# Integration and Implementation Sciences: Building a New Specialisation[1]

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## *An Overview of Integration and Implementation Sciences*

Researchers, funders and research end-users are increasing appreciating that new research skills must be developed if human societies are to be more effective in tackling the complex problems that confront us. Researchers must collaborate and integrate across traditional boundaries both within and outside the research sphere, as well as become more involved in the implementation of their research in policy, product and action. There is now a critical mass of researchers who have been developing theory and methods to deal with complexity, uncertainty, change and imperfection in order to integrate across disciplines, 'knowledges', cultures, organisations, and between research and its implementation. The development of such theory and methods has been through their application in a diverse range of interdisciplinary problem-focused areas of national and global importance. However these efforts have typically been isolated, with application limited to specific fields, with low levels of intellectual cross-fertilization and learning, and with limited exploitation of the significant synergies between approaches. There is now growing acceptance of these methodologies in mainstream research and as increasing numbers of researchers are attracted to these approaches, there is considerable reinventing of the wheel.

The time is ripe for coalescence and co-ordination – for bringing these approaches together as a new specialisation of Integration and Implementation Sciences.

In essence the specialisation draws together five key theoretical and methodological strands – systems thinking, participatory methods, complexity science, diverse epistemologies, and inter- and trans-disciplinarity – as well as a host of undocumented methods, which have been developed to respond to specific problem-based needs. The vision is to bring together and provide a clear identity for a large and critical 'college' of peers.

Like statistics and epidemiology, the specialisation will advance through application to a diverse range of problems, so that collaboration with research teams that have advanced content expertise is central. The contribution of Integration and Implementation Sciences will be to increase, and enhance the quality of, use of systems thinking, participatory methods, complexity science, diverse epistemologies, inter- and trans-disciplinarity and other integrative and implementation methodologies. These will complement, rather than replace, traditional disciplinary and specialist perspectives. Such research also involves the development of new partnerships with policy makers, business and civil society. Indeed finding ways to work with research end-users that accommodate respective interests and safeguard academic freedoms is an important challenge. New roles, such as

boundary spanners and knowledge brokers, are being developed, and also need clarification and systematisation.

Collaborations between researchers with skills in Integration and Implementation Sciences, researchers with advanced content knowledge and research end-users (including those affected by the research) will enhance the ability to tackle complex social, environmental and technological problems, as well as improving the accessibility of Integration and Implementation Sciences approaches, approaches which are themselves considerably strengthened through the collaborations.

### *Why a New Specialisation?*

*Calls for New Approaches*

Researchers, research funders, policy makers, business and civil society are grappling with how research can best meet pressing social, environmental and technological challenges.

A 1999 UNESCO report[2] stated:

> *… it must be recognized that the relationship between scientific research, education, technological innovation and practical benefits is much more diverse and complex today than in the past, and frequently involves many players other than researchers. The progress of science cannot be justified purely in terms of search for knowledge. In addition, it must be defended … through its relevance and effectiveness in addressing the needs and expectations of our societies.*

Similarly, in the context of sustainable development, Agenda 21, a key document generated at the 1992 Rio Earth Summit and being implemented world-wide, called for:

> *supporting new scientific research programs, including their socio-economic and human aspects, at the community, national, subregional, regional and global levels, to complement and encourage synergies between traditional and conventional scientific knowledge and practices and strengthening interdisciplinary research related to environmental degradation and rehabilitation* (Article 35.9[a] UNCED 1992[3])

The OECD[4] has also made a similar point about the knowledge-based economy:

> *The science system, essentially public research laboratories and institutes of higher education, carries out key functions in the knowledge-based economy, including knowledge production, transmission and transfer. But the OECD science system is facing the challenge of reconciling its traditional functions of producing new knowledge through basic research and [education] … with its*

> *newer role of collaborating with industry in the transfer of knowledge and technology.*

A recent report by Australia's Chief Scientist[5] stated that

> *Integrating the innovation system across all points can increase the chance of generating more products and processes that enhance our lifestyle. The innovation system is dependent on strong links between all players, government, industry and research performers.*

and further:

> *By and large, our competitors and economic partners are adopting different combinations of integrated measures to strengthen their capacity to innovate. Although the pace of progress across these countries fluctuates, they are constant in their drive towards knowledge-based economies.*

Gibbons, Nowotny and colleagues[6] have called for recognition of "Mode 2" knowledge production. Here problems are defined in the context of application rather than a disciplinary framework, the focus is on developing a transdisciplinary approach, the research is carried out by heterogenous non-hierarchical groups that come together transiently and that are based outside universities, the researchers interact with the relevant social actors to ensure a greater degree of social accountability, and quality is judged by a wider range of criteria, using reflexive processes. Mode 2 knowledge production challenges the traditional role of universities.

Other analyses have reflected on the essential elements of universities that must be protected in this era of change. A collection of essays by Australian academics on "Why Universities Matter"[7] focuses particularly on values and ideals of university life and work. In the US context, Bok[8] focuses particularly on pressures on universities to commercialise, examines what universities can learn from business, and cautions against activities that can undermine or distort the foundations of academic work.

*Implementing New Approaches*

Grappling with the new role for research has not been confined to rhetoric. Policy makers, in particular, have used their funding clout to bring about change in the conduct of research. I provide only a small number of examples here, drawing particularly on the Australian context which I know best.

In Australia, the Cooperative Research Centres Program, established in 1991[9] is a clear example where researchers are charged with crossing disciplinary and organisational boundaries, as well as extending beyond the scientific domain. Integration is part of the Cooperative Research Centres' mandate, but they are left to define what integration means and how they will achieve it[10].

In the CSIRO (Commonwealth Scientific and Industrial Research Organisation; Australia's premier non-University based research organisation), the importance of integrating research both within the organization and beyond it has been recognized as a key challenge for the future. For example, their most recent strategic plan[11] states:

> *We have decided that many of the land and water issues affecting the sustainability of agriculture, mining, mineral processing, manufacturing and the built environment can best be dealt with via large-scale integrated work … with appropriate advisory and management mechanisms in place to ensure that customer groups in the relevant production-based sectors can exert appropriate influence on those projects.*

Further, CSIRO has recently introduced a program of research and development in Social and Economic Integration, which seeks to incorporate social and economic sciences and perspectives into its traditionally biophysical research areas[12].

Land and Water Australia is one of Australia's leading funding bodies for research and development in natural resource management. They have recently adopted integration as a key theme for their current and future development. Their 2001-2006 Strategic Plan[13] states that

> *… to be useful and influential, … R&D must be closely integrated with other policy instruments and with the objectives of key stakeholders at policy and management levels. This is a major priority of the Land & Water Australia Board and a critical emphasis within this Strategic R&D Plan.*

There have also been major developments in other countries. Of particular importance is the European Commission's 6th Framework Program funding mechanism, which allocates over 80% of its 16 billion Euro budget to projects that 'integrate and focus' European research. It has further introduced 'integrated projects' as a new funding mechanism within that program[14].

The US National Science Foundation has "Promote Partnerships" as one of its "three core strategies that guide the entire agency in establishing priorities, identifying opportunities, and designing new programs and activities":

> *Collaboration and partnerships between disciplines and institutions and among academe, industry and government enable the movement of people, ideas and tools throughout the public and private sectors. Furthermore, these partnerships optimize the impact of people, ideas and tools on the economy and on society*[15].

The 2001-2006 Strategic Plan of the National Science Foundation also recognises that "The escalating complexity of science and engineering is moving research toward a collaborative mode with greater focus on intellectual integration" (p. 11).

