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Strengthening community operational research through exchange of tools and strategic alliances

Gabriele Bammer

National Centre for Epidemiology and Population Health, Research School of Population Health, The Australian National University, 62 Mills Road, Acton ACT 2601, Australia

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ABSTRACT

Community operational research (COR) would benefit from forming strategic alliances with other areas of scholarly endeavor involved in tackling complex social and environmental problems. Intellectually this would strengthen COR as a community of practice, expanding its repertoire of tools and increasing uptake of COR concepts and methods by researchers outside COR. Banding together would also increase influence in research and higher education policy making to promote widespread uptake of the best ways of tackling complex problems and ensuring there is adequate funding and institutional support. A new discipline of Integration and Implementation Sciences (I2S), which aims to be a conduit between COR and others tackling complex social and environmental issues, is described, along with its origins. The role of I2S as a conduit is illustrated by presenting six tools and toolkits, which have been developed outside COR, but which may enhance its practice. They are: (1) knowledge co-production toolbox, (2) change management toolbook, (3) collaboration and team science field guide, (4) engaging and influencing policy toolkit, (5) ethical matrix and (6) matrix for distinguishing three different kinds of unknowns.

1. Introduction

Has community operational research (COR) been influential enough in helping society tackle complex social and environmental problems, such as global warming, the obesity epidemic and poverty? As an interested and supportive outsider, I suggest that it has not.

I take as a given that there are mainstream academic forces that prevent COR from being more influential, but articulating these is not of concern here. Instead, I focus on two steps that COR could take to counter these forces in order to become a major player in addressing complex real-world problems. The first involves expanding the repertoire of concepts and methods that form the mainstream of COR. The second is to join with other communities of practice and other like-minded researchers to develop sufficient political clout to ensure that engaged, action-oriented approaches to complex problems can no longer be ignored.

COR is one of many communities of practice tackling the complex social and environmental issues facing society (Johnson, 2011a; Midgley & Ochos-Arias, 2004a; Ritchie, Taket, & Bryant, 1994). Others include action research (e.g. Bradbury, 2015), interdisciplinary research (e.g. Frodeman, Klein, & Pacheco, 2017), transdisciplinary research (e.g. Bergmann et al., 2010; Hirsch Hadorn et al., 2008), systemic intervention (Midgley, 2000), system dynamics (e.g. Sterman, 2000), complex systems science (e.g. Mitchell, 2009), sustainability science (e.g. Clark & Dickson, 2003) and change management (e.g. Nauheimer, 1997). Right now, these communities of practice are just as siloed as conventional disciplines. As is the case with disciplines, there are some interactions; COR for example intersects with action research, systemic intervention and other forms of systems thinking (see examples in Midgley & Ochos-Arias, 2004a). Nevertheless just as interactions across disciplines are limited, so too are intersections across the many communities of practice that deal with complex problems. Furthermore many researchers and research teams working on complex problems are not members of any of these communities of practice—they are referred to here as non-aligned—and independently devise concepts and methods for dealing with elements of complexity, such as integration across disciplines, learning from stakeholders and seeking to influence change.

The aim of this paper is to encourage much greater exchange of concepts and methods among those tackling complex real-world problems, in order to increase awareness of COR, as well as to expand the repertoire of COR. The intention is also to promote the development of alliances across the various related communities of practice, in other words connecting community operational researchers, transdisciplinarians, sustainability scientists etc., in

E-mail addresses: Gabriele.Bammer@anu.edu.au, gabriele.bammer@anu.edu.au

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addition to linking in non-aligned researchers and research teams. The purpose of building alliances is increased power and influence, which would give community operational researchers and others tackling complex social and environmental issues a greater voice in influencing research and higher education policy, as well as how funding for research and education is distributed.

As these objectives indicate, this paper is a mix of the scholarly and the political. It seeks to enlist community operational researchers in a cause—that of forming strategic alliances with other areas of scholarly endeavor involved in tackling complex social and environmental problems (often also referred to as 'wicked' problems; Rittel & Webber, 1973 or VUCA (volatility, uncertainty, complexity, ambiguity, see for example Codreanu, 2016)). The intellectual purpose is to strengthen the communities of practice and the tools they use for tackling complex issues. The political purpose is to develop enough clout to ensure that these communities of practice and the tools they have developed are routinely incorporated in research teams and that this is adequately funded and rewarded.

Of course, it is important to recognize that COR alone cannot remedy the situation. The willing involvement of other communities of practice is also required. With its history of intersections, especially with action research and systems thinking, COR is ideally placed to reach out to these other communities and to help lead the formation of an effective large alliance. I have also previously made a much less detailed case to action researchers (Bammer, 2015a).

I briefly outline the origins of these ideas, including the major drivers for this paper. I then describe a proposal for new discipline of Integration and Implementation Sciences (I2S), which aims to be a conduit between COR and others tackling complex social and environmental issues, both other communities of practice and non-aligned researchers and research groups. The potential benefits for COR are, first, to make its concepts and methods more widely known and accessible and, second, to broaden the repertoire of concepts and methods that community operational researchers can draw on in their own work. Six methods in the second category are then presented. The paper concludes with suggestions for next steps, specifically addressing ways through which community operational researchers could use I2S to promote COR, enhance ways of dealing with complex social and environmental issues and strengthen their influence in research and education policy making.

