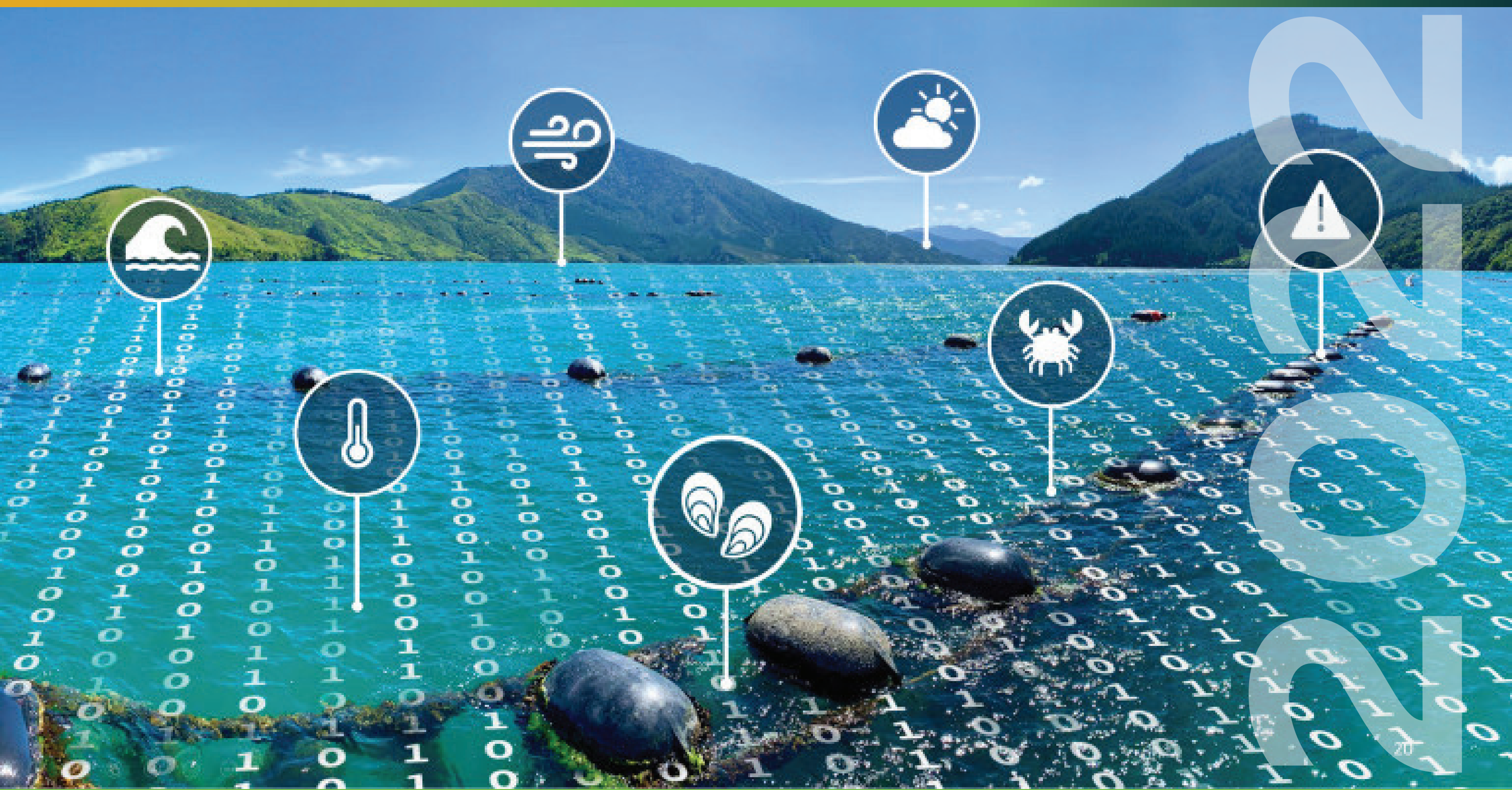


He hiringa hangarau, he oranga tangata

Building New Zealand's Capacity for Science-based Open Innovation

National Science Challenges

SCIENCE FOR TECHNOLOGICAL INNOVATION

Kia kotahi mai – Te Ao Pūtaiao me Te Ao Hangarau

ONLINE ISBN: 978-0-473-66462-6

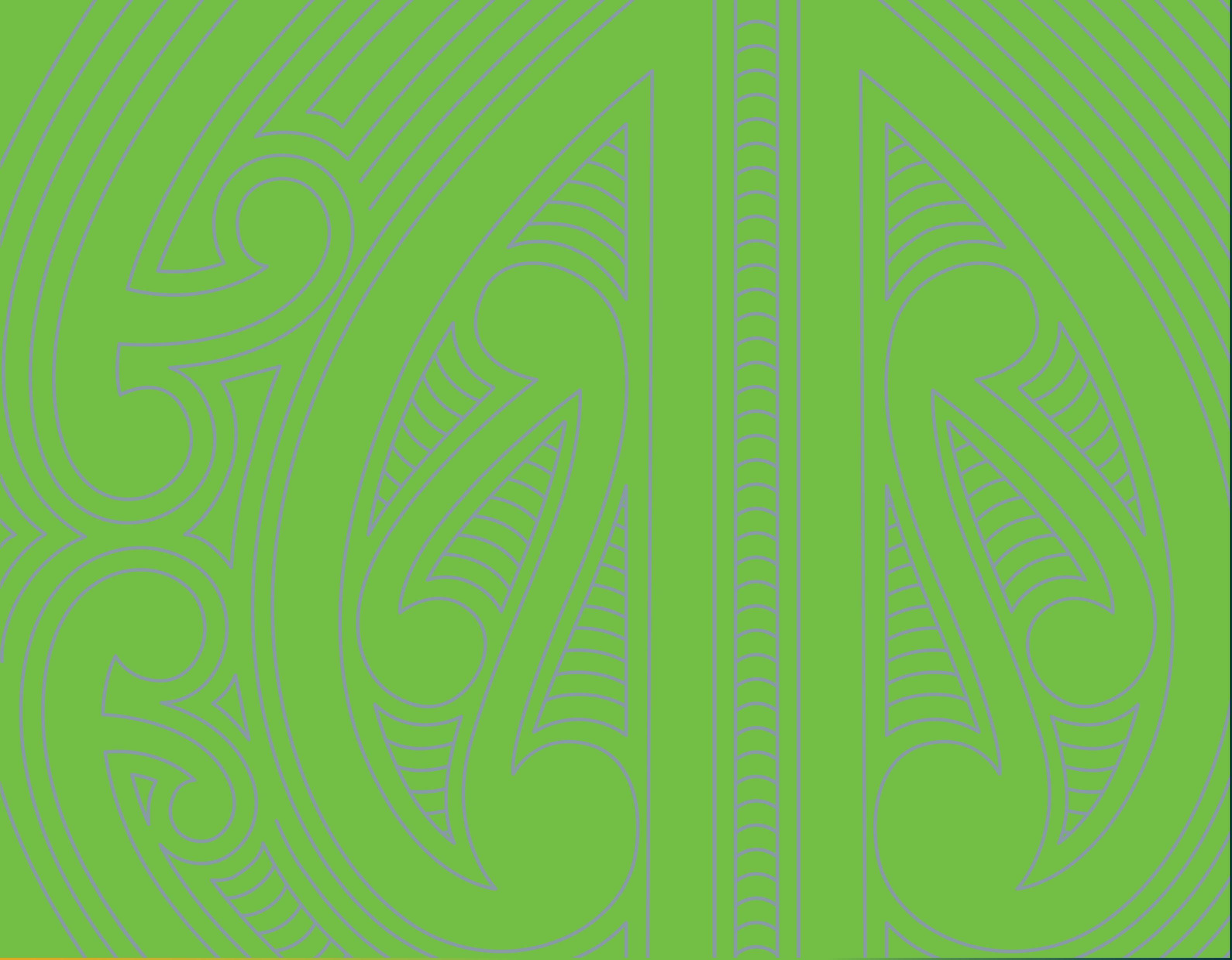


Illustration designed by Tyler Dixon, Waikato-Maniapoto, Ngāti Porou, Ngāi Tūhoe, Ngāi Tahu depicts a Mangopare (Hammerhead shark). It symbolises the strength in duality to be found in uniting Māori knowledge with western science.

Cover image: Precision aquaculture Spearhead has developed technology to provide better data for aquaculture farmers. *Image by Dana Briscoe, Cawthron Institute.*

Contents

Research and development and innovation are essential components of New Zealand's economic and social wellbeing

Overview

For many years there have been questions as to the best way that research and science can contribute to New Zealand's prosperity. We know that our research and science is world-class, with praise for its high quality and quantity. But it is unclear how excellent research publications link to research users, with enterprises mostly relying on outsourcing rather than investing in technologies developed through New Zealand research and development (R&D).

Additionally, there are long-standing issues as to how the research and science system responds to Māori economic and social aspirations. This includes, as the WAI 262 decision has made apparent, the need for the sector to protect mātauranga Māori.

These criticisms have placed the New Zealand science sector under pressure, with growing demands from funders, policymakers, industry and Māori for measurable research impact.

What is the solution? While there is no one single answer, there are many practical things that can be done, some of which have been present in the research and science sector for some time and some that are more recent developments.

In this second report, the Building New Zealand's Innovation Capacity (BNZIC) research programme has identified several implementation actions. These suggestions are based on our examination of international and New Zealand-specific shifts affecting the research, science and innovation sectors. We have summarised these shifts into four broad trends, with one specifically focusing on Māori innovation. To guide our research, we have posed a set of questions about each trend, the answers to which guide us towards addressing some of the criticisms that have arisen over the years.

Based on these questions, this report presents findings, observations and case studies. This gives us an evidence base to suggest practices and pathways towards new sets of routines in the research and science sector. While many of our suggestions concern disparate parts of the sector, we see them as interconnected elements. And while some of our suggestions may reflect comments made previously, our research provides a substantial evidence-base for these comments.

Finally, we note that the BNZIC programme has investigated some parts of the research and science sector and not others. Our focus has been on individual and team skills and capacities in relation to the organisations within which they operate. Such a focus has been under-researched in the New Zealand science and innovation system.

◀ A nurse, Georgia, demonstrates the blood glucose control system based on the same foundation models used in SfTI Spearhead project, 'Home and community based care – Type 2 diabetes', in Christchurch hospital intensive care unit. *Image courtesy of University of Canterbury.*

What is Building New Zealand's Innovation Capacity research programme?

Building New Zealand's Innovation Capacity (BNZIC) is a multi-method longitudinal research programme (2016-2024) into mission-led, collaborative, stretch science within the Science for Technological Innovation (SfTI) Challenge. Through this research we seek to systematically assess and then promote new and more effective ways of equitably accelerating innovation connecting physical science and engineering to businesses and Māori enterprises.

In this way, we aim to address some of the criticisms of the science sector. We do this by examining individual and organisational skills as well as the importance of relationships and ability to engage across the science and society divide to create research impact. Our approach has been to identify, implement and evaluate a suite of internationally robust innovation processes, while at the same time adopting and adapting novel processes to New Zealand's distinctive science and engineering research context.

BNZIC is unique in that it looks at two connected areas within the science innovation system: **human capacity**, which includes people skills and abilities for activities such as leadership, innovation management or commercialisation, and **relational capacity**, which covers the ability to engage within and across disciplines and sectors, in this case by scientists connecting and communicating to as well as being connected with the wider ecosystem for maximum impact. This extends the science system's emphasis on technical capacity, that is knowledge and skills associated with research and undertaking research in science and engineering, to other factors that affect how technical capacity can be leveraged more effectively.

The Aim of BNZIC's Research Programme

Through cutting edge research, there will be new and more effective ways of equitably accelerating physical science and engineering innovation to businesses and Māori enterprises.

This multi-method programme provides a unique opportunity for real-time, longitudinal research into the 'enablers' and 'barriers' in collaborative stretch science.[1] Internationally, there is extensive research into how to enhance the benefits from science, so an important focus for BNZIC is on why the transformation of research inputs into outputs might or might not differ in New Zealand compared to other countries. Our approach has been in part to identify, implement and **evaluate** a suite of internationally robust innovation processes, while at the same time adopting and adapting novel processes to New Zealand's distinctive science and engineering research context.

This is our **second report** that extends upon the insights of our 2019 interim report.

Reference

[1] Woodfield, P. J., Ruckstuhl, K., & Rabello, R. C. (2021). *Charting a Course of Action: An Insider-Outsider Approach. Technology Innovation Management Review*, 11(7/8), 48-64.

PART ONE

This section is an overview of New Zealand's science and innovation system, drawing upon recent reports that have highlighted some of the challenges facing New Zealand's high-tech research, science and innovation.

PART TWO

In Part Two we outline some of the global science and innovation research trends that New Zealand is following and, in some cases, leading. We examine these trends and the theories behind them to provide context to the issues discussed in the previous section. International literature also provides indicators and models as to which parts of our science innovation system can change relatively easily and which parts require different practices, resources, and people.

PART THREE

This section lays out our observations, findings and insights building on our overview of the New Zealand science system and the theoretical trends in Part Two. This section is a synthesis of our researchers' published and non-published work. It also brings in additional research that is related to or pertinent to the insights. Part Three identifies strategies and practices that can develop the human and relational capacities to address SfTI's mission to enhance the capacity of New Zealand to use physical and engineering sciences for economic growth and prosperity.

PART FOUR

In this section we identify implications of our research for various parts of our science and innovation system.

Key Questions and Summary of Potential Actions

Moving Beyond Traditional Science

KEY QUESTION

- *When science problems are so fundamental that even the scientists are unsure as to how they are best addressed without several iterations, what strategies engage non-scientists or those from outside a particular discipline to co-innovate in upstream 'blue-skies' or fundamental science questions?*

1.1 Plan for new collaborations in a structured way
Upstream or early engagement when the science is still uncertain is problematic. Non-science partners are unlikely to share scientists' values and views because of differences in their day-to-day priorities, demands, and institutional frameworks. Teams and particularly Principal Investigators need to be aware of and plan for this in a structured and systematic way.

1.2 Redesign how teams are brought together
It is essential to rethink the processes through which teams are brought together to develop collaborative science-based open innovation projects. The models developed through SfTI – mission labs and the C-K design for innovation approach offer strong potential to deliver an effective open innovation science research programme efficiently.

1.3 Recognise and support the role of the intermediary
Innovation intermediaries act as an 'agent or broker in any aspect of the innovation process between two or more parties'. They play important but often under-appreciated roles in creating a shared understanding and collaboration across innovation participants. Support is required for not only explicit intermediaries (those who exercise recognised innovation brokering functions between organisations) but also implicit intermediaries who are essential to achieving a research objective, but whose role is often not recognised.

1.4 Shift locations to catalyse co-innovation
Visiting stakeholder places has allowed SfTI researchers to better canvas needs and values, generate practical scientific insights more rapidly, enhance trust, and shift mindsets to understand and welcome different world views.

Opening Science for Open Innovation

KEY QUESTIONS

- *Are New Zealand firms with high absorptive capacity more likely to use open innovation strategies?*
  And what would they use it for?
- *What if those firms are Māori – does this equally apply?*
- *To what extent do New Zealand firms use closed innovation, and is it holding them back from superior performance?*
- *In relation to solving advanced technological problems, what evidence exists of the other types of OI models being successfully implemented?*
  If so, what accounts for their success?

2.1 Encourage broader collaboration to develop greater absorptive and desorptive capacity
Absorptive and desorptive capacities have been shown to be critical drivers of innovation outcomes in New Zealand, including for Māori firms, but are not currently as widespread as needed for increased success with open innovation. These capacities are needed both by those in the science sector as well as external collaborators to benefit from inbound/outbound flows. Evidence from a range of SfTI projects indicates that broader external collaboration boosted science outcomes (partly through having a lead user/market pull perspective when developing the technology), while also generating additional funding and new collaboration opportunities. These outcomes provide a platform for future collaborations.

2.2 Support the development of Coopetition or Network Open Innovation
Intellectual Property (IP) concerns are a common barrier. Increased opportunities and experience in working together assist in enhancing relational capacity of the partners, which in turn can contribute to successful collaboration with others in the future. Those in the science sector are well positioned to facilitate opportunities for industry to understand and access public IP and are in a strong position to assist in customising or developing the technology further.

2.3 Develop new contracting processes to protect mātauranga Māori
Māori cultural capital can generate superior performance when cultural capital is combined with high human and relational capital. However, access to and benefit from science-based open innovation can founder without a suitable approach to Māori notions of IP and protection of mātauranga Māori. It is essential to design new contracting processes to acknowledge and protect mātauranga and Māori cultural interests will be crucial. Alongside this is the need for specialist training to understand how to skilfully use these new processes.

Opening Science for Māori Innovation

KEY QUESTIONS

- *How is Māori science and innovation policy impacting on individuals, teams or Māori partners?*
- *What are some of the enabling practices that can support Māori innovation when viewed from a Māori perspective and what changes would be required to implement these?*

3.1 Use a range of strategies to counteract aronga takirua
Māori scientists are currently facing aronga takirua, or cultural double-shift, which imposes substantial strain, tension, and work burn-out. Strategies at the system and organisational levels to counter-act this can include: offering more 'weighting' in research funding to Māori relationship-builders, and developing a whānau-like caring and mentoring approaches, especially for Māori Early Career researchers. Supporting specific Māori capacity-development for Māori can also mitigate aronga takirua effects.

3.2 Architect processes to enhance Māori collaboration and absorptive capacity
There are several underestimated but essential boundary-spanning roles played by Māori within and outside the science sector. The Māori non-scientist 'matchmaker' brings together diverse organisations and individuals by establishing and managing partnerships. Many teams need to go beyond matchmaking and construct science-based open innovation research methods with Māori enterprises. Enhancing Māori absorptive capacity to take advantage of such science innovation can include research co-design, funding Māori partners as research leads, and incorporating junior Māori researchers, even at the under-graduate or pre-tertiary education stage.

3.3 Enhance control over Māori data in research ecosystems
Indigenous data sovereignty (IDS) emphasises tribal or tribal nation self-determination and autonomous decision-making. Increased digitisation of cultural heritage resources and taonga and international collaborations involving genetic research from biological taonga, limits Māori ability to maintain their rights and interests.

Many New Zealand research institutes are involved in research employing mātauranga Māori however there were only three policies that specifically mentioned mātauranga Māori or Māori data, and only one IP policy addressed Māori genomic data. Therefore, additional policy guidelines, consultation frameworks and institutional practice protocols need to be developed, alongside potential digital tools such as Traditional Knowledge labels and Biocultural labels to deal with taonga.

Developing entrepreneurial behaviours

KEY QUESTIONS

- *What capabilities enable individuals to collaborate across boundaries?*
- *What are the different ways to organise capabilities within teams? Who should have these capabilities in teams?*
- *How can these capabilities be developed?*

4.1 Reward science-based open innovation capabilities

We have developed a typology, based on our observations of SfTI scientists, that suggests four different science orientations: traditional scientists, tech-transfer scientists, 'A-shaped' entrepreneurial scientists and 'T-shaped' science entrepreneurs. Scientists may adopt some or all of these orientations depending on their career stage, project aims, institutional context, and individual motivation. While we have not quantified the balance amongst the various roles across the New Zealand science sector, it is likely that 'traditionalists' are more highly represented than other types. Hence, there is merit in identifying further incentives for those who have, and to encourage, a more societal and industry orientation. In particular, this will reward Māori at an earlier career stage.

4.2 Provide professional support and development to enhance entrepreneurial capabilities

PIs have a range of roles, some that align to a more traditional science identity and some that demand a more entrepreneurially focus. To align these various elements is complex, and is usually 'learned on the job'. This can lead to a sense of disconnect between core science identity and job expectation, sometimes experienced as violating a scientist's core science role. Establishing role clarity and more targeted support can mitigate against this.

4.3 Support PIs to develop team entrepreneurial capabilities

Our research has highlighted how prior social ties affect the nature of external engagement and the innovation outputs. In some teams, there is such strong centralised control of relationship engagement that other team members leave this aspect to that person. In other teams (or at particular project stages), relationship development is more devolved, particularly where teams have yet to develop strong relationships and ties to partners.

This suggests that some team arrangements more easily facilitate partner relationships than others. In other teams, where engagements are more tightly controlled, there may need to be deliberate recommendations of capacity development to a broader range of team members.

Team leaders are especially important in this respect, including how leaders empower individual team members to pursue innovative ideas during or after a particular project. Our research identifies that the configuration and leadership of a team can lead to more or less encouragement for entrepreneurial capabilities.

4.4 Link entrepreneurial capacity development to day-to-day needs

Research identifies three main factors that affect transfer of skills and knowledge gained through capacity development to research projects:

- the value placed by scientists on capacity development;
- the extent to which capacity-development design mirrors the tasks scientists typically undertake; and
- the opportunity to use the newly developed skill.

Our research shows that some of SfTI's capacity development activities resonate more strongly than others, suggesting that one or more of the factors are in play.

PART ONE

New Zealand's science and innovation system

In this section we highlight some significant changes that have occurred in Aotearoa New Zealand's research, science and technological innovation system, particularly with respect to **high-tech 'stretch' science and innovation**. We identify the rationale behind these changes, some key impacts, and their implications for individuals and organisations.

Science and innovation 'snapshot'

Research and development (R&D) and innovation have been a central feature of New Zealand economic and social policy for a number of years.[1] Underlying this is a drive to improve New Zealand's productivity that has for some time relied on 'cheap' labour or outsourcing rather than investment into developing or embedding new technologies that can drive high-value 'weightless' businesses.[2]

Significant energy has gone into understanding some of the underlying reasons for this low productivity. Amongst other things, there have been concerns about low business expenditure on R&D (BERD) and an inability to demonstrate how investment in science has added 'value' to the economy, despite the strength of the scientific workforce as measured by such things as number of science and technology graduates or the excellence of academic publishing.[3] Policies such as the 2012 Business Growth Agenda or the 2013 He Kai Kei Aku Ringa were launched in part to target areas of high-value whether in manufacturing and services, biotechnology or ICT or, in the case of Māori, better engaging with the innovation system to lift Māori productivity.[4]

Unsurprisingly, the science sector itself has come under scrutiny, with increasing demands for demonstrable research impact. While Crown Research Institutes were set up to be industry facing, new forms of research entity have joined them such as Callaghan Innovation, Centres of Research Excellence (CoREs), National Science Challenges (NSCs), Strategic Science Investment Fund (SSIF) programmes and platforms, Regional Research Institutes and R&D 'accelerators' such as Kiwinet and the Product Accelerator. Added to these are independent research organisations such as the Malaghan or Cawthron Institutes as well as university tech-transfer offices seeking to show how their research can be used for innovation. This range of new research configurations have in part been in response to the need to more readily move research focus into areas of emerging opportunity such as aerospace, renewable energy, and health technologies[5] while reviewing past research approaches to land-based industries.[6]

From an **end-user or firm-level perspective**, a central question remains 'what is or is not working in the New Zealand science and innovation sector'? According to a recent Productivity Commission report,[7] the dairy industry receives useful research services from many Crown Research Institutes (CRIs), universities and various combinations of research networks. However, the sector is characterised by fragmentation with multiple, and sometimes competing, small-scale research entities and projects. This can inhibit 'big mission' challenges such as reducing greenhouse gas emissions or reducing nitrate leaching. Similar concerns are raised in the horticulture sector where innovation efforts are said to be hard to navigate, siloed and disconnected from industry needs, although elements of the sector (such as kiwifruit) are very open to innovation.

In contrast, the health-tech sector appears reasonably well-funded with strong linkages between companies and research institutes, but perhaps not enough emphasis on commercialisation. In the software sector, one of the key issues was the need to attract and retain suitably qualified staff, which might be tackled through a more dynamic ecosystem involving active leading firms and top universities as well as enhanced digital infrastructure.

What of the **Māori end-user**? Again in the Productivity report, there are many examples of positive relationships with science and technology organisations, particularly where research relationships have taken the time needed to develop an approach that, as suggested under the Vision Mātauranga policy, accepts Māori knowledge as a valid way to understand a science problem.[8] Equally, there are examples where ill-preparedness to work within a cultural framework have led to 'transactional' relationships, prioritising the researcher's rather than the Māori organisation's needs.[9] As outlined in a recent report,[10] Māori are increasingly demanding more of the science and innovation system.

From a **science organisation perspective**, a recent review of CRIs[11] found both positives and negatives in the current configuration of the science and innovation sector. Much of this is applicable to other research organisations such as universities and private research organisations.

Positives included:

- Provision of core underpinning science and science services;
- Building partnerships with Māori;
- Increasing workforce diversity;
- New collaborative initiatives;
- Early-stage collaboration (particularly through Kiwinet) is effective.

