



Eleven enablers of science thought leadership to facilitate knowledge exchange in environmental regulation

Stefan Kaufman^{a,*}, Anthony Boxshall^b

^a BehaviourWorks Australia at the Monash Sustainable Development Institute, Monash University, 8 Scenic Boulevard, Clayton, Victoria, Australia

^b Integrative Environmental Research, School of Biosciences, Science Faculty, University of Melbourne, Parkville, Victoria 3010, Australia

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ABSTRACT

Evidence informed environmental policy and decision-making remains aspirational. Knowledge exchange literature indicates necessary supportive elements and activities but acknowledges a gap in understanding of interpersonal and relational aspects. Inquiry is particularly lacking into the roles and potential of internal expert advice, especially in the micro-level instrumental decisions regulators make daily. We identify these characteristics as 'science thought leadership' (STL) and explore their role in experiences of successful decision support in environmental regulation. Forty-four cases in Victoria, Australia, and Florida, USA, were identified and analysed via appreciative inquiry methods. The cases prioritized in this process highlight environmental regulatory decisions, administrative in nature yet part of the policy cycle, as important sites of STL. STL is a set of characteristics and capabilities underpinning effective knowledge exchange, leading to better evidence-informed decisions. It is a series of 11 inter-related personal, professional and organisational enablers pivotal in cases when problem definition is contested, and legitimacy must be demonstrated. Integration, expertise and decisiveness in uncertainty is present when organisations and management value science and experts, and are externally accountable to justify decisions. Based on the findings, we present a conceptual model of STL and a checklist for its presence to assist both government and universities to recognize, work with and support STLs as crucial facilitators of evidence informed decision making.

1. Introduction

There is an extensive literature defining and exploring the critical roles of credibility, relevance and legitimacy in effective science policy interfaces (SPIs) in global scale processes such as negotiations on climate change, biodiversity and sustainable development (Sarkki et al., 2015; Cash et al., 2003). In this context, Sarkki et al. (2015) review of literature defines as:

- Credibility: the (perceived) quality, validity and adequacy and reliability of the knowledge, evidence and arguments exchanged
- Relevance (or salience): the ability to match knowledge with policy and societal needs, and the extent to which knowledge is usable.
- Legitimacy: the (perceived) fairness and balance of knowledge exchange at the science policy interface

It is likely these characteristics are important sub-global scales also. In national and state government policy and administration, evidence

informed decision making is more aspirational than reality (Donaldson, 2017). This is particularly problematic in environmental and public health policy and its administration, where using scientific knowledge and evidence to define problems, options and evaluate solutions is similarly both critical, and a basis for legitimacy. Gluckman (2016) notes that providing scientific advice to government takes place within an (multi-stakeholder) ecosystem - where a combination of actors both internal and external to government, provide advice that is formal and informal. Importantly: *All of this comes in many guises and is conditioned by context. For instance, there will be different mechanisms for regulatory advice, program development, and cabinet-level decision-making* (Gluckman, 2016, 969). This noted, SPIs as defined by Sarkki et al. (2015) conceivably operate at multiple scales, being: organizations, initiatives, or projects that work at the boundary of science, policy and society to enrich decision making, shape their participants' and audiences' understandings of problems, and so produce outcomes regarding decisions and behaviours'. To our knowledge however, the characteristics of successful knowledge exchange at the science-policy interface have not

* Correspondence to: Monash Sustainable Development Institute, 8 Scenic Boulevard, Clayton 3800, Melbourne, Victoria, Australia.

E-mail address: stefan.kaufman@monash.edu (S. Kaufman).

been examined in environmental regulatory decision making.

Gluckman's observation (above) usefully complicates and contextualises Caplan's (1979) seminal description of the research-policy gap in public decision making. He described public sector executive decision makers' use of evidence in the 'two communities' model. Executives had ready access to internally provided evidence for 'micro-level instrumental decision making', e.g. for program and service design and delivery. However, policy making and goal setting, or 'macro-level' decision making, was far less supported. Not only were executives still dependent on internal evidence (for better or worse), when it came to 'conceptual utilization' of externally produced research and evidence, executives were heavily reliant on their own and advisors personal access to, and synthesis of informal, non-empirically grounded resources, via processes best characterized as "eclectic... parochial... (and determined by) chance" (Caplan, 1979, 466–67).

Thus two, separated, communities are described- policy makers, and researchers: poorly connected, speaking different languages, differently motivated and functioning with misaligned rules (Caplan, 1979). Despite the significant impact of this model in research and discourse (including the structure of recommendations from this journal article), the neat description has not been born out in empirical research, and an important spectrum of two-way interaction falls between the two communities (Newman et al., 2016; Newman and Head, 2015; Sarkki et al., 2015; Gluckman, 2016). The respective, idealised cycles of policy and research may indeed be misaligned, but in messy practice, include opportunities to interact positively at multiple points. This paper contributes to expanding our understanding of the role of internal intermediaries in environmental regulation decision making as a specific, underexamined science policy interface.

1.1. Why is knowledge exchange in environmental regulation so hard?

In environmental policy and practice, lack of integration of natural and social sciences expertise and evidence further adds complexity (Van Kerkhoff, 2008; Cairney, 2016; Michaels, 2009). Recognised barriers to the exchange of diverse knowledge in environment management (Cvitanovic et al., 2015; Cvitanovic et al., 2016) include cultural differences (e.g., goals, epistemologies, value frames), institutional incentives and priorities (i.e., neither policymakers nor scientists are rewarded for interacting with each other), and the timeliness and accessibility of (published and) peer reviewed science, which is not synchronous with when and how decision-makers need to make decisions.

Principles for knowledge exchange in environmental management have emerged in response (Reed et al., 2014; Cvitanovic et al., 2015). In summary, they suggest that researchers:

- design any research with an end-use in mind from the outset
- identify and embed the relevant stakeholders in the project and actively engage them throughout the production and delivery of the science
- to ensure that as many stakeholders as possible experience results early and often, and finally
- monitor, evaluate and adapt this cycle.

When evaluation of such efforts does occur however, there are still significant gaps between goals and aspirations (Karcher et al., 2021).

In narratives of the science policy interface acknowledging complexity, effective knowledge exchange depends to a large degree on constructive exchanges between Caplan's two communities at multiple points. Indeed, there is also room for much more nuanced, multi-actor models of exchange. e.g. (van Kerkhoff and Lebel, 2006; Contandriopoulos et al., 2010).

While many names have been given to moving knowledge between and within heterogeneous groups into a use (e.g., knowledge exchange, transfer, translation and more; e.g., Contandriopoulos et al., 2010), fundamentally some form of interactive translation and integration, not

just dissemination, has been found to be vital in systematic reviews of effective practices of research use (Grimshaw et al., 2012; Lavis, 2006; van Kerkhoff and Lebel, 2006; Sarkki et al., 2015; Hoffmann et al., 2022). For example, Bammer (2013) suggests four important translation activities:

1. sharing what is known, including what has worked and has not worked, so that policy makers and practitioners can develop effective actions
2. identifying remaining unknowns to help policy makers and practitioners take these into account, as well as to reduce, or at least be better prepared for, unintended consequences
3. critiquing current and proposed policy and practice
4. providing new ideas for policy and practice.

Pannell et al. (2018) point out that the chain between environmental research and its benefits through policy change include multiple stages and links. Each presents challenges and entails time lags, and if any link fails, the chain breaks. For these and many more reasons, it is not surprising that there have been numerous calls for brokering and intermediary functions to close the gap in using evidence, well beyond environmental regulation (including Caplan, 1979). 'Bridging workers' across the domains of policy and research, and across disciplines and sectors, are particularly crucial in complex decision making contexts (Michaels, 2009; Shaxson and Gwyn, 2010; Van Kerkhoff, 2008; Olejniczak et al., 2016).

