

New Zealand Science Review

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Cover: The cover design depicts symbols of the environment, from the sea, to the land and the sky. The puhoro flowing through with mangopare and koru represent people working together for understanding and learning of mātauranga science. The manaia faces represent some of the Māori atua as guardians over the environments. The mountain top of knowledge is shown with a small mountain behind it, representing a better understanding for the next generation. Symbols of wood grain, fish scales, rocks represent the testing done for better understanding and protection for the samples and the environments.

Artist: Keanu Townsend (Keanu Arts) a Ngāti Whātua artist raised in the Tauranga and Kaipara regions. His designs, Ta Moko, and painting work can be found across Aotearoa and he has a passion for all Maori arts.

Instructions to Authors

New Zealand Science Review provides a forum for the discussion of science policy. It also covers science education, science planning, and freedom of information. It is aimed at scientists, decision makers, and the interested public. Readability and absence of jargon are essential.

Manuscripts on the above topics are welcome, and should be emailed to the editor (editor@scientists.org.nz).

As well as full papers, short contributions, reports on new developments and conferences, and reviews of books, all in the general areas of interest detailed above, are invited. The journal may also accept reviews of a general nature and research reports.

Full manuscripts (with author's name removed) will be sent for peer review, and authors will be sent copies of the reviewer's comments and a decision on publication. Manuscripts should not normally have appeared in print elsewhere, but already published results discussed in the different, special context of the journal will be considered.

Manuscripts should be accompanied by biographies of not more than 100 words on each author's personal history and current interests. Authors are also expected to supply a suitable

high-definition passport-size photograph of themselves. This will be published with the article.

Articles may be submitted in MS Office Word, rich text format, or plain text. Diagrams and photographs should be on separate files (preferably eps, tif, jpg, at 300 dpi), not embedded in the text.

All tables and illustrations should be numbered separately – Tables 1, 2, 3, 4, etc., and Figures 1, 2, 3, 4, etc. – and be referred to in the text. Footnotes should be eliminated as far as possible. Diagrams and photographs will be printed in black and white, so symbols should be readily distinguishable without colour, and hatching should be used rather than block shading. However, colour may be used if the author or the author's institute is willing to pay for the added cost.

References should preferably be cited by the author–date (Harvard) system as described in the Lincoln University Press *Write Edit Print: Style Manual for Aotearoa New Zealand* (1997), which is also used as the standard for other editorial conventions. This system entails citing each author's surname and the year of publication in the text and an alphabetical listing of all authors cited at the end. Alternative systems may be acceptable provided that they are used accurately and consistently.

Foreword

Juliet Gerrard¹ and Tahu Kukutai²

It is our great pleasure to write the foreword to this special issue of *New Zealand Science Review*, which is the first of two dedicated to *Mātauranga and Science in Practice*. These landmark publications provide a timely contribution to ongoing dialogue about what a distinctively Aotearoa New Zealand science system should look like, informed by the research and experiences of those working at the nexus of mātauranga and science. There is much to learn from them.

Like many other countries, Aotearoa New Zealand is confronted with enormous environmental, societal and technological challenges that require our scientists and researchers to go beyond the ordinary. Māori are often at the pointy end of these challenges but are unlikely to be in positions of power to define and drive responses. This needs to change. We need multiple ways of thinking, knowledge systems and approaches to understand and respond to complex challenges including climate change, food insecurity, biosecurity, health inequities, poverty, and the disruptive impacts of digitalisation. This means investing in our comparative advantages, making the most of the opportunities that they present, and enabling communities to contribute to solutions.

The interface of science and Indigenous knowledge is an obvious area where Aotearoa New Zealand is genuinely unrivalled. Mātauranga Māori – defined as Māori knowledge, Māori methods of knowledge creation, and Māori ways of knowing (Mercier & Jackson, this issue) – is the Indigenous knowledge system of this land. Mātauranga has survived and evolved as a dynamic and generative knowledge system despite extensive efforts to expunge it through legal, social and political means (Simon & Smith 2001; Smith 1999; Ward 1995). The vision, crystallised in this issue, is for mātauranga to flourish again and to create collective benefit in ways that are context-appropriate and acceptable to Māori.

We have solid foundations on which to build. The significance of mātauranga in the Aotearoa New Zealand science system, including through the Vision Mātauranga policy (Ministry of Business, Innovation and Employment 2018), has few parallels in other countries. Thanks largely to the incredible commitment of Māori leaders, there are significant cohorts of Māori PhDs and sufficient Māori Principal Investigators to ‘fill an Air New Zealand Airbus A320’ compared to a telephone box 20 years ago (Ruru *et al.*, this issue). The achievements of Ngā Pae o te Māramatanga in this regard is stellar, with hundreds of Māori PhD graduates emerging from this Centre of Research Excellence. Increasingly, Māori researchers operate comfortably in two or more knowledge systems and are adept at interfacing mātauranga with diverse disciplinary knowledge. Working across knowl-

edge systems requires an intellectual flexibility that provides a space for innovative thinking to ‘expand the intellectual scope of our nation’ (Walker 2005). The papers in this issue that describe efforts to build capacity and capability are inspiring, emphasising the focus on ensuring veracity and rigour as part of teaching practice. It is a pleasure to see the mātauranga-science interface blossom with a focus on the future. The Prime Minister is personally supportive of this kaupapa and is supporting two internships to undertake a future-focused project centred on Te Tairāwhiti (<https://www.pmcasa.ac.nz/2019/10/08/we-are-excited-to-announce-two-new-internships-to-complete-a-tairawhiti-centred-project/>).