*Examples of Issues where the Key Deficiency is Lack of Integration and Implementation*

All of these initiatives are responses to the growing appreciation that a major deficiency in the ability to tackle key national and global problems lies in the inability to amalgamate knowledge created by different disciplines with the experience of key actors and interest groups and then to effectively use that knowledge to bring about social improvement.

For example there are 10 risks described in the 2002 World Health Report[16] which account for one-third of premature deaths world-wide. These are risks for which proven cost-effective interventions are available. But human society seems unable to implement integrated solutions in a wide-spread, large-scale and coherent manner.

Despite some successes, in many areas concerned with sustainability, such as global climate change and biodiversity loss, research evidence and consensus among leading researchers about recommended actions has had little impact on government policy, business practice or the actions of local communities in either rich or impoverished countries[17].

Many factors contribute to the inability to implement integrated interventions, including:

- disciplinary, intra- and inter-organisational, and sectoral silos, reinforced by dominant institutional structures, assumptions and reward systems,
- marginalisation and fragmentation of successful research approaches,
- lack of system-wide reflection on and learning from case studies,
- inability to "scale-up" successful small scale interventions, and
- lack of recognition that barriers to integrated implementation are amenable to research. Too often these barriers are greeted with resigned frustration and a view that that they are too hard politically, too sensitive culturally and too intransigent on an individual level.

The examples above show that the calls for improved integration and implementation are widespread and diverse. Nevertheless, while they broadly run along the same themes, the calls do not cohere into a single, easily definable problem or solution. One of the tasks for Integration and Implementation Sciences will be to define the similarities and differences across this range of contexts, and so build a more robust, sophisticated and subtle approach to these issues.

*Marginalisation of the Existing Critical Mass of Researchers*

As I outline below, there are increasing numbers of researchers developing skills in integration and implementation. But while it can be argued that there is the critical mass of researchers to provide the foundation for a new specialisation, the field is far from cohesive. Instead, the field is characterised by:

- relatively small research groups operating in limited networks, many outside formal academic institutions. Those operating inside Universities tend to be independent centres or an uncomfortable fit within a larger department.

- multiple small professional associations[18], which conduct relatively small-scale conferences and which have few links with each other. Unlike the annual conferences of many of the established disciplines and specialisations, which have 20,000 or so participants, attendance at these conferences is likely to be of the order of 500 people. The point is not that large conferences are necessarily better, but that the "college" represented is substantially larger in the established academic areas.

- no well-established high-impact journals. Although there is a growing number of journals[19], many are newly established and some are only being published sporadically.

- an orientation to consultancy work, which is in high demand from government agencies, business, and other practitioners.

- an enthusiastic undergraduate and postgraduate student body, which faces very limited career opportunities within universities.

- no clearly defined curriculum and no clearly defined relationship with established disciplines and specialisations. There is teaching in both undergraduate and graduate areas, but the development of curriculum is somewhat idiosyncratic, with no agreement on core curriculum elements or on standards or accreditation. There are no standard textbooks. There are also different views about whether students should be required to have a solid education in a discipline before being educated in Integration and Implementation Sciences.

- no unifying name or mission. While some areas that are embraced by Integration and Implementation Sciences seek cohesiveness through associations such as the International Society for the Systems Sciences and Action Learning, Action Research and Process Management, there is little overlap, even though there are many important synergies.

Marginalisation has many consequences for the field. The preponderance of small groups that are not well networked leads to considerable duplication and reinventing of the wheel. Productive cross-fertilisation of ideas is limited, which in turn means that the field does not reach its potential in terms of progress. The practical demand for the

approaches encompassed under Integration and Implementation Sciences by policy makers, business, and other practitioners and the associated emphasis on consulting, often leaves little time for reflection, let alone for theory and methodology building.

Multiple groups of small size have costs associated with lack of economies of scale. For example, such groups often have no administrative support, with a disproportionate extra load on research and teaching staff. A disproportionate amount of effort may also have to go into fund raising, especially for self-funded groups either inside or outside the academy. In time the enthusiasm and energy of staff is ground down, limiting opportunities for networking, let alone innovation.

All this can also contribute to low standing within the academy and a perception that the field lacks rigour and attracts only low quality staff and students. This perception is exacerbated by the lack of high impact journals and the other accoutrements of established disciplines and specialisations.

Even so, there are costs to developing a specialisation. The current diffuse networks have the benefit of inclusivity, and there will certainly be debate and dispute about the boundaries and mission of the new specialisation. But the debates can be structured to help sharpen thinking and to develop a greater sense of collegiality among researchers who are now only dimly aware of each other.

### *What Does Integration and Implementation Sciences Cover?*

Two of the defining characteristics of Integration and Implementation Sciences are firm rooting in practical application and the centrality of collaboration. Individuals can make only limited progress in isolation.

Further, Integration and Implementation Sciences have a broad reach in the theory, methods and problems engaged. The approaches used in Integration and Implementation Sciences aim to provide more effective ways of tackling complexity, uncertainty, change and imperfection. These approaches build on systems thinking, participatory methods, complexity science, diverse epistemologies, inter- and trans- disciplinarity, and a host of undocumented methods, which integrate across disciplines, ‘knowledges’, cultures, organisations, and between research and its implementation in policy, products and practice.

#### *Complexity, Uncertainty, Change and Imperfection*

**Complexity** has many dimensions, including an extensive array of factors, with both linear and nonlinear connections and interdependencies and a range of relevant political, cultural, disciplinary and sectoral perspectives. In addition, geographical and temporal scales can be huge.

A necessary adjunct to complexity is **uncertainty**. In dealing with any complex problem, there will always be many unknowns, including about ‘facts’, causal and associative

relationships, and effective interventions. Some unknowns result from resource limitations on research; some result from methodological limitations; and some things are simply unknowable.

The unknowns are compounded by constant **change**; change occurring on many fronts including biological evolution (eg the development of new communicable diseases), scientific, technological and economic developments, in international relations and manifold intended and unintended consequences of local, national and international policy and programs.

Perfect knowledge and solutions are impossible. **Imperfection** too has many dimensions. Dealing with complexity involves setting boundaries to the approach taken and where boundaries are set is crucial in determining what is included, excluded and marginalised. Uncertainty and change also necessarily lead to imperfection. Further, social issues are deeply contextualised so that an excellent solution in one person's eyes is anathema to another.

*Systems Thinking, Participatory Methods, Complexity Science, Diverse Epistemologies, Inter- and Trans- disciplinarity and Other Approaches*

The key theoretical and methodological strands underpinning Integration and Implementation Science are systems thinking, participatory methods, complexity theory, diverse epistemologies, inter- and trans- disciplinarity and a host of undocumented methods. These provide a range of conceptual and methodological tools for dealing with complexity, uncertainty, change and imperfection, including modelling, decision and risk analyses, deliberative democracy processes, principled negotiation processes and so on.

Systems thinking

Systems thinking is the twin of analytical thinking and concerns itself with the properties of wholes, rather than parts. Systems thinking encompasses several schools of thought[20] and most texts on systems thinking are centred on an historical description of the development of the field, as a counter to reductionism and, depending on the branch of systems thinking, also positivism[21]. While many systems methods have been developed[22], less progress has been made in terms of agreement on key theoretical concepts. Checkland[23] suggests that there are two sets of common elements:

- emergence and hierarchy, and
- communication and control.

For Integration and Implementation Sciences, hierarchy is valuable in terms of providing a structured way of thinking across scale, showing that systems are not closed, providing a big picture view, including interactions between local and global, and showing linkages, including between sectors and stakeholders. Hierarchy also sets the context for emergent properties, in other words properties that exist at one scale, but not at others. For example, wetness is an emergent property of water, a property that cannot be predicted from its component gaseous elements, hydrogen and oxygen.