1.1. Where do these ideas come from?

Starting in 2000, I connected with many communities of practice, including those listed above, and also interacted with many individual (non-aligned) researchers and research teams tackling complex problems in the areas of population health, environment, and policing and security. The driver was that two years before I had come to the end of leading a large seven-year study, which brought together over 100 representatives of disciplines and stakeholders and which aimed to change policy and practice on a complex social issue, namely treatment for heroin dependence (Bammer, 1997). The methods and processes we used to define the problem, bring together different viewpoints, manage value conflicts, deal with uncertainties and inform policy were largely intuitive. By and large they worked well and, as this kind of research was still relatively uncommon, the work attracted interest and admiration. Nevertheless, by the end of the research, I realized how much we had operated by the seat of our pants and wondered what was "out there" that we could have drawn on.

This led to an interest in identifying and connecting with relevant communities of practice, especially to identify concepts and methods that are useful for tackling complex issues. I attended conferences, met individually with key players, joined relevant societies, and read. Among the first conferences I attended were the World Congress of the Systems Sciences, 2000 in Toronto (which was also the 44th Annual Meeting of the International Society for the Systems Sciences; http://isss.org/world/conferences/toronto2000) and the 43rd Annual Conference of the UK Operational Research Society in Bath in 2001.

So why did I not join the COR community? Although COR and each of the other communities listed above had something important to offer, none of them was attractive as a potential "home". There were two key reasons. First, I realized that in the heroin treatment research project I had already intuitively mixed and matched tools from various communities of practice, and that if I had been fully aware of what was "out there" this mixing and matching would have been conscious and deliberate. No one community of practice seemed to cover all the terrain that I was interested in. Second, the communities of practice were all small-scale. I was surprised that conferences, even those that were international, generally had well below 500 attendees. Decades before in 1980, I was part of the neurosciences community, where the annual international conference even then had 9000 attendees (this had subsequently grown considerably). The point here is not that large conferences are necessarily better; instead it is that the number of conference attendees is indicative of the size of the academic community, which will affect its intellectual strength and political influence. Consequently, I started to think about how to make mixing-and-matching across communities of practice more feasible and, at the same time, how to develop a large powerful community.

I was also interested to understand more about non-aligned researchers and teams. As my own ideas progressed into the formation of Integration and Implementation Sciences (described in more detail below), I accepted invitations to join research teams in three areas: population health, environment, and policing and security, and interacted with a wide range of other researchers in these areas. By-and-large I found that they were quite happy to muddle through on the elements of their complex projects that required what I refer to as integration and implementation. They devised concepts and methods when they needed them and were largely uninterested when told there was already a significant body of knowledge that they could draw on.

I have concluded that there are three primary reasons for this. First, those researchers are already stretched to full capacity. The idea that there is another set of skills they need to master is overwhelming. Second, there is no pressure on them to use existing concepts and methods—there are no rewards if they do and no penalties if they do not. On the contrary, there are 'penalties' for using existing concepts and methods, which is directly related to the third reason. This is that there is no easy way for those researchers to get access to useful concepts and methods when they need them. There is no central repository; instead information about relevant concepts and methods is widely dispersed across the peer-reviewed and grey literatures. Further there are challenges to finding appropriate experts who could bring concepts and methods to teams. The experts are members of the existing communities of practice, which means that (a) their numbers are limited and (b) the concepts and methods they have expertise in may or may not match with a team's needs. Currently there would be a significant time penalty and no guarantee of success for a non-aligned team to try to find and use existing concepts and methods.

In summary, this survey of the "lie of the land" led me to the following conclusions:

1. There are multiple communities of practice tackling complex social and environmental issues, including COR, but they are largely isolated from each other. Much could be gained in terms

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of better ways of tackling complex problems if they came together to figure out how to build on each other's efforts, starting with ways of sharing and improving concepts and methods, jointly referred to here as 'tools'.
2. There is also almost no connection between the communities of practice developing relevant tools and the bulk of researchers and research teams tackling complex social and environmental issues—those that I refer to as non-aligned.
3. By-and-large the ways that non-aligned researchers and teams think about complex problems are not easily translated into any of the existing communities of practice; for example, most would not see themselves as comfortably fitting into a COR perspective.
4. Building bridges between existing communities of practice and non-aligned researchers and teams might also most easily begin with a focus on sharing tools.
5. The ability to share tools requires a repository for storing them.
6. The bulk of non-aligned researchers are unlikely to have the capacity or desire to develop significant new skills in research integration and implementation. Instead, non-aligned research teams are likely to look for specialists with these skills to join their teams. Currently specialist skills are limited to small isolated communities of practice and the available numbers are not enough to go around.

All this led me to think about forming a new discipline of Integration and Implementation Sciences (also referred to as I2S; Bammer, 2013) that would house the repository of concepts and methods and that would draw on and support the existing communities of practice. In terms of specialist training, I2S would both support the existing communities of practice and train a new cadre of specialists with the ability to work across the communities of practice. The new specialists would be the first port-of-call for non-aligned research teams seeking to improve ways of tackling complex social and environmental issues. I2S specialists would bring in colleague specialists from particular communities of practice, as and when appropriate. An I2S discipline would also provide a focal point for developing alliances leading to a critical mass of researchers tackling complex social and environmental issues, which would have the necessary political strength to influence both the uptake of the methods and the necessary institutional support.

2. The Integration and Implementation Sciences (I2S) framework

2.1. Relationship with other communities of practice

As described above, the idea of establishing I2S is to provide common ground for communicating across the various communities of practice and with non-aligned researchers and research teams. It deliberately focuses on concepts and methods as areas where similarities can most readily be found and built on. The aim is not to subsume existing communities of practice, but to provide a way of linking them to each other and making them more accessible to non-aligned researchers and research teams, through the development of a shared repository of tools and a new cadre of specialists. (This paper concentrates on the development of a shared repository of tools, leaving the training of specialists to one side.)