However, as this issue reminds us, there is still much to do. One of the barriers is an inadequate understanding of mātauranga within the broader science community. The question of whether there is such a thing as ‘Māori science’ pops up from time to time and the ensuing debate is often less than constructive. The measured account of this debate from Georgina Tuari Stewart and her answer: ‘there is no right or wrong answer to the question of Māori science and the question can never, therefore, be considered fully settled’ is both insightful and challenging. It challenges readers to be comfortable with incommensurability, provides a useful way of coming to that conclusion and inspires exploration of the interface of orthogonal knowledge systems. Here it is instructive to reflect on Tā/Sir Mason Durie’s (2005) observation that, just as Indigenous knowledge cannot be verified by scientific criteria, nor can science be adequately assessed according to the tenets of Indigenous knowledge. Rather, ‘Each is built on distinctive philosophies, methodologies and criteria’. Contests about the validities of the two systems distract from ‘explorations of the interface’, and the ‘subsequent opportunities for creating new knowledge that reflects the dual persuasions’ (p. 2).

Tuari Stewart’s paper underscores the inherent power imbalance between mātauranga and science, and the wrongheaded sentiment that one has to claim features of the other in order to gain legitimacy and resource. It also cautions against a reductionist approach that would view mātauranga solely as an ‘input’ into science solutions, or as supplementary to ‘real’ scientific knowledge (Broughton & McBreen 2015), which detracts from the opportunities that solving problems using dual knowledge systems might provide.

This issue also shows how much science has to learn from mātauranga and kaupapa Māori approaches. The latter approach of embedding practice in society and grounding the project in a community of acceptance before it starts, is the very model of ensuring impact and connectivity. Often those trained in Western traditions, however fine, struggle to grasp this until it is perhaps too late. How many technologies will be developed in isolation before we learn that we need to engage our publics sooner, not later, to make sure there is cultural license to proceed? To turn the tide on anti-science sentiment we need to reframe our science as ‘here to serve’, and ‘here to listen’. Science in Aotearoa

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New Zealand, and indeed the world, has much to learn from Māori ways of doing, as well as ways of knowing, to bridge these divides. The Hepburn paper describes this beautifully in their comparison of scientific process and community-led decisions. And this blurring of benefit, participation and knowledge is eloquently described in Ruckstuhl and Marti's piece. Those trained in Western traditions might dismantle this way of working as not 'pure', hypothesis-driven science, but this unpicking presents no advantage for understanding and harnessing a knowledge system that was not designed as such, and has no desire to meet this particular abstract (and yes, undeniably powerful in other contexts) ideal. Why not see what advantages it might bring to the practice of using knowledge to make te ao hurihuri better for all? Why not complement science's great reductionist strength with more holistic thinking, and see what we find at the interfaces? In short, scientists may get further by stepping off their self-appointed pedestal and listening to other views and other ways of knowing in order to retain and regain societies' trust. In so doing, let's make the most of our excellence in 'arguably one of the newest research fields on the block, albeit with ancient veins' (Smith 2018, p. 22).

Finally, we wish to thank the Editors, Ocean Mercier and Anne-Marie Jackson, for the opportunity to reflect on this special issue. As remarkable wāhine Māori working at the mātauranga-science interface, both have worked tirelessly to uphold the mana of mātauranga in a system that has often been less than welcoming. This impressive collection of papers is a testament those efforts.

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Mātauranga and Science – Introduction

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Mātauranga Māori is not like an archive of information but rather is like a tool for thinking, organising information, considering the ethics of knowledge, the appropriateness of it all and informing us about our world and our place in it. (Mead 2003, p. 306)

Māori have become a pivotal force in New Zealand's science system, with the torsion of tikanga Māori inviting the system to open its doors to indigenous values. Increasingly mātauranga Māori – encompassing Māori knowledge, Māori methods of knowledge creation and Māori ways of knowing – is being consulted, aligned with or brought into conversation with science. As the guest editors for *Mātauranga and Science in Practice*, we wanted a space in which people who are engaged at these interfaces could share their experiences of working with mātauranga alongside New Zealand science, bound as it is by inherited norms, practices, institutional traditions, and various Crown policies. The audience for this conversation includes tohunga, philosophers, scientists, kaumātua, researchers, academics, kaiako, communities, public servants, kaimahi, students and anyone else who is interested in science, more broadly, and the unique contribution that an Aotearoa New Zealand science could make to the world.

Public science policies – particularly Vision Mātauranga – present an expectation to researchers and educators that their practice will engage with mātauranga Māori. The research, curriculum and project design that has emerged from this is ground-breaking and world-leading, but may go unremarked, and may have occurred by accident, or trial and

error as much as by design. For what purpose is this work done, and what are the outcomes? What are the opportunities and challenges of this work? How are science research projects formulated alongside mātauranga, in practice? Mason Durie (2005) spoke of certain values that ought to drive practice at the interface: are these being realised? Are there genuinely mutual benefits of this work? What capabilities are needed in relationship building (or reframing), understanding other ways of knowing and bridging knowledge systems? This special issue foregrounds the experiences of Māori scientists, researchers and educators, presenting them alongside their Pākehā and tauwiwi allies. We present a variety of cases that span institutions, disciplines and domains. We invited submissions on a variety of themes, suggesting that prospective authors consider Vision Mātauranga and other policies, Treaty principles, institutional policy and practice, pūtaiao (science) and mātauranga in Western institutional settings, Indigenous knowledge or traditional ecological knowledge, science-mātauranga interfaces in educational, policy and research settings, and how mātauranga and science produce innovation.

We are delighted that Prof. Juliet Gerrard, as Chief Science Advisor to the Prime Minister, and Prof. Tahu Kukutai, member of the Advisors' Forum, have co-written a foreword for this issue. Gerrard is known for tackling the plastics problem, but she has also shown leadership in prioritising the contribution of mātauranga to science, shaping a more diverse science system and transforming our ideas about who is (and thus can be) a scientist. Kukutai is known for her ground-breaking demographic research with communities and long experience in working at epistemological interfaces. These two wahine toa model productive conversation between mātauranga and science.