In part, this focus on intermediaries since Caplan recognizes that in practice, decision makers rarely have the opportunity to consider a fraction of the relevant evidence on a given problem, analyze its implications, or to identify, let alone fill, critical gaps in knowledge (Cairney, 2016; Head, 2016). Cairney (2016) notes related internal and interpersonal challenges for decision makers in environmental regulation and policy: they work in complex, quickly changing environments. They necessarily must draw on two kinds of shortcuts: 'rational' - pursuing clear goals and prioritizing certain kinds and sources of information; and 'irrational' - drawing on emotions, gut feelings, deeply held beliefs, favored advisors (who themselves struggle at the edges of their expertise and available evidence), and habits (Cairney, 2016; Burgman, 2016; Sutherland and Burgman, 2015). Perhaps even more so than in general public decision making (Newman et al., 2016; Cherney et al., 2015), in environmental and public health regulation we should expect a strong reliance on readily available, internal advice and personal networks, in relevant and accessible forms, at the right time, to meet the needs of decision makers (Head, 2016; Cairney, 2016; Lavis, 2006; Easton, 2018).

Further, evidence is only one input into public decision-making; there are layers of mediation between research, policy and its implementation (Lavis, 2006; Lavis et al., 2009; Cvitanovic et al., 2015; Head, 2008). The championing of evidence in contention with both legitimate and more questionable inputs into public decision making is usually done by scientifically literate individuals, with specialist skills and traits, who also need an understanding of the decision-making process. We note that this role is not limited to depth experts and specialists, nor qualified and/or practicing scientists (De Barro et al., 2014; Robinson and Wallington, 2012; MacKeracher et al., 2018). People in these roles are called many things – knowledge brokers, policy analysts, technical specialists, regulatory intelligence officers (even 'Nigels' (Sparrow, 2008, 2009)) and evaluators (Michaels, 2009; Shaxson and Gwyn, 2010; Olejniczak et al., 2016; Quarmby, 2016; Sparrow, 2000). The above analysis highlights the significance of SPI attributes of credibility, relevance and legitimacy in knowledge exchange in public administration and regulation, and not just at the scale of global science policy interfaces (after Sarkki et al., 2015). That said, it also highlights the critical, and underexamined role of internal experts and intermediaries in these processes.

In particular, in this paper, we respond to a call for more research

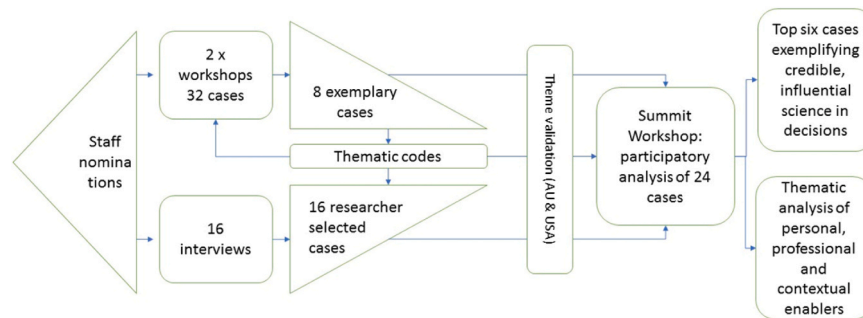


Fig. 1. Process map for the science thought leadership discovery process, including methods used.

into good practices for knowledge exchange into decision-making in environmental management and regulation (Reed et al., 2014; Cvitanovic et al., 2016). There are still few studies looking into the crucial enabling elements that lead to successful knowledge exchange, particularly in the context of environmental regulation. The crucial interpersonal and relational traits that drive accessible, effective and efficient uptake of science into decision-making, has been identified as a specific gap in our understanding of knowledge exchange at the science policy interface (Cvitanovic et al., 2016). The characteristics supporting success in this interpersonal element of championing knowledge exchange does not have a collective name. In this research, we explore the notion that while champions of knowledge exchange are not the decision makers, nor formal leaders, they share particular characteristics or capacities as science ‘thought leaders’.

1.2. Science thought leadership

‘Thought leadership’ for this project emerged in 2014 from our primary research host organisation as a term to describe a key role of internal experts and intermediaries. Thought leadership is sometimes used colloquially to describe influence, trend setting and ‘soft’ leadership. McCrimmon (2005) builds particularly on this last element to suggest: “In an organisational context, thought leadership is simply the successful championing of ideas laterally to peers or upwards to superiors, and occurs by any mix of example, logical argument, factual presentation or inspirational emotional appeal”. Importantly, this often occurs outside of and in complement to formal decision making roles.” (McCrimmon, 2005).

Such an activity can obviously occur in many ways, on many topics, but the introduction above highlights the criticality of such a role or capacity in effective knowledge exchange, and the term itself is commonly used inside public sector organizations and in public discourse (Drezner, 2017). For the purposes of our research, ‘science thought leadership’ is when people using, brokering or providing evidence are (simultaneously): influential, credible and valued in supporting decision making in their organization and its context.¹

A study of participants’ use of interpersonal influence in policy debates found that transformational characteristics, especially inspirational appeals, were among the most effective tactics to influence setting the vision for, and resolving issues in, public policy debates (Jensen, 2007). Well-honed transformational characteristics emphasizing the ability to articulate the mission, a vision, and providing inspirational

motivation have been found to be weak in public sector leadership, which may also partially explain the relatively weak role evidence plays in many decisions (Trottier et al., 2008; Lavis, 2006; Cvitanovic et al., 2016). Conversely, expert advice and judgement, can, when rooted in knowledge and a field of practice, with the experience of feedback from thousands of cases, lead to ‘virtuoso’ performances of being able to provide the right evidence, in the right way, when its needed (Dreyfus, 1992; Burgman, 2016; Flyvbjerg and Sampson, 2011).

Note we do not argue that STL is a replacement for, nor superior to, other important elements of knowledge exchange. A number of complementary solutions to maximizing the ability for science to be engaged with decision-making processes have been identified by Cvitanovic et al.’s (2016) review.

Noted enablers include:

- applying new models of knowledge exchange
- using co-production approaches
- embedding scientists in decision making processes
- employing knowledge brokers
- creating boundary organisations across disciplines, research, policy and practice
- publishing better products and vehicles for disseminating scientific information (e.g., knowledge synthesis reviews, policy forums etc), and
- working to create enabling conditions for both research institutions and users (e.g., changing organisational incentives and goals for desired behaviours).

Science thought leaders are likely to be important in all the above activities. Yet the role of science thought leaders, and what capabilities and characteristics are required to be one, is a gap in understanding and merits further investigation. A better understanding is needed of exactly how science thought leadership contributions in knowledge exchange help to reframe the understanding of problems, and possible responses to them, in ways that colleagues and decision makers find credible, influential and valuable.

1.3. Aim and motivation

We aim to understand how, when and why credible, valued and influential integration of science occurs in environmental regulatory decisions - science thought leadership. By identifying and analyzing instances of science thought leadership in detail, we expect to articulate its contributions to better knowledge exchange, through understanding the characteristics of the people and the contexts that exemplified science thought leadership in environmental regulators.

Establishing this can inform both internal experts and academic researchers wishing to have more influence on policy and major administrative decisions (see gaps highlighted in Cvitanovic et al., 2016 and the characteristics embedded in the 10 principles articulated by Gluckman (2014) on science advice to Government). This knowledge can also

¹ Notably, this is an ‘internal’ definition which emerged in 2014 in the context of the organization hosting the primary research of this paper, reflecting the importance of better recognizing, and supporting the thought leadership of internal scientific experts and intermediaries in evidence informed decision making. The research team and organization were not, we believe, aware of the discussion of credibility, relevance and legitimacy in global science policy interfaces occurring at roughly the same time (Sarkki et al., 2015), possibly indicating a co-evolving ‘practice-theory’ gap – (after Thomas et al., 2022) - which this paper contributes to addressing.