This connection would then aim to underpin intellectual diversity among communities of practice, as well as allowing the communities of practice to become more aware of their overlaps and differences. It would also allow non-aligned researchers and research teams to decide if they wanted to align with one community of practice or if they wanted to mix-and-match tools from different communities. The connection also aims to build the political strength discussed earlier.

While some will be concerned about "reducing the complexities of practice to the implementation of method alone" (Midgley & Ochos-Arias, 2004b, p. 2), the reason for the focus on tools is that it provides a relatively safe and straight-forward space for interacting. Given that many of the researchers involved are highly committed to thinking about more than methods, this will inevitably lead into deeper explorations of how complex problems are tackled.

The I2S framework described below is a proposal. If it is to achieve its aim of connecting disparate communities of practice and non-aligned researchers, it needs to be "owned" by them and therefore redeveloped and modified by them. This will require a systematic process that allows all communities of practice to be fully engaged, as well as enabling appropriate input from non-aligned researchers and teams. This is not yet achievable, but is something to aim for.

2.2. Relationship to COR

It is not possible to trace back to their origins all of the ideas that contributed to I2S, but some influences of COR and closely aligned areas of practice are clear. The first is the common interest in making change happen. This is central to COR (see for example Johnson, 2011a; Midgley & Ochos-Arias, 2004a; Ritchie et al., 1994) and, as described below, forms one of the three domains of I2S. Engaging with and changing communities—community development—is the focus of COR and is included in I2S. The focus of I2S is broader, and more than is the case for COR, also encompasses change in government and business, and specifies both policy and practice as areas of change. Like COR, I2S honors community knowledge, as specified below in Domain 1. And as described for Domain 1, I2S is more specific about bringing together all relevant knowledge from disciplines and stakeholders and therefore casts a wider net around relevant knowledge than is sometimes the case for COR.

While systems thinking and COR are often closely entwined, not all COR takes a systems approach (Jackson, 2004). Systems thinking is central to I2S and is specifically highlighted in each of its three domains, in 'Question 2′ in the framework described below. I2S has also specifically encompassed Midgley's boundary critique (Midgley, 2000) as part of Question 2, with aspects of that work also permeating other elements of the I2S framework. The focus of COR on values or ethics (see e.g. Johnson, 2011a; Midgley, 2000) is also evident in Question 2 of the I2S framework.

Conceptual and mathematical modeling (Johnson, 2011a) are central to much COR and its parent, OR, as well as to systems thinking more generally. Modeling is also a highly valued component of I2S, as one important set of methods for synthesizing knowledge, dealing with uncertainties and supporting decision making. But modeling is not the only set of methods used, with methodological pluralism (e.g. Jackson, 1988; Midgley, 2000), also known as multimethodology (Mingers & Gill, 1997) or multimethod approaches (e.g. Johnson, 2011a, 2011b), inherent in both COR and I2S.

The area of the I2S framework least influenced by COR is Domain 2 "understanding and managing diverse unknowns". COR is not alone among the existing communities of practice in paying little attention to the unknown. Smithson, whose work has heavily influenced this section of I2S, has written that unknowns are a blind spot in western thinking (Smithson, 1989) and I2S aims to remedy this oversight. Indeed COR has not been completely oblivious to this topic, dealing especially with uncertainty (see, for example Friend & Hickling, 2005; Murray & Grubesic, 2011; Ritchie & Taket, 1994).

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I should note that the influence of COR on I2S was mainly through conferences and personal contacts, rather than the references cited above, although Midgley (2000) was important. As this paper highlights, much more can be learnt from the COR literature, but a comprehensive review is beyond the scope of this paper and, indeed, is best conducted as a collaborative exercise. Such an exercise will look for ideas and methods missing from the I2S framework, as well as overlaps, such as between the evaluation of process encompassed by Question 5 in the I2S framework and the development of evaluative questions by Midgley et al. (2013).

2.3. Three domains and five questions

The I2S framework is presented diagrammatically in Figs. 1 and 2. As already described, it seeks to provide common ground and a repository for the diverse concepts and methods useful for dealing with complex social and environmental problems through a structure of three domains (Fig. 1) and five questions (Fig. 2). The three core domains are:

1. Synthesizing disciplinary and stakeholder knowledge.
2. Understanding and managing diverse unknowns.
3. Providing integrated research support (combining the synthesized knowledge with an approach to the remaining unknowns) for policy and practice change.

Undertaking the tasks integral to each of the I2S domains requires an array of concepts and methods, with the most relevant being chosen for a particular problem and its circumstances. Detailed thinking about these tasks is assisted by addressing five questions. Each of the questions is briefly described to set the scene for the discussion of tools which follows. These five questions are presented in Fig. 2.

Let us start with the question "how?", which is question 3 in Fig. 2. This question directs researchers to think about the specific concepts and methods for knowledge synthesis, understanding and managing unknowns, and supporting policy and practice change. Knowledge synthesis can use dialogue or modeling methods, for instance. Understanding and managing unknowns can involve methods to accept unknowns such as hedging or developing scenarios. Supporting policy and practice change methods can include co-production of knowledge or advocacy.