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Anne-Marie Jackson (Ngāti Whātua, Ngāti Kahu o Whangaroa, Ngāpuhi, Ngāti Wai) is a Senior Lecturer at the School of Physical Education, Sport & Exercise Sciences, Te Koronga, Te Tiaki Mahinga Kai, University of Otago. She has a doctorate in Māori studies and physical education, examining rangatiratanga and Māori health and well-being within a customary fisheries context. Her research focuses on the examination of Māori conceptualisations of physical education and health, rangatiratanga and the right to self-determination, the role of the Tiriti o Waitangi for Māori health and Māori approaches to research.



We received many submissions and have split the contributions across two issues. In this, Special Issue I, we present five articles on varied topics. The triple project of: building Māori capability in science; building non-Māori capability in tikanga, kaupapa Māori and mātauranga; and reshaping policy and institutional systems is evident in all of these contributions.

Is there such a thing as Māori science? Can mātauranga Māori be considered a science? These questions have long been debated, polarising opinions on either side. In *Mātauranga and Pūtaiao: the 'Māori science' debate in education*, Georgina Stewart gathers the key arguments on both sides and takes a fresh and clear-eyed look at them. She acknowledges that the question can probably never be resolved, questioning whether it necessarily needs to be. She considers the impact of the political, philosophical and epistemological aspects of the debate in relation to policy, education and public science. School teachers and students encounter these tensions quite early, through Pūtaiao, the Māori language science curriculum. The Māori science debate remains a critical question in the development of rangatahi capability in and across dual knowledge systems, and may be crucial in their decision to continue on as scientists. Engagement in this 'provocation and opportunity for learning' is critical to understanding the broader political, philosophical and epistemological tensions that Māori in New Zealand science must navigate.

Anne-Marie Jackson leads a host of authors engaged in leading or steering Te Koronga, a Māori research excellence mission based at the University of Otago. In their 'thoughtful and constructive' contribution *Towards Building an Indigenous Science Tertiary Curriculum*, they present their experience of building curriculum and capacity in science at Otago University as a case for seeding and growing Indigenous sciences within tertiary institutions more broadly. With a clear goal to lift Māori academic staff numbers at Otago University from 3% to 15% (population parity), their work is a response to the rising crescendo of calls (see McAllister *et al.* 2019; Naepi 2019) for universities, Tertiary Education Commission and associated bodies, to urgently address the dire paucity of Māori and Pasifika academic staff. This submission is presented as a 2-parter, with Part II to appear in Issue II of NZSR's *Mātauranga and Science in Practice*.

In *Whāia ngā pae o te māramatanga: our horizons of pursuit*, we hear from past and present directors of Ngā Pae o te Māramatanga (NPM), New Zealand's Māori Centre of Research Excellence. Jacinta Ruru, Linda Waimarie Nikora, Tracey McIntosh, Tahu Kukutai and Daniel Patrick consider how NPM has, over its 17 year history, built Māori capability and leadership in research, and addressed key challenges and opportunities at the interface between mātauranga and science. As a Māori-led nationwide institution, NPM has built wide networks, providing opportunities for trans-institutional and trans-disciplinary Māori research that produce positive outcomes for communities, as well as ameliorating some of the institutional hostility that Māori researchers experience. A spotlight is thrown on some of their key Māori researchers who credit NPM with making their careers. Indeed, NPM has supported the growth of

Māori research capacity to the point that NPM researchers are now bidding for their own Centres of Research Excellence. It is hard to argue that NPM has been anything but a transformative force in not just research, but positive societal change.

We turn the spotlight onto the educational and development needs of scientists next. Chris Hepburn and co-authors seek to better prepare science students for career work in context, alongside and with Māori communities, for example. Key to this is developing students' ethical, social, environmental and cultural capabilities. In *Teaching the next generation of scientists to support communities in their restoration of ecosystems and ways of life*, they discuss a University of Otago 'Field Methods' course, a collaborative endeavour that connects science students with the community at Kāti Huirapa ki Puketeraki, supporting customary fisheries management in a way that provides mutual benefits for all involved.

Finally, in *The high-tech interface*, William John Martin and Katharina Ruckstuhl discuss their involvement in one of the National Science Challenges as Kāhui Māori members. While there are few Māori with science and technological capacity as researchers in their theme, Science for Technological Innovation, Māori are nonetheless involved in contributing and building human relational capacity. Their Te Tihi o te Maunga model is a 3-dimensional guide to mapping projects within the Challenge, identifying strengths within these projects in relation to Māori knowledge, participation and benefit, and identify gaps across the sector. It is a model that could be used to assess Māori or Indigenous participation and benefit within any system.

Special Issue II will be released shortly. Papers in that issue will continue discussing mātauranga in educational and research contexts. The collective experience gathered here forms a resource that helps us all to better understand how this work can advance Aotearoa New Zealand's public knowledge ecosystem.

**Ngā mihi ki a koutou katoa
Ocean and Anne-Marie**

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Mātauranga and Pūtaiao: the question of 'Māori science'

Georgina Tuari Stewart*

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Abstracts

Ka hoki atu te pepa nei ki te tohe mō te 'Pūtaiao Māori': ko tētahi taha e kī ana ko te Mātauranga Māori tētahi momo pūtaiao taketake nei nō mua mai; ko tērā atu taha e whakahē ana i taua kerēme. Ko ngā taha e rua e kaha whakapono ana ki ā rāua ake tohe, e kaupare ana hoki i ā tērā atu taha. Ki ētahi mātanga, ehara tēnei tohe i te wānanga noa iho nei, ko tētahi tauira ko ngā kaiako pūtaiao o ngā kura e pēhia nei e te haepapa kia eke ā rātau tauira Māori, e mahi nei hoki i raro i ngā kaupapa here o te ao mātauranga kua whakaaweawetia e te whakaaro kia pōwhiritia tēnei mea te ahureatanga ki ngā wāhanga katoa o te marautanga ā-kura.