To this, we would also add that a distinguishing feature of New Zealand's science and innovation system is its relative inter-connectedness, with few degrees of separation in terms of identifying expertise that can be 'tapped into' quite quickly. This may explain why, in some high-tech fields of research, the same individuals appear on many projects across the sector as a whole, particularly where such skills are in high demand. This equally applies to business contacts, where within SfTI we have observed that there was a general willingness for industry to become involved as advisors or reference groups.

Negatives, however, included:

- overlaps and fragmentation in the science system in some areas of research;
- the cost of collaboration and concerns about intellectual property (IP);
- ongoing competition among CRIs and with other parts of the science system;
- lack of adaptivity, such as assembling cross-disciplinary teams with new research capabilities to tackle areas of emerging priority;
- Māori under-representation in the science system generally, with those in the system stretched because they are often implicitly expected to assist with cultural double-shift or 'aronga takirua';
- the issue of cultural appropriation, as embodied by Wai 262;
- the high cost, effort and time to prepare competitive bids relative to low success rates and value of contracts;
- CRI commercialisation portfolios lack the scale and diversity to manage risk.

In addition to the above, Covid-19 has accelerated or exacerbated some of the risks in parts of New Zealand's high-tech system. For example, we were struck by the reliance on international PhD students to fulfil particular niches in many of our project teams. With the borders closed, it became apparent that New Zealand has not been able to recruit into advanced science areas such as data modelling or software engineering. Will these be continuing gaps? Will it force a rethink on how New Zealand recruits and retains its skilled future innovation workforce? Additionally, the 'work-from-home' culture enforced by Covid-19 has had an impact on individuals across all sectors re-assessing their priorities. While entrepreneurial cultures can drive innovation, they can also lead to employee 'burn-out', risking organisations' ability to deliver expected R&D outcomes sustainably.[12]

Third, while businesses have been willing to advise science teams, when it comes to owning potential Intellectual Property from that advice or involvement, businesses potentially move into a competitive framing, making collaboration less likely. Given engagement with businesses is seen as important for increasing impact, "how can this be overcome to deliver value for 'fragmented' industries, as noted by the Productivity Commission?"[13]

Impacts for organisations and individuals

What does this 'snapshot' indicate? First, research, science and innovation can contribute and are expected to work toward enhancing New Zealand's economic and social well-being. Second, over a number of years new or re-oriented organisational forms have arisen to be responsive to this mandate, including to meet the specific needs of Māori. Third, there are many examples where government-funded support for science and technology has been essential to the growth of enterprises as well as to the health and well-being of the general public and the environment.

However, each new initiative also creates added complexity not only in navigating new organisational forms with new research priorities and mandates but also in developing new sets of expectations at the individual level along with the need to develop or connect different types of relationships across organisations. Given that individuals are often involved in multiple organisational forms simultaneously, this complexity requires that competing pressures be resolved.

As the snapshot highlights, there have been many policy, strategy, funding streams, organisational and network changes. These have been implemented separately to address various 'failures' in the innovation system. Both the CRI review and Productivity Commission reports identify weaknesses and also potential remedies. However, our research focus is at a different level. While we are interested in the broader macro-levels of the system – which we turn to in the second section of this report – we also are interested in organisations themselves, the individuals within those organisations, their relationships with each other and their practices and technologies that together are the innovation system.

There are many 'systems' theories that can help explain and account for what we have seen in our research. Such theories underpin our research into understanding New Zealand's science and innovation 'culture(s)'. We use this word guardedly and in a defined-sense, which we explore in the next section.[14] We believe it helps to explain why some groups and individuals are able to respond to science innovation policy shifts and why others find it difficult, irrelevant or an unnecessary 'tick-box' to be grudgingly accommodated.

> *"Each new initiative also creates added complexity not only in navigating new organisational forms with new research priorities and mandates but also in developing new sets of expectations at the individual level."*

While it is relatively easy to label individuals as either the accelerators or blockers of change, we know that it is much more complicated than this. For example, competitive funding might seem to be an important driver of innovative science – science that can connect to 'real-world' problems. But given low individual success rates, is it in fact an innovation blocker with applications written, at least on paper, to ensure success through risk avoidance and protecting track records?

Our research implicitly brings to light crucial assumptions by examining models that take a different approach.

Some of our research has focused on individual propensities and capabilities (the micro-level) and how to guide, train or educate for **science-based open innovation**, a term which we define more precisely in the next section. We have examined a host of other factors, particularly the practices and 'tools' that enable teams and groups to establish, organise and inter-relate to each other and to businesses and Māori organisations. And while macro-level policy and funding underpin our research, values and cultures that are enacted through communities of practice, organisations and institutions also play a role in our research.

In the next section, we traverse some of the international literature that lies behind our research and that can help to contextualise features of the New Zealand innovation system. While New Zealand has its own distinctiveness, such as its reliance on primary exports and the increasing rise of the Māori economy, its approach to innovation is also reflective of a number of international trends.

References

[1] Ministry of Business, Innovation & Employment (2019). *Growing Innovative Industries in New Zealand: From the Knowledge Wave to the Digital Age - MAI I TE AO MĀTAURANGA KI TE AO MATIHIKO NEI*. Wellington: Ministry of Business, Innovation & Employment. Retrieved from: https://www.mbie.govt.nz/dmsdocument/5866-growing-innovative-industries-in-new-zealand-from-the-knowledge-wave-to-the-digital-age.

[2] Conway, P. (2017). *Achieving New Zealand's productivity potential, OECD Productivity Working Papers, No. 10*. Paris: OECD Publishing. Retrieved from: https://doi.org/10.1787/e8a2d791-en.

[3] Ministry of Business Innovation & Employment. (2018). *Research, Science and Innovation System Performance Report*. Wellington: Ministry of Business, Innovation & Employment. Retrieved from: https://www.mbie.govt.nz/dmsdocument/1499-research-science-and-innovation-system-performance-report-2018.

[4] BERL Economics. (2011). *The Māori Economy, Science and Innovation*. Wellington: Te Puni Kōkiri.

[5] New Zealand Government. (2019). *New Zealand's Research, Science & Innovation Strategy* (Draft for Consultation). Wellington: Ministry of Business, Innovation & Employment. Retrieved from: https://www.mbie.govt.nz/dmsdocument/6935-new-zealands-research-science-and-innovation-strategy-draft-for-consultation.

[6] Crawford, R. (2021). *Focused innovation policy: Lessons from international experience*. Wellington: The New Zealand Productivity Commission: Te Kōmihana Whai Hua o Aotearoa. Retrieved from: https://www.productivity.govt.nz/assets/Documents/focused-innovation-policy/Focused-innovation-policy.pdf.

[7] Lewis, G., Garden, S., Shafiee, H., Simmons, G., Smith, J. (2021). *Frontier firms: Four industry case studies*. Wellington: The New Zealand Productivity Commission: Te Kōmihana Whai Hua o Aotearoa. Retrieved from: https://www.productivity.govt.nz/assets/Documents/four-industry-case-studies/Frontier-firms-Four-industry-case-studies.pdf.

[8] Cram, F., Henare, M., Hunt, T., Mauger, J., Pahiri, D., Pitama, S., Tuuta, C. (2002). *Māori and Science: Three Case Studies*. Auckland: Auckland UniServices Limited, The University of Auckland. Retrieved from: http://www.rangahau.co.nz/assets/CramF/Cram%20Maori_science.pdf.

[9] Rauika Māngai. (2020). *A Guide to Vision Mātauranga: Lessons from Māori Voices in the New Zealand Science Sector*. Wellington, NZ: Rauika Māngai. Retrieved from: http://www.rauikamangai.co.nz/wp-content/uploads/2021/05/Rauika-Ma%CC%84ngai_A-Guide-to-Vision-Ma%CC%84tauranga_FINAL.pdf

[10] Kukutai, T., McIntosh, T., Boulton, A., Durie, M., Foster, M., Hutchings, J., Mark-Shadbolt, M., Moewaka Barnes, H., Moko-Mead, T., Paine, S-J., Pitama, S. & Ruru, J. (2021). *Te Pūtahitanga: A Tiriti-led scienc epolicy approach for Aotearoa New Zealand.* Auckland: Ngā Pae o te Māramatanga. Retrieved from: http://www.maramatanga.co.nz/publication/te-p-tahitanga-tiriti-led-science-policy-approach-aotearoa-new-zealand

[11] Ministry of Business, Innovation & Employment. (2020). *Te Pae Kahurangi: Positioning Crown Research Institutes to collectively and respectively meet New Zealand's current and future needs*. Wellington: Ministry of Business, Innovation & Employment. Retrieved from: https://www.mbie.govt.nz/assets/te-pae-kahurangi-report.pdf.

[12] Haar, J., Daellenbach, U., O'Kane, C., Ruckstuhl, K., & Davenport, S. (2021). Top executives work-life balance, job burnout and turnover intentions: Moderated-mediation with knowledge sharing culture. *New Zealand Journal of Employment Relations 46* (1), 1-22.

[13] Lewis, G., Garden, S., Shafiee, H., Simmons, G., Smith, J. (2021). Frontier firms: Four industry case studies. Wellington: *The New Zealand Productivity Commission: Te Kōmihana Whai Hua o Aotearoa*. Retrieved from: https://www.productivity.govt.nz/assets/Documents/four-industry-case-studies/Frontier-firms-Four-industry-case-studies.pdf.

[14] Stephenson, J., Barton, B., Carrington, G., Gnoth, D., Lawson, R., Thorsnes, P. (2010). '*Energy cultures: A framework for understanding energy behaviours.' Energy Policy*, Vol.38(10), pp. 6120-6129.

PART TWO

Global trends in research, science and innovation

Aotearoa New Zealand has a science innovation ecosystem that is unique in some respects yet also has similarities to systems found elsewhere. We briefly outline four broad trends drawn from local and international research literature to provide context to the issues discussed in the previous section. Such literature provides a basis for understanding which parts of our science innovation system are amenable to change relatively easily and which parts require different practices, resources, and people.

At a fundamental level, SfTI as an innovation organisation in the science sector has set out to change practice: in how it brings research teams together; in how it provides support for the research projects in a 'hands-on way'; in how it relates to its key industries and partners; and in how it supports individuals. A practice is a 'routinized type of behaviour which consists of several elements, interconnected to one another'.[1]

These interconnected elements include objects, mental models/activities, knowledge and understanding, know-how and states of emotion. Practices are inherently social and involve shared understandings of how 'things are done': they are what individuals do while interacting with and shaped by the context in which they operate.

In this report, we spend some time unpicking the context so that we are able to understand scientist and organisational habits. In turn this helps us better recognise some of the nuances and complexities of the issues that SfTI is trying to address to achieve its mission.

Top: Underground wireless data acquisition system – (l-r) Kevin Wang, Akshat Bisht and Sean Wu.

Centre top: Nitrate sensor arrays – Leonie Jones (Ngāpuhi, Ngāti Kahungunu ki Wairarapa).

Centre bottom, bottom: All of researchers workshop 2019.

TREND ONE
Beyond Traditional Science

Increasingly stakeholders expect, and government funders dictate, that non-scientists are involved in the development, organisation and outcomes of the science and technology sectors. This expectation has been built up and expanded on through concepts such as Mode 2 and 'post-normal' science in contrast to Mode 1 traditional or 'normal' science[2] (see Table 1).

Table 1: Comparison of knowledge production in science (Adapted from Gibbons[3] & Nowotny et al[4]).

Mode 1 (Traditional Science)
Theoretically driven
University and institution centered
Discipline based and uni-disciplinary
Experimentally focused
Hierarchical
Investigator produced
Prioritizes scientific autonomy
Seeks universality
Mode 2 (Beyond-traditional Science)
Application oriented
Subject to multiple accountabilities – university, institute, political, economic, public stakeholders
Interdisciplinary/transdisciplinary
Multiple and mixed methods
Mostly heterarchical
Co-produced with multiple stakeholders
Socially distributed, collaborative, transparent
Embedded in local contexts and cultures

As Table 1 shows, traditional science research involves different sets of people, expectations and practices, with the cultures, beliefs and values that derive from particular modes also being distinct. The traditional science process has innumerable strengths and achievements, not least of which are an in-built 'universalist' frame of reference, a clear methodological approach that ensures rigorous and robust scrutiny of scientific claims as well as shared language and concepts.[5,6,7,8] However, this mode on its own cannot tackle real-world social, environmental or economic 'global challenges' or 'missions' (such as those of the National Science Challenges), given uncertain facts, disputed values, high stakes and the need for quick decisions.[9] In such circumstances, 'citizen scientists', specific communities, non-governmental or business organisations provide local, culturally-situated and contextualised knowledge to complement science knowledge.[10] In the New Zealand context, this includes mātauranga Māori.

Despite their significant differences, addressing missions and global challenges require individuals, teams and organisations to **operate across *multiple* modes.** From an R&D innovation perspective, this has been well understood for many years with theories and models that promote interaction between users and scientists, typically including a role for government. Thus, there are national-level innovation policies,[11,12] including calls for public financing that pro-actively shapes markets and creates innovation directions.[13] There are also theories, such as 'Triple Helix'[14] that posit the necessity of government, business and science organisations together creating innovation, finding application in innovation/knowledge clusters,[15] science parks,[16] and innovation ecosystems.[17] To these, formal and informal physically co-located collectives have been added virtually networked hybrid open innovation collectives such as Living Labs[18] and Knowledge Innovation Communities.[19]

A clear shift is that funding bodies want to see tangible policy-relevant outputs and outcomes from their investment as well as a range of other impacts, including benefits for Māori. Hence, different organisational forms have developed over the years. In the New Zealand science innovation system, we can see from Table 2 that various science modes are represented in different forms of 'hybrid' funding and organisational mechanisms, seeking to leverage the benefits of both the science 'pull' factors from society and the 'push' factors from science.

This push/pull dichotomy is often represented in the innovation 'pipeline' with fundamental research via traditional science subsequently advanced and pushed out to commercial use. Science and innovation theory, though, indicates that science discovery that is pushed out into eventual societal use is no longer, and perhaps never has been, the pre-eminent approach. Non-scientists increasingly demand early participation in, co-construction of, or insight into basic research and discoveries.

Table 2: 'New Zealand funding and organisational mechanisms (Adapted from Smart et al.[20]).

	Scientific specialist contributor	Non-scientific specialist contributor
Science led	• Marsden Science	• Citizen/crowd science • Endeavour-funded science • VM-funded science • National Science Challenges • Centres of Research Excellence • CRIs
Non-science led	• Iwi R&D e.g. VM capability funded science • Industrial R&D • Technology transfer/spin-out • Callaghan-Innovation • Wiki-science	• Backyard inventor • Traditional knowledge practitioner

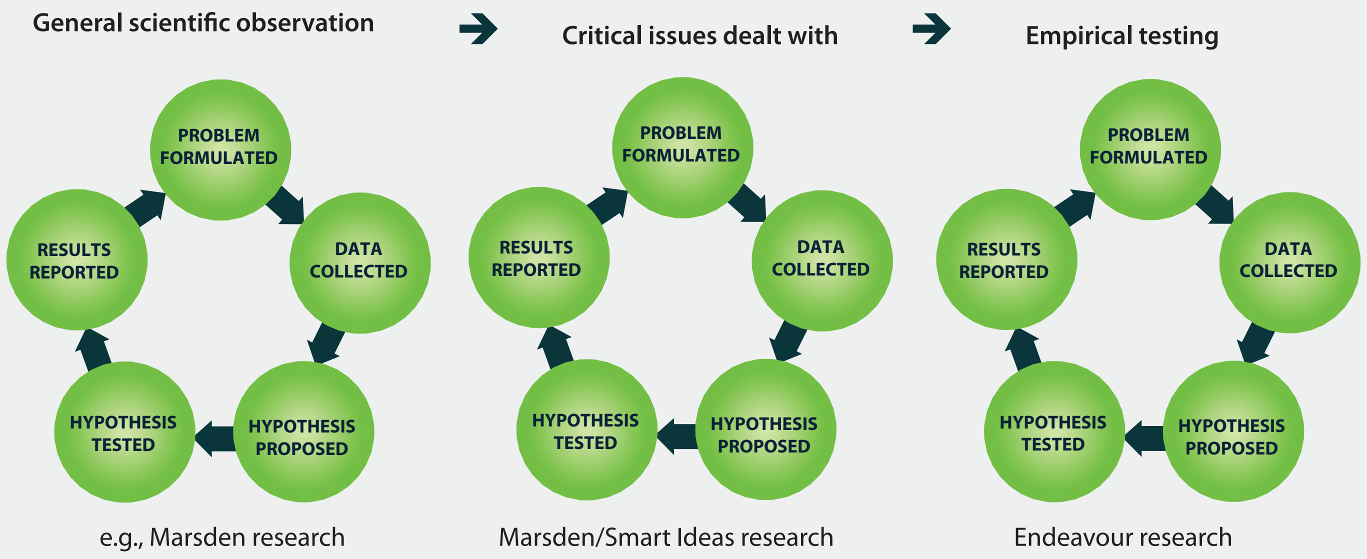
This earlier or 'upstream' engagement can create issues for both scientists and potential users in high-tech science fields. NASA's Applied Science Readiness Levels (ASRLs)[21] assess whether a science proposition is progressing through three iterations of five science 'phases' before it is 'mature' enough to be considered for technological development (See Figure 1).

What matters is not that there are several iterations, but that the phases are a necessary and expected part of science methodology to ensure rigour, reproducibility and to address uncertainties. However, what happens when scientists are asked to innovate with those who are not familiar with, not interested in, or do not have the time to understand this methodology?

Resolving science uncertainty is an exciting aspect of science, providing motivation and challenging science teams to 'achieve the impossible.' Arguably, scientific uncertainty is why science thrives: it distinguishes why scientists do what they do. This, though, is rarely a primary driver for a collaborator. In addition, greater uncertainties can hold scientists back from collaborating, including with non-scientists.

While commercialisation of basic science – as conceived of in a 'pipeline' model – is a valuable means by which scientists can create economic and social impact, there are other options to transfer academic knowledge out into various domains. One under-examined area is subsumed under the term 'academic engagement', defined by Perkmann et al. as "knowledge-related interactions by academic researchers with non-academic organisations (… that) include collaborative research, contract research and consulting as well as informal activities such as providing ad hoc advice and networking with practitioners".[22]

Figure 1: Early innovation pipeline process (adapted from NASA's Applied Science Readiness Levels Phases).



Perkmann et al.'s review of the academic engagement literature highlights:

- engagement beyond the university takes many forms (collaborative research, consulting, contract research, patenting or academic entrepreneurship), with the first three much more prevalent than the latter two (which align more to commercialisation);
- academic engagement is more likely undertaken by senior, male, well-established scientists who have strong connections across the academic community, more publications and more government grants. Academic engagement is complementary to, if not essential for, research productivity;
- similarly, industry collaboration can eventually produce a virtuous cycle with respect to productivity, publications, grants and prominence;
- related to the previous point, academic engagement provides more accessible opportunities for academic scientists to mobilise key resources and funding to support their core research agendas;
- relative to commercialisation, academic engagement is driven and influenced more by individual-level factors than institutional or university level factors.

For both academic engagement and commercialisation, academics must build and broaden their strategic skills to effectively broker the transfer of the developed technology, regardless of institutional restrictions.[23] This is in effect puts the scientist into a user role that has been advocated internationally by Baglieri and Lorenzoni.[24] They argue that scientist-user PIs are able to transfer research to market application by leading a process that iteratively brings together multiple perspectives and mobilises expertise to solve the technological problems.

> *"The point we make here is that encouraging or even **mandating academic engagement with non-academics is beneficial at a number of levels.** However, it comes with its own set of issues given it can rely on individual capacities."*

KEY QUESTION

- *When science problems are so fundamental that even the scientists are unsure as to how they are best addressed without several iterations, what strategies engage non-scientists or those from outside a particular discipline to co-innovate in upstream 'blue-skies' or fundamental science questions?*

Insights into our findings are provided in **Part Three Beyond Traditional Science.**

TREND TWO
Opening Science for Open Innovation

The opening up of science (or 'open science') suggests that science knowledge should be transparent, accessible, shared and developed through collaborative networks.[25] Such open science would enhance public good outcomes and, through new commercially developed tools, services, and products, also lead to private economic benefit. Open science has both its supporters and those who view it more cautiously.

On the one hand, as has been apparent in the context of the Covid-19 pandemic, open science data repositories have enabled knowledge sharing at an unprecedented scale and speed, leading to the rapid development of vaccines. On the other hand, and in the context of the pandemic, not all communities have benefited equally from open science, whether within a particular country or across nations. Indigenous people have concerns that the ideal of open science merely replicates exclusions that are inherent in the science system more generally.[26]

One of the promises of open science is a pathway to open innovation, with this pathway recently termed as '**open innovation science' (OIS)**. This is defined as 'a process of purposively enabling, initiating, and managing inbound, outbound, and coupled knowledge flows and (inter/transdisciplinary) collaboration across organisational and disciplinary boundaries and along all stages of the scientific research process.'[27] As with any pathway, there is a direction and hence ways to manage or guide the direction. This forms a core theme examined within BNZIC's research.

Open innovation (OI) proposes that enterprises will be more successful in innovating and creating value if they acquire, assimilate and exploit knowledge from both inside and outside their organisation relative to operating in a **closed** innovation mode. The literature has primarily looked at business organisations and frequently not identified which types of OI have proven most beneficial. As we noted in a previous report, and as we will show through our empirical observations, OI theory in a New Zealand context raises a range of questions as well as some answers, particularly with respect to timing of engagement. For example, **science teams are not fixed in terms of remaining more or less open**, with a variety of individual, team and partner contextual factors having an influence on the extent of this. New Zealand organisations are also noted to invest less in R&D relative to international firms, suggesting that no **(or little) innovation may be occurring**, which restricts the extent of business 'pull' for researchers to be open.

More recently, literature on OI has addressed trends toward open science, particularly in the context of being able to solve complex technological problems.

> *"International research shows that **science-based OI**[28] allows firms access to cutting-edge scientific and specialist knowledge but that high **absorptive capacity (AC)** (i.e., high levels of scientific/technical understanding and ability to translate into an organisational setting) is required to identify scientific knowledge that has potential to be turned into marketable products."*

Thus, a firm's AC is the main determinant of the productivity of its science-based OI. For Aotearoa New Zealand, we wanted to know, is it the same?

KEY QUESTIONS

- *Are New Zealand firms with high AC more likely to utilise OI? And what would they use it for?*
- *What if those firms are Māori – does this equally apply?*

We address these in **Part Three Opening Science for Open Innovation**.

What happens if a firm already has high AC? Some researchers argue that closed innovation is an efficient way to integrate less complex science knowledge, and that therefore OI would not provide superior firm performance given the increased risks, costs and time associated with communicating and coordinating with external partners.

Where firms have low AC, OI options[29] include:

- **Science-based OI** – collaborations between firms and universities, government labs, and other research institutes in the science sector allow problems to be addressed with external expertise.
- **Coopetition OI** – when OI is created between firms in the same industry. For example, they can collaborate for upstream activities, such as Research and Development (R&D), but compete in downstream activities, such as sales. OI helps them jointly deal with complexity based on similar absorptive capacity drawing on their common knowledge bases.
- **Network OI** – where multiple players, networks, ecosystems, or consortia participate to deal with increasing complexity in technological development. Network OI can connect organisations that have specific project expertise in their fields and collectively solve highly complex problems. Several empirical studies support the idea that network OI is the most efficient form for dealing with high levels of complexity.
- **Crowd-sourcing OI** – where a problem-solving task is outsourced to the public. Research shows that it can provide optimal outcomes when relevant project expertise is lacking but mostly in cases where there are only moderate levels of complexity.

Given the above, research tentatively suggests that where there is high AC and the complexity of the technology development is also high, then science-based or network OI are warranted. In other cases, other types of OI (e.g., coopetition, crowd-sourcing) or even closed innovation are relevant strategies.

Table 3: Absorptive Capacity and the complexity of technology development (Lee, et al.[30]).