However, the I2S framework recognizes that focusing on these tools alone is not enough. Attention must also be paid to issues

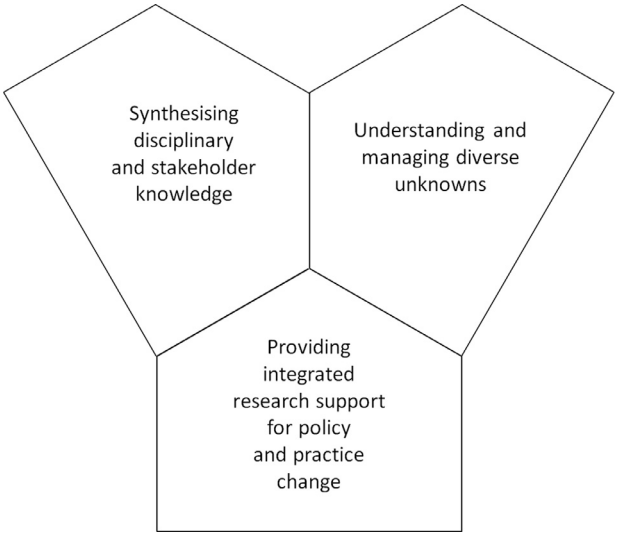

Fig. 1. The three domains of the Integration and Implementation Sciences (I2S) framework (Bammer, 2013).

such as the purposes of the research, how disciplines and stakeholders are chosen and how circumstances affect the conduct of the research. Three of the other questions in the framework cover these topics: Question 1: for what and for whom?, Question 2: which knowledge, unknowns, and aspects of policy and practice?, and Question 4: context?.

Question 1 "for what and for whom?" ensures that the researchers have explicitly thought about the aims and beneficiaries of the research. Beneficiaries include those whose perspectives are used in the knowledge synthesis and understanding and management of unknowns, as well as those who will benefit from the policy and practice change.

Consideration of which knowledge, unknowns, and aspects of policy and practice in question 2 directs researchers to think about overarching issues relevant in each domain. In particular:

- Which systems view or views will they take?
- How will they decide what or who is potentially relevant (scoping), for example among the disciplines and stakeholders?
- How will they decide what to actually focus on and who to include (boundary setting)?
- What metaphors do they use to think about the problem and possible solutions (framing)?
- How they will deal with values and value conflicts?
- How they will manage the collaborations required for the research, especially harnessing differences central to the partnership and managing differences that may get in the way of effectively working together?

Question 4s examination of context prompts consideration of the circumstances in which the research is conducted, especially three aspects that may influence the research and the uptake of the findings. First is the big picture context, such as the history of the problem and the political circumstances in which change is proposed. Second is the authorization for the research and action, in other words who has asked for and is funding the research and who will need to sanction any policy or practice changes. Third are the organizational facilitators and barriers for the research, which involve the structures and cultures of the organizations involved. An example of a structural organizational barrier would be the lack of social sciences researchers in an institution that proposes to conduct research that crosses the natural and social sciences. A cultural organizational facilitator would be a welcoming attitude of a government department to research input, for instance.

The fifth and final question is: outcome? This directs the researchers in evaluating and learning from the decisions made for each of the other questions. The focus is on process outcomes and, although there are no perfect ways to undertake this kind of research, some choices are better than others. Questions for assessing outcomes are drawn from the other questions in the framework and include: Did the research meet its aims and effectively target the intended beneficiaries? Was a good choice made for the systems method used or would another systems method have been more appropriate for the problem? Was an effective knowledge synthesis method used? Were the organizational facilitators effectively utilized? A comprehensive list of questions for assessing outcome is provided in Bammer (2013 – see especially Chapters 8, 15, 22 and 29).

As well as providing a structure for developing a repository of concepts and methods for dealing with complex problems, the domains and questions also aim to ensure that each of these aspects is addressed in research on complex social and environmental problems. Several concepts and methods will be required for any research project, and they will often intersect. The choice of each tool will influence the appropriateness of other tools, so that effective use of the framework requires iteration. In other words,