This paper revisits the 'Māori science' debate: on one side, the claim that Mātauranga Māori is a traditional indigenous Māori form of science; on the other, the denial of such a claim. Both sides strongly believe in their arguments and reject those of the other side. This debate is more than simply academic for some practitioners, for example, school science teachers, who are increasingly held responsible for the achievement of their Māori students, and who are working under education policies influenced by ideas of including cultural content in all areas of the school curriculum.

Introduction: researching the 'Māori science' question

This article revisits the simple question: is there such a thing as Māori science? This question is phrased in simple terms to enable me to undertake a philosophical inquiry of maximum clarity. It is important to note that this is a theoretical question, while remaining cognisant of its underlying significance to conversations in national science funding. But the situation 'on the ground' is far, far more complex than can be captured in this 'pure' question stated in bald terms, as simply as possible. This article draws on my 25+ years of experience in Pūtaiao, which suggest there is no right or wrong answer to the question of 'Māori science'; the question can never, therefore, be considered finally settled. The aim of this article is to provide a balanced synopsis of the arguments for and against the concept of 'Māori science' in hopes of making a useful contribution to the current discussions.

One answer to the question of 'Māori science' is that yes, mātauranga Māori is a traditional indigenous form of science

from Aotearoa (Peters 1993); the other answer is a firm no (Nola & Irzik 2005). Many who deny the concept of 'Māori science' regard it as nonsense, and part of the growth to dangerous levels of 'anti-science' attitudes in society (a clear statement of this position was made in Matthews 1995). Supporters of both answers seem sure of their grounds, not realising it is not a question that can be answered with scientific certainty. This apparently simple question of whether or not 'Māori science' exists is actually extremely complex and invokes considerations at many levels, from epistemology to politics. Claims have been made on both sides that the opposition's views are blinded by politics or privilege. This debate is one specific instance of a larger philosophical debate between universalism and relativism (Herrnstein Smith 2005; Putnam 2004). But the 'Māori science' debate is not only academic: it can have real effects in the work of school science teachers, for example, who are increasingly held personally responsible for the achievement of their Māori students under current policies (Ministry of Education 2011). Similar policies are also being taken up for tertiary-level science teaching. The aim of this article is to delineate the reasoning used to defend the two answers or positions, and in the process clarify the nature of 'Māori science' and the applicability of this concept.

This research aligns with Kaupapa Māori principles (Smith 2012) and post-qualitative approaches to inquiry (St. Pierre 2018). For example, I include insights from my experience as a teacher and developer of Pūtaiao in schools – an auto-turn positioning me as an insider-researcher, a position supported by the principles of Kaupapa Māori research methodology especially in its philosophical and ethical aspects (further discussed in Stewart 2017a). This article draws on previously-published research on Māori science education, but covers more territory than extensive literature reviews would allow.

In 1993, when I started teaching intermediate and secondary Pūtaiao (the Māori word for 'science' – capitalised when referring to the Māori-medium school subject) I was devising the curriculum and accompanying lexicon as I went: te reo Māori was the primary language of the classroom, but I had to plan all the content: topics, texts and activities, and above all an underpinning model of the subject that made sense both in Māori terms and in science terms. At the time there was no curriculum or resources – all

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that happened later. I have written about these experiences elsewhere (Stewart 2010, 2011a).

I began from the traditional accounts of Rangi and Papa (Father Sky and Mother Earth) and their many godly children, including Tāne (god of the forest), Tangaroa (god of the oceans), Tāwhirimātea (god of winds) etc., who act as guardians and metaphors for knowledge of the different elements and domains of the natural world. Since Māori knowledge includes 'the gods' or knowledge of spiritual realms, while science does not, I drew a diagram in which mātauranga Māori (Māori knowledge) is a large circle, and science is a smaller circle inside it. This differs from the more typical 'Venn diagram' model with two intersecting circles used to show the overlap between science and Māori knowledge (Roberts 1998; Simon 2003). The benefit of my 'superset' model of the relationship between science and mātauranga Māori is that it makes all of science, not only in some domains such as ecology, relevant to Māori and Māori school students.

The question of whether or not Māori knowledge is a science became important in planning to teach Pūtaiao, but Māori science education is one of the few scenarios when the question of 'Māori science' arises outside the academy (McKinley *et al.* 1992). The question of 'Māori science' has traditionally been of little relevance as perceived by the scientists themselves. In this sense, the 'Māori science' debate is notable for the disjunction between its large theoretical heft and its tiny base of practical and perceived importance.

The next section summarises and considers both sides of the binary question, is there such a thing as 'Māori science'? The third section briefly sketches the relevance of this debate to current policy debates in science education and public science funding, and the conclusion considers the larger educational potential of the 'Māori science' debate.

Reviewing the question of 'Māori science'

Any discussion about whether or not 'Māori science' exists faces the prior difficulty of succinctly but adequately defining science. Much literature on multicultural science education, including the majority of papers on the 'Māori science' question, falls into the trap created by this difficulty. The 'Māori science' debate (and, more generally, the 'multicultural science' debate (Hines 2003) encompasses complex questions in philosophy, science, culture, identity, technology and politics, so it is hardly surprising that much of the published commentary is flawed and falls apart on closer examination. Standard disciplinary philosophy of science would say, for example, that reason 1 listed below is about technology, not science, and that reason 2 is based on an inadequate concept of science as 'nature study'. Nevertheless both reasons have some merit, and are often rehearsed as arguments in favour of the concept of 'Māori science'.

