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A conceptual template for integrative human–environment research

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Abstract

Knowledge integration, the blending of concepts from two or more disciplines to create innovative new worldviews, is a key process in attempts to increase the sustainability of human activities on Earth. In this paper, we describe a 'conceptual template' that can be used to catalyse this process. The template comprises (a) a list of high-level concepts that capture the essential aspects of any significant human–environment problem, plus (b) broad lists of low-level basic concepts drawn from a range of disciplines. Our high-level concepts, which we call 'conceptual clusters', are labelled *Dynamics & System*, *Organisation & Scale*, *Controlling Models*, *Management & Policy*, *Adaptation & Learning*, and *History*. Many of the clustered, lower-level concepts are synonyms and thus provide possible connections between disciplines—for this reason we call them 'nexus concepts'. We suggest that a conceptual template like that presented here can provide strong support to the initial phases of integrative research programs.

Keywords: Sustainability; Human–environment research; Knowledge integration; Dialogue; Cognition; Conceptual blending

1. Introduction

Research into environmental and natural-resource issues is concerned with extending our understanding of how the world works and of how we can better manage our interaction with that world. As local, regional and global communities have become more aware of environmental degradation and the complexity and fragility of coupled natural-social systems, there has been an increasing focus on issues of sustainability. Concurrently, because effective policy-making must start from a good understanding of the system to be managed, there has been a growing dissatisfaction with research that is carried out in a purely reductionist, discipline-based manner. Discipline-based research is necessary, because it provides us with essential insights into the mechanisms of our world, but such efforts are by definition focussed on sub-systems of that world and cannot provide the systemic approaches that are needed to support the transition to sustainability.

This problem is now widely recognised, and around the world efforts are being made to develop integrated (interdisciplinary, transdisciplinary) approaches to research and training. This work has led to the creation of new subjects such as human ecology, conservation biology, political and historical ecology, environmental and ecological economics, and environmental history that include and encourage integration

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(see, for example, Crumley, 1994; Balée, 1998), and has extended the 'disciplinary reach' of existing subjects (such as geography and anthropology) that already have a strong systemic focus.

But the long-standing separation of the disciplines has produced profound divisions between the natural sciences, the social sciences and the humanities. We no longer have the luxury of glossing over this situation. Our efforts to develop effective policies need support from almost all forms of human knowledge. In particular, we urgently need to improve our understanding of the interactions between people and their biophysical environment—interactions that are driven by human aspirations and social and cultural institutions, but that are ultimately constrained by the laws of nature. In the face of mounting evidence that human activity is beginning to have a significant negative impact on the environment, and that environmental degradation can severely affect human welfare, the integration of knowledge across a wide range of sources is not an option. It is essential.

Many researchers in the international community have taken up the integration challenge. For these workers the question is no longer why, but *how* and *what*, to integrate. There are two obvious, overlapping areas of action. First, it is necessary to tackle the well-known and formidable *cultural barriers* to integration. These barriers include the fear and lack of trust that leads many individuals and 'schools' to defend their disciplinary territory, discipline-focussed funding and institutional arrangements, and the divisive effect of discipline-based peer review processes (see, for example, Snow, 1959/1965; Saul, 1992; Pickett et al., 1994, 1999; Dovers, 2001; van Kerkhoff, 2002). The most tenacious barriers reflect attitudes that begin to grow early in childhood and that are reinforced throughout our lives. Many of these attitudes are the inevitable products of our educational systems—systems where children often learn to focus exclusively on 'the right answer', to hide the errors and differences of opinion that can lead to deeper insights, and to see specialisation as the primary sign of educational achievement (Snow, 1959/1965). The erosion of such cultural barriers will take considerable time and patience, in part because their foundations lie so deep within the structure of our societies, and in part because the process must necessarily engage scholars and administrators who are not yet committed to integration.