		Complexity	
		High	**Low**
Project Expertise	**High**	Science-based OI Network OI	Closed innovation
	Low	Coopetition OI	Crowd-sourcing OI

KEY QUESTIONS

- *To what extent do New Zealand firms use closed innovation, and is it holding them back from superior performance?*
- *In relation to solving advanced technological problems, what evidence exists of the other types of OI models being successfully implemented? If so, what accounts for their success?*

We address these in **Part Three Opening Science for Open Innovation.**

TREND THREE
Opening Science for Māori Innovation

The Vision Mātauranga science and innovation policy reflects a unique space in New Zealand's science and research landscape.[31] The VM policy induces us to consider issues of social legitimacy in technological innovation, which in turn gives rise to the development of new modes of science organisation and science governance. As a policy framework, VM provides opportunity to empower Māori knowledge, people and resources as a foundation for a thriving science system.[32]

While Vision Mātauranga is specific to New Zealand, it reflects a global trend to review the role of science in colonisation and the ongoing structures that have discounted, denied, or disparaged Indigenous voices and knowledge in science and technology. The post-colonial Indigenous rights movement that manifested in New Zealand in the sovereignty protests of the 1960s and 1970s[33] drew attention to the growing assertion of Indigenous and non-Western science as a knowledge system with a long history of contribution to its own and broader science traditions.[34] Indigenous and post-colonial science scholars[35,36,37] have noted that Western scientific knowledge 'is *not* the "sum of all knowledge"'[38] but it is one of many types of knowledge. Despite the ethnocentrism that has construed Indigenous knowledge as pseudo- or unscientific or an artefact of a former life,[39,40] Indigenous knowledge has adapted to European technology, while maintaining its frame of reference[41]. Such understandings have been reflected in international conventions and declarations such as the Declaration on the Rights of Indigenous People (2007),[42] the Convention on Biological Diversity (1992)[43] and the Nagoya Protocol (United Nations 2015).[44]

Debates as to whether Indigenous science *is* science[45] are unsurprising, given the differences between modes of knowledge production advocated for complex science projects. Such debates often lead to binaries, such as in Table 4.

Binaries can obscure the larger mission that the use of diverse knowledge sets can create solutions for common and shared problems, sometimes described as 'two-eyed seeing' or 'interface' research.[47,48] While such aspirations may seem self-evident, Indigenous people have not necessarily benefited from scientific and technological research, especially when a Mode 1 approach is the sole approach. Rather, as colonial experience has taught, traditional Indigenous knowledge has often been appropriated without acknowledgment or recompense. Examples of this include Brazilian rubber and Andean cinchona bark (from which quinine is made) being transferred by the British to Kew Gardens and then used to develop industries in Malaya and India respectively.[49]

Table 4: Mātauranga Māori-science binaries (Rauika Māngai[46]).

Mātauranga Māori	Science
Holistic	Analytical
Accepted truths	Skeptical
Based on environmental encounters	Measurement & replication
Centrifugal thinking	Centripetal thinking
Highlights similarities	Highlights differences
Practitioners older	Practitioners younger
Time enhances knowledge	Time ages science
Steadily evolving	Knowledge constantly changing

More recent examples include attempts to patent Ojibwe wild rice, Mexican maize and Hawaiian taro[50] and an anti-malaria drug based on a French Guianan indigenous community's traditional medicinal knowledge.[51] In New Zealand, Mary Kay Inc., a US-owned marketing business that distributes cosmetic items, has filed many patents, citing New Zealand endemic or near-endemic species in the claims, including five patent families referring to kānuka.[52]

Decolonisation efforts are emerging across the academy informed by both Indigenous rights and JEDI (Justice, Equity, Diversity, Inclusion) movements.[53] Diversity, inclusivity and equity are an increasing feature and requirement of New Zealand's science system as well, with MBIE stating that "diversity is vital for our science system to realise its full potential."[54] **There are, however, mixed results on the success of such policies in practice.** International research has shown that diversity and inclusion policies in science teams can often lead to accusations of 'tokenism' with, paradoxically, less integration of minorities into teams.[55] Team diversity is more likely to be impactful when minority scientists are more evenly represented and integrated into organisational environments (area, sector, jobs, organisations, informal networks).

There is a fundamental distinction between diversity as the mere presence of minority scientists on teams or in workplaces and their complete integration.

> *"Representational diversity is essential but not sufficient to promote 'full' integration and diversity, as well as innovation. It has even been suggested that the critical mass of a minority group in the workplace must be more than 15 per cent to reduce the impact of inclusion from being token."[56]*

To mitigate against tokenism, suggested practices have included mentoring, sponsorship, cross-communication, increasing informal ties and social accountability (e.g., tying managerial reputation to goals). We comment on these more fully in **Part Three**.

Increasingly, Indigenous people seek not only diversity and inclusion in science and technology, but also equitable benefit sharing from science discoveries and control, often couched in terms of Cultural Intellectual Property (CIP) and Indigenous sovereignty. Such terminology has been particularly to the fore in terms of data sovereignty that more broadly relates to how individuals, collectives or nations have control over data within and beyond their national borders.[57]

> *"While Indigenous Data Sovereignty (IDS) shares similar concerns of the nation state to control flows of data, in some ways IDS is a challenge against the nation state with an emphasis on tribal or tribal nation self-determination and autonomous decision-making,[58] one that reprioritises cultural and scientific knowledge within the realm of 'dominating' (western) science production."*

Particularly in relation to privacy, IDS challenges individualist approaches espousing collective principles based on long-held world views and practices.[59] It is also a chance for Indigenous people to contribute their unique and legitimate knowledge, expanding sciences' possibilities.

This equally applies to intellectual property (IP) rights, where scholars have noted that it seems illogical to Indigenous people that a patent can be awarded to an 'inventor' to 'improve' plants and seed varieties when it is based on thousands of years of traditional knowledge.[60]

This points to the different notions of what can be considered a right to claim ownership, control use, and hence capture benefit. On the one hand, the suite of tools that make up contemporary IP regimes – patent, copyright, design patent, trade secret, geographical indications and plant varieties – are designed to encourage and reward creativity and innovation in science, technology and the arts, and hence imply what protections and rewards can be expected. On the other hand, there is criticism that exclusionary principles of IP are inconsistent with customary protocols and laws governing the use of Indigenous resources and traditional knowledge with a complex set of custodianship responsibilities of collectively held resources for future generations.

Such responsibilities may be articulated in terms of Cultural Intellectual Property Rights as in Indigenous conventions like the 1994 Mātaatua Declaration and the Declaration on the Rights of Indigenous Peoples.

The Waitangi Tribunal report WAI 262, *Ko Aotearoa Tēnei*, which addresses Māori claims to cultural and intellectual property rights, reiterated the limitations of IP law to 'protect the underlying knowledge or philosophy embodied in the work or consider customary law, customary rights and customary interests in the resources or works.' The Tribunal also reaffirmed Indigenous peoples' rights to develop their resources to enhance prosperity and economic development.[61]

KEY QUESTIONS

- *How is Māori science and innovation policy impacting on individuals, teams or Māori partners?*
- *What are some of the enabling practices that can support Māori innovation when viewed from a Māori perspective and what changes would be required to implement these?*

We provide insights in **Part Three Opening Science for Māori Innovation**.

TREND FOUR
Developing Entrepreneurial Behaviours

As we noted for earlier trends, particular modes of science follow their own methodologies, norms and values. Hence, moving from performing Mode 1 science to practices associated with other modes is not necessarily intuitive. It requires different sets of attitudes, skills, tools and practices, not only at an individual level but also in how teams construct themselves. At a broader level, institutions also need to reorganise themselves to enable these practices.

Shifting science modes requires complex and ongoing negotiation and **re-construction of academic and entrepreneurial identities** through adapted and novel behaviours. This has been well-canvassed in the literature for some time with many models and typologies identifying the types of capabilities and behaviours that enable individuals and teams to operate across the science-technology boundary. There are barriers to such engagement because academia and potential collaborators have different norms, values, language and understanding, as illustrated in Table 5.

Table 5: Academic and entrepreneurial role identity compared (from Jain et al.[62]).

	Academic	Entrepreneurial
Norms	Universalism	Uniqueness
	Communism	Private property
	Disinterestedness	Passion
	Skepticism	Optimism
Processes	Experimentation	Focus
	Long-term orientation	Short-term orientation
	Individualistic/ Small group	Team management
Outputs	Papers	Products
	Peer recognition/ status	Profits

From the perspective of the individual scientist, there is significant pressure to try to bridge these divides,[63] but there is little research on how scientists and in particular successfully funded Principal Investigators (PIs) learn or receive preparation for such roles.

There is also little research on the enablers and barriers to scientists transiting across or between these roles. One idea is that certain identities, for example an 'entrepreneurial scientist', are '**produced' through actions** and that this, in turn, produces particular 'stand-alone' elements of their identity.[64] More specifically, a scientist discussing the potential commercial applications of his or her research idea in a workshop [one identity element] may produce another identity element (entrepreneurial-researcher). The theorisation allows for identity elements to both stand alone and to come together to form more complex wholes. Such a view expands beyond simplistic binaries that often characterise discussions about scientists' dispositions (i.e., is or is not 'entrepreneurial'). Taking an identity elements approach allows for analysis of the actual actions connected to scientist's identity. This suggests that **some actions are more likely to produce particular types of scientist identity.**

Scientists' orientations are complex and analysing them must allow for this. Adopting a hybrid analysis, such as that shown in Table 6, can identify some of the underlying beliefs and motivations that drive the behaviour of individual scientists. These need to be interrogated if non-traditional orientations are a desired objective.

Such hybrid analysis matches other research that suggests that scientists adopting non-traditional modes have different competencies. For example, a Type III 'hybrid entrepreneurial' orientation seems to align with what is described as **A-shaped skills**,[66] whereby an individual is able to integrate different disciplines (i.e., the two 'legs' of the 'A') and graft them together to execute a task. Individuals with such a skill set are more likely to understand phenomena from a higher level of abstraction and to form the metatheories needed to push scientific boundaries. While such individuals may be interested in applying their knowledge to the other domain (e.g., product development), their identities are firmly academic.

Extending this, Type IV 'entrepreneurial' scientists might be viewed as having **T-Shaped competencies.**[67] Individuals with T-shaped talents are not just technical specialists in a particular domain (the downward stroke of the 'T') but also have interactional expertise and the ability to "speak the language" of another domain (the horizontal stroke of the 'T').[68] Acquisition of communication skills is fundamental to all researchers, but communication in this sense is more than the ability to use the language of the other domain.[69] T-shaped individuals are **fully conversant with the systems or worldviews** of the other domain (whether that system is industry or Māori), whereby identity, work routines and relationships are 'fused' into the science role.

Table 6: Hybrid orientations towards university-industry links (from Lam[65]).

	Beliefs about academic and industry boundary	Extent and modes of engagement with industry	Main motivating factors	Perceived legitimacy of commercialization	Boundary work strategies and role identities
Type I 'Traditional'	• Believes academic and industry should distinct and pursues success strictly in academia arena	• Some collaborative links but of an intermittent nature	• Mainly to obtain funding for research	• Resistance • An assault on academic ethos and autonomy	• Boundary separation and expulsion • Retain academic role identity
Type II 'Traditional hybrid'	• Believes academic and industry should be distinct, but also recognises the need to collaborate	• Mainly collaborative links with intermittent involvement in some commercial activities	• Funding for research most important	• Accommodation • Not desirable but an inevitable development	• Boundary testing and maintenance • Protect dominant academic identity
Type III 'Entrepreneurial hybrid'	• Believes in the fundamental importance of science-business collaboration but recognises the need to maintain boundary	• Continuous engagement in a range of collaborative and commercial activities	• Funding for research most important • Application of research, know-ledge exchange and networking also important	• Incorporation and co-optation • Pursue commer-cialization but not all its associated meanings	• Boundary negotiation and expansion • Hybrid roles but retain focal academic identity
Type IV 'Entrepreneurial'	• Believes in the fundamental importance of science-business collaboration	• Continuous engagement in a range of collaborative and commercial activities • Strong commercial ties with firms	• Application of research most important • Funding for research, knowledge exchange and networking also important • Personal pecuniary gain relevant	• Acceptance and veneration • Commercial practices embedded in work routines	• Boundary inclusion and fusion • Fuse dual role identities

While both T-shaped and A-shaped skills positively influence team performance in knowledge creation, acquiring such skills is an expensive, time-consuming task, so perhaps not everyone in a team needs these skills.[70] Noting that such skills may be desirable, and even necessary, the **barriers to individuals acquiring such skills need to be recognised** as well as those that affect when or whether individuals choose to apply them.

Finally, while much research focuses on the capabilities and orientations of individuals, our enquiries have led us to consider how such capabilities are deployed internally in teams and in and amongst institutions. For example, teams need to integrate their knowledge to develop new products or processes. But how does this happen? Some research has suggested that innovation teams need **integrative capacity**, which is the degree to which a science team integrates diverse skills and activities into a coherent whole.[71,72] Integrative capacity transcends the limits of a particular subject through the integration of multiple ideas, viewpoints, and methodologies.[73,74,75,76] In turn, this engenders trust and a shared purpose, particularly important when problems are complex, novel or not well-understood.

This has led us to identify the important roles of science-based open innovation intermediaries. At their simplest, innovation **intermediaries** – whether an individual person or an organisation – act as an 'agent or broker in any aspect of the innovation process between two or more parties' (p.720[77]). However, this definition disguises many of their diverse functional roles that may span from integrating internal team dynamics (i.e., integrative capacity) to system level co-ordination or integration.[78]

There are many situations in which the effective functioning of New Zealand's science innovation system depends on the assistance of intermediaries. However, the role of an intermediary is not always immediately apparent.

Science-based Open Innovation Intermediaries

Individuals – often (but not always) the Principal Investigator or 'leader' of a project – who has a range of intra-team functions such as:

- championing a project,[79] by scanning, scoping and filtering technical options for projects[80,81] to make it understandable for the team.
- overcoming team resistance to integrate external knowledge[82] whether socio-economic or technical knowledge from another domain.
- removing or helping to navigate organisational uncertainty.[83]

Sub-groups in an organisation (such as tech-transfer offices) that may:

- support a team's information exchange with external entities and with accessing key resource and expertise.[84,85]
- architect new collaboration processes when upstream knowledge practices still unclear[86] e.g., Kāhui.[87]
- Help a team scale-up their research through prototyping, help with training.[88,89]
- Protect results through IP rights advice and management.[90]

Innovation system organisations e.g., Kiwinet, innovation incubators that help:

- select the right collaborative partners by bridging capability gaps, innovation needs and vision.[91,92,93]
- promote diffusion and technology transfer.[94]

KEY QUESTIONS

- *What capabilities enable individuals to collaborate across boundaries?*
- *What are the different ways to organise capabilities within teams? Who should have these capabilities in teams?*
- *How can these capabilities be developed?*

In **Part Three Developing Entrepreneurial Behaviours** we examine the roles and functions of some of these different types of science-based open innovation intermediaries.

References

[1] Reckwitz, A. (2002). Toward a theory of social practices: A development in culturalist theorizing. *European Journal of Social Theory, 5*(2), 243-263.

[2] Funtowicz, S., & Ravetz, J. (1993). Science for the post-normal age. *Futures, 25*(7), 739-755.
Carayannis E., & Campbell D. (2006). "Mode 3": meaning and implications from a knowledge systems perspective. In: Carayannis EG., & Campbell DFJ., editors. Knowledge creation, diffusion, and use in innovation networks and knowledge clusters. A comparative systems approach across the United States, Europe and Asia. Westport: Praeger. pp. 1-25.

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

[4] Nowotny, H., Scott, P., & Gibbons, M. (2003). Introduction: 'Mode 2' revisited: The new production of knowledge. *Minerva, 41*(3), 179-194.

[5] Stock, P. and Burton, R.J. (2011). 'Defining terms for integrated (multi-inter-trans-disciplinary) sustainability research', *Sustainability, 3*, 1090-113.

[6] Gibbons, M., Limoges, H., Nowotny, H., Schwartzman, S., Scott, P., Trow, M. (1994). *The New Production of Knowledge.* London: Sage.

[7] Nowotny, H., Scott, P., Gibbons, M. (2003) *Re-thinking Science: Knowledge and the public in an age of uncertainty*. Cambridge: Polity Press.

[8] Smart, P., Holmes, S., Lettice, F., Pitts, F.H., Zwiegelaar, J.B., Schwartz, G., Evans, S. (2019). 'Open Science and Open Innovation in a socio-political context: knowledge production for societal impact in an age of post-truth populism.' *R&D Management, 49*(3), 279-297.

[9] Ravetz, J.R. (1986). 'Usable knowledge, usable ignorance: incomplete science with policy implications,' in W. C. Clark and R. C. Munn (Eds), *Sustainable Development of the Biosphere*. New York: Cambridge University Press, 415-32.

[10] Tebes, K. & Thai, N. (2018). 'Interdisciplinary Team Science and the Public: Steps Toward a Participatory Team Science', *American Psychologist*, 73(4), 549-62.

[11] Lundvall, B.A. (1992) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter Publishers.

[12] Freeman, C. (1995). The 'National System of Innovation' in historical perspective. *Cambridge Journal of Economics, 19*(1), 5-24.

[13] Mazzucato, M., & Semieniuk, G. (2017). Public financing of innovation: new questions, *Oxford Review of Economic Policy, 33*(1), 24–48.

[14] Etzkowitz, H., Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. *Research Policy, 29*(2), 109-123.

[15] Porter, M. (2000). Location, competition and economic development: Local clusters in a global economy. *Economic Development Quarterly, 14*(1), 15-34.

[16] Ylinenpa, H. (2001). *Science parks, clusters and regional development*. In Proceedings of 31st European Small Business Seminar, Dublin: Dublin Institute of Technology (pp. 1-13).

[17] Beudry, C. Burger-Helmchen, T., Cohendet, P. (2021). Editorial: Innovation policies and practices within innovation ecosystems. *Industry and Innovation*, 28(5), 535-544.

[18] Leminen, S., Nyströmd, A.G.,Westerlunde, M. (2020). Change processes in open innovation networks – Exploring living labs. *Industrial Marketing Management*, 91, 701-718.

[19] Fammels, M. (2016). *Introduction to the EIT and its Knowledge and Innovation Communities (KICs)*. 10442/15235, 00-40. Retrieved from: https://eit.europa.eu/what-are-eit-knowledge-and-innovation-communities-kics

[20] Smart, P., Holmes, S., Lettice, F., Pitts, F. H., Zwiegelaar, J. B., Schwartz, G., & Evans, S. (2019). Open Science and Open Innovation in a socio-political context: knowledge production for societal impact in an age of post-truth populism. *R&D Management*, 49(3), 279-297.

[21] Millis, M. G. (2005). Assessing Potential Propulsion Breakthroughs. *New Trends in Astrodynamics and Applications II—An International Conference* (pp. 1-23). New Jersey: National Aeronautics and Space Administration.

[22] Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., Pablo, D., Fini, R., Geuna, Al., Grimaldi, R., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni, F., Salter, A., Sobrero, M. (2012). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy, 42*(2), 423-442.

[23] O'Kane, C., Cunningham, J. A., Menter, M., & Walton, S. (2020). The brokering role of technology transfer offices within entrepreneurial ecosystems: an investigation of macro–meso–micro factors. *The Journal of Technology Transfer, 46*(6), 1-31. https://doi.org/10.1007/s10961-020-09829-y

[24] Baglieri, D., & Lorenzoni, G. (2014). Closing the distance between academia and market: experimentation and user entrepreneurial processes. *The Journal of Technology Transfer, 39*(1), 52-74.

[25] Vicente-Saez, R., Martinez-Fuentes, C. (2018). Science now: A systematic literature review for an integrated definition, *Journal of Business Research*, 88, 428-436.

[26] Hudson, M., Nanibaa'A, G., Sterling, R., Caron, N. R., Fox, K., Yracheta, J., ... & Carroll, S. R. (2020). Rights, interests and expectations: Indigenous perspectives on unrestricted access to genomic data. *Nature Reviews Genetics, 21*(6), 377-384.

[27] Beck, B., Bergenholtz, C., Bogers, M., Brasseur, T.M., Conradsen, M.L., D., Di Marco, D., Distel, A.P., Dobusch, L., Dörler, D., Effert, A., Filiou, B., Frederiksen, L., Gillier, T., Grimpe, C., Gruber, M., Haeussler, C., Heigl, F., Hoisl, F., Hyslop, K., Kokshagina, O., LaFlamme,M., Lawson, C., Lifshitz-Assaf, H., Lukas, W., Nordberg, M., Norn, M., Poetz, M., Ponti, M., Pruschak, G., Priego, L., Radziwon, A., Rafner, J., Romanova, G., Ruser, A., Sauermann, H., Shah, S.K., Sherson, J.F., Suess-Reyes, J., Tucci, C.L., Tuertscher, P., Vedel, J.B., Velden, T., Verganti, R., Wareham, J.,Wiggins, A., & Sunny Mosangzi Xu. (2020). The Open Innovation in Science research field: a collaborative conceptualisation approach, *Industry and Innovation*, 1-52. DOI: 10.1080/13662716.2020.1792274

[28] Lee, Y., Fong, E., Barney, J.B., Hawk, A. (2019). Evidence from the U.S. Pharmaceutical Industry. *California Management Review, 62*(1), 144-166. doi:10.1177/0008125619883617

[29] ibid.

[30] ibid.

[31] Broughton, D. & McBreen, K. (2015). Mātauranga Māori, tino rangatiratanga and the future of New Zealand science. *Journal of the Royal Society of New Zealand, 45*(2), 83-88.

[32] Rauika Māngai. (2020). *A guide to Vision Mātauranga: lessons from Māori voices in the New Zealand science sector*. Wellington: Rauika Māngai.

[33] Erueti, A. (Ed.). (2017). *International Indigenous Rights in Aotearoa New Zealand*. Wellington: Victoria University Press.

[34] The International Council for Science. (2002). *Science, traditional knowledge and sustainable development.* http://unesdoc.unesco.org.ezproxy.otago.ac.nz/images/0015/001505/150501eo.pdf.

[35] Agrawal, A. (1995). Dismantling the Divide Between Indigenous and Scientific Knowledge. *Development and Change, 2* (3), 413-439.

[36] Durie, M. 2004. *Exploring the interface between science and indigenous knowledge*. 5th APEC Research and Development Leaders Forum, Christchurch.

[37] Posey, D. A. (2004). *Indigenous knowledge and ethics: A Darrell Posey reader* (Vol. 10). Psychology Press.

[38] Tsosie, R.A. (1999). Privileging Claims to the Past: Ancient Human Remains and Contemporary Cultural Values. *Arizona State Law Journal*, 31, 619.

[39] Scott C. (2011). Science for the west, myth for the rest? The case of James Bay Cree knowledge construction. In: Harding Sandra, editor. *The postcolonial science and technology studies reader*. Durham, NC: Duke University Press; p. 175–197.

[40] Bielawski E. (1990). *Cross-cultural epistemology: cultural readaptation through the Pursuit of knowledge*. Edmonton: Department of Anthropology, University of Alberta.

[41] Pool I. (2015). *Colonization and development in New Zealand between 1769 and 1900. The seeds of rangiatea*. London: Springer International Publishing.

[42] United Nations (2007). *Declaration on the Rights of Indigenous. New York: United Nations*. Retrieved from: https://www.un.org/development/desa/indigenouspeoples/wp-content/uploads/sites/19/2018/11/UNDRIP_E_web.pdf

[43] United Nations. (1992). *Convention on Biological Diversity*. Rio de Janerio: United Nations. Retrieved from: https://www.cbd.int/doc/legal/cbd-en.pdf

[44] United Nations. (2015). *Conference of the parties to the convention on biological diversity*. Retrieve from: https://treaties.un.org/doc/source/docs/UNEP_CBD_COP_DEC_X_1-E.pdf

[45] Stewart, G. (2019). 'Mātauranga and Pūtaiao: the question of "Māori science". *New Zealand Science Review, 75*(4), 65-68.

[46] Rauika Māngai. (2020). *A guide to Vision Mātauranga: lessons from Māori voices in the New Zealand science sector*. Wellington: Rauika Māngai. https://www.rauikamangai.co.nz/wp-content/uploads/2021/05/Rauika-Ma%CC%84ngai_A-Guide-to-VisionMa%CC%84tauranga_FINAL.pdf

[47] Marshall, B.M.,& Marshall, A. (2012). 'Two-eyed seeing and other lessons learned within a co-learning journey of bringing together indigenous and mainstream knowledges and ways of knowing', *Journal of Environment Studies and Science,* 2(4), 331-40.

[48] Durie, M. (2004). 'Understanding health and illness: research at the interface between science and indigenous knowledge', *International Journal of Epidemiology*, 33(5), 1138-43.