The case for 'Māori science'

These lists, distilled from my years of research into Pūtaiao, summarise the main reasons for and against the proposition that mātauranga Māori counts as science:

1. Traditional knowledge enabled Māori ancestors to live and flourish in harmony with the natural world in Aotearoa, employing sustainable technologies such as kūmara pits and harakeke (flax) fishing nets and lines.
2. Many items of traditional Māori knowledge are based on accurate, detailed observations of macroscopic natural phenomena (plants, animals, astronomical patterns, etc.), capable of generating data of scientific validity and interest.
3. The cosmogenic Māori nature narratives work together as an overarching paradigm of knowledge, replacing in that role the science framework of theories and commitments that underpins the modern/Western worldview (Roberts *et al.* 2004).
4. Māori knowledge is not necessarily restricted to the three-dimensional reality of the laws of physics, and therefore may have access to wisdom that Western science has disallowed within its canon.
5. The original meaning of the word 'science' comes from the Latin word meaning 'knowledge' so on grounds of epistemic fairness, mātauranga Māori deserves to be recognised as valid knowledge, i.e. as a form of science, in its own right.
6. Mātauranga Māori can also be understood as a critical Māori viewpoint on science and its applications in society in Aotearoa-New Zealand – for example, as a Māori critique of scientific racism and justifications for colonising damage done to Māori people, culture and environments.
7. Mātauranga Māori sometimes seems to know more than science about very complex phenomena, such as the essential nature of a human being, or the mysteries of reality: mātauranga Māori has values and metaphors that can provide fresh views on epistemology, or philosophical questions of knowledge.

The case against 'Māori science'

1. The laws of science apply equally at all times, in all places, to all human beings; in other words, science is based on universalism (or universalist philosophical commitments).
2. Resulting from the above point, science is an acultural (or trans-cultural) form of knowledge, so to place a cultural modifier (such as 'Māori') before the word science is incoherent i.e. makes no sense.
3. Science knowledge is based on empirical experimentation and testing using well-established methodological norms (the 'scientific method') i.e. science tests itself against empirical reality.
4. Science knowledge has well-defined criteria and a vast archive of experience that ensure it adheres to the highest epistemic standards and is the 'best' possible knowledge about reality available to humans.
5. Science knowledge is subject to ongoing revision as empirical knowledge advances; in other words science is 'fallible knowledge' that changes over time in ways that orthodoxy or faith-based knowledge does not.
6. Scientific research is subject to the scrutiny of a community of peers, and this community ultimately decides the current status of scientific knowledge on any topic.
7. Science enabled the rapid advances in human knowledge and its applications that characterised the post-Enlightenment rise of modern European culture

across all facets of human endeavour, to a previously unprecedented size, level of sophistication, and global dominance.

Is there such a thing as 'Māori science'?

The problems with the first two reasons for 'Māori science' have already been noted above. Reasons 3 and 4 are less common but are sometimes presented as arguments in favour of 'Māori science' (Roberts *et al.* 2004), though most scientists reject these two claims because any system of knowledge that does not adhere to the key science theories and philosophical commitments is, by definition, not science. Reasons 5, 6 and 7 in favour of the concept of 'Māori science' are more complex. Regarding reason 5, to argue that 'Māori knowledge' is a science by definition changes the meaning of 'science' so begs the answer "it depends on what is meant by the word 'science'". If **any** recognisable form of knowledge is 'a science', then yes, so is Māori knowledge or mātauranga Māori. In addition, in the anthropological sense of a body of natural knowledge fit to cross oceans and sustain the life of an identifiable human culture, perhaps Māori knowledge does deserve to be considered a 'science'.

Reason 6 gets entangled with nationalistic myths, promulgated in a deliberate philosophical attack on Māori knowledge (Jackson 1992) and embedded in scientific knowledge as 'the truth' about Māori and about the national history of the country. As part of the dominant story of the nation told in the media and school curriculum, these myths feed the imaginary of national identity: of what it means to be from Aotearoa-New Zealand. There is no reason to think scientists should be any more immune than the general public to these subtle curricula of colonisation (Stewart & Bunting 2015). Their lack of recognition that renders them invisible also renders them powerful – this is the power of discourse: discourse as power (Foucault), and the absent presence (Derrida).

The short answer to the question of whether there is such a thing as 'Māori science' is therefore 'it depends'. It depends on what is meant by 'science' and it depends on the purpose for asking the question. It is not an unqualified yes: it is **not** the case, for example, that there is a base of traditional Māori knowledge that can replace the standard school science curriculum – or at least, not with the same outcomes that mean 'success' in the current system. The idea that scientific data can be swapped for oral texts and so forth is clearly ridiculous. Argument 7 for Māori knowledge works better as an argument in favour of 'Māori philosophy' rather than 'Māori science'. All knowledge including science is based on a philosophy of knowledge, but the two words, 'science' and 'philosophy' have different meanings, so the concept of 'Māori philosophy' does not imply that there must be 'Māori science' apart from in the restricted senses noted above.

The criteria of science and laws of nature may be universal, but there is a very large gap between epistemic ideals and the way science plays out in society. As a human product, science is subject to human failings and weaknesses, including the influences of non-scientific ideas such as sexist or racist ideas. For example, the colonisation of Aotearoa was carried out under the banner of a now outdated form of science, which included ideas such as the 'Family of Man'

in which Māori people were considered 'less evolved' and hence biologically inferior to British (White) people (McKinley 2003). Darwin's then-new theory of evolution was famously mis-applied to humans to argue that Māori as the 'inferior race' would naturally die out (Stenhouse, 1999; Te Ara - The Encyclopedia of New Zealand, 2018).