Table 1
Participation by phase.

Phase / Organisation	Establishment	Exploration	Consolidation	Summit workshop
EPA Victoria	33 Staff (workshops)	33 Staff (workshops)	~ 50 staff (presentation prior to USA phase of the study)	20 previous participants 5 senior decision makers (workshop)
External	NA	5 Victorian government 3 Victorian academics 2 NGO 2 consultants 3 FDEP 1 US EPA (Interviews)	FDEP Nature Conservancy World Bank (Meetings and presentations)	3 academics 2 Victorian government (workshop)

help organisations wanting to foster decision making more informed by evidence to better identify, support and develop conditions and individuals that facilitate it.

2. Research methods

2.1. Method

An appreciative inquiry (AI) method was used (Cooperrider and Whitney, 2005): where organisations collect and learn from ‘peak experiences’ or cases with their staff. These peak experiences or case are significant instances where staff felt particularly effective, enabled and fulfilled in their work (Mone, 2008; Cooperrider and Whitney, 2005). The peak cases in this study were gathered and validated throughout the process (Fig. 1) by both internal and external parties. In the context of interdisciplinarity and integration, appreciative inquiry can be valuable for creating a shared understanding of problems and opportunities, and integrating visions, world views and values. As such, AI has utility both in organisational settings, and between teams of researchers and expert practitioners (McDonald, 2009: 97–99).

To analyze possible cases, and ‘verify’ them as significant or ‘peak’, ‘exemplary’ cases, our approach also draws on an application of AI applied in developmental evaluation: used to understand and support innovation in conditions of complexity and uncertainty via participatory evaluation of multiple cases and activities across a program or intervention, and between diverse contexts (Davies and Dart, 2005; Patton, 2011). While a positive in terms of its application to organizational change and action research (Cooperrider and Whitney, 2005), it’s important to note that AI is a method that focuses on learning from strengths rather than identifying the impact of deficits, i.e. it does not directly assess the effectiveness of a lack of something (i.e., the enablers of STL in this study). AI focuses on the presence of something the participants experienced and draws its strength as a method from reflecting on the impact of that presence.

2.2. Study context

2.2.1. Environment Protection Authority of Victoria

Between 2011 and 2016, the Environment Protection Authority of Victoria (EPA Victoria) underwent substantial reform in response to multiple external inquiries, a series of reforms recommended by a Ministerial Advisory Committee and internal reviews (Brouwer, 2009; VAGO, 2010; Krpan, 2011; Victorian Government, 2016; MAC, 2016; DELWP, 2017). Some recurring themes across all reviews were a lack of clarity about when and how to enforce the law, insufficient systems, processes and data to inform good decision making, insufficient science-based decision-making and a confused picture of how the regulator balanced competing interests across government, industry and the community (Curtis and Kaufman, 2020; Windholz, 2016). Major reforms stemmed from these reviews and the subsequent Government responses leading to a new Environment Protection Act for Victoria,

Australia, a major injection of resources and a large-scale organizational transformation (EPA Victoria, 2018), including reforms to the science and expertise capability of the EPA Victoria and the establishment of a Chief Environmental Scientist with responsibilities to advise the Authority and Minister. Many of these issues were being aired, and reforms highlighted, and being developed, but not yet published and enacted, at the time of this study.²

2.2.2. Florida Department of Environmental Protection

In the period 2013–2016, the Florida Department of Environmental Protection (FDEP), Florida, U.S.A had been sharing the ‘Environmental Problem Solving’ (EPS) process (Herbster, 2013) with EPA Victoria. EPS is a regulatory problem-solving approach which is strongly analytical, and evidence driven, and facilitates dialogue between staff and decision makers by integrating top-down and bottom-up processes. It was developed and disseminated by the FDEP based on Malcolm Sparrow’s synthesis of effective regulatory ‘craft’ (Herbster, 2000; Sparrow, 2000). The chance to compare experiences of science thought leadership in the two different contexts was thought to be potentially useful and insightful by the study team, given the contemporary exchange of operational strategy and decision-making processes at the time of the study.

2.3. Process overview

The project used an iterative and multi-method research approach between December 2014 and September 2015. Fig. 1 outlines the process we used to identify exemplary cases of science thought leadership and facilitate reflective analysis and discussion on how and where it applies.

To summarise: staff initially confidentially nominated potential instances of STL in an survey. All staff participating were invited to workshops to further develop and begin to evaluate cases, resulting in 32 potential examples of STL and eight ‘short listed’ exemplary cases. A nominal group technique process inductively identified personal, professional and organizational factors present in cases (Harvey and Colin, 2012). Simultaneously, the researcher and project steering team selected interviewees from outside of the EPA that they judged were potentially relevant examples, creating another 16 cases. Shortlisted cases and themes were tested for relevance with partner organisations in Australia and the US. Finally, a summit workshop, inviting all participants plus key organizational stakeholders analyzed 24 cases. This included participants deductively applying themes generated earlier in the process, but focused on iteratively selecting cases that were felt to exemplify science thought leadership were shortlisted, with consensus justification for choices discussed and recorded, resulting in a final ranked ‘six’ exemplary cases. A detailed discussion of implementation, including recruitment, group processes, and decision making can be

² Representatives of the MAC inquiry secretariat observed the project summit workshop.

found in the Appendix One.

2.4. Participant overview

Forty-eight internal and external participants engaged in substantial way in process described above are outlined in Table 1, below. Most participants were general staff from the organisation's science, compliance and enforcement, statutory policy and approvals and permitting functions. All participants were invited based on the relevance of their role to the study. No senior manager in the host organisation provided peak experiences in earlier phases; we think this is most likely as the workshop timing and length may have been unsuitable for them³. While the 16 in-depth interviewees were predominantly government employees in Victoria and Florida from agencies other than the EPA or FDEP, they also included three individuals then working in university research, consultancy and a non-government organisation. While it was visible to workshop participants who was participating in a workshop, the reflections from cases were de-identified when discussed in plenary. However this was unnecessary as, although asked, no participants requested de-identification who shared cases. Final summit workshop participants included senior managers and leaders compared to the earlier workshops.

3. Results

Analysis of 24 peak experiences (i.e., those cases of significant instances where staff felt particularly effective, enabled and fulfilled in their work) in the final summit workshop identified 11 key elements of STL and 6 exemplary cases. The workshop used individual, and group facilitated theme extraction by asking participants to consider and nominate patterns both as individuals and as a group. Clustering by salience allowed prominent patterns to be identified leading to identifying a total of 11 overarching themes across 4 categories of enablers: Situational (2), Personal Enablers (3), Professional Enablers (3), and Organisational Enablers (3). As above, we identified the 'top 6' cases demonstrating STL in action. These were ranked by participants in order of 'most exemplary' in the summit workshop, and presented along with consensus reasoning for the choice, and an abridged summary of relevant challenges and enablers in Table 1, below. They are available in detail in the Appendices Two and Three, along with a full list of all cases from the project. Each of the exemplary cases detailed there provides a case study narrative of a given situation, the key challenges, and what got participants through them (enablers), as is summarized in Table 1, and readers are encouraged to pause here and review the two page caselets before proceeding. Table 2.

3.1. Situational elements emerging from common challenges

Despite the diversity of cases, there were a high consistency in the challenges encountered and overcome identified in the review by participants (Fig. 2). This leads us to highlight the following two overarching themes as situational elements of STL, summarizing the relevant challenges.

3.1.1. Emergent from multiple actors -

Science thought leadership is an emergent capability involving multiple people, roles, functions and disciplines.