Communication and control are important in terms of understanding vicious and virtuous cycles, effective points of intervention, and sources of unintended effects.
Troncale[24] is aiming to unify the physical and life sciences by developing a broader range of common elements:

- Hierarchies and emergence to deal with scale
- Flows, interactions, networks to deal with supply
- Boundaries, limits and fields to deal with identitySymmetry and duality to deal with form
- Feedback and regulation to deal with adjustment
- Stability and equilibrium to deal with constancy
- Cycles and cycling to deal with tempo
- Chaos and origins processes to deal with beginnings
- Variation, development and evolution to deal with change.

There is likely to be considerable value to Integration and Implementation Sciences in a detailed consideration of these common elements and their application to complex social, environmental and technical problems. There has already been considerable work on boundaries as social and personal constructs, which determine what is included, excluded and marginalised and the intimate link between boundary judgments and value judgments[25].
Systems thinking, then, provides tools for dealing with complexity and, through risk analysis and similar methods, for dealing with uncertainty. There is still considerable scope for development of systems theory and methods. There is growing appreciation of the need to work with affected stakeholders in understanding any particular system, but considerable development in linking systems thinking and participatory methods is still warranted. Much systems thinking occurs within a positivist framework, but some forms of systems thinking have embraced different epistemologies, for example critical systems thinking is located in a critical social science perspective[26]. But the value of marrying systems thinking with different epistemologies still remains largely unexplored. Systems thinking, of course, was the foundation for complexity science and systems thinking is highly congruent with inter- and trans-disciplinarity.

Participatory methods

Participatory methods are various forms of structured engagement between researchers and relevant social actors, such as community representatives, business groups and policy-makers[27]. They recognise the importance of individuals, societies and cultures as aspects of complexity.

Participatory methods encompass a wide range of engagements[28] and can involve from two to many parties and a range of disciplines and sectors; they can be short or long-term; they can challenge elites or be controlled by them; and they can vary in the degree to which they empower marginalised groups. Participatory methods enable practitioners and researchers to learn together about problems of mutual interest in a way that provides reciprocal benefits. They can combine their perspectives to build new concepts, insights and/or practical innovations, which they could not produce alone. Brown and

colleagues[29] have developed a framework for thinking about participatory methods, which can provide an underpinning for Integration and Implementation Sciences.

The framework has four key elements:

- Paradigms, goals and interests
- Relationships and organisation
- Methods and technologies
- Contextual forces and institutions.

In other words, engagement between researchers and practitioners must take into account different social, political and ethical paradigms, different engagement goals and interests and different expectations about accountability. Further, the relationships and organisation must be able to accommodate power differences, build trust, and develop effective control, ownership, work-division and decision-making processes.

Methods and technologies can be divided into four types: a) focused puzzle solving, b) issue exploration and agenda setting, c) intervention and assessment and d) long-term domain development[30]. Participatory focused puzzle solving methods are appropriate when answers are needed to well-defined problems. They make efficient use of the comparative advantages of each party and do not require expensive on-going relations. Issue exploration and agenda setting methods are appropriate when multiple views are needed for understanding complex, ill-structured problems. They allow many voices to be involved in identifying issue patterns and implications and set the stage for wide participation in problem solving. Participatory intervention and assessment methods document, analyse and improve the quality of interventions and best practices. They focus on existing programs and activities and are particularly useful for identifying costs and benefits of possible solutions. Finally, participatory long-term domain development methods involve ongoing co-inquiry to build perspectives, theory and practice in new domains. These methods are particularly useful in providing in-depth analysis over the longer term of poorly understood problems. They can produce new paradigms for understanding intractable problems and lead to fundamental changes in theory and/or practice.

The final element of the framework is contextual forces and institutions, which involves taking into account the broad range of global, national and local political, social, economic and other forces at play at the time of the engagement. It also takes into account the impact of the auspices under which the participatory methods are conducted and of the institutional bases of the researchers and practitioners.

Participatory methods therefore provide ways of bringing stakeholders into the consideration of complex problems. Ideally this allows those affected to have a say in how uncertainties and imperfections will be dealt with. There is however, still little to guide researchers on which methods to use and little consideration, outside individual experience, of key issues, such as how to build trust. The need for closer links between systems thinking and participatory methods has been outlined above. This is also true for

links between complexity science and participatory methods, but the need here is even less well recognised. There are also important challenges in linking participatory methods and diverse epistemologies. For example, in positivist frameworks, participation often involves fairly superficial 'consultation'. On the other hand, interpretivist frameworks, which value all views equally, provide little guidance on how complex decisions should be made. Despite their names, inter- and trans-disciplinarity generally include involvement of affected stakeholders, so that there are close links with participatory methods[31].

Complexity science

Complexity science has spun off from systems thinking and specifically tackles systems with self-organizing, emergent properties and nonlinear dynamics. Much of complexity science is highly mathematical and other conceptual approaches are poorly developed.

Complexity science deals with systems that share some or all of the following characteristics[32]:

- Comprised of many elements or subsystems connected together in irregular ways
- Spanning a large range of dimensions and scales
- Having non-linear connections between the elements of the system
- Exhibiting hysteretic or irreversible behaviour
- Having interaction between simpler elements which allows self-organisation, that is the emergence of complex behaviour that is not determined by information or controls imposed externally.

Key concepts in complexity science include[33]:

1. Emergent order, namely that spontaneous order and organisation can arise from flux and disorder in natural systems
2. Adaptive, evolutionary, self-organisation, namely that systems can change actively and evolve over time
3. Non-linear dynamics, namely that the whole is much more than the sum of the parts, and that properties of whole can be unexpected, complicated, and mathematically intractable
4. Dissipative structures, namely that life spontaneously evolves from simple to complex, and
5. With regard to factors that influence the evolution of complex adaptive systems: disturbance or perturbation, namely the edge of chaos where forces of order and disorder compete and attractors, namely the tendency of an evolving system to move towards a particular state.

Higginbotham and colleagues[34] have applied complexity science to thinking about health, but the principles they have developed have broader relevance to Integration and Implementation Sciences, namely that:

- Local interaction can produce global order and global order can affect local behaviour
- The role of disturbance or perturbation can be both creative and destructive
- Small changes to initial conditions can generate massive changes to system behaviour
- Dynamic interaction of local and global levels of complex systems determines their properties. Such interaction may be subject to ordering influences that are internal to the system or may be universal features of all types of complex adaptive systems
- Interactive causal relationships exist within and between entities and are at their richest at the edge of chaos, the point between order and disorder
- Complex systems can self-organise and evolve towards states of increased complexity
- Complex adaptive systems can form patterns and follow predictable paths of development. The identification of attractors or states, to which a system finally settles, is one clue as to why certain patterns (order) and not others are createdThe properties of complex adaptive systems cannot be reduced to their constituent parts
- There is order in what appears to be chaotic; order can spontaneously arise from fluctuations or perturbations within a system.

Of all of the approaches described here, complexity science is the one best established within universities. It is an area which is currently attracting considerable funding and development for its mathematically-based approaches. But there is extensive scope for development in the application of complexity science to on-the-ground problems and in making complexity science accessible and understandable to a range of stakeholders. Complexity science tends to be narrowly inter-disciplinary, in other words it brings together disciplines that are closely related (such as mathematics, engineering, statistics) and tends to be framed within positivist epistemology.

Diverse epistemologies

Appreciating diverse epistemologies involves valuing different ways of understanding the world. In terms of Integration and Implementation Sciences this has two aspects. One is appreciating the different world-views of different social actors. The second is appreciating that different epistemologies can guide the conduct of research.

