Hand-rails in the swamp: Testing the Integration and Implementation Science framework in complex real-world research

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Research teams internationally are addressing complex social and environmental problems. Such problems are typically messy, confusing and not amenable to technical solutions alone. Schon (1995), who described such complex problems as 'swamps', also suggested that it was in these swamps that the most relevant research for society was conducted. However, these swamps present particular challenges for researchers: the research is conducted on a real-world situation, where decision-makers are trying to tackle complex problems in real-time and where their decisions have an impact; the problems are highly complex; the processes often have time, resource and knowledge constraints; each point in the process happens once and actions, both mistakes and successes, have consequences; and they are often highly political and highly conflicted (Robson-Williams *et al.*, 2018).

Transdisciplinary research is a response to try to navigate the swamp however it is relatively new in terms of the evolving relationship between science and society (Roux *et al.*, 2010) and evidence for the effectiveness of such research is being sought by funding organisations (Wiek *et al.*, 2014). An example of this is the mission-led National Science Challenge, 'Our Land and Water' in New Zealand. The mission is to enhance the production and productivity of the primary sector, while maintaining and improving the quality of land and water for future generations. The importance of co-innovation and transdisciplinary approaches is acknowledged, however, there has been both scepticism about transdisciplinarity and resistance to rethinking research design.

To contribute to the body of evidence on the effectiveness of transdisciplinary approaches, we used qualitative and quantitative methods to evaluate the Integration and Implementation Science (i2S) framework (Bammer, 2013). We hypothesised that the greater attention that research programmes paid to the elements in each of the three domains of the i2S framework, the more useful and usable their research outputs would be considered to be by a range of next users.

Seven case studies were chosen that covered a range of environmental and agricultural problems, included both research for policy and research for practice change and were considered complex in at least two of the following dimensions: scientific uncertainty, degree of stakeholder disagreement and degree of systemic lock in (after Arkesteijn *et al.*, 2015). Case study data were collected from a variety of sources: workshops with research teams to get descriptions of the case study, and interviews and surveys of end users to get perceptions of usefulness of the research process and outputs on a domain basis and overall. All of the workshop and interview data were assessed for the extent of consideration of the i2S framework elements and perceived usefulness, respectively.

To extend the analysis, a preliminary assessment based on publicly available information was made of the effectiveness of the case studies based on four categories of effects; usable products, enhanced capacity, network effects and structural changes (Wiek *et al.*, 2014). This is to understand if the extent to which a project considered the elements in the i2S framework and was considered useful, was reflected in its effects.

A correlation of 0.79 was found between the extent to which a case study considered the elements of the i2S framework in each of the domains, and the perceived end user usefulness of the research process and outputs. This relationship was consistent across all three domains, with correlations of 0.84, 0.78 and 0.81 for domains 1, 2 and 3 respectively. The overall evaluation by end users showed similar results, with a strong correlation (0.81) between the mean project assessed fit with i2S elements and overall end user evaluation. All of these correlations are significant at 95% ($p < .05$).

One potential concern with the methodology was that assessing the extent to which a case study considered the elements of the i2S framework did not explicitly capture how well those elements were actually managed. The significant correlation of 0.74 between the extent to which a case study considered i2S elements and project team self-evaluation of how well they performed, suggests that assessing the extent of consideration does, to a degree, capture how well the elements were managed. There was also a significant correlation between the project team self-evaluation and the perceived end user assessment of usefulness (0.67). These data indicate that the team self-evaluation was a slightly poorer predictor of perceived usefulness than the extent of consideration of the i2S elements, with case study teams tending to underestimate their performance in their self-evaluation.

The preliminary assessment of the effects of the case studies (after Wiek et al, 2014) suggests that the case studies that had greater effects, as documented in publicly available material, were also those that were regarded as more useful by end users and that had considered the variables in the i2S framework to a greater extent.

This research contributes to the body of evidence investigating the links between transdisciplinary research practice and the quality of research outputs and subsequent effects. The findings suggest that the concepts contained within the i2S framework are important for generating useful and effective research and could provide a handrail in the swamp for researchers.

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