All case studies bar one involved more key actors and 'communities' than just those of scientist and a decision maker, i.e. multiple people and

roles. There was frequently variety in contributing roles, including scientists, operational staff, project managers, brokers, decision makers and often representatives of varied external stakeholders. Ensuring there is influential, credible and valued science in regulatory decisions is a multi-role and function task. This emerged out of multiple contributions.

3.1.2. Problem focused

Science thought leadership is particularly needed when gaining agreement on problem definitions is challenging, amongst issues of legitimacy and competing values and interests.

Gaining agreement on the problem being addressed was most cited, followed by issues of demonstrating legitimacy (most prominently externally, but also internally), integrating different values and interests and balancing hunches/opinions with evidence. See also organizational factors, below.

3.2. Personal enablers of science thought leadership

Personal enablers relate to intrinsic characteristics like motivations, values and beliefs – i.e. qualities that arguably need to be recruited for and/or encouraged to the fore where present, rather than being easily trained. Participants identified 8 personal characteristics as most relevant across multiple examples (Fig. 3).

This leads us to highlight the following three 'personal' overarching themes in this category.

3.2.1. Balanced public good focus -

Science thought leaders apply reason and evidence to support decisions that balance competing interests to achieve the public good.

This characteristic was perhaps best expressed as the desire of participants to use reason and evidence to make a positive difference. As a scientist in one of the cases voted as best exemplifying credible, valued and influential science in decision making said: *It was a great job for me because it's one of the few areas that you're allowed to be a good scientist in carrying out this duty of environmental protection under the confines of the law. Where you effect the most change by working within the system (C11).* Rather than a license to act on one's own beliefs or ego, this is a reflective effort to identify and achieve the greater public good: *We live up to that aspiration when our decision-making processes and communications move debates or concerns in the community to accept, if not support, a balanced regulatory decision (C2).*

3.2.2. Persistent, positive & generous

Science thought leaders are persistent, positive and generous.

None of the examples shared were free of challenges, and often required multiple attempts from participants over long-time frames to achieve a positive influence on the decision. *Over twenty years there was a diverse group of people involved, many just for one to three years. A lot of it was almost being a teacher and mentor to new people on the committee and decision makers around it, actively engaging them in the process so far (C11).* Persistence over time is also significant in that it allows other enablers to come into play. *We were initially very unhappy when the tribunal blocked the preferred solution. Officers showed tenacity and perseverance, this was backed up by strong leadership ... acknowledgement of other victories that had been achieved We commissioned more science to test/model the effectiveness of other options ... kept on talking with the different players, maintained the relationships. (B8).*

3.2.3. Bravely reframe problems with evidence

Science thought leaders are valued for courageously reframing understanding of problems and solutions with reference to evidence and analysis.

Consistent with (McCrimmon, 2005)'s definition, science thought leaders were recognised for their ability and confidence to recast problems in insightful, disciplined and evidence based ways that transcend management hierarchy. In one of the exemplary cases, where agency staff were able to detect and implement a solution to a bias in research

³ This may also reflect the phenomena sometimes colloquially referred to as "every prophet is stranger in their own land" i.e. invitations to participate were accepted by senior people outside the host organisation with relative ease, whereas the project internally may have suffered from being seen as relatively accessible and thus taken for granted.

Table 2

Overview of six exemplary cases of science thought leadership identified in the project's closing participatory summit workshop, in order of 'most' exemplary as voted in the most significant change process.

Rank/ID/Title	Context	Significance/Why chosen	Challenges	Enablers
(1) C5: Restoring the Everglades in a statutory attainment program	DEP Florida Everglades multi-stakeholder group implementing the governor's restoration strategy after decades of court cases.	The story demonstrates the importance of transparency and integrity, in a multi-agency approach, with clear success outcomes defined by science, and reflecting non-human aspects of the environment. All of this was achieved with resilience, respect and accountability.	Disagreement on the problem Difficulty demonstrating legitimacy externally	Internal and External accountability Knowledge/experience Relationships/ Networks Resilience Public good orientation Management support
(2) A12: Agreeing on 5-year plan priorities based on intelligence analysis.	EPA Victoria: Identification of priority cross-functional problems to tackle in the 5-year plan 2011–2016	The story shows the value of testing gut feel with analysis, hard science and logic, then distilling and communicating it effectively to help EPA choose what to prioritise.	Disagreement on the problem Difficulty demonstrating legitimacy internally Balancing expert and practitioner hunches with evidence	Knowledge/experience Decisiveness in uncertainty Relationships/ networks Valuing diverse knowledge/skills
(3) B8: Responding to poor environmental quality at Brooklyn, Melbourne	EPA Victoria: Task force responding to an industrial estate in Melbourne's west, surrounded by residential areas, with long running and high impact odour and dust issues.	Exemplifies integrating policy, science, government and community, bringing people together inside and outside of EPA, and it got a concrete outcome through influence.	Disagreement on the problem Difficulty demonstrating legitimacy externally	Resilience & Persistence Dedicated team Valuing diverse knowledge/skills External accountability
(4) B10: Supporting technology investment decision making	EPA Victoria: Technical support for an external panel assessing Hazardous Waste Fund proposals for R&D aimed at landfill diversion towards more circular solutions.	The story shows confidence and courage in challenging authority and the status quo; delivered with clear, concise and quality assured science, credibly communicated in a business case; with the outcome of enabling decision makers to consider evidence, not just acting on gut feel.	Disagreement on the problem Difficulty demonstrating legitimacy externally Lack of organizational support	Knowledge/experience Relationships/ networks Using evidence Management support
(5) C11: Developing biological water quality assessment criteria	DEP Florida: Work contributing to, and eventually leading, a technical committee charged with the development of biological water quality assessment criteria.	The story shows an understanding of roles, their own and others, and the need to relate scientists and engineers/assessment officers' views; and the need to integrate the scientific and political needs; with a view to making it all work.	Disagreement on the problem Difficulty demonstrating legitimacy externally Balancing expert and practitioner hunches with evidence	Resilience/persistence Knowledge/experience Relationships/ Networks Public good orientation Valuing diverse knowledge/skills
(6) C12: Building scientists skills to support litigation	DEP Florida: Mentoring and supporting staff to participate effectively in legal cases as scientific experts.	Demonstrates that just good science is not enough, you need to be able to communicate and show the link to the decision the regulator makes. You must have appropriate evidence. You may have good science, but that is not the same as good evidence.	Difficulty demonstrating legitimacy externally Balancing expert and practitioner hunches with evidence	Translation/communication External accountability Organizational support

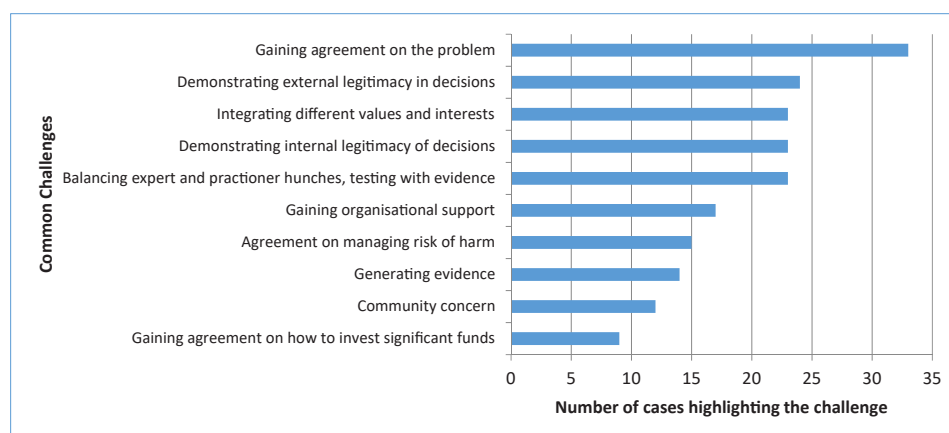


Fig. 2. Common challenges overcome in cases.