Along with growing appreciation that people view the world differently, there is increasing emphasis on the development of tools for understanding different world-views and for enabling diverse groups to work together[35]. Often this has centred on diverse groups within the same cultural context, but there is now also growing interest in the development of transcultural competence[36].

Much has been written about different epistemologies that guide the conduct of research, but I will focus here on illustrating this using Neuman's[37] comparison of positivism,

interpretive social science and critical social science. These epistemologies are compared on a number of dimensions of research.

1. The reason for research:

Positivism: to discover natural laws so that people can predict and control events

Interpretive social science: to understand and describe meaningful social action

Critical social science: to smash myths and empower people to change society radically

2. The nature of social reality:

Positivism: consists of stable preexisting patterns or order that can be discovered

Interpretive social science: consists of fluid definitions of a situation created by human interaction

Critical social science: is conflict-filled and governed by hidden underlying structures

3. The nature of human beings:

Positivism: self-interested and rational individuals who are shaped by external forces

Interpretive social science: social beings who create meaning and constantly make sense of their worlds

Critical social science: creative, adaptive people with unrealised potential, trapped by illusion and exploitation

4. The role of common sense:

Positivism: clearly distinct from and less valid than science

Interpretive social science: powerful everyday theories used by ordinary people

Critical social science: false beliefs that hide power and objective conditions

5. What theory is:

Positivism: a logical, deductive system of interconnected definitions, axioms and laws

Interpretive social science: a description of how a group's meaning system is generated and sustained

Critical social science: a critique that reveals true conditions and helps people see the way to a better world

6. Characteristics of an explanation that is true:

Positivism: is logically connected to laws and based on facts

Interpretive social science: resonates or feels right to those who are being studied

Critical social science: supplies people with tools needed to change the world

7. Characteristics of good evidence:

Positivism: is based on precise observations that others can repeat

Interpretive social science: is embedded in the context of fluid social interactions

Critical social science: is informed by a theory that unveils illusions

8. The place for values:

Positivism: science is value-free; values have no place except when choosing a topic

Interpretive social science: values are an integral part of social life; no group's values are wrong, only different

Critical social science: all science must begin with a value position; some positions are right, some are wrong

While many researchers are clear about the epistemological approach they use in their work, for others the importance of understanding their epistemology has never been raised. They are likely to conduct research as they have been taught, without questioning the underlying world-view. In the past, this was largely true of researchers using positivist epistemology, but as other approaches have become more common, it is now also true of researchers using other epistemologies. It is now also becoming more common for researchers to use a mix of elements from different epistemologies.

One of the challenges for Integration and Implementation Sciences is the development of hybrid epistemologies[38], especially in encouraging social actors to broaden their world-views. In terms of research, there is also the challenge of integrating across different epistemologies.

Inter- and trans-disciplinarity

Interdisciplinarity synthesizes discipline-specific insights, while transdisciplinarity aims to produce a common conceptual framework through which disciplinary perspectives can be joined.

It can be useful to contrast multi-, inter- and trans- disciplinarity. In a multi-disciplinary approach different disciplines separately examine the same problem and their findings are placed side-by-side to gain a more comprehensive view. In an inter-disciplinary approach, different disciplines work together on the same problem, looking particularly for areas of synthesis and overlap. A trans-disciplinary approach aims to develop a new common conceptual framework that provides a new level of coherence for the different disciplines.

In essence, inter- and trans-disciplinarity are both processes for achieving integration. In some instances this is confined to integration across disciplines, but increasingly includes integrating also the perspectives of research end-users or those affected by the research.

Klein[39] suggests that there are five phases in the interdisciplinary process:

- Having all the disciplines abstain from approaching the topic solely along the lines of their own monodisciplinary methods

- Trying to formulate in an interdisciplinary way the global question, acknowledging all aspects as well as the total way the aspects are networked
- Translating the global question into the specific language of each discipline
- Constantly checking the answer to this translated question by checking for its relevance in answering the global question
- Agreeing upon a global answer that must not be produced by any one particular discipline but rather integrating all particular answers.

She also argues that there are four models of integration:
1. *Common group learning* - a group bounded process in which the final outcome is common intellectual property.
2. *Modeling* - a process in which a formal model is the key integrative device, whether constructed by the team or imported from outside.
3. *Negotiation among experts* – a process that focuses on the overlaps and linkages between separate expert-produced outcomes. 4. *Integration by leader* – based on dividing and allocating parts of the problem according to members' expertise and using a 'hub and spokes' communication pattern

In a transdisciplinary process there are two general ways of developing a common conceptual framework, namely:

- having an individual synthesise findings from a multitude of disciplines to provide a comprehensive explanation of a complex issue, or
- constructing a team who bring their combined resources to focus on problem-solving[40].

Inter- and trans-disciplinarity are in many ways the fore-runners of Integration and Implementation Sciences, particularly focusing on integration. The terms themselves are limiting, because of their explicit focus on 'disciplines', even though in practice integration ranges outside the academic realm and is oriented to producing change. In addition, the foundations of inter- and trans-disciplinarity in systems thinking, participatory methods, complexity science and diverse epistemologies tend to be implicit rather than clearly articulated.

<u>Other approaches</u>

Many researchers have developed their own approaches and insights to dealing with complex social, environmental and technological problems. Some of these have not been documented and doing so is an important task for Integration and Implementation Sciences. In addition, approaches and insights that focus on the 'sharp end' of implementation may well eventually warrant a category of their own.

Van Kerkhoff[41] has characterised four dimensions of research, the last of which is particularly relevant here. The first dimension is the individual creativity that is the core building block of research. This can be directed to generating new pieces of knowledge or to integrating new and/or existing pieces. The second dimension involves interaction

among researchers, which is necessary for the communication of ideas and quality control, as well as the illumination of a research problem by different perspectives. These can be different theories and methods within a discipline or the perspectives of different disciplines and can be more or less integrated. The third dimension involves the interaction of the research with the larger social system within which it sits. It involves taking stakeholder perspectives into account through a range of participatory processes and other formal and informal mechanisms. The fourth dimension is relevant to the considerations here, namely change through time. The way in which research makes a difference through time becomes the concern of the researcher. Researchers, policy makers and other practitioners grapple together with the uncertainties of how the action and research contexts may change over time and how these contexts can be strategically shaped by research.

One particular manifestation of this fourth research dimension is the increasing interest in the 'translation' or 'transfer' of research into policy and practice. Gibson[42] argues that neither translation nor transfer adequately captures the complexity of the interaction and that transformation is likely to be a more appropriate concept. Gibson is particularly interested in the relationship between research and policy and argues that for research to influence policy requires more than changing the timing and format of communication about research or even creating joint projects. Instead, he suggests that for research to influence policy it must be transformed into knowledge that is invested with meaning and power that binds government to a particular view or course of action. It also needs advocacy coalitions that are inspired to see policy reflect their beliefs and values. He argues that research is either 'minted' into valuable currency for policy arguments or muted, depending on the social context of the justification, the irrefutability of the data and the immutability of the policy. Finally, he argues that research is transformed into knowledge and power when it becomes part of a policy discourse that simultaneously shapes what is being governed and provides the reason and authority for government.

The theoretical insights of van Kerkhoff and Gibson present a whole new vista for research in Integration and Implementation Sciences and provide a context in which to embed a range of other insights.

For example, Gibson's research raises the question of whether research transformation is also necessary to effectively change practice. Certainly Moore[43] has traced the increasing complexity of the research-practice interface in the US Agricultural Extension Service. Extension started with written pamphlets, but farmers found these neither useful nor convincing. The next phase was the hiring of extension workers to disseminate knowledge and this has evolved into a third phase where farmers are in a better position to use researchers for their own purposes.