Second, it is essential to develop ways to overcome existing *conceptual barriers* to integration. While many practitioners recognise the need to articulate their system of fundamental beliefs, assumptions and theories, and are willing to try, the process of comparing knowledge across disciplinary boundaries can turn out to be surprisingly frustrating and time consuming. Indeed, it can be hard enough to find common ground even within academic disciplines—particularly between observers and theorists. Moreover, as the magnitude and complexity of the environmental problem becomes ever more apparent, there is a growing call from many parts of the world for a greater plurality in the use of knowledge—for approaches that, in addition to insights from a wide range of disciplines, include community and traditional knowledge of the kind that is produced 'on the job'. Knowledge generated through everyday activity within a community is usually seen as 'just common sense', a designation that reduces its value in the eyes of 'professionals'. As soon as we move to include these more tacit forms of knowledge, the task of integration becomes even more daunting. There is an urgent need for practical methods.

In this paper, we focus on the second of these areas of action. For a brief introduction to our group (The Oslo Group) and its aims see Wasson and Underdal (2002). Recently, the Global Analysis, Integration and Modelling (GAIM) Task Force of the International Geosphere Biosphere Program (IGBP) produced a list of 23 questions intended to guide and challenge the global-change research community (Schellnhuber and Sahagian, 2002; Sahagian, 2002). These questions summarise a wide range of issues that are central to the task of including people in Earth System studies. Question 14 of the GAIM list draws attention to the need for us to develop practical methods for the integration of knowledge across disciplinary boundaries.

The integration we seek is not just across disciplines. We also need better integration within disciplines—including the integration of research results across different temporal and spatial scales, between different schools of thought, and between empirical and theoretical approaches (see, for example, the extensive discussion given by Pickett et al., 1994). It is particularly important to strive for a better blending of observation and theory because, while each strand depends on the other for support, the ratio of the two varies greatly from discipline to discipline. For example, observation and theory are typically in reasonable balance in the physical sciences, theory dominates in many areas of economics, while the reverse is true in much of ecology. Theory is strongly rejected in some areas of the humanities. In our attempts to develop practical methods for integrated human–environment research one of our principal aims must be to establish a widespread and rich interplay between observation and theory, with a particular focus on the difficult task of blending highly empirical disciplines with those that are highly theoretical.

2. Points of departure

Human systems are complex and adaptive. An adaptive system operates by gathering "information about its environment and its own interaction with that environment, identifying regularities in that information, condensing those regularities into a kind of 'schema' or model, and acting in the real world on the basis of that schema. In each case, there are various competing schemata, and the actions in the real-world feedback to influence the competition among those schemata'' (Gell-Mann, 1994, p. 17). The challenge, in the case of human–environment systems, is that of developing management schemata or theories that lead to sustainable operations. Here we use the term 'management' to refer to any goal-directed, manipulative interaction with our surroundings (including other people).

We will use the term 'theory' in a broad sense to mean a schema, model or conceptual framework that is believed to capture essential aspects of the way that some part of the world works. The term will be used to refer to a wide range of conceptual structures, from unconscious and tacit mental models, through the descriptive theories typical of many of the environmental and social sciences, to the formal mathematical theories of physics and economics. For convenience we will consider the terms 'schema', 'model', 'mental model' and 'controlling model' to be synonymous with 'theory'. A set of theories relating to a given area of activity will be called a 'conceptual framework' and we will refer to an individual's full collection of theories as his or her 'worldview'.

Not all of our theories are predictive, but we all use theory-based predictions as the basis for decisions and to anticipate events. Theories summarise our understanding of the world and thereby make our knowledge more useable. By emphasising what we believe to be the most important experiences, concepts and values, they help us to test and extend our knowledge, and enable us to approach communication, research, and management tasks in a coordinated, coherent manner.

We will define a 'feedback system' to be ''something composed of discernable parts (elements, agents) that interact to constrain each others' behaviour'', and 'dynamics' to be ''the way that the state of a system changes over time in response to both external (exogenous) forces and internal (endogenous) forces'' (Newell and Wasson, 2002, p. 5). The concept of feedback system has arisen in many disciplines in response to the need to explain commonly encountered forms of non-linear behaviour that are caused by the mutual constraints (feedback loops) that operate between the parts of the system. A study of the dynamics of feedback systems can help us to explain such 'emergent' behaviour and can improve our ability to design good policy (Senge, 1990; Forrester, 1961, 1969; Jervis, 1997; Sterman, 2000). Throughout this discussion the word 'system' will always mean 'feedback system'.