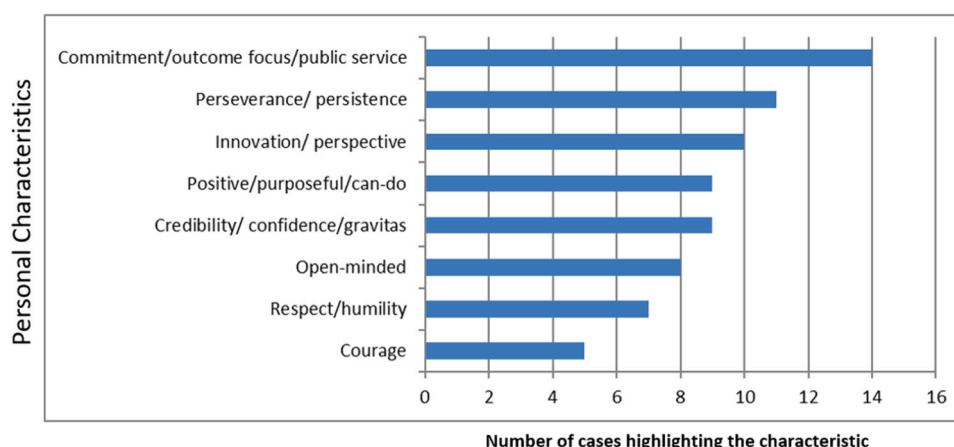


Fig. 3. Personal characteristics observed in cases of science thought leadership.

and development funding decision making, a participant reflected that: *‘Thought leaders’ are not only experts or people appointed to independent or expert panels, but also those who are working ‘on the ground’. They just need to be allowed to think, share and act on their thoughts using evidence - Sometimes this means trusting our own staff and internal experts rather than deferring to external experts (B10).* See Table 1 and Appendix Three.

3.3. Professional enablers of science thought leadership

This thematic cluster was labelled as ‘professional’ as it primarily consists of characteristic enablers that can conceivably be gained via experience, mentoring and coaching, and/or via training, rather than what may be more intrinsic, as above.

This cluster (Fig. 4) suggests the following three overarching themes of professional enablers.

3.3.1. Translators, brokers and communicators

Science thought leadership is excellence in translation across disciplines, evidence, sectors and interests.

The ability to translate, broker and communicate across the needs and interests of different disciplines, sectors and backgrounds and relate them to evidence was highly valued. This includes, but extends well beyond, good science communication skills. For example: *I found it difficult initially to align the needs of all the stakeholders into the assessment there (were) strong opinions around the core of the problem. While there was knowledge about the nature and types of data that were relevant, we lacked information that would allow us to assess and prioritise. I worked with the team to try to link their questions, ideas and opinions to data (A12).* Another of the exemplary cases was chosen because it showed the importance of integrating scientific evidence with regulatory decision making to withstand legal challenges: *just good science is not enough; you*

need to be able to communicate and show the link to the decision the regulator makes. You must have appropriate evidence. You may have good science, but that is not the same as good evidence (C12).

3.3.2. Accesses and values other expertise and knowledge

Science thought leadership depends on having, and valuing, expertise and knowledge.

While this may seem obvious, providing expertise and knowledge is highly valued. There was also evident respect and interest in other expertise and forms of knowledge, for example: *It was important that it was a cross-disciplinary team – scientists, decision makers, communicators. None of these functions could have fixed it on their own, it required all of them to be involved (B8).* Having expertise and knowledge helped gain access to decision making processes, but it was also a source of resilience in the face of adversity. *A lot of what keeps me going is that it’s just so much fun learning about all these ecosystems and how complicated they are, and then using good communication and applying that knowledge to protecting them. On the one hand, you get out there and start putting together this information and it’s just fascinating, but then you have to make sense of the complexity and then help your colleagues do some beneficial decision making with that complex information (C12).*

3.3.3. Decisive in uncertainty

Science thought leadership requires decisiveness in the face of uncertainty.

The third most significant professional theme identified was the ability to support decisions, while still taking into account uncertainty. *People vary in their unstated appetite for risk. Conventional science training encourages a greater fear of being wrong rather than the being right. But, the social value of the scientific information is that it enables decisions... you are trading off at each point in the process the possibility and the consequences of being wrong, how we would know and how soon, and being explicit about*

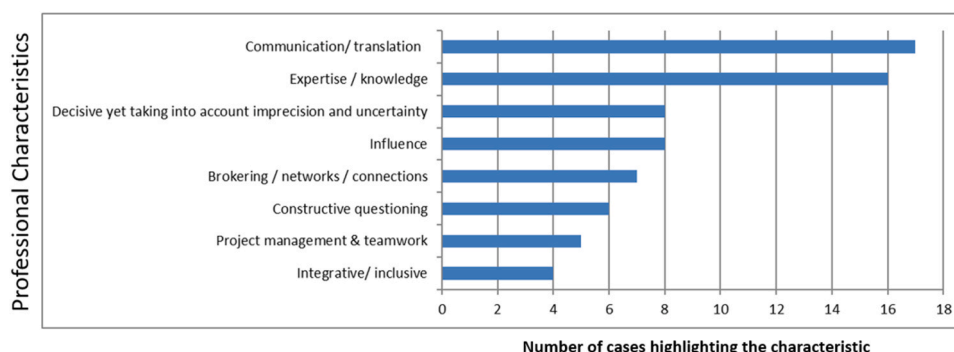


Fig. 4. Professional characteristics observed in science thought leadership cases.

what that means, it's part of the decision (C2). Another case was considered exemplary because it shows the value of testing gut feel with analysis, hard science and logic, then distilling and communicating it effectively to help choose what to prioritise (A12). Conversely, perceptions of 'paralysis by analysis' can be highly detrimental, with one participant recounting a conversation with a senior executive commenting 'science is killing this organisation', expressing frustration at a perceived lack of action due to the need to conduct further research.

3.4. Organisational and contextual enablers

This cluster of themes represent aspects that can conceivably be planned for, designed and managed by organizational leaders and architects when considering role, structures, processes and organizational culture (Fig. 5).

Three organisational and contextual aspects that we highlight as overarching themes are:

3.4.1. Decision-makers that value scientific insights –

Science thought leadership benefits from decision makers who value scientific insights while integrating them with other considerations.

Participants understood science is just one of many inputs into decision making, many of them more pressing to decision makers, and so organisational and political commitment to including science is important. One senior administrator commented: *We tried to 'leave the agency hat at the door', but also had to respect that everyone had to go back to their masters, and sometimes that meant temporarily adopting an 'agency position'. This was tolerated so long as they got back to the underlying goal of letting the science speak for itself. ... And when it threatened to go badly off track, I could go the Secretary ... to bring these people back to the table (C5).* A senior scientist involved in a national standard setting process said it worked because there was support for: *working towards what is correct rather than just what's best for our mob. Where the representatives were given the authority, at least some of them were able to represent what they believed was right and good and scientifically based (C4).* See also case C7 (Table 1 and Appendix Three). Valuing and integrating science doesn't mean prioritising it above other considerations, rather ensuring that is included as an important consideration.

3.4.2. Mutual respect between experts and management

Science thought leadership depends on mutual respect between people in expert and management roles.

Participants valued positive working relationships between people working as scientific experts, managers and decision makers, characterised by mutual respect and understanding. One participant recounted a disagreement with a decision maker about a policy position: *I*

remember us sitting down for about an hour and talking about why and what the consequences would be of moving from the ideal situation to a compromised situation. He understood exactly where I was coming from. He wasn't saying what I was doing was wrong and he didn't want to just bury it. He actually took the time to understand, to explain why that couldn't happen... we both walked out of that meeting comfortable with the decision (C7). Another senior technical advisor found it useful to take the view that: *A decision must be made... success is ensuring that those responsible for decision making in the community have facts in front of them that are complete, accurate and properly contextualised (A12).*

3.4.3. External accountability & transparency

Science thought leadership benefits from external accountability and transparency.