Further, Moore has started to catalogue the factors that made the US Agricultural Extension Service a success, including the sheer numbers of researchers and outreach workers, the training of both researchers and farmers to be reflective practitioners and the thick, strong connections between the land grant universities, experimental stations and farms.

How to make the research-practice and research-policy interface work effectively is an important research and practice challenge for Integration and Implementation Sciences. There are a number of other important research insights that can be brought to bear here, such as understandings about the importance of how issues are framed, the building of alliances and the role of research and researchers in advocacy[44]. It also provides opportunities to think about and systematise new roles, such as knowledge brokers and boundary spanners[45]. Further, it helps invigorate appreciation that research (or professional enquiry) is a scarce resource, particularly in relation to the vast number of problems confronting human societies[46]. Thus there is considerable value in maximising the use of research as an aid to lay enquiry, so that the bulk of the population are better equipped to appreciate nuance and deal with uncertainty and imperfection.

### *Where Would Integration and Implementation Sciences Sit in Universities?*

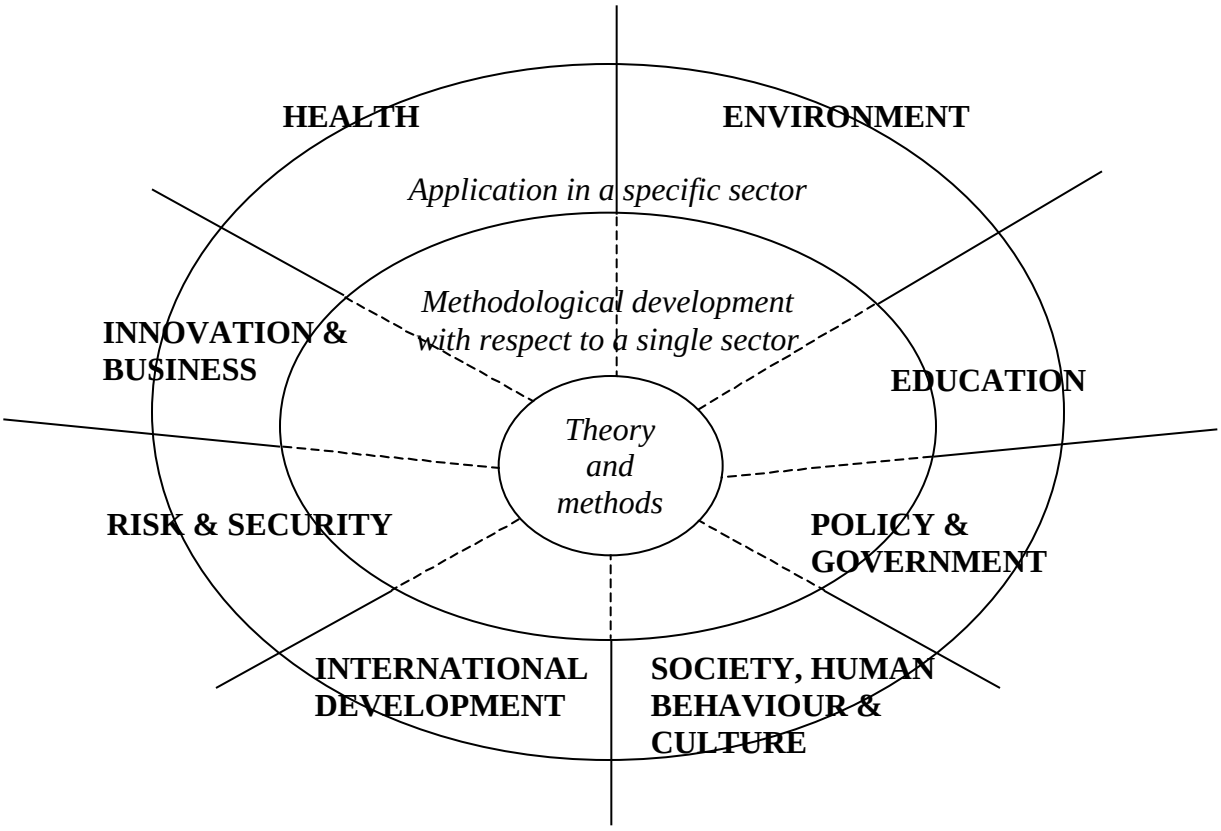
Like statistics and epidemiology, the theory and methods of Integration and Implementation Sciences are developed through engagement with practical problems. However, unlike these disciplines, there is no home base to which breakthroughs can be reported and where they can be critically assessed. The development of the specialisation of Integration and Implementation Sciences is a way of establishing such a home base.

The lack of a home base also means that those engaged in Integration and Implementation Sciences lack a unifying identity. As a consequence, researchers mainly identify either through their area of application eg as human ecologists, environmental scientists or management specialists or through a key approach or method such as action researcher or systems dynamics specialist.

Identity as a specialist in Integration and Implementation Sciences complements, rather than replaces, these existing identities. The difference that a specialisation will make is that specialists in Integration and Implementation Sciences will be able to identify with a broader cadre of researchers and develop better rounded skill sets. For example, while there is considerable overlap in their modes of operation between researchers using soft systems methods and action researchers, there is little cross-over between these groups in terms of university coursework, professional associations or even research collaboration. Soft systems researchers often have very polished systems methods, but under-developed participatory skills, with the opposite holding for action researchers. Bringing these two groups together under a unifying umbrella will increase the chances that both will bring a more highly developed set of theory and methods to bear on the problems they deal with.

The figure below[47] illustrates the relationship between the home base (the central circle labelled ‘Theory and Methods’) and the key sectors in which Integration and Implementation Sciences are applied and developed. Some researchers will work predominantly in the home base, focussing on the development of theory and methods in Integration and Implementation Sciences and applying them to a broad range of problems. Some researchers (second circle) will build detailed knowledge of a single

sector, such as environment or international development and will use this as the basis for the development of Integration and Implementation Sciences theory and methods. A third group of researchers will be less interested in the development of theory and methods, but will focus much more on their application (outside circle).




A specialisation will also provide a one-stop shop for researchers newly seeking access to integration and implementation skills. As appreciation of the need for these skills grows, more and more researchers are seeking to acquire them. Where new researchers gain a foothold currently tends to be arbitrary, as it is extremely difficult to acquire a comprehensive overview of the Integration and Implementation Sciences field, existing knowledge and key players. Thus researchers new to the area often spend considerable time searching for resources and key contacts and their early work often involves significant reinventing of the wheel.

The same holds for policy makers and other practitioners seeking to link with researchers with Integration and Implementation Sciences skills. There is nowhere for such practitioners to go to receive an overview of what Integration and Implementation Sciences can offer and to match needs with available approaches. If practitioners approach universities or other public good research organisations, the aspect of Integration and Implementation Sciences they link with, and whether they indeed manage

to link with any form of Integration and Implementation Sciences, is largely a matter of chance. Outside universities, there are now a large number of commercial, consultant-based packages available, but most are limited in the approaches they offer and there are no mechanisms for quality control.

This last sentence is not intended as a criticism of consultants practising approaches that are part of Integration and Implementation Sciences. Indeed they have largely been responsible for the development of this field. Many have left universities to set up their own businesses because this has given them more freedom to undertake the practice-based research they care about. Further, researchers who survive in universities and other research organisations are often required to be wholly or partially self-funded, often through consultancy work. Commercially-based researchers are not in a position to develop colleges of critical peers, overarching associations, robust and comprehensive theoretical and methodological bases, or curricula for undergraduate and postgraduate education, in other words to develop a specialisation. That is the role of universities. Thus the development of a specialisation will also provide a solid underpinning for commercial consultancy practice, a place where consultants can learn new or update existing skills and where they can feed back lessons from their practice-based experience to invigorate and progress the development of theory and methods[48].