[49] Brockway, L. (2011). "Science and colonial expansion. The role of the British Royal Botanic Gardens," in The *Postcolonial Science and Technology Studies Reader*, ed S. Harding. Durham; London: Duke University Press, 126–139. doi: 10.1215/9780822393849-008

[50] McGonigle, I.V. (2016). Patenting nature or protecting culture? Ethnopharmacology and indigenous intellectual property rights. *Journal of Law and the Biosciences*, 3(1), 217-226, https://doi.org/10.1093/jlb/lsw003

[51] Pain. (2016). *French institute agrees to share patent benefits after biopiracy accusations. Science magazine*. Retrieved from https://www.science.org/content/article/french-institute-agrees-share-patent-benefits-after-biopiracy-accusations

[52] Lai, J. C., Robinson, D. F., Stirrup, T., & Tualima, H. Y. (2019). Māori knowledge under the microscope: Appropriation and patenting of mātauranga Māori and related resources. *The Journal of World Intellectual Property*, 22(3-4), 205-233.

[53] Alex C. McAlvay, Chelsey G. Armstrong, Janelle Baker, Linda Black Elk, Samantha Bosco, Natalia Hanazaki, Leigh Joseph, Tania Eulalia Martínez-Cruz, Mark Nesbitt, Meredith Alberta Palmer, Walderes Cocta Priprá de Almeida, Jane Anderson, Zemede Asfaw, Israel T. Borokini, Eréndira Juanita Cano-Contreras, Simon Hoyte, Maui Hudson, Ana H. Ladio, Guillaume Odonne, Sonia Peter, John Rashford, Jeffrey Wall, Steve Wolverton, and Ina Vandebroek. (2021). Ethnobiology Phase VI: Decolonizing Institutions, Projects, and Scholarship. *Journal of Ethnobiology*, 41(2), 170-191.

[54] MBIE (N.D.). *MBIE Diversity in Science Statement*. Retrieved from https://www.mbie.govt.nz/assets/95e033c7bc/diversity-in-science-statement.pdf

[55] Smith-Doerr, L., Alegria, S. N., & Sacco, T. (2017). How diversity matters in the US science and engineering workforce: A critical review considering integration in teams, fields, and organizational contexts. *Engaging Science, Technology, and Society*, 3, 139-153.

[56] ibid.

[57] Hummel P, Braun M, Tretter M, Dabrock P. (2021) Data sovereignty: A review. *Big Data & Society*, January. doi:10.1177/2053951720982012

[58] Hudson, M., Anderson, T., Dewes, T. K., Temara, P., Whaanga, H., & Roa, T. (2017). "He Matapihi ki te Mana Raraunga"- Conceptualising Big Data through a Māori lens. *He Whare Hangarau Māori — Language, Culture & Technology*, 64-73.

[59] GIDA (2019). *Onati Indigenous Data Sovereignty (ID-SOV) Communique*. Retrieved from: https://www.gida-global.org/

[60] Tauli-Corpuz, V. (1993). We Are Part of Biodiversity, Respect Our Rights, Third World Resurgence, 36:25, quoted in Laurie A. (1994). *Whitt, Metaphor and Power in Indigenous and Western Knowledge Systems*. International Conference on Working Disparate Knowledge Traditions Together. Deakin University: Victoria, Australia.

[61] Waitangi Tribunal. (2011). Ko Aotearoa Tēnei. Legislation Direct, Wellington, New Zealan p.19. Retrieved from https://forms.justice.govt.nz/search/Documents/WT/wt_DOC_68356054/KoAotearoaTeneiTT1W.pdf.

[62] Jain, S., George, G., & Maltarich, M. (2009). Academics or entrepreneurs? Investigating role identity modification of university scientists involved in commercialization activity. *Research Policy*, 38(6), 922-935.

[63] Cunningham, J. A., & Menter, M. (2020). Micro-level academic entrepreneurship: A research agenda. *Journal of Management Development*, 39, 581-598.

[64] Norris, S. (2011). I*dentity in Interaction: Introducing Multimodal Interaction Analysis* (Vol. 4). Mouton de Gruyter, Berlin.

[65] Lam, A. (2010). From 'Ivory Tower Traditionalists' to 'Entrepreneurial Scientists'?: Academic Scientists in Fuzzy University—Industry Boundaries. *Social Studies of Science*. 40(2), 307-340. doi:10.1177/0306312709349963

[66] Leonard-Barton, D. (1995) Wellsprings of knowledge: building and sustaining the sources of innovation. Harvard Business School Press, Boston.

[67] Conley, S.N, Foley, R.W., Gorman, M.E., Denham, J., Coleman, K. (2017) Acquisition of T-shaped expertise: an exploratory study, *Social Epistemology*, 31(2), 165–183

[68] Collins, H., Evans, R., Gorman, M. (2007). Trading zones and interactional expertise. *Studies in History and Philosophy of Science Part A*, 38 (4), 657-666.

[69] Conley, S.N, Foley, R.W., Gorman, M.E., Denham, J., Coleman, K. (2017) Acquisition of T-shaped expertise: an exploratory study. *Social Epistemology*, 31(2), 165–183

[70] Madhavan, R., & Grover, R. (1998). From Embedded Knowledge to Embodied Knowledge: New Product Development as Knowledge Management. *Journal of Marketing*, 62(4), 1–12. https://doi.org/10.2307/1252283

[71] Balakrishnan, A. D., Kiesler, S., Cummings, J. N., & Zadeh, R. (2011). *Research team integration: What it is and why it matters*. In CSCW '11, Proceedings of the ACM 2011 conference on Computer supported cooperative work, Hangzhou, China (pp. 523-532). doi: 10.1145/1958824.1958905. NY: ACM Press.

[72] ibid.

[73] Fiore, S. M. (2008). Interdisciplinarity as teamwork: How the science of team science can inform team science. *Small Group Research*, 39, 251–277.

[74] Stokols, D., Hall, K. L., Taylor, B. K., & Moser, R. P. (2008). The science of team science: Overview of the field and introduction to the supplement [Supplement]. *American Journal of Preventive Medicine*, 35, 77–89.

[75] Sanford D. Eigenbrode, Michael O'rourke, J. D. Wulfhorst, David M. Althoff, Caren S. Goldberg, Kaylani Merrill, Wayde Morse, Max Nielsen-Pincus, Jennifer Stephens.

[76] Leigh Winowiecki, Nilsa A. Bosque-Pérez. (2007). Employing Philosophical Dialogue in Collaborative Science. *BioScience*, 57 (1), 55–64. Retrieved from: https://doi.org/10.1641/B570109.

[77] Howells, J. (2006), Intermediation and the role of intermediaries in innovation. *Research Policy*, 35(5), 715–728.

[78] Alberdi Pons, X., Gibaja Martíns, J. J., & Parrilli, M. D. (2014). Intermediaries and regional innovation systemic behavior: a typology for Spain (No. 2014/20). Lund University, CIRCLE-Center for Innovation, Research and Competences in the Learning Economy.

[79] Martiskainen, M., & Kivimaa, P. (2018). Creating innovative zero carbon homes in the United Kingdom—Intermediaries and champions in building projects. *Environmental innovation and societal transitions*, 26, 15-31.

[80] Smedlund, A. (2006). The roles of intermediaries in a regional knowledge system. Journal of Intellectual Capital, 7(2), 204-220.

[81] Edler, J., & Yeow, J. (2016). Connecting demand and supply: The role of intermediation in public procurement of innovation. *Research Policy*, 45(2), 414-426.

[82] Ter Wal, A. L., Criscuolo, P., & Salter, A. (2017). Making a marriage of materials: The role of gatekeepers and shepherds in the absorption of external knowledge and innovation performance. *Research Policy*, 46(5), 1039-1054.

[83] Frølund, L., & Ziethen, M. (2016). The wisdom of the intermediary: the role, function, and ways-of-being of the intermediary in a strategic program for university-industry relations. *Triple Helix*, 3(1), 1-21.

[84] Leifer, R., & Delbecq, A. (1978). Organizational/environmental interchange: A model of boundary spanning activity. *Academy of Management Review*, 3(1), 40-50.

[85] Paraponaris, C., & Sigal, M. (2015). From knowledge to knowing, from boundaries to boundary construction. *Journal of Knowledge Management*, 19(5), 881-899.

[86] Agogué, M., Yström, A., & Le Masson, P. (2013). Rethinking the role of intermediaries as an architect of collective exploration and creation of knowledge in open innovation. *International Journal of Innovation Management*, 17(02), 1350007.

[87] Amoamo, M. & Ruckstuhl K. (2021). Kāhui Māori: Distinctive Leadership in Science and Technology. In Amoamo, M., Kawharu, M., & Ruckstuhl, K. (Eds). *He pou hiringa : grounding science and technology in Te Ao Māori*. Wellington, New Zealand: Bridget Williams Books. ISBN: 9781988587486.

[88] Bessant, J., & Rush, H. (1995). Building bridges for innovation: the role of consultants in technology transfer. *Research Policy*, 24(1), 97-114.

[89] Kivimaa, P., Boon, W., Hyysalo, S., & Klerkx, L. (2019). Towards a typology of intermediaries in sustainability transitions: A systematic review and a research agenda. *Research Policy*, 48(4), 1062-1075.

[90] O'Kane, C. (2018). Technology transfer executives' backwards integration: an examination of interactions between university technology transfer executives and principal investigators. *Technovation*, 76, 64-77.

[91] Hermann, R. R., Smink, C. K., & Kerndrup, S. R. (2016). Partnerships for environmental technology development in the shipping industry: two Danish case studies. International *Journal of Innovation and Sustainable Development*, 10(3), 260-280.

[92] Klerkx, L., Hall, A., & Leeuwis, C. (2009). Strengthening agricultural innovation capacity: are innovation brokers the answer? *International Journal of Agricultural Resources, Governance and Ecology, 8*(5-6), 409-438.

[93] Hermann, R.R., Smink, C.K. and Kerndrup, S. (2016) 'Partnerships for environmental technology development in the shipping industry: two Danish case studies'. *Int. J. Innovation and Sustainable Development, 10* (3), 260–280.

[94] Roxas, S. A., Piroli, G., & Sorrentino, M. (2011). Efficiency and evaluation analysis of a network of technology transfer brokers. *Technology Analysis & Strategic Management*, 23(1), 7-24.

PART THREE

Observations, findings and insights

In this section we answer our guiding questions through observations, surveys and case studies to build insights based on our overview of the New Zealand science system in PART ONE and the theoretical trends in PART TWO.

Beyond Traditional Science: Importance of values, collaboration design processes, innovation intermediaries and locations

KEY QUESTION

- *When science problems are so fundamental that even the scientists are unsure as to how they are best addressed without several iterations, what strategies engage non-scientists or those from outside a particular discipline to co-innovate in upstream 'blue-skies' or fundamental science questions?*

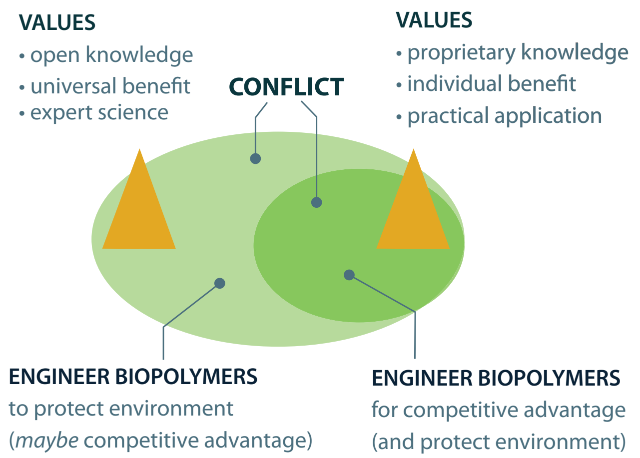
Beliefs and values underpin decisions to engage or not

We have observed over many iterations of high-tech project ideation and development with stakeholders, partners and Māori collaborators that non-traditional science modes require different relationship and engagement processes to overcome the barriers that we discussed in **Part Two**. In particular, partners are unlikely to share scientists' values and beliefs given that their day-to-day realities, pressures and organisational arrangements are different.

Given this reality, our advice is that all parties to new collaborations will need to factor this in and **plan for this in a structured manner at the start of a project.**

For example, in one Spearhead, business and scientists came together to develop printable materials from biological sources to reduce use of plastic polymers in the 3-D manufacturing process. On the face of it, both parties might be thought to have 'normative' or societally-agreed 'environmental' values that this research would be 'good for New Zealand'. Hence, engagement and ongoing interest might be expected. However, this was far from the case in the early phases of engagement. As Figure 2 shows, 'good for New Zealand' environmental ideals when looked at more closely were expressed in quite different and potentially opposing ways.

Figure 2: Barriers to collaboration (Adapted from Ahuriri-Driscoll, et al. [p.57][1]).



This went beyond matters of interpretation or 'language' barriers as to what was meant by 'good' for New Zealand. In reality, what is good for New Zealand is a belief system that is deeply practiced within communities. To get to a point where both parties might agree on 'good for New Zealand' required several iterations as well as the application of some particular tools and techniques that we outline further in this section.

Bringing teams and stakeholders together requires a structured design process

Research relationships across science disciplines (cross-disciplinary research) and beyond the science realm (transdisciplinary research) will automatically face some barriers. To mitigate these known barriers will require rethinking collaboration design.

One approach has been to redesign how teams are brought together to develop collaborative science innovation projects to deliver nontraditional science outcomes. This is seen in the way that SfTI has evolved its approach from 2015 when the first four spearheads were chosen, primarily by the research community but informed by an industry survey and analysis of New Zealand high-tech companies.

The current 'Mission design' approach initiated in 2017 (Figure 3) was based on the observation that scientists' strong prior ties within their pre-existing networks would not necessarily lead to teams crossing disciplines or organisational boundaries, from which new technology innovations would arise.

This is further constrained by scientists' current human and relational capacity. From a Māori perspective, such prior ties were also limited and mostly transactional, based on, as one of our informants described, getting 'money and then we never hear from them again'.

Our current science system has been trying to move beyond Mode 1 science through use of contestable funding that asks applicants to develop proposals taking

Figure 3: Mission design approach[2].

into account industry or Māori. However, as the CRI report and the more recent MBIE 'Green paper' indicate, such contestable funding has become 'unproductive'[3] and from a Māori perspective, indicative of a temporal relationship based on researchers' need to gain funds for their research. Hence, SfTI has been exploring new approaches through 'Mission-design'.

As Figure 3 shows, challenges with economic impact to which New Zealand science and engineering might provide solutions were identified by groups of stakeholders brought together in 'mission labs' (Stage 01). From this, potential novel solutions and the science needed to specifically develop these solutions begin to be identified, and then researchers, Māori and industry were brought together to develop fundable projects and teams (Stages 02-04).

Since 2017, eight Spearhead missions have been developed or supported to be developed. Our observation is that SfTI's revised approach since 2017 has succeeded in achieving a range of objectives:

- National 'best team' *interdisciplinary* or *transdisciplinary* teams formed, outside of established pre-existing science team networks.
- Māori concepts/mātauranga infused into the research design (as judged by Māori).
- Māori, early career researchers involved.
- Embeds a process that regularly engages key informants/partners/stakeholders/users [industry/Māori] to exchange knowledge (absorptive/desorptive capacity).
- Embeds a process whereby potential use (whether as commercial or social product or process) is factored into the research plan.

However, as Table 7 shows, not all SfTI's efforts have resulted in funded projects, some due to funding constraints and others due to the mission not translating into a fundable technology project. Additionally, SfTI had to learn how to develop and manage the science innovation process more efficiently, in order to reduce the total time it takes to develop a project and identify a suitable team from 1-4 years to closer to one year for most projects.

This efficiency gain is important in a science and innovation system with constrained resources and timeframes. One of those limited resources is people's time. Developing collaborations with unfamiliar groups to address mission concepts that require elaboration and redefinition is time-consuming. Many large-scale

Table 7: Mission-designed projects

Mission Lab Year	Mission Lab Concept	Spearhead Project	Project process start	Project contract start
2017	Intelligent Oceans	Precision farming technologies for aquaculture	2017	2018
	Robotics for small scale production and harsh environments	Adaptive Learning Robots	2017	2018
	The Digital Marae/Whare	Ātea	2017	2019
	Personalised Value Chain	Veracity	2017	2021
2018	Environment/Sustainability Technology	Clean Water Tech for restoring te Mana o te Wai	2019	2021
	Biosecurity	Biosecurity Technology	2020	2021
	Mātauranga Māori and data	Māori Data Sovereignty	2019	
	Rangatahi	Rangatahi 'Bolt-on'	2019	2022
	Space and Spatial Technology	(funding constraints curtailed development)		

trans-disciplinary research collaborations such as MBIE Endeavour grants, "platforms", and NSCs can take several years and substantial unfunded researcher time commitments to get to the funded stage, if at all.

This upfront use of human effort (time) is viewed as a cost by the researcher but seldom to the system as a whole. Many researchers have articulated this lost time as burdensome and a disincentive to the new forms of collaboration required to drive innovation with industry and Māori. At the macro policy level, there has been no incentive to change the mode of operation to achieve this stated aim of collaboration as essentially there is no 'cost' to the system. Time is not factored into or tracked in funding proposals – it is incurred at the micro-level of the individual or team. Hence, inefficiency (time) and redundancy (the ideas not funded) are occurring in the system. This aligns to our observations in Section 3 Opening Science for Open Innovation, whereby developing particular competencies to enable innovation comes with costs.

> *"If inefficiency and redundancy are in effect a product of the current New Zealand system, then it is not surprising that at the micro-level of the team and individual it is far more efficient to not collaborate, or restrict collaboration to pre-existing relationships, despite the urging of policymakers and research institutions."*

Hence, currently it will only be certain types of individuals who view it as worthwhile to persist with such engagement activities. We discuss such individuals in Section 3 Developing Entrepreneurial Behaviours.

One of the key learnings from SfTI is that these technically complex, trans-disciplinary, geographically dispersed projects need to be designed to address the already known and identifiable barriers from the beginning in order for the benefits of collaboration to be realised.

We also identified that **some project development processes are likely to be more effective and efficient than others**. Our findings in this respect are more tentative. However, we are satisfied that having a structured and theoretically defendable approach to forming open innovation science teams is crucial. One model we have examined in detail is the Concept-Knowledge (C-K) approach which is new to the New Zealand science innovation system. This methodology has been applied extensively internationally in a variety of contexts, including companies with large R&D units, research centres, industrial clusters and inter-disciplinary science teams. BNZIC researchers trialed a pilot of the C-K process in 2019 to test its applicability to the New Zealand context before running a full 'experiment' to develop the Veracity Spearhead, with a project successfully developed for a mission concept that had proved problematic.

Given the results, BNZIC researchers believe that the C-K process is one potential approach to efficiently deliver an effective science -based open innovation research programme. Moreover, we believe that such approaches have application more broadly across New Zealand's science innovation system.

CASE STUDY ONE

Concept-Knowledge

What is the C-K method?

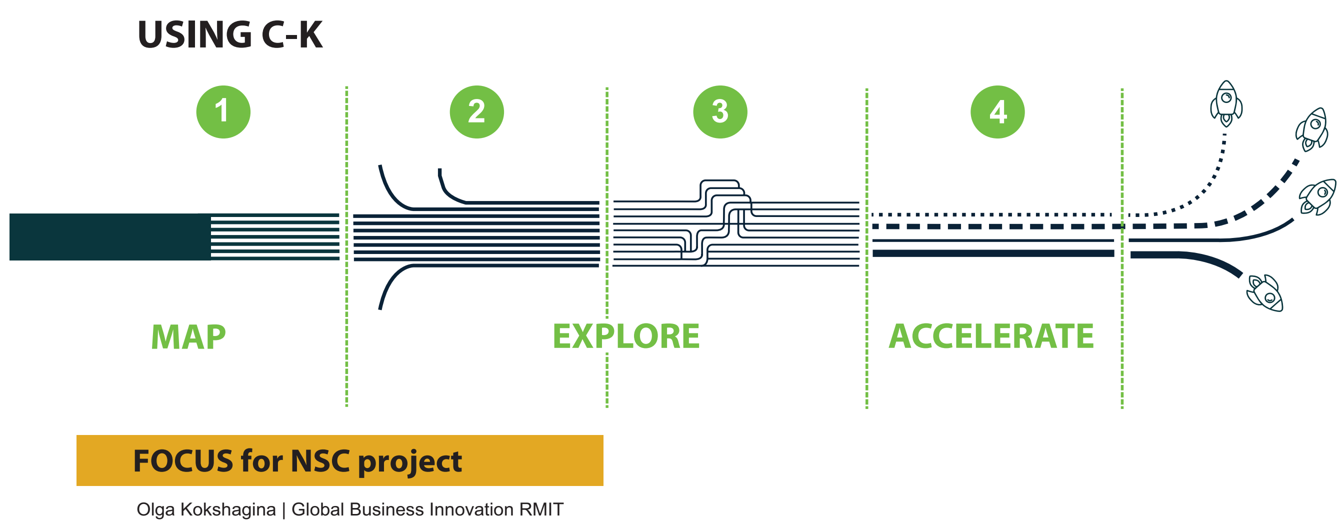
C-K is a theory of reasoning for situations that require innovative approaches and provides a structured framework to facilitate the design of yet unknown 'objects' based on existing sets of knowledge. It is particularly effective when there is a need to generate alternatives to current thinking or approaches,[4] helping to expand existing knowledge and counter 'fixation', whereby rigid allegiance to prior sets of knowledge can impede insight and hence alternative ways to address a problem, issue or approach.

C-K provides options for new/radical knowledge (science) that are built-in *upfront* to the collaboration process. This is due to how C-K's framework of knowledge exploration structures expansion of knowledge from other disciplinary domains through an interplay between creative concept (that which may be possible but yet unproven); and knowledge (that which is already possible).

C-K offers a formal framework where creative thinking, learning, knowledge structuration, knowledge sharing, and innovation principles are not external to the approach but are the central core of the theory itself.[5] In other words, C-K controls for *randomness* and *chance* of innovation by making creative insight integral to the science-knowledge collaboration process. The many *options* that are created through C-K are made transparent and continue to remain in play, should alternate science approaches be required to those that are selected for development.

C-K uses a structured three-step methodology (see Figure 4) that flexes to accommodate different types of participants e.g. technical experts, users, researchers, 'lay' stakeholders, designers. At the end of the process, researchers will have a clear idea of not only whether their science is *novel* (i.e. radical), but also whether it is *commercialisable*. In other words, it is more efficient on individual time and effort, with participants clear on whether to pursue a project or not.

Figure 4: C-K Three-step Methodology



CASE STUDY
ONE

Why C-K was used for the Veracity project

As identified earlier, the Veracity project took four years to develop from concept to final accepted proposal. BNZIC researchers noted that despite best efforts and a considerable amount of time, Veracity's forerunners of 'Personalised Value Chain' and 'Exchange in the Digital Age' failed to land on a fundable project.

With this in mind, a full C-K cycle was run entirely online over three months via a facilitator in Australia. A key expectation was that, not only would there be a 'stretchy' funded proposal from the cycle of workshops (9x60 to 90-minute sessions, i.e., 12 hours in total), but also that many of the barriers we had observed in other teams as they began and developed their research and relationships, would be overcome or mitigated (see Table 8). While the whole process was run 'virtually' (given New Zealand's Covid-19 situation), feedback from the participants was largely positive about the C-K process itself.

Table 8: Barriers to the spearhead formation

Barrier	Breakdown of the barriers
Collaboration	Disciplinary/expertise silos; lack of a common language; knowledge misalignment; self-reinforcing prior knowledge.
Team formation	Role integration; aligning objectives; alignment of technical/expert knowledge.
Time	Time taken to align expectations; time taken to build relationships and trust.
Knowledge	Access to breadth and depth of technical knowledge; agreeing on 'stretch' of and approach to the research problem; the complexity of the research problem.

"Beyond the ability to conceptualise ideas differently, the C-K process allowed me to explore the ideas of others and expand how I think about solutions. I think that C-K could be more than one dimension, in that it encourages you to think about a reality or alternative hypotheses. So, in that sense, I think that it's quite good, because it forces you to re-examine the assumptions that you're making, and what would happen if this assumption was not true."

Our preliminary analysis suggests that facilitation can support researchers to avoid barriers, such as discussion of workload and individual recognition common in research organisation settings, to focus on the central idea and project challenge, and to address that challenge using their skills and knowledge. Researchers spent more time thinking collaboratively about innovation ideas, and less about workload and recognition.

However, as with critiques of crowdsourcing, some participants whose expertise did not get included in the eventual project were unhappy that the time and ideas that they had invested was not rewarded.

CASE STUDY TWO
The Principal Investigator as intermediary

Intermediaries at all levels are crucial to a well-functioning science-based open innovation system

As noted in Part Two, intermediaries play an important but often under-appreciated role in a system seeking science-based open innovation. In this section, we focus on two different types of intermediaries – explicit and implicit intermediaries.