External accountability to explain decisions in relation to the evidence emerged as a strong strategic and immediate driver for organisations to overcome barriers to integrating science into regulatory decision making. For example, in one of the exemplary cases, appeal of agency decisions was common: *Over time, our leaders realised that if you can't show you're properly carrying out your delegated legislative authority and if you're arbitrary or capricious, not using the science, you will lose your case. So you need your data, experts and science to be able to support this, to show the validity of the decision (C11).*

Accountability can be informally and socially imposed also. For example, visibility and accountability due to community interest can also be important, especially in inter-agency decision making. In one of the final ranked cases, a shared, evidence-based understanding of the problem and preferred solution between regulators and community groups became a source of leverage in negotiating inter-agency coordination, and central government funding to support remediation of a precinct-wide problem. *The community initially disagreed (with regulatory staff) about the source of the problem. There was a lot of work needed to communicate the scientifically sound findings proving the source of the problem. Once (we) were aligned on the issue the collective influence was far greater. we issued tactical media releases, the community lobbied (politicians)... At the same time this information was also communicated to (other agencies) who could then be better influenced to make changes. (B8).* Finally, as discussed above, interpersonal accountability to explain how contributions are considered between people providing and/or using science and decision makers was also highly valued. Arguably, it would also be a key enabler of the ability to explain decisions externally and is significant in the nature of the relationship between scientists and management in the organisation (Table 3).

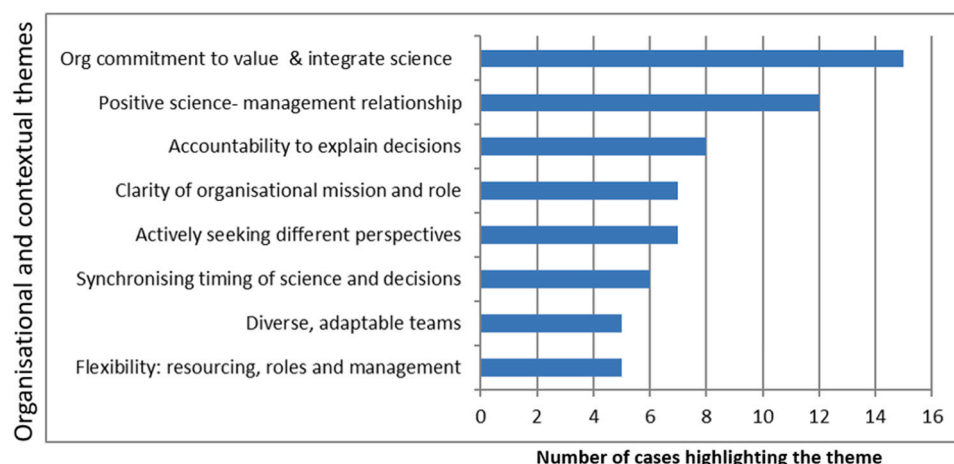


Fig. 5. Organisational and contextual themes observed in science thought leadership cases.

Table 3
Summary of categories and elements of science thought leadership.

Category	Overarching themes
Situational	1. Emergent from multiple actors
Personal	2. Problem focused
Professional	3. Balanced public good focus
Organisational	4. Persistent, positive & generous
	5. Bravely reframe problems with evidence
	6. Translators, brokers and communicators
	7. Accesses and values other expertise and knowledge
	8. Decisive in uncertainty
	9. Decision makers value science
	10. Mutual respect between experts and management
	11. External accountability & transparency

4. Discussion

4.1. Theory in practice

This work provides examples of science thought leadership and details the situational, personal, professional and organizational enablers and themes that bring it to the fore. This adds crucial missing detail and insight on how internal actors in environmental protection public decision making enable knowledge translation (Bammer, 2013) and knowledge exchange (Reed et al., 2014; Cvitanovic et al., 2016) in an under examined science-policy interface (Sarkki et al., 2015), with its own dynamics and characteristics (Gluckman, 2016; Head, 2008), now better elucidated.

Across 44 case studies, participants in an appreciative inquiry process across two different but similar environmental regulators identified exemplary cases and participated in thematic analysis. While interesting and often inspirational in themselves, the collected body of work also provides general insights into how science thought leaders operate. The narratives and generalisations from the research have expanded our understanding of what science thought leadership is, and how it might be encouraged in individuals, groups and within organisations. The overall findings can be summed up as a graphical abstract as depicted in Fig. 6.

From this work (and building on the list of enablers for knowledge exchange in decision-making processes from Cvitanovic et al., 2016), it is clear STL roles and characteristics are important for internal experts and scientists, and they run deeper and more broadly across organizational and situational contexts, and personal and professional capabilities.

Interpersonal and transactional skills are evident throughout cases – rather than lone science thought leaders, what we see are STL communities. Relational skills within and between teams of agency staff, stakeholders and executive decision-makers matter. People involved in the case studies, highlighted by others as science thought leaders, are drawing on leadership capabilities, and particularly transformational capabilities, especially those that were inspirational, and insight- and mission-orientated (as discussed in both McCrimmon, 2005; Trottier et al., 2008). Staff involved in these types of decisions show leadership, and also provide the evidence, insights and perspectives needed for senior decision makers to lead and influence too, building on the work of Jensen (2007).

The ability for science thought leaders to stay positive, engaged and involved was also seen as important. Perseverance and strong, intrinsic and public good motivation often fuel the extended work required to overcome barriers. This was apparent in many decisions discussed in the research, and not simply those with high public or political visibility. Providing decisive, credible and influential input often entails being patient and ready when a narrow window opens to make a difference, using insights and evidence that may have been first realized by the STL years ago.

Our findings also reinforce the importance of legitimacy, transparency and accountability *internal* to the organization as well as outside. Regardless of the final decision, in the peak experiences, participants often indicated that they had experienced fair and considered inclusion in a balanced decision-making process. This was as important for scientists as it was for others involved in the process – especially given the stated personal investment scientists made in the quality and value of their contribution.

Notably, more than half the cases examined faced challenges of demonstrating the internal and/or external legitimacy of decision making, suggesting that participants are aware of a reinforcing relationship between transparency, due process and the use and application of evidence internally as well as externally. It is insightful to consider what attributes of the STL enable the staff to address such challenges. We speculate from the results that it is a mix of personal (e.g., persistent, positive and generous) and professional (e.g., translating and communicating, and decisive in the face of uncertainty), as well as some organizational attributes (e.g., decision-makers who value scientific insights, and external accountability and transparency) that enable STLs to address such challenges.

