not specifically mentioning research, the reference to ‘informed decisions’ suggests that integrating research and decision-making is part of integrated catchment management. As Bellamy et al. (2002) have noted: “Researching and integrating scientific knowledge has been an underpinning principle of ICM processes in Australia.” (viii).

As this group of examples illustrate, the formal use of the term ‘integration’ has an important history in land and water management and environmental research. While integration does have a more generic use, some environmental policy-makers have formalised the concept in specific natural resource management frameworks. These frameworks are based on the principle that good management requires close, functional relationships among researchers from difference disciplines and with non-scientists.
3.3 Environmental science policies

3.3.1 United Nations Environment Program’s Science Initiative

Integration is a recurring theme in the science activities of the United Nations Environment Program (UNEP), predominantly through its commitment to environmental assessment. As early as 1975 a major UNEP program, Earthwatch, was formally defined as a “dynamic process of integrated environmental assessments by which relevant environmental issues are identified and necessary data are gathered and evaluated to provide a basis of information and understanding for effective environmental management.” (Fritz, 1998:197).

More recently, integration has begun to take a more diverse role in UNEP’s emerging Science Initiative. The Initiative aims to meet the challenges of improving the connections between science and policymaking, and creating partnerships for comprehensive environmental monitoring. While the Initiative is still in its formative stages at the time of writing, it is interesting to note that the report of their consultative process emphasised the need for integrated environmental assessments, but also extended the application of integration to inter-sectoral and inter-institutional coordination (United Nations Environment Program, 2003). The authors wrote:

Scientific institutions agreed that integration is important, especially the integration of the private sector, local government and other organizations (e.g., unions). ... A framework for integration would enhance this process and also help in the formation of institutional arrangements and science-policy dialogs. Institutional coordination was also mentioned by non-governmental organizations, as well as the need for wider participation of industry and government. Integration could also be enhanced through consideration of themes, e.g., energy. Database harmonization at the international, regional and local levels would also enhance sectoral integration. (United Nations Environment Program, 2003:9)
Their enthusiasm for the concept of integration even extended to the final conclusion of the report which stated in part:

Local and regional capacities for integrated assessment must be strengthened and integrated. (United Nations Environment Program, 2003:19)

The emphasis on institutional arrangements signals a shift from perceiving integration as a technical or methodological scientific issue to an issue of building effective relationships between scientists and managers.

3.3.2 Land and Water Australia

Land and Water Australia is a research and development funding body financed by the Australian Commonwealth Government. In their 2001-2006 Strategic Research and Development Plan, Land and Water Australia reoriented their research planning around a suite of integrative themes (Land and Water Australia, 2001). These are based on the human activities that affect management practices: perceiving and valuing the environment; organisation and governance of environmental management; living in and managing the environment; and learning and understanding about the environment. These themes are complemented by managerial arenas such as river landscapes, sustainable primary industries, vegetation, future landscapes and compatible industries. An additional category of ‘cross-cutting themes’ is also included.

Land and Water Australia describe three levels of integration:

coordination — making sure that we are avoiding duplication of effort and that no key issues are falling through the cracks between programs.
synthesis — bringing things together from different programs to create new wholes. … Expressed needs of end-users will drive the development of communication products … based on R&D outputs across several research programs.

synergy — creating new wholes that are greater than the sum of their parts, where individual elements viewed in isolation may be quite useless. This demands a sophisticated approach to program design, where the ultimate contribution that individual programs will make to the whole, is a critical design parameter (Land and Water Australia, 2001:19).

This is an unusual typology, as it allows for a whole range of integrative approaches. It defines the challenges of integration to them as research funders, rather than as an issue solely of concern to researchers and policy-makers or managers. The focus on managerial arenas encourages research that is multi-disciplinary and problem-focused; the ‘human activities’ themes emphasise research that is concerned with the connecting the practical arenas with underlying social or organisational factors.

These examples from environmental management and environmental science organisations illustrate that integration is a key concept in framing the role of research in decision-making. This has been affirmed by a survey-based study by Steel et al. (2004) who found that the 90% of the environmental managers surveyed (n=167) agreed with the statement that: “Scientists should work closely with managers and others to integrate scientific findings in management decisions”. Taken together, the emphasis on integration in each of the sectors reviewed in this section support the claims noted in the academic debates discussed in Section 2. There is clear demand for closer engagement and involvement of researchers both across the research sector and in decision-making arenas. The range of examples also provides a basis from
which these various understandings of integration can start to be analysed and compared.