*Statistics as a Useful Analogy*

So far, I have dealt with the importance of a home base for Integration and Implementation Sciences. Here I will expand on this idea, using analogies between statistics and Integration and Implementation Sciences.

Statistics is embedded in the academy at three levels. First there are home-base departments where theory and methods of statistics are developed and advanced. Second, other significant academic departments incorporate statistical training into their core curriculum and have at least some staff with a strong statistical bent. For example, disciplines like biology, psychology, sociology and geography provide core training in statistics, particularly as relevant to the discipline, and have staff and research programs with a strong quantitative orientation. In addition, multidisciplinary departments such as public health often employ statisticians who are willing to work on public health problems. Third, there is an expectation that a large proportion of staff and students throughout the academy will have a basic level of statistical competence.

Like statistics, some elements of Integration and Implementation Sciences are already embedded in other significant academic areas. For example, many departments and centres dealing with environmental issues incorporate integrated assessment, other systems approaches and participatory approaches in their teaching and research. Public health departments often have a strong orientation to participation and implementation. However the incorporation of Integration and Implementation Sciences is largely idiosyncratic and there is generally little interaction between departments with different content area expertise about core or best methods. Some approaches that are key elements of Integration and Implementation Sciences have become standard in some

established academic areas. For example, most law schools now include principled negotiation (alternative dispute resolution) in their teaching, if not research.

As I have already pointed out, unlike statistics, Integration and Implementation Sciences has no home base or shared understanding of what this area encompasses. There is also not the same level of individual competence among researchers in Integration and Implementation Sciences as there is in statistics. While many staff and students throughout the academy have basic competencies, such as building trust, thinking laterally, and seeing interconnections (and some have very advanced competencies), these tend to be seen as personal attributes rather than academic skills. Furthermore, staff and students tend to be left to their own devices in the development of these competencies.

Certainly, the building blocks for a solid home base for Integration and Implementation Sciences exist and establishing home base departments would have positive spin-offs for established disciplines and specialisations and for individual staff and students.

Statistics provides another useful analogy, namely the comfortable co-existence of diversity in statistics where some statisticians are trained predominantly in statistics and work on a variety of problems, while others have training in statistics and another discipline and work largely on a particular set of problems. It is easily conceivable that some of those trained in Integration and Implementation Sciences would work on a wide range of problems, while others would work in more depth in areas such as environmental sciences and public health.

The relationship between Integration and Implementation Sciences and traditional disciplines might be somewhat different, however, from the relationship of statistics and other traditional disciplines. Those trained in Integration and Implementation Sciences plus a traditional discipline might be expected to focus particularly on bringing that disciplinary perspective to the understanding of a complex problem rather than (or in addition to) advancing the discipline. Certainly, a key task of Integration and Implementation Sciences is to harness and build on disciplinary strengths. The disciplines have developed and continue to develop a wealth of theoretical, methodological and content knowledge. Further, the disciplines themselves recognise the importance of developing effective ways to draw together the strengths of a range of disciplines.

Statistics does not, however, provide a complete analogy. Statistics is obviously a well-developed and defined academic area. There are a range of widely adopted standard techniques and an array of known challenges which stimulate on-going research. Integration and Implementation Sciences is poorly defined, with no widespread agreement about what the field does and does not encompass. As outlined above, some methods, such as principled negotiation, are relatively well defined and accepted, while others are idiosyncratically developed and applied. Even without a clear framework, however, the scope of Integration and Implementation Sciences is likely to be considerably broader than that of statistics. Further, it seems unlikely that one core concept will lie at the heart of Integration and Implementation Sciences, in the same way

that probability forms the nucleus for statistics. This is where the real developmental challenges for Integration and Implementation Sciences lie.

*Challenges to Developing a Specialisation*

There are a number of key challenges in developing a specialisation of Integration and Implementation Sciences, including:

- achieving agreement on whether a specialisation is appropriate, likely to achieve the desired outcomes, and worth the down-sides
- constructing a coherent specialisation from disparate 'bits', many of which now have their own traditions. Some 'bits', like participatory methods and principled negotiation techniques can potentially be fully encompassed within the new specialisation. Others, such as the mathematical development of complexity science, for example, fit more comfortably within an existing discipline and might not sit well in the new specialisation. Redrawing boundaries, and possibly also reallocating resources, are important components of this challenge
- getting this specialisation accepted and implemented, both by those inside and outside the specialisation. Within the specialisation, challenges include that some may not want to refocus their identity and allegiances. Others may have identified a niche in which they are doing well and may either not see the need for, or be too overcommitted to contribute to, a larger enterprise. Those outside the specialisation may oppose it because they fear losing resources or because they see Integration and Implementation Sciences to be about personal skills rather than academic theory, method and application
- developing appropriate intellectual interfaces with traditional disciplines and newer multidisciplinary specialisations (such as environment studies or peace studies)
- overcoming unevenness in the development and application of approaches. For example, many of the components of Integration and Implementation Sciences are most developed in the environmental area, so that consideration needs to be given not only to further enhancing the skills that have been developed in the environmental area but also to diffusing them into other areas[49].
- uniting the diverse core areas of Integration and Implementation Sciences may be difficult as they have different status, require different skills and often attract different personalities. The challenge of uniting model building and facilitation methods is an example.
- finding suitable locations within universities for Integration and Implementation Sciences - locations where there is a sense of fit and where the specialisation will prosper. This needs to be an exciting and rewarding area for research and teaching, in order to continue to attract good people.

***Examples of Integration and Implementation Sciences in Action***

The examples below provide snapshots of the research Integration and Implementation Sciences covers[50].

> *Bringing together slum-dweller organizations, NGOs, researchers, urban planners, and housing authorities in multi-stakeholder data-collection and planning processes that developed sustainable, "win-win" solutions to slum resettlement in Mumbai city*[51]
> *Providing decision support to policy makers through models which incorporate stakeholder input accessed through participatory methods. Such Integrated Assessment has been used to address the impacts of global environmental changes on vector-borne disease, like malaria, globally, as well as for specific locations like Kisumu in Kenya*[52]
>
> *Assisting in creating partnerships between relevant agencies to tackle health problems in developing countries, for example, between a private foundation and a pharmaceutical company to donate drugs for the treatment of trachoma and between health, transport, police and other agencies to tackle road traffic crashes*[53]
>
> *Developing a process of co-mentoring for partnerships between respected Australian Indigenous community members and non-Indigenous researchers which has been successfully used to improve services for older Indigenous people*[54]
> *Using transdisciplinary thinking to analyze complex historical and contemporary forces shaping the epidemic of heart disease in the Australian coalfields and to select points of critical leverage for community interventions*[55]
> *Using participatory, structured, multivariate Concept Mapping methodology to help networks of public health practitioners and organizations conceptualize and address a wide array of health issues including HIV/AIDS, cervical cancer, end of life concerns, and lower prevalence chronic health conditions*[56]

The theoretical and methodological skills an Integration and Implementation Sciences specialist brings to bear address the following practical issues:

- Scoping the problem, ensuring multi-disciplinary and multi-sector involvement, and making clear where the boundaries around the problem have been set and the implications of those decisions for inclusion, exclusion and marginalisation of stakeholder groups.
- Integrative functions, ensuring that different conceptualisations of integration are made apparent and that those most appropriate for the project in hand are chosen.
- Collaborative functions, ensuring that appropriate researchers and sectoral representatives are included, that their world-views are made explicit, that their

interests are accommodated, that different strengths are harnessed, that communication mechanisms are strong, and that conflicts are appropriately mediated.