From this study, there is a complex inter-connection of characteristics needed to deliver on the list of enablers for science to engage with

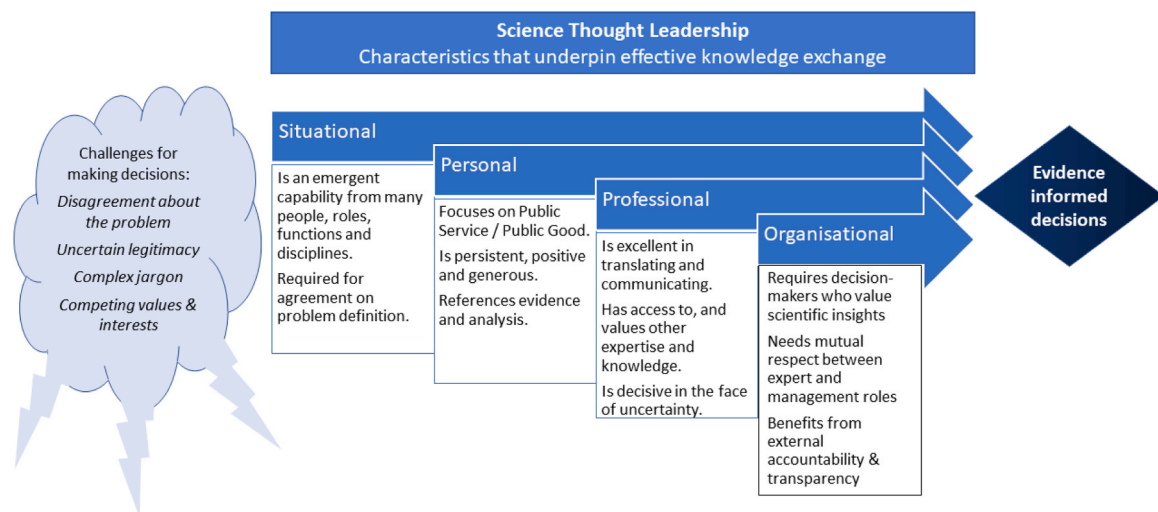


Fig. 6. Science Thought Leadership is a set of characteristics and capabilities that underpin effective knowledge exchange, leading to better evidence-informed decisions in Government agencies.

decision-making processes listed in Cvitanovic et al. (2016). While affirming the general findings of that research, this study begins to fill the knowledge gaps identified by Cvitanovic and his co-authors regarding the crucial interpersonal and relational traits that drive accessible, effective and efficient uptake of science into decision-making.

4.2. The science thought leadership– organisational, personal, professional & situational (STL-OPPS) checklist for science thought leadership

To assist with the uptake of this new information into practice we propose a checklist for supporting science thought leadership communities in organisations. We have represented this as an interconnected set of circles as we believe these are interdependent i.e. all are necessary, and none are sufficient on their own. (See the ‘STL - OPPS Checklist’ in Fig. 7). That said, we believe from the exemplary cases selected that situational elements (red) may call for organizational responses (orange) that facilitate on fostering personal (dark green) and professional elements (light green), although it is unlikely to be a linear sequence.

We suggest regulatory organizations, who routinely facing these situations, explore how to boost organizational, professional and personal elements in groups, networks and teams gathered around recurring issues. Our findings suggest that effective and purposeful knowledge exchange will be enabled, thus breaking down the barriers discussed over many years to the uptake and use of evidence in environmental decision-making (e.g., see Caplan, 1979; Bammer, 2013; Reed et al., 2014; Cvitanovic et al. 2016).

4.3. Implications for policy and regulatory practitioners and decision-makers

Public service decision makers in Australia report prioritising and most frequently accessing internal staff first for evidence and expert advice, followed by staff from other agencies. Academic organisations, consultants, and think tanks were all considered less important and less used (Head, 2016; Cherney et al., 2015). However, the public expect that governments listen to scientists (Sheppard and Gray, 2017). In the same study, it was found that Australians’ trusted sources of evidence

and advice on science and technology are doctors, universities and scientists. There is modest trust for public servants and environmental groups, and lower trust in elected state and national governments, large corporations and the commercial media (Bruce and Critchley, 2013). These patterns apply internationally (Grönlund and Setälä, 2012; Zmerli and Meer, 2017) and have been this way for much of recent history (Miller, 1974).

Our research found that when challenges around defining the problem, earning legitimacy and managing competing values and interests are encountered, ‘science thought leadership’ can help within an internal organizational decision-making context. When the right combination of characteristics are present, adaptable, persistent and reflective coalitions of different groups inside and outside regulators can work together to result in more evidence informed decisions. This study focused on the internal perception of the final decisions being more based on science. An interesting extension would be to assess the external perceptions however it was outside of the remit of this study.

Further, our results indicate STL is not only, and maybe not centrally be, about ‘big decisions’ in environmental regulation. The majority of examples recounted by participants in our study fall closer to what Caplan describes as ‘micro-instrumental’ and operational decisions (Caplan, 1979): decisions primarily affecting the agency’s efficiency and operation, and smaller external populations; where most often the primary purpose of knowledge application is to “test the acceptability of already established programs and policies, or to measure progress”. Note that our appreciative process was open to collecting and prioritizing both ‘conceptual utilization’ cases, and those at the “micro-level instrumental decision-making” (per Caplan, 1979). Both are equally interesting in the attempt to tease apart the inner workings of how those giving the internal scientific advice operate when supporting decision-making.

Importantly however, routine public decision making is both under researched, and more significant than has been assumed: the vast majority of decisions in government administer and implement laws, regulation and policies, rather than set new policy (Page, 2012). Conversely, our impression as ‘pracademics’ at the boundaries of research and practice is that while research occurs across public decision making, much of the public political and policy discussion of evidence and its use focuses on high profile public policy debates (Cherney et al., 2015) and global science policy interfaces (Sarkki et al., 2015), and not so much administrative and regulatory decisions, and how they are supported and communicated. This practice-research gap (Thomas et al., 2022) is particularly problematic given the recursive nature of the policy cycle (Althaus et al., 2018) and particularly for regulatory policy, which typically relies heavily on sunset clauses and periodic review, interspersed by public crises, inquiries and policy resets (Banks, 2015; Sparrow, 2000; Walker et al., 2008).

The case studies collected also underline the significance of ‘routine’ decisions (Page, 2012). Nine cases related to major investments of public money (in the billions - \$AUD - in at least one case), and 15 related to significant risks to health and the environment, and the wellbeing of substantial populations of people. Good evidence translation, monitoring and evaluation in such cases also has the potential to allow regulators to make a contribution to periodic review, translate learnings into new policy problems, and facilitate rapid and appropriate responses to crises (Walker et al., 2008; Sparrow, 2000; McDonald et al., 2009). There is a core role for science thought leaders to be skilled enough to engage deeply and often in these types of day-to-day decisions, embedding evidence, evaluation and adaptive decision-making.

4.4. Implications for scientists and researchers

Beyond the organisational benefits of building on this enhanced understanding of STL, these findings have important implications for the research community. For a start point, the 2014 reflection piece by a former Chief Scientist of New Zealand (Gluckman, 2014) is essential reading for both the ten principles as well as his commentary on the

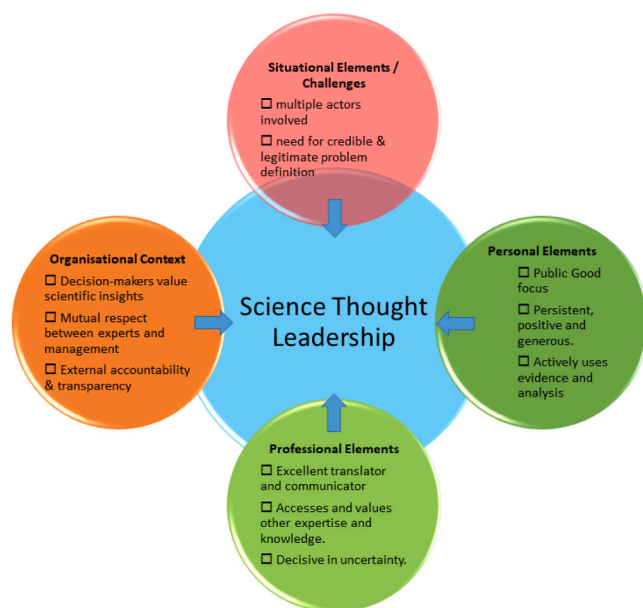


Fig. 7. Science thought leadership is more likely to emerge when the following situational, personal, professional and organizational enablers are present – The STL-OPPS Checklist.

variability of science policy interfaces (Gluckman, 2016). Our work suggests more attention is needed at the intersection of professional and personal elements and how this is nested within networks and communities, organizational context and situational elements in environmental regulation. Arguably, any lone scientist or researcher ignoring this complexity of how the 11 enabling characteristics and capabilities interact will be unable to influence the 6th principle by Gluckman (2014 – i.e., Give science privilege as an input into policy). We also hope these findings and examples will attract more research attention to seemingly small, day-to-day and administrative decision making as ‘big answers can come from small questions’ (Flyvbjerg and Sampson, 2011). Finally, this study may help researchers identify and support STLs in organisations they want to work with – if STLs are indeed an ‘underutilised’ ally rather than competition for ‘conceptual utilization’, researchers responding to the ever-increasing support and requirement to demonstrate impact may catch glimpses of past, present and future collaborators here.