4. Analysis: which boundaries? What connections?

As noted at the start of this article, in the general sense integration indicates bringing disparate elements into a whole. The key similarities and differences regarding what the different applications aim to integrate is the starting point for this analysis. Table 2 below summarises the keywords that were highlighted in the previous section in column two. Column three assigns these keywords to more generic categories, based on the elements to be integrated.

[Insert Table 2 here]

As the original quotations showed, and the second column of Table 2 reiterates, some policies and statements are quite specific about integration, others are not. Where the terms were vague, such as ‘research activity’, I have indicated the elements that others have specified in similar contexts, and noted the uncertainty with a question mark. The items in column three highlight both the consistencies and diversity of the views of integration presented in the previous sections. 12 distinct uses of the term integration can be identified in these examples. They are integration across:

1. disciplines;
2. research issues, such as water and land;
3. research and teaching
4. data
5. research methods, such as empirical work and modelling;
6. research organisations, such as universities, government agencies, and private laboratories;
7. worldviews;
8. research and application activities such as policy implementation, product development and marketing
9. sectors, such as academia, industry and government
10. management/governance arrangements by scale, such as local, regional and national government
11. management/governance organisations by issue focus, such as departments or ministries of agriculture and environment;
12. resources, such as funding.

This list of subjects is useful in a number of ways. First and most obviously, it shows the extent of the ambiguity of unspecified use of ‘integrated research’. More positively, it also shows that people who are accustomed to thinking about integrated research as one, two, or even several of these categories may be overlooking important aspects of integration. For example, if a research funder has a strong preference for integration across disciplines, he or she may fail to recognise the challenge researchers face integrating across administrative structures such as academic departments. Having said that, there is little to indicate that a ‘more-is-better’ approach to integrated research—incorporating all 12 themes into a framework or approach—will lead to improved outcomes. It does, however, raise the question of which are the most effective groupings of integration, and under which circumstances?
While this study does not attempt to answer this question, some similarities and differences between the themes on the list can be used as a foundation for exploring it further. The first six categories in the list above all refer to integration within the research sector. Disciplines, methods, issues, academic activities, research organisations all reside within scientific organisational structures or refer to research activities. The seventh category, world-views, is often associated with disciplines in a research context, but was also used in the examples to indicate differences in world-view between researchers and, say, policy-makers. The last five categories extend beyond the research sector to include integration between research and non-research organisations, or activities that involve expertise or action beyond that of research. This includes integration with people who apply research in various contexts, their organisational and sectoral ‘homes’, and funding sources. This distinction is not new—many of the authors discussed at the start of this paper noted the internal and external dimensions of integrated research. The prevailing division between inter- and transdisciplinarity has highlighted the ‘within’ and ‘beyond’ science characteristics of problem-focused work, for example.

The other difference that lies alongside the within/beyond research distinction is less commonly noted. This is whether the policies or statements referred to activities, or to structures. Activity-oriented integration includes research methods, issues and disciplines (although where disciplines are replicated in university departments, for example, may also refer to structures), decision-making, and application or dissemination activities. In other words, the integration of what people actually do. In contrast, structural integration includes organisations, sectors and administration. It involves the creation of (or at least, removal of barriers to) connections among the
formal organisational or institutional rules or conventions so that integrated research can take place. The hybrid forums mentioned in Section 2 illustrate this aspect of integration.

These two categories, within/beyond research and activity/structure can form the backbones of a framework that can be used to relate statements of what is to be integrated to questions of how integration is to take place, and the problems it is trying to overcome. This is illustrated in Figure 1.

[insert Figure 1 here]

The two axes of this framework form four quadrants: integration among science activities; integration among scientific organisations or institutions; integration between scientific and non-scientific activities; and integration among scientific and non-scientific structures. This framework shows the scope and primary focus of particular applications of the idea of integration.