The term 'Māori science' can be used with irony to critique the term 'Western science' that is itself necessitated by well-intentioned but illogical terms such as 'Indigenous science' (and its cognates including 'Māori science'). The unmarked word 'science' means or implies 'Western science' and terms such as 'Māori science' are provocations of this unmarked meaning and its implications. Clearly it is equally as facetious to speak of 'Western science' as it is of 'Māori science'. This terminological comparison highlights the fact that science is, essentially, a Western form of knowledge. Here I capitalise Western to highlight that it is a cultural term; local in the same sense as 'Māori', not universal – in other words, I use a capital letter for Western to **demote** the concept from the universal (normalised, i.e. uncapitalized), to point out its majoritarianism.

Reasons 3, 4, 5 and 6 against 'Māori science' are more a matter of degree than of kind, and do not provide robust grounds for arguing that science is completely different from Māori knowledge. The argument about 'scientific method' is outdated: a relic still found mainly in school textbooks. Reason 7 about the power of science and its applications is undeniably true, but heavily loaded, since it is now impossible to read such a statement without awareness of the catastrophe about to engulf humanity that has grown like a cancer from that power, made possible by what is described as Western philosophical blindness (Peters & Mika 2018) in which science has become enslaved to wealth.

Policy implications for science education and public science

The question of 'Māori science' is a political football in which the uninformed nature of debate tends to entrench rather than overcome oppositional attitudes on either side. The implications for science education continue to grow in urgency, as classroom teachers are being held increasingly responsible for Māori student achievement, and education policy seems trapped in the unproven belief that 'adding Māori knowledge' to the curriculum is the answer to long-standing Māori lack of achievement, which is particularly severe in science (Stewart 2017b). These pressures add to a growing base of support, even among English-medium schools and teachers, for the dubious value of translating science into te reo Māori. Science translated into te reo Māori has become synonymous with 'Pūtaiao' at the expense of any notion of 'Māori science' as a different form of knowledge, with a different philosophical basis (Stewart 2011a, 2011b). Reduction of Pūtaiao to 'science in Māori-only' supports a call for Māori philosophy (Stewart 2014).

Public science funding is the second main 'site' or real-world context of the 'Māori science' debate, dating back to a major report in the mid-1990s on the interface between science and mātauranga Māori, as part of the re-structuring of public science management and funding. In retrospect, the neoliberal reform process stimulated a round of academic debate on the question of 'Māori science' (Dickison 1994; Lomax 1996). I read these papers as part of the writing group

for the first Pūtaiao curriculum document. Since 2005, the Vision Mātauranga policy (Ministry of Business Innovation & Employment 2018) has guided inclusion of Māori knowledge in research, but scientists still seem unsure about how it applies to their work (Royal Society Te Apārangi, 2018). There is a current discussion about including Māori knowledge in university research and teaching, which is still ongoing. More detailed discussion of Māori knowledge in publically-funded science research is beyond the scope of this article, but the point is that Vision Mātauranga and the Pūtaiao curriculum are two policies that represent real-world sites where the question of 'Māori science' is particularly relevant.

Conclusion: the educational value of the 'Māori science' debate

The question of 'Māori science' is more of a nexus of semantic, philosophical and political arguments, rather than a simple yes-or-no question. Whether Māori knowledge 'counts' as science is more of a provocation than a research question to be answered; it has no simple or 'correct' answer, as the 'right' answer depends on what is meant by 'science', and the purpose of the question.

The debate about Māori science, in other words, is a specialised form of the wider debate about the nature of science (Chalmers 2013). Understood as more of a *political* than an *epistemic knowledge* claim, the concept of 'Māori science' is also a post-colonial critique of science (McKinley 2001), which can also be called 'Kaupapa Māori science' (Stewart 2010): a concept intended to sharpen rather than usurp ideas about the accepted foundations and canons of science knowledge, while remaining critically aware of science's past and current enslavement to naked power, in the form of money and social privilege.

Perhaps the best way to regard 'Māori science' is as a conundrum: the two words juxtaposed in the term represent incommensurable forms of knowledge. This disjunction creates a nexus of conflicting ideas, which acts as a provocation and an opportunity for learning, of particular importance to the self-knowledge of science and research in the national academy of Aotearoa-New Zealand. Although this article is not based in the contemporary empirical milieu, it is motivated by the danger in rushing to a final and definitive answer on whether or not Māori knowledge is a science, which could altogether miss the educational opportunity and gift presented by the provocative concept of 'Māori science'.

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Towards building an Indigenous Science Tertiary Curriculum

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Te Koronga

Te Koronga logo designed by Mr Keanu Townsend (Ngāti Whātua, Ngāpuhi, Ngāti Kahu o Whangaroa, Ngāti Wai).