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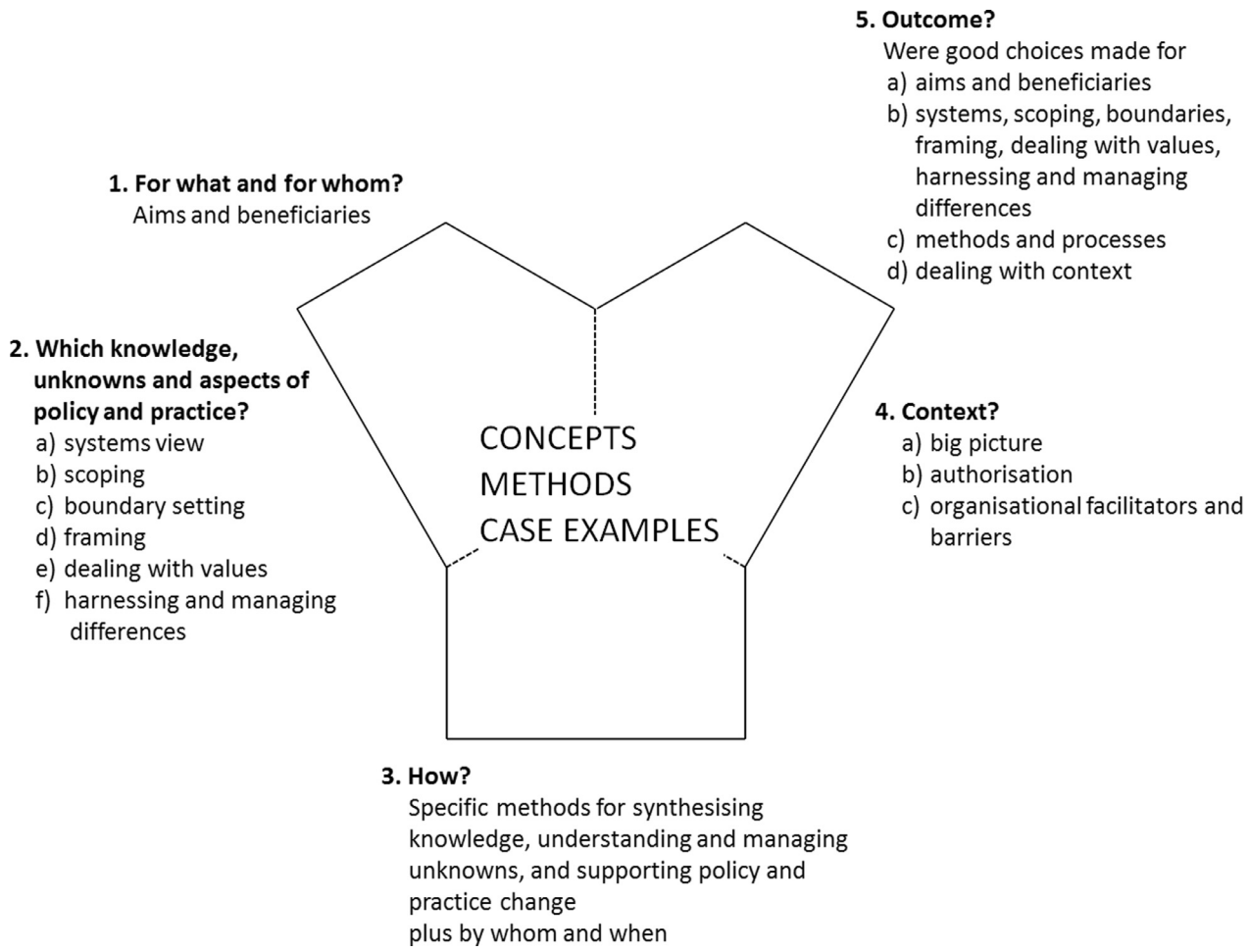

Fig. 2. The five questions of the I2S framework which are used to organize the domains (modified from Bammer, 2013).

to achieve overall congruence, each proposed tool needs to be revisited in light of the other tools chosen.

I have outlined above how COR influenced the development of I2S. An important test for the framework is that the COR community can find all of the key elements of COR in the framework. They may not be where COR members would put them or prioritized in the same way, but they are there somewhere. As touched on earlier, redesigning the framework to appropriately acknowledge each of the existing communities of practice, as well as the contributions of non-aligned researchers and research teams, is a key task for the future and requires a large systematic effort. The I2S proposal described here aims to provide a concrete starting point for this undertaking.

3. Useful concepts and methods from outside COR

A key rationale for developing the I2S framework is to make it easier for researchers tackling complex social and environmental problems to find and share useful concepts and methods, reducing the necessity to 'reinvent to wheel'. This section illustrates the point by describing six tools developed outside COR that may be useful for COR. Where the tools fit in relation to the three domains and five questions of the I2S framework is illustrated in Fig. 3. The tools were chosen to highlight the diverse research communities tackling complex social and environmental problems and with which COR could beneficially interact. Additional tools can be found in Bammer (2017).

Two tools come from other communities of practices tackling complex social and environmental problems. One is a toolkit for knowledge co-production which is a central tenet of much transdisciplinary research. The second, also a toolkit, comes from the change management community and provides tools for personal, team and larger systems change. (As an aside, this community also illustrates some of the complexities inherent in describing and working with existing communities of practice. Change management is not a unified community, often operates in the commercial rather than academic sphere, and is not necessarily focused on complex problems.) Two tools come from non-aligned research teams. One is a collaboration and team science field guide resulting from work at the US National Institutes of Health to improve the functioning of their scientific teams. The other is a toolkit for engaging and influencing policy, which is a compilation of the experience in international development of the Research in Policy and Development (RAPID) programme of the UK Overseas Development Institute. The descriptions of these first four tools have also previously featured in the journal GAIA's Toolkits for Transdisciplinarity series (Bammer, 2015b, 2015c, 2016b, 2016c). The final two tools stem primarily from disciplinary considerations applied to complex real-world problems. The examples used here are the ethical matrix, developed by an applied ethicist, and the matrix for understanding and managing unknowns which came from work in medical education.

3.1. Knowledge co-production toolbox

In the I2S framework the knowledge co-production toolbox is useful for knowledge synthesis (Domain 1, Question 3), with a few tools also relevant for supporting change (Domain 3, Question 3).

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Domain / Question	1. Knowledge synthesis	2. Unknowns	3. Supporting change
1. For what and for whom?			
2. Of what?			
- **systems**			
- **scoping**			
- **boundary setting**			
- **framing**			
- **values**	*Ethical matrix*		
- **harnessing and managing differences**	*Collaboration and team science field guide*		
3. How?	*Knowledge co-production toolkit (most tools)*	*Matrix for distinguishing three kinds of unknowns*	*Knowledge co-production toolkit (some tools)* *Engaging and influencing policy toolkit* *Change management toolbook*
4. Context?			
5. Outcome?			

Fig. 3. Tools useful for COR, developed outside COR, and organized using the I2S framework.