We define an explicit intermediary as one whose a role comes with a recognised specific innovation brokering function between individuals or organisations. Implicit intermediaries are individuals or groups who are essential to the achievement of a particular science objective but who have an additional and implied function over and above the role for which they are recognised.

Here we present four case studies.

Three cover explicit intermediary functions – Principal Investigators, University technology transfer offices and designers – and one is on the implicit role of the Pākehā principal investigator working on Māori-focused research.

Publicly funded scientists are increasingly expected to produce impactful research from which stakeholders external to the research (e.g., industry) can capture value,[6] that is, engage with and benefit from the research.[7] Publicly funded science often suffers from value 'slippage',[8] whereby the potential value capture within the public funding research ecosystem remains unfulfilled. One of our BNZIC researchers investigated 41 publicly funded principal investigators (PIs) in New Zealand to provide insight on this, with the intermediary roles of PIs highlighted as crucial.[9]

Two distinct mechanisms – boundary spanning and brokering – are instrumental for PIs to improve the impact and reach of funded research (see Figure 5 over page).

In **boundary spanning**, PIs cross academic/organisational boundaries and enlist the attention of a diverse range of otherwise disinterested ecosystem actors, such as policy makers, societal end-user communities and commercial agents.

These PIs seek to ensure their research is: closely aligned with and supports the needs of government policy priorities; producing outcomes that are translated to benefit public communities; or undertaking research that generates industry interest and opportunities for commercial application. Through purposeful engagement with separate ecosystem actors, PIs extend value capture in publicly funded research by expanding the boundaries of interest in, and use of, their research. Their efforts can generate new project ideas, expanding research funding or leading to greater application.

PIs also use their intermediary position within the public funding research ecosystem to connect otherwise disconnected constituents. **Brokering** is distinct from boundary spanning as the capturing of value in use takes place across multiple actors as opposed to boundary spanning between two positions, i.e. science to business or science to government. Through brokering, value that arises from the exchange between the research community and funding bodies through PI-led funded projects is then captured in use in an integrated manner among multiple stakeholders.

CASE STUDY
TWO

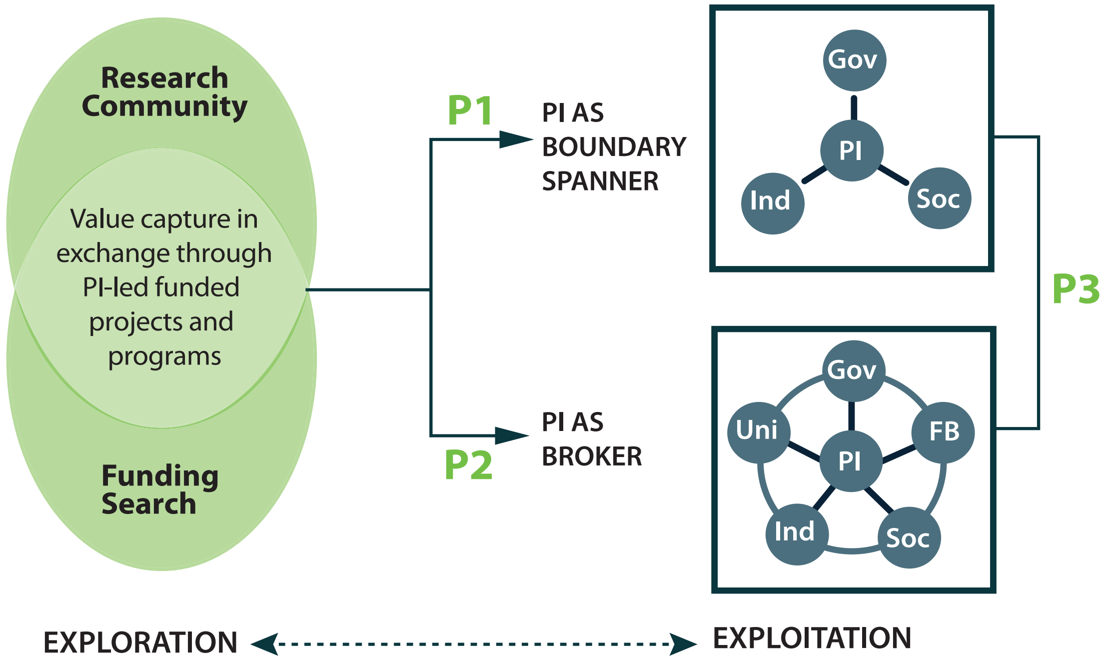


Figure 5: Scientist Impact and value capture through funded research

Through brokering, PIs skillfully identify, leverage and balance multiple ecosystem interests among policy makers, funding bodies, industry, community end-users, and universities simultaneously. As an example, a PI was able to integrate government/industry/society interest for a project that would decrease health expenditure, benefit economic productivity (e.g. job creation or limit absenteeism) and improve educational and health outcomes.

The research shows that brokering has some benefits that are less accessible through purely boundary crossing.

Specifically, the balancing approach inherent in brokering multi-stakeholder interests helps ensure that the self-interested needs of any individual ecosystem actor (be it scholarly, societal users, commercial, governmental, funding body) do not dominate at the expense of others. As the intermediary between actors, PIs not only stimulate and balance engagement among different ecosystem actors, they also increase the chances of engagement among them which can result in further value creation and capture. Such a role, however, will require the development of relevant skills and capabilities (see <u>**Section 3 Developing Entrepreneurial Behaviours**</u>).

CASE STUDY THREE

Technology Transfer Offices – innovation ecosystem brokers and intermediaries

The core role of university Technology Transfer Offices (TTOs) is to fulfil the protection and exploitation of intellectual property (IP),[10] with performance typically measured through patents, licences and start-ups/spin-off firms.[11] Research attention on TTOs has primarily focused on the extent to which they meet these performance expectations.[12] For academic scientists, TTOs are important boundary spanners between academia and industry.[13,14]

They help some academics understand the needs of industry and access critical resources, expertise and support in the commercialisation process.[15,16] On the other hand, with an increasingly constrained public funding environment, university management increasingly looks to TTOs to generate additional earnings.

Such income can both protect existing research activities and help pursue future research breakthroughs. Moreover, proficiency in research commercialisation and technology transfer activities can enhance the reputation and prestige of the university, thus helping to recruit and retain leading researchers and increase student intake.[17,18]

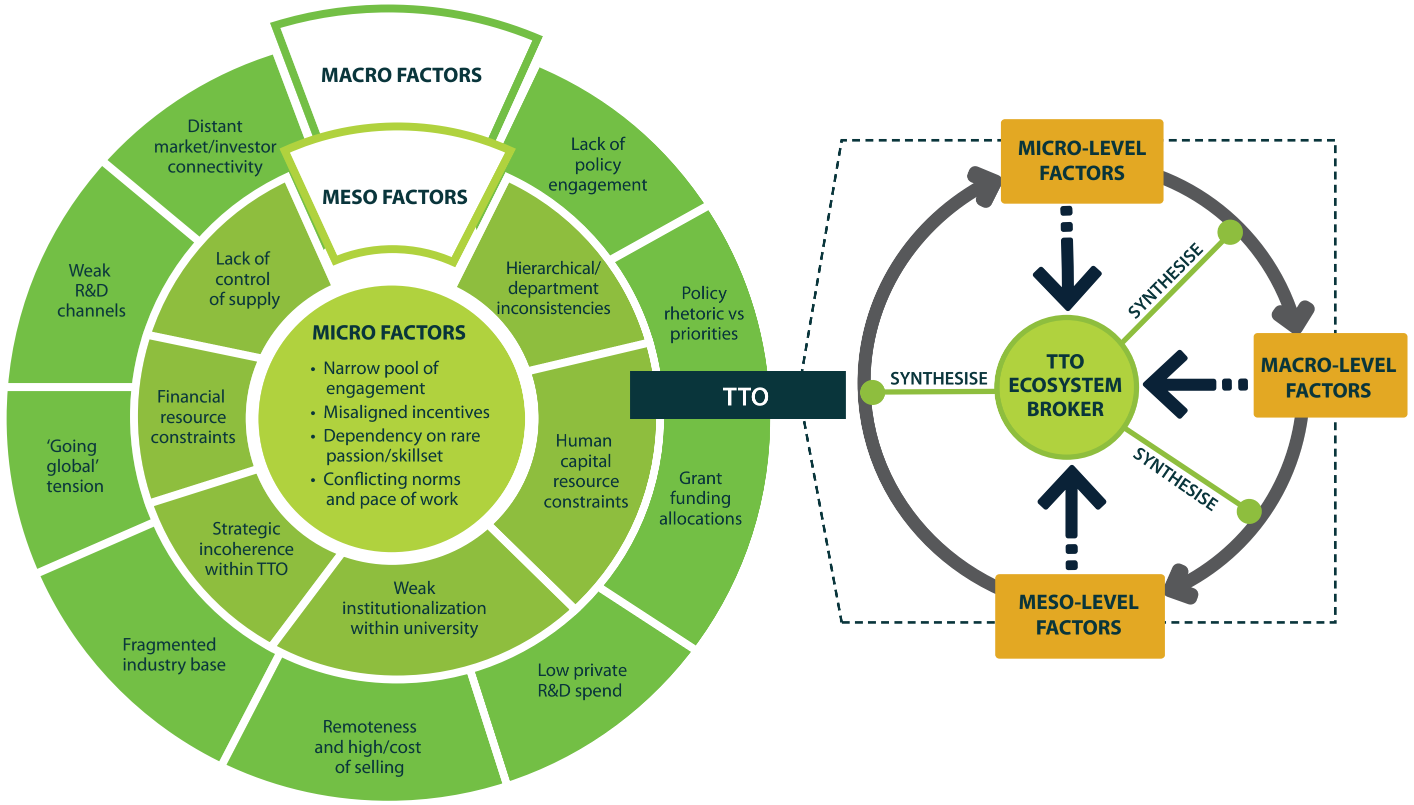
More recently, there has been increasing research attention on how TTOs build strong relationships with a more diverse set of entrepreneurial and innovation ecosystem stakeholders outside of the university. This requires **system wide brokerage capacity among TTOs**, and as such TTOs need to position their mission, structures, strategy and services accordingly.[19]

Our BNZIC study on this emerging role of TTOs examined various factors that influence the role of TTOs.[20] The research uncovered 19 factors – nine macro level, six meso level and four micro level (see Figure 6). It shows how TTOs proactively synthesize these cross-level factors, thereby expanding their widely-recognised role from **University-Industry intermediary to entrepreneurial and innovation ecosystem broker**.

More precisely, the research shows that TTOs should be understood as **critical ecosystem intermediaries** whose services help to lower barriers to value creation and to accelerate productive entrepreneurship activities in the territories in which they operate.[21] The research also highlights how TTOs need to **master a more proactive strategic approach** to effectively balance strategic actions targeted at the macro and meso levels against technology transfer operational efficiency and effectiveness at the micro-level.

Notably, BNZIC researchers identified that resource constraints within TTOs are likely to affect the extent to which they can fulfil this expanded role effectively. Because the SfTI team has acknowledged this issue at a national level or ecosystem level, dedicated commercialisation resources were allocated within the Challenge to support this important intermediation function in order to leverage the potential of brokering earlier in science projects.

Figure 6: New Zealand TTO's ecosystem brokering role[22]



Micro-level factors	Meso-level factors	Macro-level factors
• Broker connections and maximise fit between academic expertise and industry knowledge and insights.	• Ensure New Zealand Inc as a nation accrue maximum value capture benefits from international deals.	• Lobby government to extend the value chain of the research process they fund at the micro level.
• Rationalise the nature and value of agreements to academic community.	• Rationalise the nature and value of agreements to policy makers.	• Interpreting and communicate academics' science potential for macro level economic and social good.
• Systematically leverage prior connections and/orareas of expertise within the university.	• Develop cross-TTO collaborations to minimise loss of value creation opportunitites at micro, meso and macro level.	• Survey changes in public and private funding environment and position scientists' attention accordingly.
	• Systematically leverage prior connections and/or areas of expertise outside the university.	• Particulate to management the synergistic reputational benefits across levels - research funding, policy engagement, attractive work environment - that can arise from technology transfer.
	• Survey changes in public and private funding environment and position TTO attention accordingly.	

FOUR

CASE STUDY FOUR

Open innovation science and the role of designers as intermediaries

Designers are boundary spanners,[23] linking the lab, society, and the market[24] by embedding a creative and market orientation into the innovation process.[25,26] Increasingly, design is seen as a valuable contribution to open innovation, as designers move from their more recognisable concerns of aesthetic and functional design (see Table 9) to upstream involvement in product development.[27] Thus, at least in the business world, there is recognition of the value of design thinking and designers,[28] with some evidence that design-centric organisations show above-average economic performance.[29]

The design process itself acts as an interface between science and user.[30,31] By creating a physical or visual object from 'raw' science, designers help scientists imagine applications for their research while potential users imagine new uses for the science. This creation of objects (whether as sketches, plans, maps, demonstrators or prototypes) can align various stakeholder motivations in the innovation process, creating shared understanding, value and trust.[32,33] Such visible or tangible 'artefacts' act as 'boundary objects' that share, co-ordinate or translate abstract science knowledge amongst and across different expert and non-expert groups.[34,35,36,37,38] SfTI projects were at times in a non-engagement 'limbo' waiting for physical boundary objects to be developed, delaying interactions within and outside of the research team. Hence designers can accelerate necessary relationships at an earlier phase of development.

Design-led or design-informed open innovation science is not a common practice in New Zealand. Scientists frequently see designers as 'stylists' (providing first order skills – see Table 9), arguing that they themselves 'design' their research experiments, circuits, surveys, and clinical trials.[40] When a science project is in a very early phase, designers require new science-focused capabilities (third order skills). Designers may also need capabilities for coordinating partnerships within a team or with external stakeholders or that enable them to be involved in the upstream scoping of a product.[41,42,43] These 'fourth order' design skills consider how humans integrate with systems and ecosystems.[44]

To move towards third and fourth order skills requires new forms of organising innovation practice. Internationally, examples such as Massachusetts Institute of Technology's Media Lab draw on co-located groups and Harvard's University Biodesign Lab, where multidisciplinary teams of designers, engineers, and medical researchers work on wearable robotic devices.

Table 9: Orders of Design (From Rothkötter, Garner & Vajna[39]).

Order	First	Second	Third	Fourth
Process	Visual communication through signs and symbols.	The design of physical objects.	Design-thinking applied at an early science phase.	Design of systems and environments and how human beings integrate into these.
Designers' interface with science	Communicate scientific research through posters, figures, data plots, symbols, drawings, renderings.	Create new physical materials and methods for manufacturing.	Design activities investigate process of scientific research. Exploration of uncertainty to support scientific exploration.	Multidisciplinary design lab connects design and science. Designer physically located within the laboratory.
Example	Renderings of potential applications for a biophotovoltaic device.	Algal bio-ink.	Service design.	Biodesign Lab (Harvard) Media Lab (MIT).

CASE STUDY FOUR

In Germany, the Fraunhofer Institute has been running a study on the impact of designers in academic high-tech startup teams.[45] In the UK, the Design Council developed a training programme to coach scientific teams to apply divergent thinking approaches and to develop prototypes employing new technologies from their research.

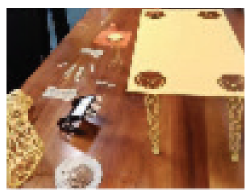
Our observations of the role of the embedded designer as a deliberate mechanism to bridge the science and industry worlds identified real value in making this a far more regular occurrence in upstream science.

These observations are based on our longitudinal observations of the additive manufacturing team's design-informed science approach[46] and our experiment of incorporating a designer in the ideation of a new Spearhead (Veracity). In the additive manufacturing spearhead, we saw designers' capabilities used across all four design orders (see Table 10).

The iterative interaction amongst industry, designers and scientists led to increased enthusiasm and alignment for the Spearhead's research, with a clearer articulation of how industry might eventually use the technology being developed. That is, the 'stretch goal' of the Spearhead (a typical Mode 1 science objective) transformed into a shared 'benefit to New Zealand' objective with value capture by multiple stakeholders. This shared value was recognised by both scientists and industry. In comparison to early interactions, the scientists became more stimulated by industry's suggestions for the direction of the science as it "forced the sciencey engineering people to go, okay, can we (develop that)?" For another, industry interactions helped "to wake up and come out of the normal lab in science and get exposed to the outside world", with a comment from a workshop observer that "maybe (the scientists) feel a little bit more open to taking on suggestions." For industry, comments such as science and industry having a "very common passion" and appreciating the chance to "work together … there are so few opportunities to actually do that" demonstrated increased alignment.

While these are positive indications of engagement, the next phase of research will indicate the extent to which industry changes its approach to R&D and whether these relationships continue or lead to new forms of business arrangements.

Table 10: Design orders in AM Spearhead

Order	First	Second	Third	Fourth
Process	Visual communication through signs and symbols.	The design of physical objects.	Design-thinking applied at an early science phase.	Design of systems and environments and how human beings integrate into these.
Example from AM Spearhead	CAD drawing of a swim fin that might be used as a target printed object. 	Demonstrators of potential uses of biomaterials using new printing techniques. 	"The (science is) getting pushed from design applications for materials specifically for them, and then the other way around where we're responding to properties and materials" (Designer).	"Maybe just as a stimulus for the bigger picture . . . as a framework for the conversation… If there is some kind of design they're thinking in terms of a big picture that provides immediately a framework for people to start hanging some of these solutions or these ideas onto" (Scientist).

CASE STUDY FIVE
Pākehā intermediaries in Māori-focused research

Māori researchers and community partners make up only a small percentage (13%) of those who have been involved in SfTI projects. Hence, much of the research activity has relied on Pākehā specialists. Here, we comment on the role of the Pākehā principal investigator (PI) who has to navigate the uncertainty of working in an unknown Māori domain. Our observation is that for those who have never worked with Māori – likely the majority – this can at first be 'scary', and 'daunting'.

Through an iterative process and an openness to stepping into a Māori world, scientists can become more reflexive. That is, these researchers become more aware of their responsibilities to not only the science but also to their Māori partners in terms of desired research results.

This in turn could leads such intermediaries to review the expectations of an academic identity, such as their university research's 'publish or perish mentality' as the following demonstrates:

> I could see the importance of building that relationship and putting that time in, even though it will not turn up in an academic paper anywhere.

Pākehā intermediaries, in bridging or brokering with Māori, continuously negotiate the space between the Māori and non-Māori worlds within a context of the science and technology. These 'negotiations' take place primarily through face-to-face interactions, where little by little the scientist readjusts their positioning, redefining their role from 'technical scientist' to 'champion' for a Māori-focused project.

> […] looking into it with a proposal that was submitted, the best one I thought was the one […] [g]etting iwi involved, it was, you know it had a plan, had a strategy, and it was about involving iwi.

Examples of this shift included increased use of te reo and comfort with/understanding of tikanga, a noticeable transformation compared to when they first started in the project. Use of te reo Māori may signal increased confidence on the part of an individual; a desire to show affiliation with the Māori partner; or the start of a more accepting approach to incorporation of 'things Māori' into their wider science practice.

> So, one of the highlights of that Taranaki hui was going out and collecting flax and weaving baskets... That very easy flow of gentle conversation is something that I guess that's special... so I've got students working on parts of the project this year, that that message is really clear to them, that kaupapa is really understood and shared...

Speculatively, this may transfer to an individual's teaching and mentoring roles, which may in turn, encourage others to work on projects that are Māori focused.

While we specifically illustrate here implicit intermediaries in Māori focused research, we have also noted others who perform equivalent functions implicitly in other projects, such as early career researchers, including students. The mechanism by which they undertake such roles would be a useful focus of future research.

Co-innovation through location

Much of our research has been examining how high-tech stretch science begins to move from the lab to industry or Māori. As we noted in Part Two, internationally there are a number of models and approaches emphasising co-location of scientists and partners or stakeholders. In New Zealand, there have been various approaches to this (e.g., with various 'innovation' precincts or science parks set up over the years). Consistent with this approach, SfTI spearhead researchers are deliberately shifting work locations and visiting relevant environments as a way to accelerate innovation. Visiting stakeholder places has allowed SfTI researchers to better canvas needs and values, generate applicable scientific insights more rapidly, enhance trust, and shift mindsets to understand and welcome different worldviews. A key observation is that the shift in physical location enabled researchers to explore knowledge from a different lens as the following quotations show:

> Having a different experience to the day to day (for example, getting a scientist to go and visit an industry or an iwi) could help understand the needs there – supporting those.
>
> Even with the vine pruning, we had professors out there in the field in a vineyard, holding secateurs, pruning vines, because you have to have some domain knowledge. You can't have zero domain knowledge, and you can't get the domain knowledge without actually being there and visiting them, and seeing what they're doing, and talking to them. You still have to involve them all the way through, so you don't do something stupid, or go down a blind alley, not even knowing it's a blind alley, or give them some brilliant solution they don't even need. […] You have to get in your mind, what is this? Get a feel for what they're doing. So, you can't do these projects without visiting what you're playing with.

Observation of spearhead researchers' interactions with industry and Māori showed the importance of site visits in facilitating the trust-building process.[47] As one researcher explained:

> Yeah, so they are trying to build a simulated forest … because they [industry] have asked [us] to visit and see the land. […] they put a lot of effort into that kind of data collection, and you need a lot of time to build that kind of small forest. It's a lot of trees. So, it's a quite generous thing that they [the industry] provide it too, […]. I think that is trust.

While industry stakeholders signal trust in the spearhead researchers by offering up resources, time and access, researchers were still expected to visit the industry's physical site to gain relevant and applicable knowledge.

"Physical settings also have the impact of influencing social interactions, collaboration, and idea generation[48] with the researchers' visit to the industry site empowering industry to co-create the direction of the research project. Not visiting may involve less time and resources, but mean that less trust, sharing and considerations of next options are the likely end results."

For Māori, co-creation processes such as wānanga can only happen onsite so that the 'context' of the research is understood, as a BNZIC researcher noted during the development of the Cleanwater tech Spearhead:

> The field trip provided further context of (the) relationship with (the) awa, highlighted mahinga kai areas where food (was) gathered, outlined impacts of extraction of shingle on fisheries and river, erosion issues highlighted, wāhi tapu identified, sites of significance, health and wellbeing, planting opportunities, retirement of land for planting, history of areas provided and aspirations for (the) area and catchment.

Such context can also lead to **additional science opportunities and a chance to extend technical knowledge** in a way that may have been unforeseen without the site visit as illustrated in the Inverting Electromagnetics – Groundwater flow Spearhead:

> Hence the marae visits, and quite selfishly in terms of a first physical test site. We had seen the […] spit – that's the land between [location] and the ocean – as an almost ideal test site for two reasons really. One is that it's relatively permeable, so the velocities are reasonably high. And secondly, the flow through the spit actually does reverse at times, so there is an ingoing flow, and as a test site that's a very valuable addition […] in terms of validation.

Overall, our research regularly identified that shared understanding, value and new possibilities were created between science team members and external stakeholders through visits to the 'home' locations of those collaborating in the science project.

KEY QUESTIONS

- *Are New Zealand firms with high AC more likely to utilize OI? And what would they use it for?*
- *And what if those firms are Māori – does this equally apply?*

Absorptive and desorptive capacities enhance performance

Two forms of open innovation are available to businesses: inbound and outbound. Inbound OI is when a company acquires and applies external knowledge to its own R&D, such as buying or licensing patents or processes developed by another organisation. Outbound OI is when innovation developed in-house is transferred (i.e., used) externally through activities such as licensing, joint ventures, or establishing spin-outs. Benefiting from open innovation relies on firms having absorptive and desorptive capacities, which support inbound and outbound flows. Absorptive capacity is the ability to identify, assimilate and effectively use externally developed knowledge and technologies in your own business. In contrast, desorptive capacity is the ability to identify opportunities for external partners to use internally developed technology and also involves the skills to help that potential external partner use, incorporate or apply that technology.

This is particularly relevant given the extent to which knowledge/IP developed by New Zealand researchers fails to get used and commercialised[49]. While aspects of these capacities relate to technical knowledge and skills, others are associated with understanding of upstream and downstream innovation management processes as well as human (influencing, collaborating, communicating) and relational capacities (building and maintaining networks). Forming teams where the necessary capacities exist or can develop is, thus, crucial to increasing the application and economic impact of New Zealand investments in R&D.

BNZIC data from a survey of 541 New Zealand, including Māori firms in 2020 established that businesses that both acquired from and transferred technologies to external providers had better financial performance than those that engaged in only one of these OI activities.