Abstracts

Ko te Koronga tētahi kaupapa mō te rangahau Māori kōunga nei, e tū nei i Te Whare Wānanga o Ōtākou (<https://www.otago.ac.nz/te-koronga/index.html>). E rua ōna wāhanga: ko te Graduate Research Excellence tētahi, ko te Indigenous Science Research Theme tērā atu. I Aotearoa nei, e ai tonu i te Whare Wānanga o Ōtākou, he āputa nui e tohu nei me whakatipu ō te Māori pūkenga, ōna āheinga hoki, ā-rangahau nei, ki ngā pūtaiao. He tauira, i Ōtākou ko tōna 3% o ngā pouako katoa i te Division of Sciences he Māori, ka mutu, ehara i te mea ka rangahau ngā pouako Māori katoa i ngā take whakawhanake Māori. Mō Te Koronga, ko tō mātou whāinga matua ā-rautaki ko te whakatipu i te tokomaha o ngā pouako Māori e hāngai ai ki te taupori, me te aro kehoheho pū ki te whakapakarihia o te mātauranga me te pūkenga Māori. E tutuki ai ngā whāinga e pā ana ki te whakawhanakehanga Māori i tā Te Whare Wānanga o Ōtākou Māori Strategic Framework 2022 (MSF), ngā whāinga ā-kaupapa here o te motu, ka mutu ko ngā whāinga o te hāpori Māori anō hoki, kua whakatauria e Te Koronga kia whakatipu i te hunga pouako Māori kia hāngai ki te taupori (ko tōna 15%), kia whakapakari hoki i te mātauranga me te pūkenga Māori i ngā pūtaiao. E whakatinanahia ai ēnei whāinga, e rua ngā rautaki e horaina nei: ko te waihanga mai i tētahi kaupapa matua hou mō te pūtaiao taketake, mō te mauri ora rānei, nō roto mai i te Division of Sciences ka tahi, me te whakawātea mai i ētahi tūranga mahi mauroa mō te pouako Māori ka rua. Ka aro pū tēnei tuhinga ki te rautaki tuatahi. Ko tēnei kaupapa matua hou mō te pūtaiao taketake: ka whakangungu i ngā atamai, Māori mai, Pākehā mai hoki, ki ngā rohenga o te ('ngā' rānei) pūtaiao taketake; ka whakapakari i ngā āheinga ā-pouako puta noa i ngā momo akoranga mā roto mai i te waihangaia o tētahi wāhi ake hou

mō te whakaako i te pūtaiao taketake/mauri ora; ka waihanga i tētahi marautanga hou kaupapa Māori nei, ka aro tonu hoki ki ngā 'ōritehanga' o te mātauranga taketake me te whakaaro Pākehā; ka takoha atu ki ō te hāpori Māori hiahia, ki ōna wawata hoki mō ngā pūtaiao e whirinaki nei ki ngā hoahoatanga Māori o nāianei, ki ngā āheinga hou hoki ka puta, ka whakatutuki anō hoki i tā Te Hikina Whakatutuki rautaki ko Vision Mātauranga Policy, Diversity in Science, me ō Te Whare Wānanga o Ōtākou whāinga i te Māori Strategic Framework.

Koinei te tuhinga tuatahi o ngā mea e rua nā ngā kaituhi: ka kōrero tēnei tuhinga o te Special Issue tuatahi i te take tonu o tētahi wāhi whakaako mō te pūtaiao taketake/mauri ora. Ko tōna hoa haere ka tāngia ki te Special Issue tuarua, ka aro pū tonu ki tētahi mehanga i Ōtākou, ki te hanganga mai o tētahi marautanga pūtaiao taketake, ki ngā momo whakaakohanga o te marautanga anō hoki kua whakatakotoria.

Te Koronga is a Māori research excellence kaupapa (mission) based at the University of Otago (<https://www.otago.ac.nz/te-koronga/index.html>). It is composed of two parts: Graduate Research Excellence and the Indigenous Science Research Theme. In New Zealand, there is a significant need to grow Māori research capability and capacity in sciences and particularly at the University of Otago. For example, at Otago approximately 3% of all academic staff in the Division of Sciences are Māori and not all Māori staff necessarily research on Māori development issues. For Te Koronga, our top strategic priority is to grow Māori academic staff numbers to population parity with a clear focus on building Māori expertise and capability. In order to meet the objectives related to Māori development for the University of Otago Māori Strategic Framework 2022 (MSF), as well as national policy goals, and importantly Māori community aspirations, Te Koronga have set an aim to increase Māori academic staff numbers to population parity (approximately 15%) and to increase Māori academic expertise and capability in sciences. To realise these aims, two strategies are offered: firstly, to create a new indigenous sciences or mauri ora (flourishing wellness) major within the Division of Sciences and secondly to create Māori academic tenure track positions. This paper will focus on the first strategy. A new major in indigenous science will: train Māori and non-Māori scholars in the fields of indigenous science(s); build staff capacity across the disciplines through creating a new dedicated teaching area of indigenous sciences/mauri ora; create new curriculum that is kaupapa Māori-led as well as at the 'interface' of indigenous scholarship and Western ways of thinking; contribute towards Māori community needs and aspirations in sciences that build on current Māori networks as well as new opportunities that emerge and will address Ministry of Business, Innovation and Employment's Vision Mātauranga Policy, Diversity in Science strategy and Otago University's Māori Strategic Framework goals.

This is the first of two papers by the authors: this paper in the first Special Issue will address the rationale for an indigenous sciences/mauri ora teaching area. Its companion paper will be published in the second Special Issue and will focus on an Otago-based solution of creating an indigenous science curriculum as well as proposed pedagogies for the curriculum.

Introduction

Te Koronga is a Māori research excellence kaupapa based at the University of Otago. Te Koronga is composed of: Te Koronga Indigenous Science Research Theme and Te Koronga Graduate Research Excellence Programme (Jackson *et al.* 2015, 2016, 2017). Our moemoeā (vision) is Mauri Ora. Mauri ora is flourishing wellness. Our kaupapa (mission) is Māori research excellence based on the aspirations of Māori communities underpinned by a Kaupapa Māori approach.