This toolbox was developed by td-Net (the Network of Transdisciplinary Research; new tools are still being added periodically) and funded by the Swiss Academies of Arts and Sciences. It aims to address questions about conducting transdisciplinary research. Some of the concepts and methods in the toolbox are likely to be familiar to community operational researchers, while others are likely to be new. The aim is to provide researchers with an array of concepts and methods for knowledge co-production from which they can choose those most appropriate for their particular research problem.

The methods for knowledge co-production are briefly described below, with full details, including references, available on the website (http://www.naturalsciences.ch/topics/co-producing_knowledge):

1. Soft systems methodology leads a heterogeneous group through the process of structuring a complex problem to deciding on the most desirable and feasible change while keeping worldviews explicit throughout.
2. Toolbox approach allows disciplinary experts to understand how their own and other disciplines approach research.
3. Three types of knowledge tool examines what is, what should be, and how we come from where we are to where we should be, thereby allowing explicit deliberation and decisions on the research question.
4. Actor constellation method uncovers implicit assumptions that disciplinary experts and stakeholders have about each other's relevance for, and potential contributions to, addressing the research question.
5. Delphi method allows a group of experts to anonymously develop a considered position demonstrating the substance and degree of consensus and dissent.
6. Emancipatory boundary critique allows stakeholders to uncover normative assumptions underlying solutions to complex problems proposed by disciplinary experts.
7. Most significant change technique provides a way for researchers and practitioners to compare values and priorities in monitoring and evaluating social change projects.
8. Storywall method enables reflection on the process of co-producing knowledge with each participant explaining how they perceived and experienced the joint process.
9. Nomadic concepts is a heuristic tool for exchanging understandings of concepts across disciplinary, professional and cultural boundaries.
10. Research marketplace tool can be used to initiate bilateral and small group exchange between (sub)projects that need to be linked.
11. Venn diagram tool focuses on developing a diagram for forming groups around joint topics based on participants' backgrounds, expertise, and interests.

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12. Give-and-take matrix can be used for identifying pieces of knowledge to be shared between subparts of inter- and transdisciplinary projects.

3.2. Change management toolbook

In the I2S framework the change management toolbook is useful for integrated research support for policy and practice change (Domain 3, Question 3). This toolbook, developed by Nauheimer (1997; now maintained on The Change Management Toolbook website: https://www.change-management-toolbook.com/), presents more than 120 techniques aimed at achieving change, many of which are useful for dealing with complex real-world problems. There are three major sections covering personal, team and larger systems change. Some tools are able to be used for more than one type of change. The full list of tools and references for them are available on the website (http://www.change-management-toolbook.com/).

Personal change tools include those that help people "think outside the box" and those that help people understand their own vision and goal. Examples of these tools are:

- Walt Disney Circle to develop and assess ideas through the roles of dreamer, realist and critic.
- Assessment and change of limiting beliefs to examine the achievability of a goal, especially identifying and exploring limiting beliefs and motivation to change them using a series of structured questions.

Team change tools include those that deal with different perceptions of reality and those that make possible learning within teams. Examples of these tools are:

- Wheel of multiple perspectives to capture the perspectives of each team member about the relevant stakeholders for a problem.
- Art of dividing a pumpkin to deal with the needs of all stakeholders in a way that respects equal rights.
- After action review to make learning conscious and explicit using four questions: What was supposed to happen? What actually happened? What were the positive and negative factors? What have we learned?

Larger systems change tools include those that (1) help understand the core principles and resources at play, (2) identify vision, values and goals, (3) help understand stakeholders, (4) help find leverage for change within a system and (5) work with whole systems. Examples of these tools are:

- Scoping to delineate the systemic context of the problem. This is a nine phase process using 28 provocative questions.
- Ralph Stacey's Agreement and Certainty Matrix to assess which decision making processes should be used. It is based on the degree of agreement on what should be done among the people directly involved and the level of certainty in the information base.
- Stakeholder Analysis to categorize stakeholders in terms of ability to influence process or outcomes, extent of change (of stakeholders) required and change effort required.

3.3. Collaboration and team science field guide

In the I2S framework the collaboration and team science field guide is applicable to all three domains and relates to one aspect of Question 2, namely harnessing and managing differences, which I argue is the essence of collaboration (Bammer, 2008, 2013). A key underpinning issue is building relationships, which is the focus of the field guide. The field guide was produced to better understand and assist scientific teams at the US National Institutes of Health (Bennett, Gadlin, & Levine-Finley, 2010).

The field guide is divided into nine sections, each covering the following:

- How to… (e. g., how to foster trust).
- Ask yourself: is it working? (Under this question tips are provided for identifying successes and failures, illustrated by case studies, along with take-away messages.)

The nine sections are briefly described below and further information, including about individual tools and references, can be found in the original field guide and website (http://teamscience.nih.gov):

1. *Preparing to collaborate:* This introductory section reviews issues relevant both to participating in and leading a research team; describes the importance of mentorship; lays out the value of self-reflection, understanding personality types, and recognizing the impact of emotions; and provides tips for resolving conflict and receiving feedback from others. Links are provided to three specific tools: Myers–Briggs Type Indicator to understand personality types, Thomas–Kilmann Conflict Mode Instrument, and 360-degree evaluations for receiving feedback from others.
2. *Building a research team:* Provides tips for interviewing new team members to ascertain their approach to collaborations though assessment of values, performance, and behavior. A link is provided to the Model of Group Development, which lays out five stages of group evolution.
3. *Fostering trust:* Provides information about two types of trust (calculus-based and identification-based) and creating the foundation for trust, including a template for developing a collaborative agreement.
4. *Developing a shared vision:* Provides four key questions.
5. *Communicating about science:* Compares dialogue with debate in discussing data, interpreting results, and other aspects of research communication.
6. *Sharing recognition and credit:* Criteria for evaluating contributions are provided.
7. *Handling conflict:* Provides tips about listening, principled negotiation, and "adversarial scientific collaboration".
8. *Strengthening team dynamics:* Reviews (a) factors that prevent the development of a strong team, (b) evaluation of relationships and performance, and (c) tips for keeping a positive mood.
9. *Navigating and leveraging networks and systems*: Includes suggestions for understanding a team as a social system.