Sustainability requires good management, and good management requires good policies. Policies summarise our theories of cause-and-effect relationships within the managed system. They specify the actions that we anticipate will move a system from a specific observed state toward a more desirable state. Thus, it is not possible to design good management policies, with predictable outcomes, without a good understanding of the dynamics of the managed system. To maintain a focus on issues of system stability and resilience, therefore, we need to focus on people's informal and formal theories of the dynamics of systems. It is particularly important to look at the 'models of causality' that are used to inform management decisions. Accordingly, we identify the general area of *knowledge* most relevant to integrative research to be the basic dynamical concepts, conceptual structures, and models of causality that various individuals and groups use to explain how the world works, how it responds to human pressures, and how to best manage human–environmental systems in a sustainable manner.

If the knowledge that we seek to integrate consists of disparate models of causality, then the *integration* process cannot be simply a matter of building a 'shared language'. Single words take multiple meanings when different speakers have different models and examples in mind. We must be particularly wary of superficial approaches to developing 'better communication' that only *appear* to remove conceptual confusion—''[a] common language may still hide divergent assumptions'' (Pickett et al., 1999, p. 304).

The development of a genuine shared language, and the mutual comprehension that it supports, requires the prior development of shared conceptual frameworks. But, mutual comprehension is not the main aim of integration—it is a necessary precondition for integration. The aim of integrative research is to use a range of different worldviews as the basis for a better understanding of human–environment systems. We therefore define 'integration' to mean the *process* of constructing new worldviews by blending concepts from two or more existing worldviews. Our definition is narrower than that adopted by Pickett et al. (1994), who include the simple addition of largely unmodified parcels of information. We reserve the term 'integration' for highly creative acts of individual or collaborative 'conceptual blending' (Turner, 2001; Fauconnier and Turner, 2002) from which emerge completely new (innovative) ways of seeing the world. We have used the word '*integrative*', rather than 'integrated', in the title of this paper to emphasise the importance that we place on the *process* of conceptual blending.

People from a wide range of cultural and educational backgrounds can be shown to share many experience-based, fundamental concepts (Lakoff and Johnson, 1999). As we enter more specialised domains, however, our experiences begin to diverge and we develop a corresponding range of worldviews. At the high levels of specialisation typical of reductive research programs, it is usual to find that the conceptual frameworks of scholars from different disciplines are incommensurate in significant respects. To overcome the resultant isolation, we need integrative methods that avoid arcane techniques and depend, as far as possible, on the kinds of everyday reasoning and language used by specialist and non-specialist alike.

Finally, there are two subject areas that provide necessary parts of the foundation of an integrated approach to human–environment research. The study of feedback systems is the first of these fields. The second is cognitive science. While awareness of the importance of systems approaches is growing rapidly within the international research and management communities, the same is not true of cognitive science.

Cognitive science is the study of how people conceptualise the world. It is an interdisciplinary endeavour that works to blend evidence and insights from anthropology, computer science, linguistics, philosophy, psychology, and neurophysiology. Early work in this field was preoccupied with studies of the mind in its computer-like aspects, and so was focussed on formal structures, symbol processing, and 'thinking as computation' (Gardner, 1985), but the subject has continued to develop rapidly. Recent work, particularly in cognitive linguistics, has begun to produce a down-to-earth view of human conceptual processes and products. Lakoff and Johnson (1999, p. 78) call this new approach "second-generation cognitive science", characterising it as "the cognitive science of the embodied mind". Among the most important of the results of this work are demonstrations that much of our thought depends on 'conceptual metaphor'. Accessible introductions to these empirical studies of human cognition, and their implications for a wide range of fields, are now available (see, for example, Lakoff and Johnson, 1980, 1999; Lakoff, 1987, 1996; Lakoff and Turner, 1989; Lakoff and Núñez, 2000; Turner, 2001; Fauconnier and Turner, 2002; and the references cited therein).

Since its inception cognitive science has been characterised by a productive interplay between observation and theory. This balance has helped the field mature to the point where it can now make crucial contributions to the development of theoretical frameworks and practical methods for integrative human–environment research. Furthermore, because second-generation cognitive science depends particularly on analyses of the way that we use everyday language, it promises to support our attempts to develop accessible integration methods.