The categories of Table 2 are often ambiguous in how they can be placed in the framework. As noted earlier, claims about integration are often vague and open to considerable interpretation. For example, I have grouped integration across issues (e.g. water and agriculture) in the ‘within science, across activities’ quadrant. Others may reasonably argue that integrating water and agriculture is essential to catchment management, and thus belongs in the ‘beyond science, across activities’ quadrant. Indeed, this is partly the point. Examining specific examples in relation to Figure 1 brings these ambiguities to the fore, and encourages analysts to ask questions about
which forms of integration are most appropriate for achieving their goals. In this sense, the function of Figure 1 is not to be an unequivocal map where a particular definition or methodology is in one quadrant or another. Rather, it is a device that people can use to negotiate where their version of integration stands with respect to the divisions between quadrants, and whether that is where they should be. For example, is the most appropriate role of science in integrated catchment management that of providing an integrated product such as a model, or engaging in an integrative partnership with managers, or both?

Similarly, Figure 1 also offers insights into the second question noted at the start of this paper: how do the different uses of the term integration relate to each other? Using the quadrants of Figure 1 we can investigate what different definitions of integration imply or assume about the relationships between science and policy, and the main problems that integration is intended to overcome. The top-left quadrant, integration of activities among scientists, retains a traditional role for science: that of providing advice to decision-makers. It seeks to overcome the problems of fragmentation and the generation of scientific information that does not ‘fit’ decision-makers’ decision contexts. Integration, then, is about providing better advice to policy-makers by producing interdisciplinary, more complete, comprehensive research outputs, as in the World Summit for Sustainable Development’s calls for integrated assessment modelling, for example. The top-right quadrant, while still concerned with largely the same aim of providing better advice, frames the problem as one of needing better structural connections between researchers. Organisational structures such as discipline-based university departments, and incentive systems that favour specialisation and fragmentation over practical applicability are regarded as the
primary barriers to efforts to achieve policy-relevant science. This is illustrated by the UNEP Science Initiative’s commitment to linking databases.

In the lower left quadrant, integrating activities beyond science, the relationship between researchers and ‘non-researchers’ is often characterised as one of partnership, rather than as senders and receivers of scientific advice. The main problem is viewed as a lack of communication and connection between researchers and research users. For research to become relevant, managers or other potential ‘users’ need to be actively engaged in defining research questions, designing the research and perhaps even conducting it. In turn, researchers work with policy-makers to design scientifically informed policy. The 6th Framework Program’s ‘vertical integration’ exemplifies this approach. In the lower right quadrant, ad hoc partnerships between researchers and non-research participants are regarded as less problematic than organisational and institutional barriers that prevent researchers and users from working together more effectively. This is solved by the creation of ‘transdisciplinary’ hybrid forums that bring researchers and policy-makers or other partners together under one organisational structure, such as Cooperative Research Centres.

The framework in Figure 1 is a simple representation of the ways the different approaches to integration can be separated out, rather than the ways they can and do come together. Most of the examples presented in this paper span more than one quadrant and some, such as the European Commission’s 6th Framework Program, span them all. This is to be expected, given that they were selected for their comprehensive treatment of the concept of integration. However, the framework is
also useful in identifying and articulating the assumptions and implications of more limited uses of the term. By asking two relatively straightforward questions—does the integration extend beyond science? And does the integration involve new organisational or institutional arrangements?—answers to the rather less straightforward questions of how is the relationship between science and policy being construed? And what is seen as most problematic in connecting science and policy?—can also be identified.

5. Discussion: research sector integration

In the introduction it was proposed that demand was driving the formalisation of integration, and the previous two sections have shown that research funders and management agencies are clearly active in promoting integrated research. This section explores the concept of integration as applied in the research sector, and examines whether the framework developed in the previous section sheds new light on existing approaches.

A complete survey of the research sector is beyond the scope of this paper, but several observations can be made. Environmental sciences have a relatively long history of advocating the need for greater integration between science and policy, in spirit if not in name, and developing formal approaches to achieve it. Examples include Adaptive Management (Holling, 1978); Participatory Action Research (Chambers, 1983), Post-normal science (Funtowicz and Ravetz, 1993); and Integrated Assessment (Marten and Rotmans, 1999). However, to the extent that these approaches use the concept of integration, it tends to be as a general description rather than as a theoretically specific construct.
The concept of ‘sustainability science’—science in the service of a transition towards sustainability—has offered an overarching framework that emphasises integration. The authors who coined the phrase (National Research Council Board on Sustainable Development, 2000; Kates et al., 2001) proposed seven ‘core questions of sustainability science’. Integration is prominent in three of these questions: integrating scientific issues via new methods such as modelling; integrating research data sources; and integrating science with management. They write:

Sustainability science will therefore have to be above all else integrative science—science committed to bridging barriers that separate traditional modes of inquiry. In particular, it will need to integrate across the discipline-based branches of relevant research described above—geophysical, biological, social, and technological. The same can be said for sectoral approaches that continue to treat such interconnected human activities as energy, agriculture, habitation, and transportation separately. In addition, sustainability science will need to integrate across geographic scales to eliminate the sometimes convenient but ultimately artificial distinctions between global and local perspectives. Finally, it will need to integrate across styles of knowledge creation, bridging the gulf that separates the detached practice of scholarship from the engaged practice of engineering and management. (National Research Council Board on Sustainable Development, 2000:283).

In other words, by bringing together disciplines, issues, geophysical scales, and connecting across science and management, sustainability science encompasses both ‘within’ and ‘beyond’ science integration. However, while integration across organisations or institutions may be implicit (for example in bridging scholarship and
practice), the authors emphasise integration across research and management activities rather than structures.

Some researchers have used the concept of integration as a key concept in their methodologies for empirical research. Quinlan and Scogings (2004) emphasise the ‘two tasks’ that sustainability has set for scientists: “On the one hand, [scientists] needed to describe the interaction between bio-physical and socio-economic processes, to improve scientific knowledge of ecological relationships, and so establish a foundation for re-thinking how to do Development … On the other hand, they had to combine research with project planning and implementation.” (537). Under the subheading of ‘The concept of Integrated Research’ they write that “The ideal is for combined thought and action by different scientists in the design of research, in field work, in analysis, and in development planning; in short, a crossing of disciplinary boundaries.” (539) So while their overarching statement of the problem extends ‘beyond science’ to the connections between research and implementation, their proposed solution rests within the academic sector.

Shogren et al. (2003) have applied a methodology based on integration to the ecology and economics of conservation on private land. They write “Protecting nature on private lands effectively requires scientists and policy-makers to integrate economic and ecologic indicators of success and failure. Such integration can work at many levels—the technical integration of models, the policy integration of methods, and the political integration of mindsets.” (233). They go on to expand this trilogy of integration, and illustrate its application in their case study. They conclude that: “These three different types of integration require explicitly modelling the feedback links between systems, aligning ecosystem goals with personal landowner goals, or
accounting for the appropriateness of policy change to a variety of perspectives.” (241). Their approach to integration acknowledges the human dimensions of ecological management by emphasising the importance of policies and personal incentives or goals. However the integrative practice lies with the skills of the systems-oriented researcher, in which policy-makers are largely data sources rather than active research partners.

These examples, while few, offer some interesting insights. In particular, the empirical methodologies both acknowledge that the need for integration extends beyond the research sector, but their solutions rest largely within research (see also Kinzig et al. 2000). This raises the important question of whether research methodologies can or should step beyond their boundaries to include policy-makers and other stakeholders in any capacity other than as data sources. The sustainability science statement calls for integration across the ‘gulf’ between research and practice, but does not offer any new research methodologies for actually doing this integrative work.

It is also noteworthy that the examples shown do not make reference to each other, nor do they refer to any of the versions of integration noted in the policy literature. This lack of coordination further supports the view of integration as ‘emerging’ according to various rules of the game, in the academic arena as well as policy demand. The interest in integration on the part of the research sector attests to the potential for new and innovative research practice. Yet the imbalance across the quadrants of Figure 1 shows discord between the policy statements that consistently call for greater integration across research and application and research approaches.
that focus on integration across disciplines. There is little doubt that better interdisciplinary work can make research more relevant to policy-makers, and methodologies that enhance learning in this area are important. However, applying the framework of Figure 1 suggests that the research sector also needs to engage in, and contribute to, learning from the institutional and organisational innovations that foster integration.

7. Conclusion: is integration still a useful term?

The situation described at the start of this paper suggests that the concept of integration is at a cross-roads. Given the diversity of ways in which integration is used in environmental science and policy, it might be tempting to argue that it can never be more than a general descriptor. More cynically, it could be regarded as a catch-phrase soon to be discarded as one of last decade’s intuitively appealing, but ultimately vacuous, concepts. Alternatively, it can become a powerful tool in understanding the relationships between science and environmental management, enabling learning and accelerating innovation in research practice. These two scenarios are extreme ends of a spectrum rather than discrete outcomes, but what will push integration towards the useful end, rather than the discard pile?