3.4. Engaging and influencing policy toolkit

In the I2S framework the engaging and influencing policy toolkit is useful for integrated research support for policy and practice change (Domain 3, Question 3). The toolkit (which also covers guidance on diagnosing the problem and developing a monitoring and learning plan; not dealt with here) is based on the extensive experience in international development of the Research in Policy and Development (RAPID) programme of the UK Overseas Development Institute (Young et al., 2014).

The toolkit is briefly described here, with further details, including references for individual tools, available in the original reference and website (https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/9011.pdf). It provides methods, concepts and advice for developing an engagement strategy to influence policy, which involves:

- identifying realistic outcomes,
- identifying who or what is to be influenced,
- developing a theory of change,

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- developing and implementing a communications strategy, and
- assessing the available capacity and resources.

Three specific tools provide more of a flavor:

1. Influence and interest matrix. This maps stakeholders according to (1) their ability to influence the problem and (2) their interest or engagement with the problem. The matrix has four quadrants: stakeholders with high influence and high interest, stakeholders with high influence and low interest, stakeholders with low influence and high interest, and stakeholders with low influence and low interest. Location of stakeholders in the matrix helps identify with whom it is most productive to work and how.
2. Five questions for identifying systemic factors in the wider political and institutional environment. (i) Which branch of government holds the key to change? (ii) Where and how does political debate occur? (iii) What role do informal politics play? (iv) Is there really capacity to make change happen? and (v) How do external forces influence change?
3. Four options for communicating. This differentiates between formal and informal engagement, as well as between working cooperatively with the decision-making system ('inside' track) and staying apart, which makes a more confrontational approach possible ('outside' track). Four communication strategies result: advising (formal, inside), advocacy (formal, outside), activism (informal, outside) and lobbying (informal, inside).

3.5. Ethical matrix

In the I2S framework the ethical matrix is applicable to all three domains and relates to one aspect of Question 2, namely dealing with values. The method was developed for rational ethical analysis by an applied ethicist, specifically to recognize and resolve value conflicts about the issues confronting modern pluralistic societies (Mepham, 2000).

The ethical matrix provides a structured process for identifying, weighing and integrating different, and potentially conflicting, values among the various stakeholders concerned with an issue or problem. The matrix has three principles—well-being, autonomy and justice—which are listed on the horizontal axis, with the various stakeholders affected by the problem and decision-making listed on the vertical axis. The task then is to identify and document the ethical impacts of the matter under consideration in each cell of the matrix. Once the cells have been filled in, the relative importance of the issues identified needs to be weighed to assist in making a decision, although the process for achieving this is not well articulated. The ethical matrix can be used as a dialogue method, a desktop tool or a combination of the two.

3.6. A matrix for distinguishing three different kinds of unknowns

In the I2S framework the matrix for distinguishing three different kinds of unknowns is a tool for understanding and managing unknowns (Domain 2, Question 3). In disciplines, specific unknowns are seen as the substrate to be converted into knowledge that advances thinking in the discipline. However, for research where a problem-based perspective is taken, there may be critical unknowns that are outside the purview of any discipline (Bammer, 2013, 2016a). In addition, action often has to be taken in the absence of complete knowledge (and for complex problems it can be further argued that the nature of the problem means that complete knowledge is an impossible goal). Unknowns are the source of adverse unintended consequences and unpleasant (sometime disastrous) surprises. Even though it is impossible to consider and deal with all unknowns, the aim is to reduce their negative consequences for decision making and action. Kerwin (1993) developed a way of differentiating unknowns in her considerations of medical ignorance and the training of medical students. Smithson (Bammer, Smithson, & The Goolabri Group, 2008) adapted her ideas into the matrix shown in Fig. 4 as part of his wider thinking about ignorance and its social construction.

	Known	**Unknown**
Known	Known knowns	Known unknowns (conscious ignorance)
Unknown	Unknown knowns (tacit knowledge)	Unknown unknowns (meta-ignorance)

Fig. 4. Three kinds of unknowns (Kerwin, 1993), adapted by Smithson (Bammer et al., 2008).

The matrix provides a useful way of distinguishing between three primary categories of unknowns. The most familiar is ignorance that we are aware of, the 'known unknowns'. Most research addresses this kind of ignorance, seeking to fill known knowledge gaps. Another kind of unknown is knowledge that we do not know we have, the 'unknown knowns' or tactic knowledge. Culturally appropriate behavior is a good example.

The third kind of ignorance is what we do not know we do not know, the 'unknown unknowns'. We generally become aware of unknown unknowns in two ways. On a societal level unknown unknowns are exposed through hindsight, for instance after an event has caught us by surprise. For example before 2003, the communicable disease SARS was an unknown unknown—as a society we did not know that such a disease was developing and would strike. On an individual or community level, unknown unknowns can be exposed by interacting with people outside our usual circles, opening the potential for their knowledge to reveal an unknown unknown. For example, if I 'know' there is only one kind of rice, mixing with people from a culture or occupation (e.g. chefs) that use various varieties of rice can expose my unknown unknown.