3. A conceptual template for integrative research

The primary methodological challenge inherent in attempts to develop integrated approaches is that of crafting ways to guide research without imposing excessive constraints—this is essentially the age-old question of the possibility of deliberately enhancing creativity (Shekerjian, 1990). An indication that this is possible comes from David Bohm's work on dialogue (Bohm, 1980, 1996). The accessibility and effectiveness of Bohm's ideas have been demonstrated in workshops, and his methods have had a significant impact on attempts to establish learning organisations (Senge, 1990; Senge et al., 1994, 2000; Isaacs, 1999). Nevertheless, in its most powerful form, dialogue is not efficient; it requires large groups, essentially no agenda, and an acceptance of time scales measured in years. Few members of modern (often dispersed) research teams can afford to engage in such a resource-intensive, open-ended processes. In practice, we need approaches that are more focussed and analytic than pure dialogue, but that retain its essential openness and adaptability. We will use the term 'focussed dialogue' refer to this type of process.

Given the generally inchoate nature of research, together with our inability to predict which areas of thought will lead to useful new theories, we need to be cautious whenever we seek to increase efficiency by limiting the content of our deliberations. For this reason, it is safest to approach an integrative project at two levels simultaneously. At the higher level, the research team needs to wrestle directly with the focal problem or issue that gives shape to their project. This 'head on' attack is the approach normally adopted in interdisciplinary studies and it has the potential to reveal disagreements and misunderstandings. Such differences of perspective can then act as valuable pointers to areas where members need to focus their integration efforts.

But a high-level approach is not enough. Unless team members have already made some progress towards a common conceptual framework on which they can base a shared, detailed technical language, they will find it difficult to recognise, let alone take full advantage of, the most promising clashes of worldview. In other words, the likelihood that a group will develop a powerful integrated approach to high-level problems will depend in large measure on their ability to identify the underlying *points of contact* between their worldviews—that is, to isolate low-level, fundamental concepts that are common across the disciplines to be integrated. We will refer to such shared basic concepts as 'nexus concepts' to emphasise their potential to reveal conceptual links between apparently disparate worldviews.

A practical way to initiate and manage the required simultaneous top-down-bottom-up process is for the research team to construct what we will call a 'conceptual template'. A conceptual template consists of:

A. A short check-list of high-level concepts that capture the essential aspects of all significant human–environment problems, and

B. Associated with each of the concepts in the A list, a broad list of low-level concepts taken from the disciplines and worldviews to be integrated.

The relationship between the A and the B lists is hierarchical to the extent that each of the high-level concepts (from the A list) has associated with it a broad collection of low-level concepts (one of the B lists). We will refer to the high-level concepts of the A list as 'conceptual clusters' to emphasise their relationship to these clusters of lower-level concepts. The low-level concepts of the B lists will be referred to as 'potential nexus concepts'.

In Table 1, we present a template of the type proposed. Our conceptual clusters are listed in the first column of the table. In four cases (*Dynamics & System*, *Organisation & Scale*, *Management & Policy*, and *Adaptation & Learning*) we intend the cluster to represent two strongly overlapping high-level concepts. Our lists of potential nexus concepts are presented in the second column.

It is important to recognise that the process of constructing and refining a conceptual template is intended to help a research team to initiate and sustain richly connected discussions, without imposing too rigid a point-of-view. For this reason, the conceptual clusters need not represent a tight categorisation of potential nexus concepts, and the lists of potential nexus concepts need not be strictly hierarchical decompositions of the conceptual clusters. Also, the various lists are not mutually exclusive—a key word used to label a broad conceptual cluster can also be used to refer to a more narrowly construed nexus concept, and a potential nexus concept can be listed as a member of more than one conceptual cluster.

We suggest that the construction of the list of potential nexus concepts is a crucial part of the *integrative process*. Any research team can construct useful nexus lists by first isolating concepts that are considered to be fundamental in the disciplinary areas to be integrated—team members should work individually and take care to preserve the language conventions of each discipline. The separate lists should then be collated and searched for broad natural grouping that can be identified with our conceptual clusters. The process of grouping the initial collated list of terms, to form conceptual clusters, should help team members to recognise synonyms and so increase their chances of identifying nexus concepts.