The data also showed that investing in either one of the capacities enhanced the return from the other in terms of R&D efficiency.[50] Engaging in both forms of open innovation also accelerated innovation outcomes (as measured by the increase in new product and new process innovations). The key takeaway for New Zealand companies involved in R&D and innovation is that developing dual capacities and implementing dual strategies (the acquisition of external technologies to enhance internal innovation initiatives with a complementary focus on leveraging or licensing out other inhouse R&D externally) is more effective than operating with one of these approaches alone.

An analogous open innovation dynamic was evident in numerous Seed projects within SfTI. Having international collaborators was associated with completing milestones successfully and on time, establishing new international collaborations, and securing additional funding. International collaborators were able to provide key inputs such as data, equipment, or access to a testing environment often not available in New Zealand. Over half (54%) of such successful Seed projects also had industry-based team members, industry advisory groups, or were projects born directly out of industry engagement.

These combinations of factors created a simultaneous drive for science excellence and innovation (technology push) as well as team members playing the role of lead user (market pull) – matching the scientist-user roles advocated by Baglieri and Lorenzoni.[51] It also highlights that establishing industry connections at an early stage has substantial relevance to stretch science, as has been established for projects that have progressed to higher Applied Science Readiness Levels.

Data from other surveys on New Zealand businesses show that human capital and relational capital are also key drivers of firm innovation and new product development. New Zealand businesses that have a superior skilled workforce and whose workforce score higher on trust and collaboration are more likely to generate better innovation outcomes. This includes product and process innovation, as well as innovation speed. Thus, it is clear that investing in innovation capacities offers the potential for substantial returns across all stages of R&D and commercialisation. Only a subset of New Zealand firms, though, seem to be undertaking such investments.

Māori cultural capital supports superior innovation outcomes

Our data on Māori businesses indicates these organisations share similar benefits with respect to innovation outcomes when they have superior human capital and relational capital. A unique aspect, however, is that Māori businesses can leverage these factors to achieve superior innovation outcomes most effectively if their firm has high levels of cultural capital. Cultural capital, here, reflects a workforce's knowledge and skills towards working with and respecting Māori cultural values. Indeed, the highest levels of innovation within Māori businesses occur when they are high in cultural capital and high in human and relational capital. However, such benefits are not realised by other New Zealand businesses (non-Māori) suggesting this effect is specific to Māori businesses only.[52]

A separate survey of 146 Māori businesses found a range of capacities (including absorptive capacity, human and relational capital) were positively associated with product innovation, top talent retention, organisational performance and breakthrough sales.[53]

While firm assets were consistently important for Māori firm performance, the other factors (capacities) all have significant direct effects to other mediators, ultimately showing that better performance is achieved through a combination (p.1).[54]

Again, leveraging the benefits of innovation into performance and new sales for Māori businesses occurred more fully when multiple capacities were present and supported product development activities.

Researchers at universities, CRIs and institutes represent a primary potential source of science and engineering expertise in New Zealand. Building human, relational and cultural capacities within both the science and business sectors seems essential for realising significant economic benefits, as is encouraging more firms to engage with science and engineering research in New Zealand.[55]

KEY QUESTIONS

- *To what extent do New Zealand firms use closed innovation, and is it holding them back from superior performance?*
- *In relation to solving advanced technological problems, do we find evidence of the other types of OI models being successfully implemented? If so, what accounts for their success?*

Most New Zealand firms use closed or no innovation

Our research is consistent with other studies of businesses in New Zealand in indicating low rates of investment in R&D by many firms. With a specific focus on collaboration, we found that over 60% of firms in our sample reported having no partners for R&D. Less than 20% having only either one or two partners.[56] Thus, it is clear that for most New Zealand firms, closed innovation remains their typical mode of operating.

Of the firms with no partnerships (which were typically smaller firms), 50% reported this was because R&D or partners weren't needed, 13% viewed it as high-cost relative to value created, while only 12% indicated they had sufficient in-house capability. About 10% indicated they would start using partnerships in the future, whereas 3.5% reported they were 'unsure where to find R&D partners'. With only a small percentage viewing that they have R&D capabilities in-house, most firms appear to be undertaking little or no R&D or innovation activities.

When comparing firms, R&D partnerships are significantly higher when firms are exporting (face international competitors) and when their workforce is more educated (connected to absorptive capacity). There was a very strong positive association with the capability to manage R&D relationships, which again highlights how other capacities are crucial to engaging in open innovation. Developing such relational capabilities across all partners, including shared understanding of values and priorities, will be crucial to altering the predominant firm perspective toward innovation.

IP concerns are a frequent initial barrier to Open Innovation

Despite benefits above that have been observed from external knowledge commercialisation and open innovation, many firms in New Zealand remain reluctant to undertake such collaborations regularly. Informal observations with industry participants associated with SfTI research projects indicated their desire seek competitive advantage from any R&D investments is an additional factor affecting this. A competitive framing of all exchanges leads firms to **prefer approaches aimed at protecting their exclusive rights to any IP generated** – a desire that again reinforces in-house initiatives and closed innovation. IP Australia notes this as a potentially contentious issue, stating: "As a business, you are likely to be seeking to establish and maintain a competitive advantage."[57] With the rate of investment in R&D in New Zealand already low, this creates a potential vicious cycle that further constrains total investment.

IP concerns voiced by industry participants linked to SfTI projects did pose a barrier to them engaging with technology early.

> Intellectual Property could be tricky sometimes, especially with a company like ours. We're not a university; we actually do have lots of commercial clients quite sensitive over IP issues, and we do sometimes blur the lines between projects.

Operating collaboratively with a diversity of partners created tensions for science researchers related to IP as well, although researcher views for handling IP concerns often diverge significantly from industry. Being clear on what will occur with respect to the timing of publications,[58] a central driver for researchers associated with undertaking research, is important.

> There are IP things that can be a pain in the butt. Truly hate (it) – I wish we didn't have to deal with IP ever. I think any government-funded project should just be open-source in the first place.

> I hate the whole (IP) process. If you're a company, and you're worried that someone's going to steal your IP; 1) you've got it – you've got a head start – if they do a better job than you, it's your problem – if you want to work within capitalism, then suck it up.

However, researchers acknowledged the legitimacy and usefulness of including a market pull for relevance within their projects.

"I mean you're never going to get valuable IP and entrepreneurial outcomes if you don't have high quality research feeding into it, long term research. And the researcher should know that you're never going to get the real outcomes that you want to see, say clinically, unless there's people on the business side who are developing them into a product that can be sold. Otherwise, you're only ever operating in a local environment".

> IP, of course, is only then important and makes discussions or problems if you have IP. At the moment we don't have that, because the project is quite young, but we are expecting this would happen over the next two years. So, we talk with industry and say, this is what we do – this is what we offer – this is what we expect as an outcome – as an output – physical, tangible output. Then they have the right to say, we as an industry or as a representative want that something happens with this knowledge.

While New Zealand firms can successfully undertake R&D internally with their own people and resources for some innovations (closed innovation), other projects will only come to fruition by bringing in additional and broader expertise. Given that technology development typically requires several stages of development prior to commercialisation (as embodied in ASRLs in **Part 2**), a **more open stance toward IP** management at early phases may help to get projects started. Such a stance would set a platform for how any subsequent phases and options for involvement and investment are handled, providing signals of trustworthiness from which mutual trust may develop.[59]

CASE STUDY SIX

Competitive vs co-opetition emphasis within sectors

Open innovation with upstream or downstream partners is not occurring at a particularly high rate in New Zealand. What factors are affecting this? And for what technological initiatives might OI be more likely? Again, SfTI-supported initiatives have provided some insight to this.

Our observations have shown that some project leaders/PIs, with strong connections to industry and other key stakeholders, are in a good position to seed discussions about industry collaborations (Network or Coopetition OI). This was the case when a SfTI spearhead leader organised and brokered a two-day facilitated forum involving representatives of leading businesses in the same sector as well as the sector body's innovation manager. As might be expected, the industry managers began from a competitive positioning where gaining maximum leverage from any investments in innovation or R&D constrained their perspective on initiating joint projects.

However, a technology demonstration by a SfTI scientist at the forum and a presentation by the managing director of a New Zealand firm cooperating in another sector clearly showed the forum participants that there were projects of common interest and benefit, often where the value relative to cost was insufficient for any single business to invest. Assisting these stakeholders to identify where they may have shared needs but limited scope for leverage advantage individually was a key step that created the basis for a joint initiative to develop. Recognising their common need and that advantage relative to international competitors could provide a sufficient incentive to invest provided commitment to a joint project, an agreement to seek government support and a basis for establishing a platform for their sector.

> *"The ability **to view some issues through a coopetition or network OI lens** is vital, making it easier to address shared industry needs or applications. Again, though, such needs are best addressed by involvement of a breadth of stakeholders, starting early in the project formation stage and continuing through initial development."*

Recognising that successful technology development and associated IP might be leveraged through sales and revenue internationally was a key factor that helped to overcome their competitive inclination to firstly seek individual gain for any investment in R&D and to protect the IP. This example matches the recommendations for holistically managing coopetition tensions proposed by Tidström (2014), where clarifying and restricting the domain of collaboration to avoid competition, keeping commitments lower initially, and voluntary involvement assist in building greater mutual awareness, understanding and eventually trust.[60] However, the extent to which discussions across competitors in an industry occur currently or regularly in New Zealand sectors is unclear, as is whether they tend to include only prominent larger firms (who may have less incentive to initiate collective change) vs a diversity of potential partners including Māori and smaller organisations. The role that the science sector might play in fostering collaboration between competitors also warrants further consideration.

Opening Science for Māori Innovation

KEY QUESTIONS

- *How is science and innovation policy impacting on individuals, teams and Māori partners?*
- *What are some of the enabling practices that can support Māori innovation when viewed from a Māori perspective and what changes would be required to implement these?*

Science and innovation policy impacts individual Māori researchers at a range of levels

One of the key impacts we see is that there has been, over the lifetime of SfTI, an increasing demand for Māori researchers and engagement with Māori communities. However, as noted in the CRI review report, and as our own and others' research has shown,[61] the 'pipeline' of Māori science and technology researchers available is constrained.

At an individual Māori researcher level, this demand has led to feeling empowered on the one hand but overwhelmed on the other. Additionally, it has called into question Māori identity, and whether a Māori researcher is able to fulfil their own, their team, or their employer's expectations about their relationship role while at the same time performing a technical science role, and addressing cultural responsibilities.[62]

We comment on this more specifically in the next section. One SfTI Māori researcher described this as the difference between being a *scientist-who-is- Māori and a Māori-who-is-a-scientist*, and learning which body of knowledge to draw from.[63]

In analysis across a number of research organisations, our researchers found evidence of **'aronga takirua' or cutural double-shift** whereby Māori scientists as a result of their own or others' expectations experience significant pressure and conflict in their roles as Māori and as scientist. Thus, Māori identity can bring cultural and scientific value on the one hand while having detrimental consequences, such as burn-out, on the other.[64,65]

This is evident in the following quotation:

> "I've been pushed a bit to my limits, but that's because I wanted to learn everything so fast. But I kind of put that on myself. So I have had to re-evaluate myself to ensure that I am going to be okay physically and mentally.
>
> Everything I'm doing in terms of my mahi is constantly requiring a lot of learning, time and brain power. I love it, although I have to re-check myself so that I stay sane."

Supporting Māori researchers' te Ao Māori competencies supports innovation

What can mitigate against aronga takirua to enable Māori innovation? Apart from giving additional 'weighting' or funding to Māori research roles to allow for Māori relationship-building, research with our science teams shows that **taking a caring or mentoring approach is important**, particularly for Early Career researchers. For some, this takes the form of an individual mentor – a line manager or team leader – who **pushes boundaries on behalf of the Māori researcher**:

> "I've got an awesome mentor, she's really understanding. She's not Māori, but she just gets it. It's awesome. It helps that my boss is sticking his head out to push me into things."

For others, support can be expressed through the **science team that acts as 'whānau'** by providing support and giving direction through developing the individual's needs:

> "I had an awesome team. . . They kind of just awhi'd me along. The fact that we have a whānau environment and we have this awesome project – there's this awesome capacity (development programme) for different people from different areas. It's a real strength of our project."

Where mentoring or a whānau approach are not available in the team or the institution, other individuals or collectives act in this capacity to enable innovation. In SfTI's case, the Kāhui Māori enabled one Māori researcher to 'have a voice' and interact in the broader science system.

For others, support had to come outside the science sector all together – through direct iwi connections, even if not directly with their own iwi. This was described as a **'whangai' process**, whereby the urban-raised researcher was adopted by another tribal group, to become 'their scientist'. In this case, a **tuakana-teina** relationship evolved with the scientist teaching about the science and the tribal group teaching about the context of the science, which invariably includes issues of loss – of land, resources, te reo, economy, culture and mana.

The matter of loss is felt particularly by urban-raised or tribally disconnected Māori researchers because, as one Māori scientist noted, while colleagues may be supportive 'they just don't know what the Māori things are, and I don't know what the Māori things are too'.

This suggests that Māori scientists learning **te Ao Māori technical competencies** may require development in specific Māori domains such as being on marae, learning te reo Māori, attending tribal cultural events and understanding stories of loss specific to a particular tribal group. Knowing such 'Māori things' can lead to opportunities for innovation as suggested in the following:

> "So, he's got to work on a project and it's this perfect thing where he can work and use his skills but he can also learn along the way and figure out stuff as he goes. I remember saying that to Ta Mason Durie at a hui up in Auckland. I remember sharing a similar kōrero with him and he says 'Don't you think that's a conflict of interest?' … and before I could say anything, goes 'There's no such thing in Te Ao Māori, just opportunities.' So, yeah, what an opportunity."

Architecting new processes can enable Māori innovation in science teams

When we consider Māori scientists from an open science innovation perspective, we see that they have an important functional role as 'boundary-spanners'. These intermediary roles which we have discussed in the previous section are often under-valued.

One recognisable role is the Māori **non-scientist matchmaker** who brings together different organisations through setting up and mediating relationships[66,67,68].

For example, a number of CRIs have dedicated matchmakers with titles such as 'General Manager Māori Partnerships', 'General Manager Māori Strategy and Partnerships', or 'Research Group Leader, Te Ao Māori.[69,70,71] Likewise, SfTI has specific roles and groups, such as Vision Mātauranga Advisor and the Kāhui Māori. However, matchmaking is only the start of the journey.

For many teams, there is a need to **architect new collaboration processes with Māori,** something that is often beyond the capacity of any one person, no matter how willing. As a verb, 'architecting' is made meaningful through its execution, forcing us to consider the things we do as we create information architecture. Thus, it nudges us away from 'routine' and towards a tighter focus on process. Recognising this, SfTI has evolved its architecting processes over the years, leading to a more nuanced understanding of what does and does not work for Māori. For example, in the first round of Spearhead projects in 2015, the process used to bring the teams together was scientist driven, with a 'Māori-element' being 'grafted' into approaches and objectives that had been pre-determined. In other words, there was little attempt to architect or design collaboration processes to incorporate a Māori approach. Consequently, few Māori were deliberately involved as either researchers or stakeholders.

In the 2017 and 2019 rounds of Spearhead team and project formation, where specific Māori people and concepts were made a requirement, we see quite different collaboration processes. For example, the pre-cursor to what was to become the Ātea project was a facilitated workshop entitled 'digital marae' that involved a mix of Māori and non-Māori participants who had formally developed an Expression of Interest (EoI).

An Expression of Interest is a common method within the research and science system to flag research capability and to allow assessors to choose applications that should go forward for further consideration in situations where there is limited funding. That is, EoIs act as a sorting mechanism. Researchers have been 'enculturated' to the EoI as a competitive process and hence calling something an EoI comes with certain 'normative' expectations that may be difficult to shake off. As we observed, participants were 'already invested in a set of ideas which they found exciting'.

For the Māori participants, the fact that many Māori protocols were not able to be performed – for example, meetings taking place on a marae – meant that the process did not necessarily 'speak to' them. As one of our observers commented, while the Digital Marae workshop was billed as a type of wānanga

> *"There was tension between a wānanga 'discussion first' process and a workshop approach or foci 'to produce results now' (e.g., via quick-pace two minute/five minute brainstorming sessions). Wānanga by contrast is not restrained by time in this way. It also naturally evolves in a collective group kōrero sense where core themes, ideas or arguments 'meet' at a common consensus point. These outcomes can be achieved through workshop, but where artificial or imposed time constraints are necessary, the common points may be high level or lacking in depth."*

An additional barrier was the way that many Māori understood the notion of 'cutting-edge science', or as SfTI describes it 'stretch' science. As our overview in Section Two indicates, science-based open innovation requires that all parties have high technical absorptive capacity to turn science ideas into marketable products or processes. As we have also noted, Māori technical science capability is still developing. Hence, for Māori, **science-based open innovation needs to be complemented with other forms of innovation, such as network open innovation.** This is picked up in the following quotations:

> "People were discussing 'stretch' in terms of it not necessarily meaning technology only. It may also mean integration of people, science(s) and technology in ways that have not been done before. It might mean utilising and developing existing technology, therefore.'
>
> Our focus is our people. It's creating and maintaining and strengthening what we do with people and being able to bring them back to the whenua. So, if that's a stretch goal, if that's a sticky goal, we don't care. We don't care about terminology. Our ultimate objective is bringing our people together. Returning them so they've got a greater relationship with their whenua."

This may explain why it took almost two years for the Ātea and Te Tatari Raraunga projects to be finalised. Integrating people, science and technology in new ways that were acceptable to the kaupapa, tikanga and mātauranga involved in these two Māori-led projects meant architecting a Māori science–based open innovation process from scratch. As with the Veracity project discussed earlier, architecting new processes is crucial to successfully aligning teams for network open innovation.

Māori absorptive capacity catalyses innovation

As we have discussed in Part Two, firms that have complementary absorptive capacities are those that are most likely to be able to use science-based open innovation research, whereas in other cases other forms of open innovation may be a better response. In some of the SfTI projects where the Māori partner was already versed in commercial R&D, such as in the aquaculture project, the focus has been on the proposed technology's usefulness (in this case, underwater sensing to monitor mussel beds) to enhance the tribe's economic and social well-being. In other projects, other techniques have been needed.

While time heavy, **co-design of research** objectives, methodologies, reporting and communication has helped with developing relationships with new partners. As well, co-design supports the partner's capacity to engage with the researchers and the technology with a number of Spearhead Seed projects adopting this approach.

Another technique has been to **identify potential undergraduate or masters' students** to engage with the Māori entity as the following quotation notes:

> And then we have students which we had the pleasure to bring on board. A couple actually whakapapa to Taranaki so it feels pretty awesome to be in a position where we can try to awhi those students, and try to teach as much as I can, and to help them on their studies and share with them knowledge. They also share with us the knowledge and help us come up with ideas.

A third approach to support a Māori partner's technical capacity has been to involve them more intimately through funding them as a researcher:

> *"We've been lucky that we've been recognised as a full partner in this project going forward. That was a bit of a struggle getting that acknowledgement and we're really grateful for it.*
>
> *It's been exciting just to learn about the background of how they build these algorithms to interpret data, how they build their fixes and our researchers being able to explain that to me in plain English so that I can go out and talk to PKW whānau and tell them this is what's happening."*

In this case, the Māori partner has been a key advisor and knowledge integrator, not only to the researchers but also to the whānau, building trust in the technology and the researchers. This intermediary role is key if the potential users – the whānau – are to see value and hence want to use the technology.

Acknowledge Māori Intellectual Property

In light of the concerns raised in 'Wai 262' or *Ko Aotearoa tēnei*, Māori have particular concerns including around protection of data. Here we present findings from a BNZIC survey undertaken in conjunction with Genomics Aotearoa examining New Zealand research institutes' Māori IP understanding and practices.

CASE STUDY SEVEN
Wai 262 and New Zealand research institutions

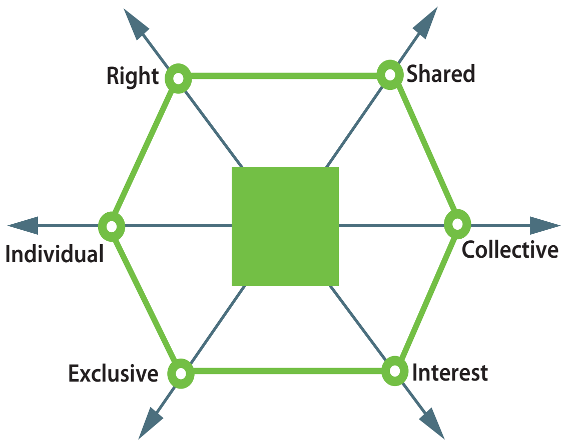
Wai 262 outlined a range of areas where Māori rights and interests ought to be considered. As a Māori research partner explained, the science sector should be 'acknowledging that our mātauranga has whakapapa and that's embedded in Taranaki and in our history'. However, attempting to align Māori cultural concepts to current IP provisions is challenging, as the two take completely different approaches of balancing rights and interests through ownership and responsibility.

Assigning Intellectual Property Rights is the basis for identifying whose interests can be recognised in future uses whether that be licensing to enable access through Creative Commons or licensing for commercial outcomes. When dealing with mātauranga and taonga, Māori have expressed the need to deal with the collective shared interest as they transition into intellectual property regimes (see Figure 7).

A BNZIC survey of 57 New Zealand research institutes (response rate 29%) revealed that while a significant proportion were involved with research using mātauranga Māori, only three of the policies made specific reference to mātauranga Māori or Māori data, and only one IP policy addressed Māori genomic data. Over the past 10 years few had sought to commercialise from mātauranga Māori, although where one institution had, there was a benefit-sharing agreement. There appeared to be very low capacity to deal with issues of mātauranga/Māori IP rights and interests within research organisations. This low level of understanding of mātauranga Māori was also reflected at the level of many individual researchers in the SfTI challenge as the following quotations from two researchers reflect:

> *"I don't think I understand really what is Māori IP and how far does it extend?*
>
> *Also, I haven't had any experience other than these workshops that we attend – yearly workshops – the National Science Challenges are connecting, and the people represent who's from Māori iwi, talking to us about all these (Māori IP) aspects. Other than that; directly, I have no experience there."*

Figure 7: Balancing Individual and Collective Interests in IP



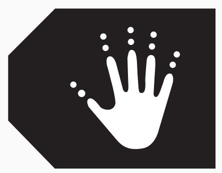
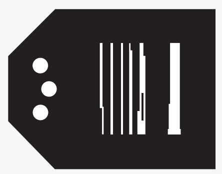
Additionally, BNZIC research showed that due to the increase in global digitization of cultural heritage resources and international collaborations involving genetic research from biological taonga, Māori ability to maintain their rights and interests is limited. And while digitization may be new, as one of our Māori partners explained, Māori have 'always been in the data space' with 'a wharenui as (the) original data repository.'

Enhancing control over mātauranga and/or Māori data within research and data ecosystems requires more than just legal interventions. To address the limits of the current IP regimes, the global Indigenous Data Sovereignty movement has looked to develop tools and approaches to articulate Indigenous peoples' interest, rights and potential governance. These include policy guidelines, consultation frameworks and institutional practice protocols of how to deal with Indigenous artefacts or taonga.[72,73,74,75,76] Also being developed are 'extra-legal' tools such as Traditional Knowledge labels, and Biocultural labels for Indigenous genetic resources (see Figure 8), that create an Indigenous digital identifier for a given taonga or dataset which ensures a record of provenance that supports ongoing governance and/or pathways for benefit sharing discussions.

BNZIC research has highlighted that in order to protect mātauranga and taonga a range of approaches is required. Additionally, as the survey showed, knowledge of these issues in research institutions is limited, and therefore there is an opportunity to develop further capacity whether of the specialists in these areas, or increased education and understanding generally.

At the very least, there needs to be a review of contract processes between institutions and Māori partners, with clauses that acknowledge and protect mātauranga and Māori cultural interests – something that SfTI acknowledged early on and now includes in all contracting documentation.

Figure 8: Overview of TK and BC Labels

TK Attribution		The TK Labels are digital markers that establish proper attribution, access, and use rights for traditional knowledge. The TK Labels are designed to be customized by Indigenous communities to reflect ongoing relationships and authority including proper use, guidelines for action or responsible stewardship and re-use of traditional knowledge.
BC Provenance		The BC Labels are digital markers that focus on accurate provenance, transparency and integrity in research engagements around Indigenous data. The BC Labels help Indigenous communities define community expectations and consent about appropriate use of collections and data. They connect data to people and environments over time.[76]

Developing entrepreneurial behaviours

KEY QUESTIONS

- *What capabilities enable individuals to collaborate across boundaries?*
- *What are the different ways to organise capabilities within teams? Who should have these capabilities in teams?*
- *How can these capabilities be developed?*

A traditional science orientation likely predominates in New Zealand's science system

As we discussed in Part Two, moving beyond Mode 1 traditional science places different demands and expectations on individuals and teams. Our observations show that SfTI researchers span the different modes (see Figure 9), with some having primarily a **science orientation** involving deep and intensive activities and relationships, while others have added a **societal/ industry orientation** with diversified and extensive activities and relationships.