3.7. Summing up this section

To reiterate, the aim of this section of the paper is to demonstrate a range of tools developed outside COR that may benefit COR. There are also several COR tools that would benefit other communities of practice and non-aligned researchers and research teams, but describing these goes beyond the scope of this paper.

4. Next steps

This final section suggests specific ways through which community operational researchers could use I2S to promote COR, enhance ways of dealing with complex social and environmental issues and strengthen their influence in research and education policy making.

4.1. Building common scholarly ground with other communities of practice and non-aligned researchers

The bulk of this paper argues that a key task for community operational researchers is to share concepts and methods with other communities of practice and with non-aligned researchers and teams. The aim is to promulgate COR concepts and methods, as well as COR as a community of practice, in addition to learning from the others about concepts and methods they have developed and find useful for dealing with complex real-world problems. Community operational researchers might therefore consider

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activities that they could initiate or join. As one example of the latter, community operational researchers might consider contributing to the Integration and Implementation Insights Blog (http://I2Insights.org), which aims to provide a forum for such interchange.

More ambitiously, it would be useful to develop one or more projects based around case studies, as a way of describing and exchanging methods, as well as testing this paper's argument about the value that I2S could potentially add to existing COR and other research on complex real-world problems. Imagine a community operational researcher and an I2S researcher working side-by-side to analyze a case from each perspective. The case study would provide a focus for discussing which methods were used, which other methods may have been useful, along with each method's strengths and weaknesses. Imagine also broadening this out to include representatives of other communities of practice—inter- and trans-disciplinarians, action researchers, system dynamicists, sustainability scientists and more—as well as non-aligned researchers. The chosen cases could be exemplars of the work of a particular community of practice and/or could specifically highlight aspects of the I2S framework, such as understanding and managing unknowns or dealing with value conflicts.

It is worth pointing out that COR and the other communities of practice do not fit together neatly like a jigsaw puzzle—instead the landscape is messy because they have different histories, worldviews and rationales. This may make finding common ground challenging and is a central reason for starting with concepts and methods, which are relatively unproblematic.

There are sufficient intersections among the various communities of practice to make sharing of concepts and methods beneficial. Further, non-aligned researchers and research teams would use existing concepts and methods where applicable rather than reinventing the wheel, if they were easy to find. The framework also recognizes – and provides a home for – useful tools developed by non-aligned researchers and research teams; these are also tools that existing communities of practice could benefit from.

4.2. Building political influence with other communities of practice and non-aligned researchers

There are at least two reasons to increase political influence by joining with other communities of practice and non-aligned researchers and teams. The first is to ensure that the concepts and methods developed for tackling complex social and environmental problems are widely and appropriately used. The second is to ensure that representatives of communities of practice for dealing with complex social and environmental problems have seats at the research and education policy tables, alongside representatives of disciplinary research.

A key reason for building a repository of concepts and methods is to improve understanding and action on complex social and environmental problems. This should result from helping researchers to identify and access the most appropriate tools for their particular research, rather than using tools that are a poor fit or wasting time and energy in reinventing tools. Encouraging researchers to use the repository will, however, not just happen; instead it will require concerted political action.

The uptake of statistical thinking and tools in quantitative research provides a useful example. It is now commonplace for funders and journal editors to ensure that grant applications and papers use the best statistical approaches by requesting specific reviews from statisticians. It is worth remembering that the discipline of statistics finds itself in its current happy position as a result of concerted political action to ensure that statistical understanding and tools are appropriately deployed. They made sure that it is no longer acceptable for statisticians to be brought into a project at the end, without input into the design, for example, or for a non-expert team to employ the methods they are familiar with, rather than those best suited to the problem. That change, which is still relatively recent, required statisticians to band together to exert their influence.

The I2S framework also sets out to provide a conduit for forming alliances to increase influence on policy decisions about research and education priorities and funding at institutional, national and international levels. The aim is to ensure that the best available ways of dealing with complex social and environmental problems receive appropriate and adequate attention. Two critical components are receiving a reasonable share of available funding and being subjected to fair peer-review processes for grants assessment, publication of results and evaluation of impact.

There are long-standing claims that "interdisciplinary" research does not fare well in the grants funding process. This has been supported in at least two empirical analyzes, specifically on Australian (Bromham, Dinnage, & Hua, 2016) and Austrian (Reckling & Fischer, 2010) grants data. Interdisciplinary research is generally used as a catch-all term in these discussions and would include, but not be confined to, COR. Although it is not clear if the reduced funding results from bias in the review process or from less adequate proposals, there are certainly potential sources of bias against interdisciplinarity in the peer-review process, including little appreciation of the kinds of unknowns that form the basis of the research questions and poor ability to assess the methods employed (Bammer, 2016a).

Banding together would help overcome current difficulties in identifying suitable reviewers for grant applications, paper submissions and impact statements. It would also allow appropriate selection and evaluation criteria to be established. The disciplines set their own standards of excellence and there is no reason why a coalition of communities researching complex social and environmental problems should not do the same. While these actions are critically important to ensure fair treatment of research on complex real-world problems, they are not sufficient to ensure a reasonable share of funding or institutional embedding of such research. This requires seats at decision making tables and strong reasoned advocacy there.

The work undertaken by community operational researchers and others tackling complex social and environmental problems is too important to remain relegated to the margins of the academic mainstream. But we will only gain our rightful place if we band together and fight for it.

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