Team members must be prepared to spend a significant amount of time in *detailed* discussions of the meaning of words. The task is made difficult by the complex mappings that can exist between words and concepts. At one extreme are homonyms—single words or phrases with multiple meanings. A salutary example is provided by Grimm and Wissel (1997, p. 323) who present an inventory of "163 definitions of 70 different stability concepts" all of which occur in published discussions of 'ecological stability'. An ever present danger, in attempts to develop a shared conceptual framework, is that of failing to recognise homonyms and the confusion that they cause. The search for low-level nexus concepts can help research teams to attack this problem. The process can reveal previously undetected homonyms and so support discussions of the different meanings that the various team members assign to the *same* technical term.

Table 1
A conceptual template for integrative research

Conceptual cluster	Potential nexus concepts
Dynamics & System	Change, behaviour, state variable, causal loops, positive feedback, vicious cycle, bandwagon effect, negative feedback, self-regulation, homeostasis, gaol-seeking, the invisible hand, policy resistance, boundary, synergy, emergence, stocks and flows, integration, rate, differential, delays, non-linear behaviour, surprise, variation, switch and choke points, bottlenecks, process, structure, function, complex adaptive systems, detail complexity, dynamic complexity, exogenous and endogenous variables, thresholds, ecosystem, slow and fast variables, resilience, stability, robustness, open system, closed system
Organisation & Scale	Hierarchy, heterarchy, semi-lattice, homogeneity and heterogeneity (spatial, temporal, and inter-agent), ecological zones, patches, matrix, holarchy, slow and fast variables, units of analysis, simplicity, complexity, landscape patterns, level of organisation, scale of observation, local, global, power, institutions, organisational structure
Controlling models	Model, mental model, conceptual model, model of causality, theory, concept, metaphor, frame, schema, cognition, risk perception, values, beliefs, 'subjective' and 'objective' knowledge, myth of nature, conceptual framework, worldview
Management & Policy	Mental models, forecasts, measurement and indicators, sampling, data quality, decision making, management, policy application, policy use, policy resistance, agency, drivers, response options, variation and variety, conflict and competition, compliance and resistance, issue and policy focus
Adaptation & Learning	Cognition, mental model, perception, creativity, surprise, adaptive strategies, indicators, anticipation, risk perception, values, beliefs, memory, modelling, communication, powerful ideas, dialogue, social learning, culture, resilience, stability, networks, trial and error, patterns of failure, experience
History	Change, events, trigger events, catastrophic events, patterns, path dependence, diversity, narrative, behaviour over time, time series, evolutionary processes, synchronic, diachronic

At the other extreme are synonyms—two or more words or phrases that label a single concept. For example, terms like 'self-regulation', 'policy resistance', 'homeostasis', 'goal seeking', and 'the invisible hand' all refer to the effects of 'negative feedback'. Richardson (1991) discusses the use, by early investigators in the social sciences, of terms such as 'vicious circle', 'the principle of cumulation', 'bandwagon effect', 'self-fulfilling prophesy', and 'schismogenisis' to refer to the phenomenon that is now commonly called 'positive feedback'. While the use of undetected synonyms hides common meanings, synonyms are essential pointers to possible nexus concepts.

The nexus lists that we present in Table 1 are idiosyncratic. They are neither general nor exhaustive. They refer to disciplines of concern to us in our collaborative work, and thus reflect our particular interests and worldviews. On the other hand, we consider our list of conceptual clusters to be general and reasonably complete. It represents a checklist of high-level issues that we believe must be addressed in *all* attempts to understand human–environment systems. In the following paragraphs we briefly state why we consider each of these conceptual clusters to represent an essential aspect of human–environment research.