Figure 9: Scientist orientations. Extended from models of Lam,[78] Casati & Genet,[79] Meyer[80].

Some SfTI researchers, whose approach aligns with **traditional science**, saw their job as "to do the research"; creating widgets that worked. Others saw their role as more **tech-transfer**, doing their science so that they could 'help' a particular business sector or community enterprise achieve its objectives. Then there are **entrepreneurial scientists**, 'A-shaped' scientists, who expand on traditional science through leveraging more extensive transdisciplinary networks. They are motivated to change scientific paradigms, often at the global level. Finally, are the **science entrepreneurs**, those who directly seek to change society through operating across disciplinary and science boundaries to actively engage in both science and societal systems – akin to 'T-shaped' scientists. Their vision is aimed at applying science to deep or abiding societal issues.

To be clear, scientists may move amongst some or all of these orientations depending on career development stage, project objectives, institutional environment, and individual motivation. These hypothetical orientations are based on our observations of individuals and at this stage of our research, we are not able to quantify the balance amongst the various roles across the New Zealand science sector, although it is likely that 'traditionalists' are more highly represented than other types. We also are not able to say whether science system rewards for an entrepreneurial orientation are sufficient or well targeted to shift individual orientations beyond the short term. We suspect that certain types of entrepreneurialism that fall within Mode 1 science orientation are more rewarded, whether through PBRF, career promotions or funding. However, we are not certain whether such incentives **reward science-based open innovation** and a more societal orientation directly. Thus, while science volume (as measured by publications), the numbers being trained (as measured by higher level degrees), and the size of science teams increases, science innovation impact has not necessarily kept pace. This is not unique to New Zealand and has been observed elsewhere.[81]

Māori researchers are more societally-oriented at an earlier career phase

Māori career trajectories are often more societally oriented as we noted in the previous section. Within a 'normal' career development pathway, scientists' careers develop from a deep understanding of their discipline to broader responsibilities that may see them develop new science paradigms. Alternately, some may be more drawn to applied applications of their science and pursue activities in tech transfer or industry R&D directly.

Māori scientists, in contrast, often need to juggle both the focused and intensive activities of the traditional scientist and, at **a much earlier career phase**, take on broader societal concerns such as the impacts of colonial experience within a discipline. Even where their focus is tech-transfer to the Māori community, such broader issues are never left behind. There are ways to mitigate this reality as we outlined in <u>Section 3 Opening Science for Māori Innovation</u>, however, our observation is that these are not the norm in practice. Hence, a **focus on early career Māori science pathways is warranted**.

To become more entrepreneurial may require 'violating' a scientist's identity

Research from our team has also shown that, similar to academic entrepreneurs, funded PIs have hybrid identities, requiring proficiency across **four crucial roles**. These roles are **research networker** and **research contractor**, which are closely aligned with traditional academic role identities, as well as **project manager** and **research entrepreneur**, which are more business/ entrepreneurial focused roles.

Effectively enacting these four roles requires that PIs develop a diverse range of skills including network initiation and management, mentoring, sustaining and developing the careers of those they recruit to their teams; project management of significant budgets, and a range of administration, human resource, legal and media duties. Additionally, PIs are increasingly expected to generate societal value by undertaking and translating science. These enlarged and diverse activities are generally learned on the job, leading to PIs at times feeling 'out of their depth' and 'violating' the scope of what they believe is their 'real', or more traditional, Mode 1 job as a scientist.[81]

> *"A key observation is that **learning through experience** is typically used to enact new roles and responsibilities closely aligned with one's core sense of self, while **learning through violating a science identity** is required for roles and responsibilities that are foreign to one's sense of self."*

With many scientists increasingly involved in activities that require an entrepreneurial orientation that also includes looking for opportunities with Māori, there is a need to **establish role clarity** and provide **appropriate**

support and professional development opportunities for PIs, particularly with respect to PI role preparation. This chimes with the theory we discussed in **Part Two**, whereby how a PI thinks about and enacts their science identity is influenced by their particular experience of performing that identity, whether through 'on the job' learning or through specific academic professional development.

Capacity development may need to be understood in relation to team orientation

Turning now to teams, SfTI's approach has been to focus on individual capacity development with the expectation that all SfTI-funded researchers should (and would) take part in at least one opportunity per year. Data indicates that even though capacity development is funded and supported centrally by SfTI, over 50% of eligible researchers within Spearhead and Seed projects have not completed any capacity development.[83] PIs did, though, undertake more capacity development.

We suggest that it is important for PIs and researchers to establish clear roles and then to prepare for these. This is particularly the case for PIs in relation to their role, not only as an intermediary who can broker relationships and span boundaries across different sectors or disciplines, but also their **role in facilitating the renewal of innovation activities within science teams.**[84]

For example, one of our findings is that there are distinct models within teams for initiating and coordinating engagements with industry and potentially other external collaborators. One model is **more centralised** with engagement funneled through a focal point or individual, typically the PI. Through this model, one team member takes responsibility for coordinating who, when and how the team engages. While other team members feed into this process and may be kept informed on this engagement activity, they primarily focus on technical challenges related to the project.

In the second model, boundary-spanning engagement is a **more devolved activity**, with multiple if not all team members independently pursuing industry-wide engagement as required in attending to their own technical tasks. Within this model, there is less focus on central and efficient coordination of external engagement activity and more emphasis on wider distributed and autonomous industry engagement.

Notably, the centralised model appears to be present within teams with **stronger prior ties amongst team members**, while the more devolved boundary-spanning model appears to be present in models in which there are weaker prior ties amongst team members.

This raises the issue of how prior ties might affect how teams and team members direct their attention.

Where strong prior ties exist, there may be some hard-wired assumptions around who is responsible or, who is best at particular activities, such as external engagement. Where weak prior ties exist, individual team members appear more likely to assume responsibilities for key outcomes themselves to legitimise their value and contribution to the team. Again, this may indicate that such team members are trying to expand their science identities through performing a particular element – in this case relationship development.

Perhaps what is important to note here is that capacity development activities need to be **nuanced in relation to team orientations**. In some types of teams such as those where there is centralised control, there may need to be specific strategies aimed at ensuring individual team members, beyond but including the PI, are given opportunities for capacity development.

How leaders structure their teams may affect how individuals develop relational innovation capabilities

One of our key observations is that the nature and number of relationships with external partners shifts during and after a project.[85] While some science teams initiate broad exchanges with a range of external actors, these engagements undergo a gradual **process of distillation** to both advance and renew the team's innovation activities (see Figure 10).

Figure 10 shows that while engagement early on in the innovation process was broad and inclusive with the involvement of many team members and outside actors, it gradually narrows to a more select and stronger set of ties between a smaller number of team members and external actors.

This distillation effect is driven by several key factors:

- the need to prioritise and secure time for pressing science and technical tasks;
- an improved ability to identify which engagements are most valuable to the immediate needs and goals of the project;
- stronger team cohesion and task coordination that have developed since the project commenced.

In the *Devising and coordinating* phase, engagements involve framing the initial ideas, listening widely and brokering new connections. New connections may bring tensions as external ideas challenge a teams' pre-conceived trajectory, perhaps leading to defensiveness or explanatory type of behaviour. This creates a shift in the team's thinking about the new ideas forcing either an *assimilation* of the ideas into the project, or rejection due to *scepticism* about whether the ideas are actionable. At this point, the team re-affirms control of the project and streamlines who they are willing to connect with, actively decreasing external involvement. In this phase a team decouples from a broad search for external partners whilst selecting and nurturing certain engagements deemed directly relevant to the project's goals.

The *distilling phase* frees up some team members to explore other science-focused initiatives and new lines of inquiry, some of significant potential, while they are still working on the original project. Such inquiries cannot be explored unless team resources are deployed to pursue them. Team leaders who encourage team members to pursue new (high potential-high uncertainty) trajectories and collaborations and who build in a degree of autonomy into their plans can be contrasted with those who organise their teams in a more highly structured and goal-oriented manner. **Incorporating flexibility to pursue exploratory lines of inquiry** alongside ongoing research project objectives serves to extend and renew the innovation activities of the team.

We observe that SfTI's contracting process of including a 'pivot' to allow an unexpected opportunity to be pursued may be one way to signal, at least at a high level, that flexibility in research should not be penalised.

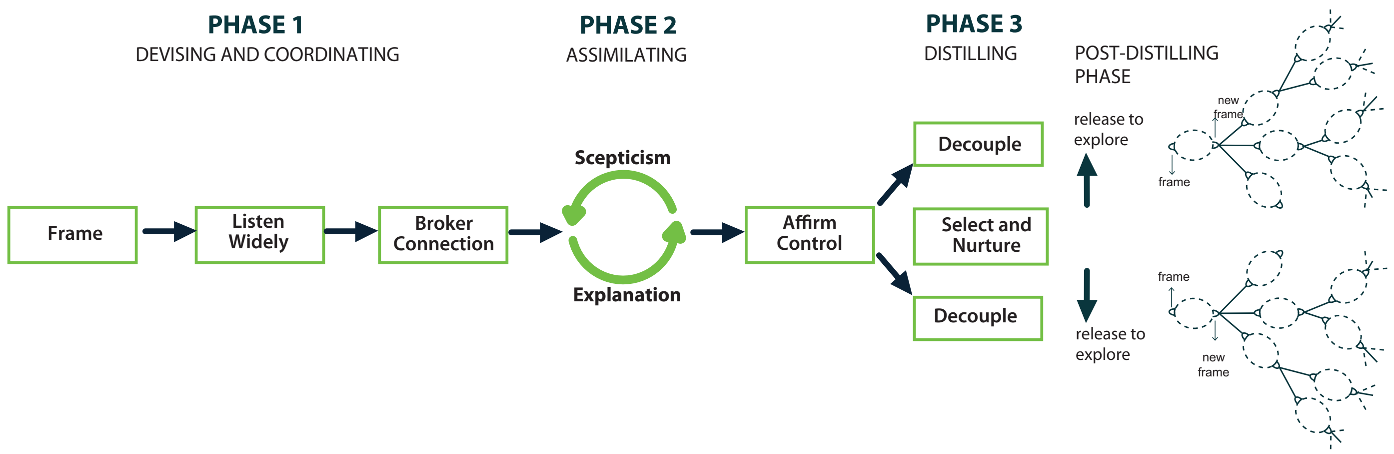
This pattern shows what we believe is an effective external engagement process of wide search for relationships and ideas, followed by honing and distilling of ideas and partners across the projects. An assumption is that once team members *repeat* the devising and coordinating phase for a *new* initiative, the already 'distilled' stakeholders are now the starting point of the next round of engagements, leading to more refined project selection and partner engagement.

From a stakeholder engagement perspective, this would seem to align with research that individuals and perhaps teams often bring with them strong prior ties that are the starting point for further projects. A question for us is whether in the repeat phase there is now increased spill-over to a more market or societal-oriented approach, or whether the type of team in which individuals find themselves is more or less enabling of a market or societal orientation. This suggests that there is a need to focus on **how leaders empower individual team members** to pursue new lines of enquiry. We suggest that this type of leadership can help build a 'pipeline' of individuals who have science-based innovation capabilities.

Capacity development that supports day-to-day needs viewed positively

There have been over 90 types of human and relational capacity development provided within SfTI, ranging from workshops on IP, Vision Mātauranga, stakeholder engagement, science media communication, and science commercialisation, along with conference attendance outside of individual technical specialty, and leadership and pitching coaching. As well, up until 2020, there have been 'all-of-researcher' workshops that bring together research teams across all of the projects to engage in 'non-science' capacity development. However, such opportunities have not been a focus for some, often because researchers feel under time constraints

Figure 10: Phases in science team engagement



to complete the science milestones in their research contracts. This aspect has not yet been explored in any depth.

What we can say is that there are some types of capacity development that individuals have found valuable. To help us understand the impact of these capacity development opportunities in both the short and medium term, and how this might affect the science system more broadly, we are looking to training and development models such as Baldwin and Ford's Training Transfer Model.[87] Although traditionally used in an organisational context, it can be modified to reflect the context of relational and human capability development in SfTI.

"Transfer" in the model refers to whether training, or in this case any form of capacity development, is used by the individual and results in increased individual and therefore, team or organisational performance. Three main factors affect transfer. First, is the individual themselves, and how they value the capacity development, its relevance to them and whether it supports their individual learning needs. Preliminary findings from SfTI data suggest that **some early career researchers demonstrated greater uptake of development opportunities**, and their evaluation of these opportunities tended to be more positive.

Second, the design of the capacity intervention, and the extent to which it closely mirrors the organisational or research task that will be undertaken, is a key transfer predictor. For example, we see **strong support for Vision Mātauranga opportunities and the all of researcher workshops**. From a capacity development perspective, these align well and are likely to reflect the value they provide the researcher in multiple areas of their work. Similarly, researchers may benefit from the networking and intellectual stimulation opportunities, as these are likely to be complementary to many researchers' other work roles.

The third aspect is the work environment, and integral to this is the opportunity to use the newly developed skill through support from the workplace. Again, in SfTI, researchers tend to be more **positive about the capacity development if it is important to their day-to-day needs**, reflecting the need for SfTI to continually adapt and be responsive to the capacity requirements.

Success can be reflected through the participants' 'learning' (knowledge and skills gained from the capacity development) and 'retention' (using these learnings post-capacity interventions) of their capacity opportunity as well as 'motivation to use'. In SfTI this has been captured through interview data and capacity evaluations. Ideally, in SfTI we would like participants to reach 'maintenance' (acquired skills are used without thinking) and 'generalisation' (acquired skills are applied across a range of circumstances).

Since its initial funding, SfTI sought to build the capacity of individuals within the science system, with generalisation as the top-level outcome. The final stage of BNZIC research aims to explore these latter two outcomes in more detail.

References

[1] Ahuriri-Driscoll, A., Hudson, M., Foote, J., Hepi, M., Rogers-Koroheke, M., Taimona, H., Tipa, G., North, N., Lea, R., Tipene-Matua, B., & Symes, J. (2007). Scientific Collaborative Research with Māori Communities: Kaupapa or Kūpapa Māori? AlterNative: An International Journal of Indigenous Peoples, 3(2), 60–81. https://doi.org/10.1177/117718010700300020

[2] SFTI (n.d.). Spearhead project development process. Retrieved from https://www.sftichallenge.govt.nz/for-researchers/funding-and-get-involved/spearhead-project-development-process/

[3] Ministry of Business, Innovation & Employment. (2021). Research, Science and Innovation: Te Ara Paerangi Future Pathways Green Paper. Wellington: Ministry of Business, Innovation & Employment. Retrieved from: https://www.mbie.govt.nz/dmsdocument/17637-future-pathways-green-paper

[4] Ullah, A. S., Rashid, M. M., & Tamaki, J. I. (2012). On some unique features of C–K theory of design. CIRP Journal of Manufacturing Science and Technology, 5(1), 55-66.

[5] Hatchuel, A., Le Masson, P., Weil, B., Agogué, M., Kazakc¸ AO., & Hooge, S. (2015). Multiple forms of applications and impacts of a design theory – ten years of industrial applications of C–K theory. In: Chakrabarti A, Lindemann U (eds). Impact of design research on industrial practice—tools, technology, and training. Springer, Munich, pp 189-209.

[6] Blume-Kohout, M. E., Kumar, K. B., & Sood, N. (2014). University R&D funding strategies in a changing federal funding environment. Science and Public Policy, 42(3), 355-368.

[7] D'Este, P., Ramos-Vielba, I., Woolley, R., & Amara, N. (2018). How do researchers generate development firm. Administrative Science Quarterly, 42 (4), 716-749.

[8] Lepak, D. P., Smith, K. G., & Taylor, M. S. (2007). Value creation and value capture: a multilevel perspective. Academy of management review, 32(1), 180-194.

[9] O'Kane, C., Zhang, J. A., Cunningham, J. A., & Dooley, L. (2020). Value capture mechanisms in publicly funded research. Industrial Marketing Management, 90, 400-416.

[10] Cunningham, J. A., & Menter, M. (2020). Micro-level academic entrepreneurship: a research agenda. Journal of Management Development. https://doi.org/10.1108/JMD-04-2020-0129

[11] Holgersson, M., & Aaboen, L. (2019). A literature review of intellectual property management in technology transfer offices: From appropriation to utilization. Technology in Society, 59, 101132.

[12] O'Kane, C., Mangematin, V., Geoghegan, W., & Fitzgerald, C. (2015). University technology transfer offices: The search for identity to build legitimacy. Research Policy, 44(2), 421-437.

[13] Phan, P.H. & Siegel, D.S. (2006). The Effectiveness of University Technology Transfer. Series on Foundations and Trends in Entrepreneurship. Boston: Now Publishers.

[14] Tseng, F. C., Huang, M. H., & Chen, D. Z. (2020). Factors of university–industry collaboration affecting university innovation performance. The Journal of Technology Transfer, 45(2), 560-577.

[15] Markman, G. D., Gianiodis, P. T., Phan, P. H., & Balkin, D. B. (2005). Innovation speed: Transferring university technology to market. Research Policy, 34(7), 1058-1075.

[16] Siegel, D. S., Waldman, D. A., Atwater, L. E., & Link, A. N. (2003). Commercial knowledge transfers from universities to firms: improving the effectiveness of university–industry collaboration. The Journal of High Technology Management Research, 14(1), 111-133.

[17] Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. Research Policy, 29(2), 109-123.

[18] Markman, G. D., Siegel, D. S., & Wright, M. (2008). Research and technology commercialization. Journal of Management Studies, 45(8), 1401-1423.

[19] Secundo, G., De Beer, C., Fai, F. M., & Schutte, C. S. (2019). Increasing university entrepreneurialism: qualitative insights from the technology transfer office. Measuring Business Excellence, 23(3): 253-268.

[20] O'Kane, C., Cunningham, J. A., Menter, M., & Walton, S. (2021). The brokering role of technology transfer offices within entrepreneurial ecosystems: An investigation of macro–meso–micro factors. The Journal of Technology Transfer, 46(6), 1814-1844.

[21] Stam, E., & Van de Ven, A. (2021). Entrepreneurial ecosystem elements. Small Business Economics, 56(2), 809-832.

[22] Fig. 2, from O'Kane, C., Cunningham, J. A., Menter, M., & Walton, S. (2021). The brokering role of technology transfer offices within entrepreneurial ecosystems: An investigation of macro–meso–micro factors. The Journal of Technology Transfer, 46(6), 1814-1844.

[23] Verganti, R. (2003). Design as brokering of languages: Innovation strategies in Italian firms. Design Management Journal, 14(3), 34-42.

[24] Wilkes, S., Wongsriruksa, S., Howes, P., Gamester, R., Witchel, H., Conreen, M., ... & Miodownik, M. (2016). Design tools for interdisciplinary translation of material experiences. Materials & Design, 90, 1228-1237.

[25] Borja de Mozota, B. (2011). Design Strategic Value Revisited: A Dynamic Theory For Design As An Organizational Function. In: R. Cooper; S. Junginger; T. Lockwood (Eds.), The Handbook of Design Management. Oxford, Berg, 544 P.

[26] Dedehayir, O., Mäkinen, S. J., & Ortt, J. R. (2018). Roles during innovation ecosystem genesis: A literature review. Technological Forecasting and Social Change, 136, 18-29.

[27] Luo, J. (2015). The united innovation process: integrating science, design, and entrepreneurship as sub-processes. Design Science, 1, e2.

[28] Hernandez, R. J., Cooper, R., Tether, B., & Murphy, E. (2017). The value of design in innovation: Results from a survey within the UK industry. The Design Journal, 20(sup1), S691–S704

[29] Westcott, M., Sato, S., Mrazek, D., Wallace, R., Vanka, S., Bilson, C., & Hardin, D. (2013). The DMI Design Value Scorecard: A new design measurement and management model. Design Management Review, 24(4), 10–16.

[30] Bonsiepe, G. (1995) The chain of innovation science–technology–design, Design Issues 11, 33–36.

[31] Boren, M., Chan, V., & Musso, C. (2012). The path to improved returns in materials commercialization. Mc Kinsley on Chemicals, 12-20. Retrived from: https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Operations/Our%20Insights/The%20path%20to%20improved%20returns%20in%20materials%20commercialization/The%20path%20to%20improved%20returns%20in%20materials%20commercialization.pdf

[32] Simeone, L., Secundo, G. & Schiuma, G. (2017), Knowledge translation mechanisms in open innovation: the role of design in R & D projects. Journal of Knowledge Management, 21 (6), 1406-1429.

[33] Wrigley, C. (2017). Principles and practices of a design-led approach to innovation. International Journal of Design Creativity and Innovation, 5(3-4), 235-255.

[34] Carlile, P. R. (2004). Transferring, translating, and transforming: An integrative framework for managing knowledge across boundaries. Organization science, 15(5), 555-568.

[35] Corsaro, D. (2018), "Crossing the boundary between physical and digital: the role of boundary objects", IMP Journal, 12 (2), 216-236.

[36] Hsiao, R. L., Tsai, D. H., & Lee, C. F. (2012). Collaborative knowing: the adaptive nature of cross-boundary spanning. Journal of Management Studies, 49(3), 463-491.

[37] Marheineke, M. (2016). Designing boundary objects for virtual collaboration. Springer Gabler: Germany.

[38] Wenger, E., McDermott, R. A., & Snyder, W. (2002). Cultivating communities of practice: A guide to managing knowledge. Harvard business press: Cambridge.

[39] Rothkötter, S., Garner, C., & Vajna, S. (2019). Design Capability for Science-based Innovation. Transformations, 1045.

[40] Driver, A., Peralta, C., & Moultrie, J. (2010). An exploratory study of scientists' perceptions of design and designers. In D. Durling, R. Bousbaci, L.-L. Chen, P. Gauthier, T. Poldma, S. Roworth-Stokes, & E. Stolterman (Eds.), Conference Proceedings: Design & Complexity (pp. 372-382)

[41] De los Rios, I. C., & Charnley, F. J. (2017). Skills and capabilities for a sustainable and circular economy: The changing role of design. Journal of Cleaner Production, 160, 109-122.

[42] Sumter, D., Bakker, C., & Balkenende, R. (2018). The role of product design in creating circular business models: A case study on the lease and refurbishment of baby strollers. Sustainability, 10(7), 2415.

[43] Wilkes, S., Wongsriruksa, S., Howes, P., Gamester, R., Witchel, H., Conreen, M., ... & Miodownik, M. (2016). Design tools for interdisciplinary translation of material experiences. Materials & Design, 90, 1228-1237.

[44] Buchanan, R. (1992). Wicked problems in design thinking. Design Issues, 8(2), 5–21.

[45] Rothkötter, S., Garner, C.C., & Vajna, S. (2019). Design Capability for Science-based Innovation. Conference Proceedings of the Academy for Design Innovation Management, pp.1065-1054. Retrieved from: https://www.aacademica.org/del.giorgio.solfa/219.pdf

[46] Ruckstuhl, K., Costa Camoes Rabello, R., & Davenport, S. (2020). Design and responsible research innovation in the additive manufacturing industry. Design Studies, 71.

[47] Christensen, P.H. (2007). Knowledge sharing: moving away from the obsession with best practices. Journal of Knowledge Management, 11(1), 36-47.

[48] Johns, T., & Gratton, L. 2013. The Third Wave of Virtual Work. Harvard Business Review 91(1-2), 66–73.

[49] Ministry of Business, Innovation & Employment (2019). Research, science and innovation strategy. Draft for consultation. Crown copyright.

[50] Aliasghar, O., & Haar, J. (2021). Open innovation: Are absorptive and desorptive capabilities complementary? International Business Review, 101865. https://doi.org/10.1016/j.ibusrev.2021.101865.

[51] Baglieri, D., & Lorenzoni, G. (2014). Closing the distance between academia and market: experimentation and user entrepreneurial processes. The Journal of Technology Transfer, 39(1), 52-74.

[52] Haar, J., Martin, W. J., Ruckstuhl, K., Ruwhiu, D., Daellenbach, U., & Ghafoor, A. (2021). A study of Aotearoa New Zealand enterprises: how different are Indigenous enterprises? Journal of Management & Organization, 1-15. doi:10.1017/jmo.2021.6

[53] Haar, J. (2020). The performance of Māori firms: A strategic management approach. New Zealand Work Research Institute. Auckland, New Zealand.

[54] ibid.

[55] ibid.