- Practical application, including transformation into policy or action, ensuring that those who can implement the research are part of the research process or kept closely in touch with it and that the political aspects of the research are dealt with.

### *Next Steps*

For the specialisation of Integration and Implementation Sciences the reach its potential, considerable developmental work is required and many of the outstanding challenges have been presented earlier. The challenges are both intellectual and practical and essentially fall into three areas:

- strengthening the intellectual base of Integration and Implementation Sciences,
- promoting networking and collaboration between researchers and practitioners interested in Integration and Implementation Sciences, and
- embedding Integration and Implementation Sciences in universities[57] and in funding programs.

### *Conclusion*

Integration and Implementation Sciences are critical for "integration", "policy relevance", "evidence-based practice", and "innovation", which are key concepts now driving research. The challenges are substantial, but the critical mass of researchers and approaches means that rapid development is possible. This promises intellectual excitement and fulfillment, as well as effective practical outcomes in tackling the complex social, environmental and technological issues human societies confront.

There is a growing network of researchers and practitioners interested in integration and Implementation Sciences. We invite you to join us.

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[1] This overview was prepared by Gabriele Bammer, with input from Lorrae van Kerkhoff. Useful comments were also received from Yoland Wadsworth, Susan Goff, Lesley Treleaven and Steve Dovers. This version: 19 September 2003, with minor amendments. Comments and discussion welcome; please send to Gabriele.Bammer@anu.edu.au.

[2] UNESCO (1999) Introductory note to The Science Agenda--a framework for action, In *Science for the 21st Century: a new commitment,* World Conference on Science, UNESCO, Budapest. pp.469.

[3] UNCED 1992. *Agenda 21*. Online source. URL: http://www.un.org/esa/sustdev/agenda21text.htm

[4] OECD (1996) *The knowledge-based economy*, Organization for Economic Co-operation and Development, Paris, pp. 46; quotation from *p. 7*.

[5] Batterham, R. (2000) *The chance to change: final report by the Chief Scientist*, Commonwealth of Australia, Canberra; quotations from p 11and 41

[6] Gibbons, M., C. Limoges, H. Nowotny, S. Schwartzman, P. Scott and M. Trow (1994). The new production of knowledge. The dynamics of science and research in contemporary societies. London;

Thousand Oaks, California; New Delhi, Sage; Nowotny, H., P. Scott and M. Gibbons (2001). Re-thinking science. Knowledge and the public in an age of uncertainty. Cambridge, Polity Press in association with Blackwell Publishers.

[7] Coady, T. Ed. (2000) Why Universities Matter. A conversation about values, means and directions. St Leonards, NSW, Allen and Unwin.

[8] Bok D. (2003). Universities in the marketplace. The commercialization of higher education. Princeton and Oxford, Princeton University Press.

[9] Cooperative Research Centres are geographically dispersed virtual centres, based on existing organisations, and are expected to draw together a range of research organisations and research end-users. They may be commercially oriented, in which case the end-users tend to be business groups, or public-good in which case government departments and community groups may be the end users. There are usually between 55 and 65 Centres in operation at any given time, ranging across six sectors: environment; manufacturing technology; agriculture and rural based manufacturing; medical science and technology; information and communication technology; and mining and energy. They are co-funded by government (competitively) and partner organisations, initially for seven years, with the option of one renewal.

[10] van Kerkhoff, L (2002) "Making a difference": Science, action and integrated environmental research. Unpublished PhD thesis. School of Resources, Environment and Society, The Australian National University.

[11] CSIRO, 2000, CSIRO strategic plan 2000-2001 to 2002-2003. Online source. URL: http://www.csiro.au/reports/StrategicResearchPlan2000to2003/StratResPlan2000to2003.pdf p. 8

[12] http://www.csiro.au/index.asp?type=blank&id=SEI_Home

[13] Land and Water Australia (2001) Strategic R&D plan 2001-2006. Land and Water Australia, Canberra.

[14] European Commission (2002) The Sixth Framework Program in brief. Online source. URL: http://europa.eu.int/comm/research/fp6/pdf/fp6-in-brief_en.pdf.

[15] http://www.nsf.gov/pubs/2001/nsf0104/nsf0104.doc, p.9

[16] World Health Organisation (2002) World Health Report 2002. Reducing risks, Promoting healthy life. http://www.who.int/whr

[17] Board on Sustainable Development Policy Division National Research Council (1999) Our common journey: a transition toward sustainability, National Academy Press, Washington, D.C.; Cash, DW; Clark, WC, Alcock, F; Dickson, NM; Eckley, N; Guston DH; Jaeger, J; Mitchell, RB; 2003 'Knowledge systems for sustainable development' Proceedings of the National Academy of Sciences, 100: 8086-8091.

[18] Professional associations which could be said to cover significant approaches in Integration and Implementation Sciences include the Association for Integrative Studies; the Systems Dynamics Society; the Society for Human Ecology; the International Society for Ecosystem Health; Action Learning, Action Research and Process Management; the Society for Values in Higher Education; Council on Health Research for Development; and the International Association for Conflict Management.

[19] These include Issues in Integrative Studies, Systems Research and Behavioural Science, Ecosystem Health, Public Administration, Global Change and Human Health, Action Research, and Integrated Assessment.

[20] Schools of thought encompassed by systems thinking and some of their key practitioners include General Systems Theory *(Bertalanffy, Boulding, Bateson, Mead);* Systems Analysis & Systems Engineering *(RAND);* Systems Dynamics *(Forrester, Sterman, Richardson);* Cybernetics *(Wiener, von Neumann);* Operations Research*(Churchman, Ackoff);* Soft Systems Practice *(Checkland);* Learning Organisations *(Senge);* Critical Systems Thinking *(Jackson, Flood, Midgley)*

[21] See, for example, Checkland, P. (1984). Systems thinking, systems practice. Chichester, John Wiley and Sons; Midgley, G. (2000). Systemic intervention: Philosophy, methodology, and practice. New York, Kluwer Academic/Plenum Publishers; Capra, F. (1997). The web of life. A new synthesis of mind and matter. London, Flamingo; Senge, P. M. (1990). The fifth discipline. The art and practice of the learning organisation. London, Century Business; Troncale, L. Workshop Handout "A comprehensive Introduction to the Systems Sciences" at World Congress of the Systems Sciences, Toronto 2000

[22] Methods include: clustering theory, comparative systems analysis, computer modeling and simulation tools, control theory, critical path methods, decision analysis, divergence mapping, flowcharting, game theory techniques, input-output analysis, lifecycle analysis, linkage proposition analysis, network theory, optimisation theory, relational data base analysis, scenario building etc (Troncale, L. Workshop Handout

"A comprehensive Introduction to the Systems Sciences" at World Congress of the Systems Sciences, Toronto 2000)

[23] Checkland, P. (1984). Systems thinking, systems practice. Chichester, John Wiley and Sons

[24] Troncale, L. Workshop Handout "A comprehensive Introduction to the Systems Sciences" at World Congress of the Systems Sciences, Toronto 2000

[25] Midgley, G. (2000). Systemic intervention: Philosophy, methodology, and practice. New York, Kluwer Academic/Plenum Publishers

[26] Midgley, G. (2000). Systemic intervention: Philosophy, methodology, and practice. New York, Kluwer Academic/Plenum Publishers

[27] I use the overarching term 'practitioners' to refer to these groups.