3.1. Dynamics & System

The behaviour of human–environment systems cannot be understood in terms of linear chains of cause and effect. Their behavioural complexity arises endogenously from the mutual constraints imposed by the parts of the system on each other. The consequent feedback effects can cause a range of unexpected and unwanted responses to apparently straightforward management actions (Tainter, 1988; McPhee, 1989; Richardson, 1991; Meadows et al., 1992; Tenner, 1996; Jervis, 1997; Sterman, 2000; Newell and Wasson, 2002). It follows that an understanding of the non-linear dynamics of feedback systems is one of the foundation stones of an integrated approach to human–environment research. It is also important to recognise that, because of its wide applicability, system theory must necessarily form a significant part of the conceptual foundations of any true interdisciplinary language (von Bertalanffy, 1969; Abraham et al., 1992).

3.2. Organisation & Scale

The behaviour of a feedback system depends on its internal organisation; that is, on the network of interactions between its parts. One of the principal challenges in the study of human–environment systems is to understand the interactions between phenomena that occur at different temporal and spatial scales. In hierarchical systems there is a direct correlation between scale and organisational level. The coupling between the parts of an heterarchical system can be much more complex—particularly when human perceptions and interventions are involved (Alexander, 1965; Kontopoulos, 1993; Crumley, 2003). Thus, our ability to build integrated models with adequate explanatory power depends directly on our understanding of issues of organisation and scale. In addition, our ability to establish effective integrative research depends on us understanding (and countering) the crippling effects of the current practice of organising research on the basis of hierarchically structured disciplines.

3.3. Controlling models

All human perception, thought and action depends on mental models (theories, cognitive frameworks, worldviews). Such models exert a controlling influence over the behaviour of individuals and their interactions within society. Furthermore, the perceptions and actions of the members of research teams are just as much controlled by their mental models as are the perceptions and actions of the 'subjects' of their investigations (Kuhn, 1962; Clarke, 1972; Chalmers, 1976; Saul, 1992; Collins and Pinch, 1993). It follows that all scholars, even those in disciplines that eschew formal theory, use a variety of theories to guide their work. We can expect to make little real progress in our attempts to understand the dynamics of human–environment systems, or our attempts to build integrative research methods, until we accept the need to include studies of human cognition in our agenda. Our chance of achieving success in both of these aspects of our endeavour depends directly our ability to see the world through the eyes of other people. Useful references include Lakoff and Johnson (1980), Adams (1995), and Lakoff and Johnson (1999).

3.4. Management & Policy

A distinguishing characteristic of human–environment systems is that they are 'managed'. It is not possible, therefore, for us to understand and influence the dynamics of such systems without developing an understanding of the active role played by managers and policy-makers. While the field of management science and operations research is usually focussed on improving management and policy-making processes, it can also help us to appreciate the systemic impact of human decision-making and action (Forrester, 1961, 1969; Senge, 1990; Sterman, 2000). It is equally important for us to try to understand and improve the way that research and research teams are managed—for example, many of the operational policies that are widely accepted within the academic community are inimical to integrative research (Pickett et al., 1999).

3.5. Adaptation & Learning

Adaptation is a process that operates in both natural and artificial systems. In all cases it involves 'learning from experience' to improve the fit between an organism (system, organisation) and its environment (Holland, 1992). Adaptive processes are, therefore, of basic concern in any study of ways to improve the sustainability of human–environment systems. The process of learning from experience in management contexts depends on our ability to detect patterns of policy success and failure (Ashby, 1952/1965; Kolb, 1984; Argyris and Schön, 1996; Newell and Proust, 2005). The effects of complexity and uncertainty can make such 'adaptive management' extremely difficult (Holling, 1978; Walters and Hilborn, 1978; Holland, 1992; Walters, 1986; Walters and Holling, 1990; Lee, 1993; McLain and Lee, 1996; Dovers and Mobbs, 1997). A better understanding of the way individuals and groups learn in complex systems is necessary if we are to accelerate our approach to sustainability (Pahl-Wostl, 2002). We also need to be aware of the ways that research groups learn from experience so that we can maximise the effectiveness of our endeavours.