[56] Haar et al. (2019). Understanding R&D in New Zealand Firms: A Mixed Methods Study. ISPIM Florence.

[57] IP Australia (2022). Potentially contentious issues. https://www.ipaustralia.gov.au/tools-resources/ip-toolkit/business/successful-collaboration#Potentially%20conetntious%20issues, retrieved August 2022.

[58] ibid.

[59] Daellenbach, U., & Davenport, S. (2004). Establishing Trust during the Formation of Technology Alliances. The Journal of Technology Transfer, 29(2), 187-202. https://doi.org/10.1023/B:JOTT.0000019537.61121.c3.

[60] Tidström, A. (2014). Managing tensions in coopetition, Industrial Marketing Management, 43(2), 261-271.

[61] Ministry of Business, Innovation & Employment (2019). Research, science and innovation strategy. Draft for consultation. Crown copyright.

[62] Smith, L., Hemi, M., Hudson, M., Roberts, M., Tiakiwai, S., & Baker, M. (2013). Dialogue at the Cultural Interface. A report for Te Hau Mihi Ata: Mātauranga Māori, Science & Biotechnology. University of Waikato, Hamilton.

[63] Amoamo, M., Kawharu, M., & Ruckstuhl, K. (2021). He Pou Hiringa: Grounding science and technology in Te Ao Māori. Wellington, New Zealand: Bridget Williams Books. ISBN: 9781988587486.

[64] ibid.

[65] Haar, J., & Martin, WJ. (2021). He aronga takirua: Cultural double-shift of Māori scientists. Human Relations, April, 1-27. doi:10.1177/00187267211003955.

[66] Katzy, B., Turgut, E., Holzmann, T., & Sailer, K. (2013). Innovation intermediaries: a process view on open innovation coordination. Technology Analysis & Strategic Management, 25(3), 295-309.

[67] Smedlund, A. (2006). The roles of intermediaries in a regional knowledge system. Journal of Intellectual Capital, 7 (2), pp. 204-220.

[68] Edler, J., & Yeow, J. (2016). Connecting demand and supply: The role of intermediation in public procurement of innovation. Research Policy, 45(2), 414-426.

[69] Land Research New Zealand (2021). Partner with us. Retrieved from: https://www.gns.cri.nz/Home/About-Us/Structure-People/Executive#tania; https://www.scionresearch.com/about-us/about-scion/our-people/people/forest-science/shontelle-bishara.

[70] GNS Science (New Zealand), (2021). About us. Retrieved from: https://www.gns.cri.nz/Home/About-Us/Structure-People/. Accessed 14/12/2021.

[71] Scion (2021). About Scion. Retrieved from https://www.scionresearch.com/about-us/about-scion. Accessed 14/12/2021.

[72] Belcourt, T., Iglioliorte, H. & Robinson, D. (Eds). (2021). Promoting and Protecting the Arts and Cultural Expressions of Indigenous Peoples: A Compendium Of Experiences And Actions. Canada, CA. Department of Canadian Heritage.

[73] Boța-Moisin, M & Gujadhur, T. (2021). Documenting Traditional Cultural Expressions: Building a Model for Legal Protection Against Misappropriation and Misuse with the Oma Ethnic Group of Laos. part of Securing Cultural Intellectual Property Rights for the Oma of Laos - Traditional Design Digital Library, funded by Voice Global under the Laos Sudden Opportunity Grant – V-19100-LA-SO.

[74] Inuit Circumpolar Council. (2021). Ethical and Equitable Engagement Synthesis Report: A collection of Inuit rules, guidelines, protocols, and values for the engagement of Inuit Communities and Indigenous Knowledge from Across Inuit Nunaat. Synthesis Report. International.

[75] Karuk Resource Advisory Board (2014) Protocol on Karuk Tribe's Intellectual Property Rights Research, Publication and Recordings. Karuk Tribe. Retrieved from: https://sipnuuk.karuk.us/digital-heritage/protocol-karuk-tribe%E2%80%99s-intellectual-property-rights-research-publication-and.

[76] Hudson, M., Thompson, A., Wilcox. P., Mika, J., Stott, M., Brooks, RT., & Warbrick, L. (2021). Te Nohonga Kaitiaki. Guidelines for Genomic Research on Taonga Species. Te Kotahi Research.

[77] Local Contexts (2021). Grounding Indigenous Rights. Retrieved from: https://localcontexts.org/. Accessed 14/12/2021.

[78] Lam, A. (2010). From 'Ivory Tower Traditionalists' to 'Entrepreneurial Scientists'?: Academic Scientists in Fuzzy University—Industry Boundaries. Social Studies of Science. 40(2), pp. 307-340. doi:10.1177/0306312709349963.

[79] Casati, A., & Genet, C. (2014). Principal investigators as scientific entrepreneurs. The Journal of Technology Transfer, 39(1), 11-32.

[80] Meyer, M., Kearnes, M. (2013). Introduction to special section: Intermediaries between science, policy and the market, Science and Public Policy, 40(4), pp. 423–429, https://doi.org/10.1093/scipol/sct05.

[81] Gold, E. R. (2021). The fall of the innovation empire and its possible rise through open science. Research Policy, 50(5), 104226.

[82] O'Kane, C., Mangematin, V., Zhang, J. A., & Cunningham, J. A. (2020). How university-based principal investigators shape a hybrid role identity. Technological Forecasting and Social Change, 159, 120179.

[83] SfTI Challenge. (2022). Interim Capacity Development Report: Accelerating Science Innovation through human and relational skills development. June, Online ISBN: 978-0-473-64593-9. https://www.sftichallenge.govt.nz/assets/Uploads/SfTI-Interim-Capacity-Dev-Report-June-2022.pdf

[84] O'Kane, C., Mangematin, V., Zhang, J. A., & Cunningham, J. A. (2020). How university-based principal investigators shape a hybrid role identity. Technological Forecasting and Social Change, 159, 120179.

[85] O'Kane, C., Haar, J., Mangematin, V., Daellenbach, U., & Davenport, S. (2021). Distilling and renewing science team search through external engagement. Research Policy, 50(6), 104261. https://doi.org/10.1016/j.respol.2021.104261.

[86] Baldwin, T. T., & Ford, J. K. (1988). Transfer of training: A review and directions for future research. Personnel psychology, 41(1), 63-105.

[87] ibid.

PART FOUR

Implications

This report has identified four key trends affecting open innovation science. Each trend provided a springboard whereby we posed a set of questions, relevant to the New Zealand science and innovation system that we answered through our findings, observations, strategies and illustrative case studies. This evidence base allows us to suggest enabling practices and pathways towards new sets of routinised behaviours made up of disparate but interconnected elements.

In this final section, we outline the implications of our recommendations for various parts of the New Zealand and innovation science sector.

These recommendations have implications for the wider science and innovation sector. Moving beyond traditional science is a complex balance amongst policy, funding, organisational structure, team and individual orientation.

FOR POLICY-MAKERS AND FUNDERS

1. We see policy and resourcing that encourage or even mandate engagement as important at the individual level as this requires researchers to adopt an end-user attitude and to practice entrepreneurial skills. However, this is only a partial solution given that it is likely most researchers fall into the category of traditional scientist.
2. To encourage entrepreneurial capabilities, and particularly 'tech-transfer' or 'T'-shaped orientation, consideration should be given to additional national-level programmes and incentives. This would benefit Māori researchers in particular.
3. Tech transfer offices are important innovation intermediaries whose services help to lower barriers to value creation and accelerate productive entrepreneurship activities in the territories in which they operate. However, they face a number of barriers to fulfil a more strategic role within the broader science and innovation ecosystem. Some of these barriers need to be addressed by 'home' organisations. However, others might be addressed through streamlining cross-TTO collaborative effort.
4. Funders need to set expectations about how research collaborations are instigated to address missions or societal challenges. We see bottom-up expertise as crucial to identifying the innovation areas. However, bringing together such experts needs to be funded. Aligned to this, we see a need to craft the next stages of research to get to workable and realistic technologies that can be taken up by industry or Māori. Some of this can be embedded within the project itself, for example design expertise. In other cases, particularly where the mission pathways are ambiguous, specialist facilitation and guidance is essential. We believe making this an expectation and funding this would reduce the burden felt by individual researchers and be more efficient.
5. Funders should incorporate flexibility into contracts to encourage flexibility to pursue exploratory lines of inquiry alongside ongoing research project objectives. SfTI's contracting process of including a 'pivot' to allow an unexpected opportunity to be pursued may be one way to signal that flexibility in research should not be penalised.
6. There is a role for policy makers and funders in supporting specific innovation ecosystems. This is not the same as funding particular industries, although industries are central to this. Nor is it the same as funding particular locations or regions, although in some cases location or region may be central to an innovation ecosystem. Policy makers can work with particular industries or regions – however, the science and R&D needed should be facilitated in collaboration with the science sector. This includes the necessity for mātauranga Māori.
7. We suggest that there is a need for a national discussion about a more open stance towards IP given it can be a barrier to upstream industry engagement and collaboration.
8. Likewise, while specific advice around Wai262 is still being developed, we see a role for policy makers to clarify and then standardise Māori IP contracting clauses. Some of this is starting to happen at the individual organisation level. However, it is not yet uniform.
9. Funding Māori researchers' cultural capacity also supports innovation. There may be a case for funding this at a national level.

FOR RESEARCH INSTITUTIONS

10. Given the strategic importance of TTOs in the innovation ecosystem, more focus should be on strategic actions targeted at the macro and meso levels augmenting technology transfer operational efficiency and effectiveness at the micro-level.
11. To encourage entrepreneurial capabilities, particularly a 'tech-transfer' or 'T'-shaped orientation, there need to be stronger organisational rewards and incentives. Māori researchers, in particular, would benefit.
12. Institutions should consider how to support early career Māori researchers. This includes mentoring, tuakana-teina relationships with senior researchers and whānau-like support activities.
13. PIs may experience feeling 'out of their depth' and 'violating' the scope of what they believe is their 'real' or more traditional role as a scientist. Institutions should support PIs through professional development to prepare them for entrepreneurial activities.

FOR PRINCIPAL INVESTIGATORS AND TEAM LEADERS

14. PIs need to understand the types of relationship model that can characterise a team's operation, particularly where strong prior ties are centralised around core individuals. This supports the need for focused professional development of other team members' relational capacity.
15. PIs and team leaders can have a strong impact not only on technical capability but also on entrepreneurial thinking and relationships.

FOR INDIVIDUAL RESEARCHERS

16. Understanding orientations can support a researcher to identify the most pertinent capacity development options to enhance entrepreneurial capabilities.

FOR MĀORI

17. As Māori researchers are often more societally oriented at an earlier stage of their career, funding engagement roles and activities within grants is warranted.
18. New collaborative formats should be architected with Māori. This includes co-design of objectives, methodologies, reporting and communication with partners. Locations such as marae or environments with strong Māori involvement should be part of this and may involve Māori-specific processes, such as wānanga. This enhances Māori absorptive capacity but it is time heavy.
19. Māori partners who act as key intermediaries should be recompensed for this.
20. To address the limits of the current IP regimes, in particular in relation to data, consultation frameworks and institutional practice protocols should have greater Māori input. Māori should also consider using 'extra-legal' tools such as Traditional Knowledge and Biocultural labels.

Glossary

Absorptive capacity (AC) – The capacity to detect, translate, integrate, transform, and apply external information, research and practice in an organisational setting, typically associated with its level of scientific/ technical understanding.

Aronga takirua – The dual foci (western and Māori) faced by Māori scientists working in multiple roles within a research team.

Collaborative science – Science attained via collaboration or group work.

Cross-disciplinary research – Research involving two or more academic fields.

Cultural capital – Cultural intelligence and knowledge as well as the ability to apply it.

Cutting-edge research – Research that is at the forefront of a field of activity.

Desorptive capacity (DC) – The capacity to recognise chances to leverage an organisation's knowledge and distribute it to other organisations.

Downstream science – Later phases of science after experimental science that lead to the commercialisation of science.

High-tech 'stretch' science – Science seeking to build new knowledge that is innovative and difficult to achieve, where there is a risk of not being successful.

Human capacity – People skills and abilities for influencing, collaborating, and communicating.

Māori data sovereignty – Māori data governed by Māori for Māori governance.

Longitudinal research – Research on individuals or groups across multiple points in time or an extended period.

Mission-led science – Scientific endeavour seeking knowledge creation and application driven by a common purpose or mission addressing complex issues.

Open-innovation – Open innovation is the practice of organisations obtaining ideas from external sources as well as using internally-generated ideas externally.

Principal investigators (PIs) – The person responsible for leading and managing a research grant, cooperation agreement, contract, or other funded project.

Relational capacity – Skills and capability to engage with others within and across disciplines and sectors. Specifically, it refers to building and maintaining networks with industry, Māori and other scientists across disciplines.

Science innovation system – The people, institutions (including research organisations and businesses), and infrastructure engaged day-to-day in innovating, researching and connecting with each other in a wide range of activities that contribute to science and innovation.

Science sector – Organisations that carry out and support research, science and innovation.

Science-based open innovation – The activity of organisations relating to distributed innovation processes, involving purposively-managed flows of scientific knowledge across organisational boundaries.

Technical capacity – Technical expertise relating to research in science disciplines.

Transdisciplinary research – Collaborative research across disciplines, organisations and sectors that advance and integrate knowledge.

Upstream science – Early science that includes basic research, problem definition, and proof-of-concept.

Contributors

DR KATHARINA RUCKSTUHL

An Associate Professor and Associate Dean Māori at the Otago Business School, University of Otago, Dunedin. Katharina has strong connections to her tribal group of Ngāi Tahu, with whom she has governance and commercial director roles. Katharina co-leads the Building New Zealand's Capacity programme and is also a Vision Mātauranga (Māori knowledge) leader for the Science for Technological Innovation National Science Challenge. She is a Director of ORCID, an Associate Director of the Dodd-Walls Centre of Research Excellence and a member of the Indigenous caucus of the IEEE working party on Standards for Indigenous people's data. She has published in the Māori language, resource extraction in Māori territories, Māori entrepreneurship and data sovereignty.

DR URS DAELLENBACH

A Professor in Management at Te Herenga Waka – Victoria University of Wellington's Business School. Urs research interests have focussed on value creation and capture, governance and control, with specific emphasis on contexts associated with strategic decision making for R&D and innovation. His research has been published in leading journals including Research Policy, Strategic Management Journal, R&D Management, Long Range Planning, Industrial & Corporate Change, the Journal of Management Studies and Strategic Organization. With Dr Ruckstuhl, he is a co-leader of the Building New Zealand's Capacity programme in the 'Science for Technological Innovation' National Science Challenge.

DR RAFAELA COSTA CAMOES RABELLO

A Research Fellow in the Building New Zealand's Capacity Spearhead. Rafaela holds a PhD in Social Investment in the energy sector and a Master's degree in Education, awarded by the University of Otago, New Zealand. Rafael also has a degree in Psychology from Centro Universitário de Brasília, Brazil. Rafaela has worked with corporate social responsibility and education for over 10 years. Her expertise lies in corporate social responsibility and social investment, responsible innovation, design-led approaches for innovation, and higher education (good teaching and effective learning methodologies).

DR OMID ALIASGHAR

A Senior Lecturer at Auckland University of Technology. Omid is also Vice president of the Academy of International Business-Oceania Chapter. His research focuses on how firms generate and exploit novel ideas in order to gain and sustain their competitive positions in international markets. His research has been published in leading journals such as the Industrial Marketing Management Journal, Journal of Small Business Management, and International Business Review. He has also received nominations for awards, such as the finalists for the 2021 Alan M. Rugman Most Promising Scholar(s) Award at the Academy of International Business (AIB) conference.

DR MARIA AMOAMO

A Research Fellow in the School of Business at Otago University. Maria's research draws on organizational management theory to examine elements of Māori social and economic development to understand the modes of economy and innovation capability within which Māori enterprise operate. She also has research experience in cultural and indigenous tourism and in the area of social anthropology. Since 2016, Maria has contributed to the Vision Mātauranga research theme of the National Science Challenge: Building New Zealand's Capacity for Science-based Innovation.

DR LOUISA CHOE

A postdoctoral research fellow with the Building New Zealand's Capacity team (BNZIC) within the Science of Technological Innovation National Science Challenge and is currently based at the University of Otago.

KIRSTY DE JONG

A senior policy advisor at Manatū Taonga Ministry for Culture and Heritage. Kirsty worked in Innovation Policy at the Ministry for Business, Innovation and Employment after spending three years as a researcher with the BNZIC Spearhead. Her research focused on the behavioural aspects of the 40+ Seed projects and the larger Rangatahi, or youth-led Spearhead project involved in the SfTI Challenge. Before joining the Challenge, Kirsty was with The Behavioural Insights Team – a social purpose research company that advises on public policy and service delivery design using an evidenced-based understanding of human behaviour. She has a Master's in Museum and Heritage Practice with Distinction from Victoria University of Wellington and Undergraduate degrees in Marketing and Art History.

DR JARROD HAAR

A Professor in the Department of Management at Auckland University of Technology and has tribal affiliations of Ngāti Maniapoto and Ngāti Mahuta. Jarrod's research approach spans broadly across a wide range of management topics, but with a strong focus on Human Resource Management and Organizational Behaviour. Jarrod is a Fellow of the Royal Society Te Apārangi and serves on the Marsden Fund Council and convenes the Economics and Human Behaviour Marsden panel. He is also a Research Fellow of the Australia & New Zealand Academy of Management (since 2012), an Associate Fellow of the Human Resource Institute of New Zealand (HRINZ) and won the inaugural HRINZ HR Researcher of the Year Award in 2016.

MAUI HUDSON

Affiliates to the Whakatōhea tribe and is the Deputy Chair of the Whakatōhea Maori Trust Board. Maui works at the University of Waikato where he is an Associate Professor and Director of Te Kotahi Research Institute. Prof Hudson has co-authored a number of ethics guidelines including Te Ara Tika: Guidelines on Maori Research Ethics, Te Mata Ira Guidelines for Genomic Research with Maori, and the He Tangata Kei Tua Guidelines for Biobanking with Maori. He is a founding member of SING Aotearoa and Te Mana Raraunga Maori Data Sovereignty Network, helped establish the Global Indigenous Data Alliance, and co-led the development of the CARE Principles for Indigenous Data Governance.

DR WILLY-JOHN MARTIN

(NGĀTIWAI, NGĀTI WHĀTUA, NGĀPUHI AND NGĀTI TAMATERĀ)

Is dedicated to actualising Māori aspirations in science. Willy-John was previously the Manager Vision Mātauranga and Capacity Development at the Science for Technological Innovation National Science Challenge, and was founding deputy chair of Rauika Māngai. Formerly a biomedical researcher, he is a PhD Alumnus of the Malaghan Institute. In Melbourne, he established the Walter and Eliza Hall Institute's first Indigenous research initiative in its 100-year history and was a founding member of its institute-wide cultural competency programmes. He is now the inaugural Pou Pūtaiao/ Director, Māori Research, Science and Innovation at the Ministry of Business, Innovation and Employment.

DR CONOR O'KANE

An Associate Professor in Otago Business School's Department of Management. Conor researches strategy and innovation processes, particularly in the context of academic entrepreneurship and technology transfer. He teaches strategy, entrepreneurship and innovation at undergraduate, postgraduate and executive level and is Director of Otago Business School's Master of Entrepreneurship programme. His research has been published in leading international journals including Research Policy, Technovation, Long Range Planning, Industrial Marketing Management, R&D Management, the Journal of Business Research, Small Business Economics and the Journal of Technology Transfer.

DR PAULA O'KANE

A Senior Lecturer in Human Resource Management in the Department of Management at the University of Otago, Dunedin and director of the HRM major. Paula's main research interests are in work organisation, performance management and talent management. She is also an expert in qualitative research, specifically qualitative data analysis software. Paula's research has been published in leading journals such as Organisational Research Methods, Human Resource Management Journal and Studies in Higher Education. Within Science for Technological Innovation she is exploring the impact of capacity development on the Aotearoa Science System.

DR JESSE PIRINI

A Senior Lecturer and Co-Director of The Atom – Te Kahu o Te Ao Innovation Space at the Wellington School of Business and Government, Victoria University of Wellington. Jesse's research explores how researchers respond to open innovation initiatives and what capability development can support them to be successful in working with industry. Jesse also contributes to the Vision Mātauranga research theme of the National Science Challenge: Building New Zealand's Capacity for Science-base Innovation, and supports Māori economic development through his trustee role with Te Matarau a Māui.

KATIELEE RIDDLE

(RONGOWHAKAATA)

An ENRICH Scholar, Ngā Pae o te Māramatanga and SING Alumni, and admitted Barrister and Solicitor of the High Court of New Zealand. Katielee completed a Bachelor of Laws with Honours and a second major in Theatre Studies at the University of Waikato in 2020, and has since specialised in Māori Intellectual Property and Indigenous Data Sovereignty at Te Kotahi Research Institute. This has also led to her involvement within the DSI space, as well as working with the Local Contexts Hub.

DR DIANE RUWHIU

(NGĀPUHI)

An Associate Professor in the Department of Management at the Otago Business School, Associate Dean Māori of the University's Graduate School and a Commissioner on New Zealand's Productivity Commission Diane has a logistics background, having worked in the Royal New Zealand Airforce before completing a BCom, PGDip(Tourism), MCom and PhD at Otago University. She teaches critical management studies, particularly in Indigenous/Māori management and organisation. Her research interests include: Understanding the dynamics of Māori economy and enterprise and exploring the intersection of mātauranga Māori with science and innovation.

DR ROGENA STERLING

(PĀKEHĀ OF MAEATAE, STIRLINGSHIRE (SCOTLAND) DESCENT, HE IRA TANGATA/INTERSEX)

Is currently a kairangahau/research officer at Te Kotahi Research Institute and is the first open intersex person to receive a PhD in Aotearoa. Rogena has published and presented in the areas of human rights, Māori/ Indigenous data sovereignty, CARE principles, Covid-19 and social well-being, and (inter)sex issues of inclusion and equality. In addition, has taught in the areas of law and social policy. They have governance experience in various organisations and trust boards including Intersex Aotearoa, Pacific Women's Watch, and a ministerial appointment to the Winston Churchill Memorial Trust Board. They have been on human rights and intersex advisory panels and bodies for government ministries in Aotearoa New Zealand.

DR SARA WALTON

An Associate Professor in the Department of Management at the Otago Business School. Sara teaches and researches in sustainability, climate change and business at the Otago Business School, University of Otago. Sara is the director of the Master of Sustainable Business programme and Co-Director of the Otago Climate Change Network. Sara has been involved in many applied projects including leading a team of researchers on an Australian Aid funded project to Vanuatu, working with Oxfam and Women in Business in Samoa and an OceanaGold funded project to exploring land use surrounding a gold mine. Sara is currently involved with the Science for Technological Innovation science challenge, Āmiomio Aotearoa a Circular Economy for New Zealand, a team developing a Just Transitions Guide for New Zealand and a project on building industry readiness for climate change.

DR PAUL WOODFIELD

A Senior Lecturer in the International Business, Strategy, and Entrepreneurship department at AUT. Paul's research focusses on innovation and entrepreneurship and characterised by what occurs 'in-between' or 'across' disciplines, organisations, and contexts. He has particular interest in family firms, traditional industries, and the role of knowledge in innovation. Paul is on the Building New Zealand's Innovation Capacity research team in the 'Science for Technological Innovation' National Science Challenge. He holds a Master of Business Innovation and Entrepreneurship, and a PhD in Management from the University of Auckland. He also has an industry background as a consultant in the construction industry.

CONTACT US – WHAKAPĀ MAI

Katharina Ruckstuhl
Otago Business School
University of Otago
PO Box 56, DUNEDIN 9054, New Zealand
e-mail: katharina.ruckstuhl@otago.ac.nz
Phone: +64 3479 4916

Urs Daellenbach
School of Management
Victoria University of Wellington
Rutherford House, 23 Lambton Quay
WELLINGTON 6011, New Zealand
e-mail: urs.daellenbach@vuw.ac.nz
Phone: +64 4463 5732

Science for Technological Innovation
National Science Challenge
c/o SfTI Programme Office
Callaghan Innovation
PO Box 31310, Lower Hutt
WELLINGTON 5040, New Zealand

e-mail: SfTIChallenge@callaghaninnovation.govt.nz
twitter: @sftichallenge
LinkedIn: Science for Technological Innovation (SfTI)

ONLINE ISBN: 978-0-473-66462-6

National Science Challenges
SCIENCE FOR TECHNOLOGICAL INNOVATION
Kia kotahi mai – Te Ao Pūtaiao me Te Ao Hangarau