[28] Methods include action research, Delphi methods, consensus building, rapid rural assessment, Search conferences, Executive Sessions, and numerous intuitive unnamed methods. Key references include Reason, P. and H. Bradbury (eds, 2001). Handbook of action research: Participative inquiry and practice. Sage; Susskind, L., S. McKearnan and J. Thomas-Larmer, Eds. (1999). The consensus building handbook. A comprehensive guide to reaching agreement. Thousand Oaks, London, New Delhi, Sage Publications; Emery, M. (1999). Searching. The theory and practice of making cultural change. Dialogues on work and innovation Volume 4. Amsterdam, John Benjamins Publishing Co.; Fisher, R., W. Ury and B. Patton (1991). Getting to yes. Negotiating an agreement without giving in. London, Random House Business Books; Hough, L (2002) 'A meeting of the minds. What happens when the Kennedy School's executive sessions unite practitioners and academics together?' Harvard University John F Kennedy School of Government Bulletin, Spring, 32-37.

[29] Brown, LD.; Bammer, G.; Batliwala, S.; Kunreuther, F. 2003 'Framing practice-research engagement for democratizing knowledge.' Action Research, 1, 81-102. While this framework was developed for engagements aimed at democratising knowledge, it has more general relevance.

[30] First developed in Brown, L. D. (Ed.). (2001). *Practice-Research Engagement for Civil Society in a Globalizing World*. Washington, DC: CIVICUS and Hauser Center for Nonprofit Organizations.

[31] This tends to be less true of what might be called 'narrow' interdisciplinarity, in other words when related disciplines work together in a purely research context. Examples include engineers mathematicians and physicists working together to develop a new technology or sociologists, anthropologists and psychologists developing a new theory of human behaviour.

[32] Draft report of the Science Investment Focus Group on Complex Systems Science, February 2002 http://www.dar.csiro.au/css/documents/fin057_0202_sifg.doc

This reference also points out that there are three broad approaches to complexity science:

1. ynamical systems theory. This uses methods that employ non-linear differential or difference equations to capture the dominant behaviour (often the emergent behaviour) of systems with very many degrees of freedom by a low dimensional set of differential equations

2. Network theory which concentrates on the structure and typology of the links between the system elements and the controls that these exert on the behaviours of the system3. Adaptive computing which covers a wide range of so-called agent-based models, where elements of a system are allowed to interact in a virtual environment. The elements and the initial rules of interaction are specified a priori but the evolution of the system thereafter is unconstrained.

Complexity science analysis tools include fractals, chaos theory, lattice models, renormalisation group theory and non-equilibrium thermodynamics.

[33] Higginbotham, N., G. Albrecht and L. Connor, 2001. Health Social Science. A transdisciplinary and complexity perspective. Melbourne, Oxford University Press

[34] Higginbotham, N., G. Albrecht and L. Connor, 2001. Health Social Science. A transdisciplinary and complexity perspective. Melbourne, Oxford University Press

[35] Senge is one researcher who has developed such tools, including looking for leaps of abstraction; mismatches between espoused theories and theories in use; the left-hand column technique; balancing enquiry with advocacy; and scenarios, computer simulations and internal board of directors. Senge, P. M. (1990). The fifth discipline. The art and practice of the learning organisation. London, Century Business

[36] Koehn PH & JN Rosenau (2002) Transnational competence in an emergent epoch. International Studies Perspectives 3, 105-127.

[37] Neuman, W. L. (1994). Social research methods. Qualitative and quantitative approaches. 2nd Edition. Boston, Allyn and Bacon. This is taken almost verbatim from Table 4.1 on page 75.

[38] This term comes from Louis Lebel, personal communication August 2003.
[39] Klein, J. T. (1990). Interdisciplinarity: History, theory and practice. Detroit, Wayne State University Press
[40] Higginbotham, N., G. Albrecht and L. Connor, 2001. Health Social Science. A transdisciplinary and complexity perspective. Melbourne, Oxford University Press
[41] van Kerkhoff, L (2002) "Making a difference": Science, action and integrated environmental research. Unpublished PhD thesis. School of Resources, Environment and Society, The Australian National University.
[42] Gibson, B 2003 From Transfer to Transformation: Rethinking the relationship between research and policy. PhD project, National Centre for Epidemiology and Population Health, The Australian National University.
[43] Moore, M. H. (1995). Learning while doing: linking knowledge to policy in the development of community policing and violence prevention in the United States. Integrating crime prevention strategies: propensity and opportunity. P.-O. Wikstrom and R. V. Clarke. Stockholm, Swedish National Council for Crime Prevention**:** 301-331.
[44] See e.g. Chapman, S. (2001) Advocacy in public health: roles and challenges. International Journal of Epidemiology, 30, 1226-1232.
[45] See e.g. Williams, P. (2002). "The competent boundary spanner." Public Administration **80**(1): 103-124; Cash, DW; Clark, WC, Alcock, F; Dickson, NM; Eckley, N; Guston DH; Jaeger, J; Mitchell, RB; 2003 'Knowledge systems for sustainable development' Proceedings of the National Academy of Sciences, 100: 8086-8091
[46] Lindblom, C. E. (1990). Inquiry and change. The troubled attempt to understand and shape society. New Haven, Yale University Press and Russell Sage Foundation.
[47] The figure was developed by Lorrae van Kerkhoff.
[48] Given that consultants rely on the methods and other intellectual property they develop to make their living, incorporating these into the academy will also be a challenge.
[49] See, for example, the literature on sustainability science, eg Clark, WC and NM Dickson 2003 "Sustainability science: the emerging research program" Proceedings of the National Academy of Science, 100: 8059-8061
[50] More information about researchers and their projects can be found at http://www.anu.edu.au/iisn. Bear in mind that this represents only a fraction of researchers involved in Integration and Implementation Sciences.
[51] Batliwala, S. 2003 Bridging divides for social change: practice-research interactions in South Asia. Organization 10: 595-615; also www.sparcindia.org
[52] Martens, P. et al. (1999) Climate change and future populations at risk of malaria. Global Environmental Change, S9, 89-107
[53] Reich, M.R. ed. 2002 Public-Private Partnerships for Public Health. Cambridge MA., Harvard Center for Population and Development Studies and http://www.hsph.harvard.edu/hcpds/publications.html
[54] Dance, P.; Brown, R.; Bammer, G.; Sibthorpe, B. 2000 Needs for Residential Aged Care and Other Services by the Older Indigenous Population in the ACT and Region. Report for the ACT Office of the Commonwealth Department of Health and Aged Care
[55] Higginbotham, N., G. Albrecht and L. Connor, 2001. Health Social Science. A transdisciplinary and complexity perspective. Melbourne, Oxford University Press
[56] Trochim, W. (1989). An introduction to concept mapping for planning and evaluation. In W. Trochim (ed) A special issue of Evaluation and Program Planning, 12, 1-16 http://trochim.human.cornell.edu/research/epp1/epp1.htm Accessed 30 May 2003.
[57] An established academic specialisation can offer:

- a more clearly defined scope for Integration and Implementation Sciences and complementarities with existing disciplines and specialisations
- a more robust theoretical base which will be a well-spring of innovation
- a large and critical 'college' of peers to evaluate current and future research and practice.

These allow for both the cross-fertilisation of ideas and advancement of knowledge, as well as opportunities for quality control. Care must be taken to ensure that the specialisation does not become too narrowly defined and lose its richness and that it does not develop in a lop-sided way, for example, that

mathematical modelling takes precedence over participatory techniques. Developing the specialisation includes:

- finding a location in the academy conducive to growth and the development of the ideas underpinning Integration and Implementation Sciences
- developing both undergraduate and graduate curriculum
- producing textbooks and systematic reflections on case studies
- building an overarching professional association and encouraging interlinkage between smaller existing professional associations
- building up top-ranking peer-review journals.