There can be little doubt that the multiplicity of meaning across so many areas, with the various definitions and typologies that are beginning to emerge, generates confusion. Yet the profusion also has a positive implication: that integration captures something common in attempts to understand and strengthen relationships between environmental research and management, across a wide range of activities and sectors. The general level agreement that integration offers new and exciting
possibilities for well-informed, robust environmental management strategies is fostering organisational, methodological and political innovations. Experiments in hybrid research organisations such as the Cooperative Research Centres, the promotion of new research paradigms like sustainability science, and strong financial commitments to integrated modes of research are examples of the different contexts in which people are working out the details of how to realise these possibilities.

This review has shown that despite the shared terminology of integration, the experience and expertise people are gaining in this area are largely disconnected. This leaves questions of how to develop more effective, integrated practices—in research, science policy and funding, and environmental management—either unanswered or answered by too many voices saying different things. The lack of coherence can also lead policy-makers to undervalue integrative processes and outcomes, simply because they are hard to identify and account for, especially in comparison to more ‘solid’ goals such as commercialisation.

The need for a shared code or paradigm is apparent, but it must be recognised that it can only emerge from dialogue among those voices, if all the relevant partners are to accept it. If integration is to deliver what it is assumed to promise—better environmental management outcomes—lessons will need to be drawn from all groups with a stake in achieving those outcomes. Understanding what people mean by integration, and being able to recognise the implications of those meanings, is a first necessary step towards being able to identify what works in practical terms. The framework presented in this paper offers one tool to help encourage, expand and enrich that learning process.
Acknowledgements

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<table>
<thead>
<tr>
<th>Description</th>
<th>Integration of…</th>
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<tbody>
<tr>
<td>Vertical integration</td>
<td>… the full “value-chain” of stakeholders from those involved in knowledge production through to technology development and transfer. Principal stakeholders, including users, should be involved and help gear the project towards attaining the expected impact.</td>
</tr>
<tr>
<td>Horizontal integration</td>
<td>… a range of multidisciplinary activities.</td>
</tr>
<tr>
<td>Activity integration</td>
<td>… various research activities from across the full research spectrum with each other and with other types of activity, including take-up activities, protection and dissemination of knowledge, training, etc, as appropriate.</td>
</tr>
<tr>
<td>Sectoral integration</td>
<td>… private and public sector research organisations, and in particular between academia and industry, including SMEs.</td>
</tr>
<tr>
<td>Financial integration</td>
<td>… public and private funding, with overall financing plans that may involve the European Investment Bank and co-operation with Eurêka.</td>
</tr>
</tbody>
</table>

Table 1: European Commission 6th Framework Program forms of integration.

<table>
<thead>
<tr>
<th><strong>Source:</strong></th>
<th><strong>Keywords</strong></th>
<th><strong>Theme:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. European Commission 6th Framework Program</td>
<td>Knowledge production and technology development and transfer, Multidisciplinary, Research activities, Research activities and dissemination, Research and teaching, Public and private sectors, Public and private funding</td>
<td>Research and application</td>
</tr>
<tr>
<td>3. World Summit on Sustainable Development</td>
<td>Interdisciplinary, Intersectoral, Science and decision-making, Public and private institutions</td>
<td>Research and teaching</td>
</tr>
<tr>
<td>UNEP Science Initiative</td>
<td>Issues, Data, Private sector, government etc, Science-policy dialogs, Themes</td>
<td>Issues, Research and application, Sectors, organisations, Issues</td>
</tr>
</tbody>
</table>
“Sector’ can be used in two ways. In this example the WSSD have used ‘sector’ to refer to groupings such as ‘environment’ ‘development’ ‘health’ etc. I have used the term ‘issue’ to refer to this category, and used ‘sector’ to refer to the structures that people work within, such as government, industry, community, research.

Table 2: Themes of integration

<table>
<thead>
<tr>
<th>Land and Water Australia</th>
<th>Sectoral integration</th>
<th>Sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coordination</td>
<td>Research issues</td>
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<tr>
<td></td>
<td>Synthesis</td>
<td>Application activities</td>
</tr>
<tr>
<td></td>
<td>Synergy</td>
<td>Ideas</td>
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</table>
Figure 1: a framework for analysing integration