4.5. Comments on the research design

The appreciative inquiry method (Cooperrider and Whitney, 2005; McDonald et al., 2009) worked well in this research in that it enabled very diverse people from a broad range of organizational hierarchies, roles, functions and disciplines to build a common set of examples and themes, across two state regulatory and national contexts. They could agree on enablers and examples of when science was credible, influential and valued in regulatory decision making.

However, the research design and method also raises some limitations worthy of exploring for future uses. First, as a participatory appreciative inquiry, the method relies on involving motivated, interested people in an action learning and research process to generate insights and actions relevant to them and their context. They needed time and motivation to commit to the process. Within both organisations, there likely were many more examples we missed. Some of them may have been peak experiences, that awareness, time, interest and preference may have precluded. Similarly, the process did not seek to capture examples of important decisions that did not, but could, or perhaps should, have had a greater level of knowledge exchange support. We can’t and don’t attempt any summative statement evaluating the general state or level of influence of science, or scientists, in decision making in the participating organisations.

Second, it is worth reiterating a point made in the Methods that by its very nature appreciative inquiry is a method that focuses on the presence of something positive the participants experienced and draws its strength as a method from reflecting on the impact of that presence. It does not and cannot assess the lack of something in a decision-making process. Using appreciative inquiry we cannot assess what would occur in the absence of enablers if a regulator claimed to have STL but could not identify the enablers. In this study the enablers occurred as responses to an honest reflection of the barriers present by participants (both internal and external to environmental regulators). This stated, we would also counsel skepticism when confronted by a claim of evidence informed decision making in a regulator which lacks the personal, professional and organisational enablers we’ve identified.

Third, the design prioritised generating insights and recommendations of relevance to the host organisation, rather than attempting a comparative study between agencies in Florida, USA and Victoria, Australia, or profiling regulatory decision making in broader contexts. Interviewee, theme and case validation and the summit workshop, as well as engagement with the literature cited in this paper, give some confidence that findings and recommendations are transferable and relevant to other contexts. Primarily, however this study provides in depth insights into cases from Victoria, Australia, and to a lesser extent, Florida, USA. These are potentially relevant to broader comparative surveys and studies of science in government decision making (for example see Page, 2012, and Newman et al., 2016), but generalizability

of these insights requires further research. It would be particularly useful to test the applicability of enablers we’ve identified in other contexts of knowledge exchange in different science policy interfaces, and in relation to contributions highlighting their own supporting principles, enablers and characteristics (e.g. Sarkki et al., 2015; Gluckman, 2016).

Finally, we have no independent assessment of the quality of the scientific evidence and analysis narrated in the case studies, nor of the ultimate public good outcomes nor any unintended consequences of the decisions (beyond those captured in the appreciative questions). The mixed nature of the summit workshop group and the qualifications and experience of the participants means that it is unlikely that egregiously bad decisions and outcomes would be highlighted as exemplary, however it cannot be ruled out either. It is important to note that at the time of publication (some 8 years after the research), the authors do not know of any of the decisions that have been overturned, reviewed or otherwise come under public or regulatory question. Ultimately, the cases selected norms of good practice and success that were justifiable and supported in the participatory group process – as is inherent to the method (Mone, 2008; McDonald et al., 2009; Cooperrider and Whitney, 2005).

The internal validity of the findings is supported by the iterative research design, and the considered preparation and deployment of interviews and participatory workshops (McDonald et al., 2009; Cooperrider and Whitney, 2005; Patton, 2011). This included individual, small group and large group activities to provide opportunities for individuals to express private beliefs (Harvey and Colin, 2012), and those moderated by norms and group dynamics to be expressed, recorded and reviewed by participants.

4.6. Further work

An interesting question arising from this work is can science thought leaders be made, or are they born? The answer is outside of the scope of this research, but it appears the situation, organization and the individual all have influence.

Further validation must include triangulation of peak experiences of science thought leadership identified by the participants with other sources of evidence about whether they were indeed good decisions. If they are, then how to seed, enhance and spread identified STL elements becomes very interesting. If not, they remain useful as an insight into the beliefs of those who *think* they are supporting evidence informed decisions.

Building on the above and our counsel for skepticism when confronted by a claim of STL enablers without other proof of an actual evidence-base in decision-making by environmental regulators, there is an opportunity for others repeating a study like this to look in more detail at the role of STL in decisions deemed to *not* have had much (or enough) scientific input into a final decision. The use of appreciative inquiry in this study did not enable that question to be asked, but as authors we consider it is a fruitful line of inquiry for others to consider.

Finally, we focused on the most identified top 11 themes for brevity, but there were others that were listed by multiple participants in the research. Elements in the middle range frequency of responses (e.g., *gravitas* in Fig. 3 or *influence or networks* in Fig. 4) could be promising for further investigation.

5. Conclusion

Six exemplary cases derived from 44 experiences suggest 11 crucial enabling themes required for science thought leadership to live and thrive in networks and communities within regulatory organizations. We represent them as an interconnected set of circles to highlight the need for all elements (See the STL OPPS Checklist in Fig. 7). Our findings suggest that ensuring science informs regulatory decision making is a team effort extending well beyond individual scientific experts, but which requires them to be centrally involved. The situational themes

showed science thought leadership requires cooperation between multiple players, all contributing different types of expertise. These include decision makers, project managers, organisational subject matter experts, communicators and knowledge brokers as well as technical experts.

These findings may be of value for scholars, policy makers and practitioners who seek to identify and work with such groups of people within organisations. The reported characteristics suggest topics of possible goals, indicators and metrics for monitoring, or assessing, the potential for science thought leadership to facilitate knowledge exchange in organisations working at the science-policy interface. This could support further research into where the best return on investment is when building or enabling new science thought leadership in an under examined area of knowledge exchange at the science-policy interface.

The literature discussed and the findings of this study also highlight the critical need for and value of evidence and research in routine regulatory decision making, even if it is outside of high-profile policy debates, and is focused on the “micro-level instrumental decision-making”. Evidence informed decision making depends on the right people and the right knowledge being available, at the right time. Decision makers and policy leads wishing to realise aspirations of evidence informed policy need to pay close attention to the performance of current administrative activity in reviewing existing, and creating new policies and implementation frameworks, as well as the availability of science thought leaders to enable effective knowledge exchange.

Science thought leaders have impressive personal characteristics, which our Florida host commented were important in a career in public service in general, not only science thought leadership. This research offers a guide to the kinds of attributes into which organisations requiring science thought leaders to underpin effective knowledge exchange may wish to recruit and enhance. Public servants who are persistent, brave, positive and generous, and who consistently reference evidence and analysis in their contributions are good to work with in any case, and most likely, they are also science thought leaders.

Declaration of Competing Interest

No known conflict of interest exists. SK was an employee of the host regulator while conducting this project, and now works in the university sector. The research activity was undertaken with the support of EPA Victoria's Mark Payton Scholarship for leadership development. AB was a science executive in the host regulator during the time of the research, leaving in 2017, and now works in the university sector.

Data Availability

We have shared the data we have permission to share via the six case stories and thematic analysis. All other material was collected and used in confidence.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.envsci.2023.06.018](https://doi.org/10.1016/j.envsci.2023.06.018).

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