3.6. History

Adaptive mechanisms of all kinds require the use of history (Holland, 1992). Methods of adaptive management are no exception. First, we need to remember and retain those approaches that have worked well in the past. Second, in order to develop an understanding of the dynamics of complex human–environment systems, we need to observe the way that a wide range of behavioural variables change over a variety of time scales. Because some of these changes will be unexpected, and can take tens or hundreds of years to appear, a sound approach to adaptive management requires a broad range of historical observations that stretch over times that can greatly exceed human lifetimes. Given that we cannot easily experiment with human–environment systems, and that deleterious effects can have 'locked-in' by the time they are detected, we cannot afford to ignore the lessons of the past (Lowenthal, 1985; Neustadt and May, 1986; Boyden, 1987; Crumley and Marquardt, 1987; Cronon, 1993; Dovers, 2000; McNeill, 2000; Sterman, 2000; Newell and Wasson, 2002; Proust, 2004).

4. Conclusion

In this paper, our aim has been to generate insights into the practical problems encountered in integrative human–environment research. We consider that those who seek to blend knowledge from the natural sciences, the social sciences and the humanities need to develop approaches that:

- utilise rich interactions between observation and theory,
- depend on both reductive research and integrative group processes,
- nurture imagination and creativity while remaining reasonably efficient,
- are accessible to people from many backgrounds and worldviews,
- focus on the use of clashes between worldviews to catalyse new insights,
- emphasise basic dynamical concepts and models of causality, and
- take account of the cognitive nature of both 'subjects' and 'researchers'.

As an example of a practical approach to the task of developing methods that satisfy these criteria, we present a 'conceptual template' that links a set of high-level 'conceptual clusters' with lists of lower-level 'nexus concepts' (Table 1). We believe that such templates can play several key roles in integrative research

First, they can help in the search for research topics that will be important within the wide international effort to reach sustainability. In this context, the high-level conceptual clusters can be used as a checklist of major research areas that require intensive observational and theoretical effort. On the basis of the discussion presented in Section 3 (above) we consider that studies of the dynamics of human–environment systems are of paramount importance, because they have the potential to guide and cohere our overall knowledge-integration efforts. Specific concerns within this general arena include the interaction between phenomena at different temporal and spatial scales, human cognition, the processes of management and policy-making, the process of adaptation, and the development of analytical uses of history.

Second, they can provide workable approaches to knowledge integration. They can do this by emphasising the need to search for nexus concepts—basic concepts that appear to be different, when seen from existing disciplinary points-of-view, but that turn out to be equivalent when looked at more fundamentally. Such connections provide the necessary starting point for conceptual blending and can contribute to the construction of a genuine shared language.

Third, they can encourage us to investigate the nature of the research team itself. The research team is a subsystem of the system under investigation because it influences, and is influenced by, the wider system. It follows that *all* of the high-level concepts listed as conceptual clusters in Table 1 must be addressed in attempts to understand the behaviour of the research team and to design research approaches that will be effective and adaptive. Such investigations need to be a routine component of any integrative research project.

Modern cognitive science can play a particularly important role in the research itself and in the development of integrative research methods. First, it is not possible to develop an understanding of the dynamics of human systems without studies of human cognition. The interacting 'parts' of human systems are people—cognitive 'agents' whose behaviour is controlled by their mental models. Cognitive agents can learn from experience. That is, they can change their own mental models, and the perceptions and behaviours that are controlled by these models, in response to events that they perceive as important. Whether such changes are made consciously or unconsciously, they can significantly alter the dynamics of the wider system. Second, the development of conceptual templates and other approaches to focussed dialogue, and their use in attempts to establish productive cross-disciplinary conversations, will be accelerated if we can improve our understanding of the nature of human understanding and the processes whereby new ideas emerge from the blending of old ideas.

While our attention in this paper has been focussed on the development of practical methods for conceptual integration, we remain deeply aware of the strength and persistence of existing cultural, institutional and social barriers to integration. Nevertheless, we believe that individuals and small groups can contribute in essential ways to the rapidly growing international effort to alleviate the situation. The crucial step is to *do* integrative research. We need to initiate projects that help us to learn from experience, that allow us to test proposed integration methods, that *demonstrate* the value of integrative research, and that promote the growth of trust and understanding across disciplinary boundaries. Such practical activities are essential in our attempts to forge the *similarities* between our worldviews into robust communication links—links that are strong enough to enable us to use the *differences* between our worldviews to create powerful new approaches to sustainability.

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