This paper describes the ethos of Te Koronga which is based on an ancient incantation to locate our kaupapa within Māori and indigenous ways of knowing. The national political context in relation to policy and strategic objectives within the research and science system is highlighted including the opportunities that exist for Māori. The local environment is outlined, specifically focusing on the University of Otago, the academic institution that hosts Te Koronga, and highlighting the issues of Māori academic staffing within the Division of Sciences. The core kaupapa (underlying focus) of this paper is to highlight the systemic issues and realities of Māori academic staffing in sciences in Aotearoa (New Zealand) and the focus of the companion paper is to offer a solution that is locally based but may have implications for other institutions nationally and internationally.

Ethos of Te Koronga

Te Koronga derives its name from the opening phrase of the first karakia (incantation) used for entrance into the whare wānanga (ancient schools of learning). Karakia is a form of ancestral scholarship that is an integral part of fostering a Kaupapa Māori space; a strategy for anchoring scholars to (re)focus their attention to pathways of academic research excellence (Jackson *et al.* 2015). In Te Koronga we recite, we practice, and we discuss and deliberate on the content and intent of karakia in our modern space. We discuss how we can draw upon mana atua (power derived from the gods) to imbue our space and our minds. To consider ancestral wisdom is part of the process in maintaining the integrity of our aspirations within the academy. The kaupapa (core purpose) is grounded in the phrase, 'te koronga', whose philosophy is derived from karakia and mōteatea (chant) meaning to both yearn and to strive for higher forms of knowledge. It is our contention that a kaupapa-based programme, with a requisite space, is required within the academy to allow Māori to reach their potential.

The Māori search for, and acceptance of, higher forms of knowledge has its roots in the stories associated with the kete wānanga (baskets of knowledge) and whatu kura (stones of knowledge) (Marsden 1992). These three baskets and two stones were retrieved from the highest reaches of the heavens from the space occupied by Io-matua-kore (Supreme Being) and placed in Whare Kura, a lower level in the heavens, in reach of mere mortals. It is from these baskets that our ancestors derived their knowledge and constructed whare wānanga to transmit this knowledge from generation to generation. The acquisition and preservation of knowledge has always been part and parcel of pre-European Māori society and an essential element of physical survival and cultural integrity of tribal identity. Tribal lore can be found embedded in whakapapa (genealogical traditions), karakia, mōteatea (Ngata & Jones 2006), whakataukī (proverbs), pēpeha (cultural paradigm for marking identity) (Mead & Grove 2003), and pūrākau (cultural narratives) (Lee 2009) and is underpinned by the concept of mana: the notion of preserving the cultural integrity of tribal identity.

Tribal knowledge is periodically passed down from one generation to the next using a variety of methods; some of those methods required the enculturation of chosen acolytes trained in the discipline of memory retention (Hakopa 2011).

over a long period of time in institutions known as wānanga (Marsden 1992; Royal 1998). The wānanga concept has its roots in the exploits of Tāne-nui-a-Rangi, one of the sons of Ranginui (Sky Father) and Papatūānuku (Earth Mother) who is reputed to have scaled the heavens and returned with the kete wānanga, two stones or whatu kura and the 'blueprint for the constructing the *whare wānanga* to house this sacred knowledge' (Hakopa 2011, p. 12, italics in original). The idea that our ancestors pursued sacred forms of knowledge and built structures to house and pass on this knowledge has implications for us and how we challenge and grow students, academics and our programmes within the academy. What we are concerned with in the first instance are the tools required to access higher forms of knowledge and secondly, creating a space within the academy where we can develop the necessary skills to wield those tools.

The phrase 'te koronga' is borrowed from a karakia used at the opening session of the ancient institution known as wānanga and is used widely in karakia and waiata. In this karakia, te koronga is described as an ardent desire towards higher learning.

The implication is to seek (desire) after the sacred paths of Tane; to become better informed and as skilled as the ancestor Māui (tikitiki-ā-Taranga). With this working definition of Te Koronga, what follows is a description and analysis of the national political milieu of research and science within Aotearoa with a focus on opportunities for Māori.

National policies and strategies for Māori research in sciences

New Zealand government policies, strategies and science funding requirements requires all researchers to consider how outcomes affect Māori. A key driver has been the Vision Mātauranga (VM) policy (Ministry of Research, Science & Technology 2007), which the then Minister of Science approved in 2010, and was subsequently implemented by the Ministry of Business, Innovation and Employment (MBIE) following Ministry restructuring in 2012. VM is designed to unlock the 'innovation potential of Māori knowledge, resources and people' (Ministry of Research, Science & Technology 2007, p. 1) to benefit New Zealand. The VM policy has been applied by most government science funding agencies, e.g. MBIE including National Science Challenges (NSCs), Centres of Research Excellence (CoREs) administered by the Tertiary Education Commission (TEC), Marsden Fund administered by the Royal Society and Crown Research Institutes (CRIs) to address Treaty of Waitangi obligations by ensuring that research must consider Māori needs and perspectives, and also reduce inequities and barriers for Māori to access resources. However, some government agencies have reduced VM requirements, for example the Health Research Council requires applicants to respond to Māori needs and recommends applicants become familiar with the VM policy, whereas other agencies do not always have VM requirements, e.g. Callaghan Innovation (see for example <https://gazette.govt.nz/notice/id/2018-go4863> and <https://gazette.govt.nz/notice/id/2018-go4864>). Alongside VM, the New Zealand Health Strategy (Ministry of Health 2016) and Diversity in Sciences (Ministry of Business, Innovation & Employment 2018a) statements highlight that health and

science systems need Māori leadership and expertise for better outcomes.

VM broadly includes research requirements that agencies use to meet Treaty obligations and reduce inequities for Māori. Implementation of VM has created the need for more Māori researchers, with Te Reo Māori (Māori language), tikanga (protocols/cultural practice) and science discipline skills within Aotearoa New Zealand. For VM to be embedded in science, a commitment for change is essential within each science funding agency and research institution at governance, leadership, grant-assessment panels and within research teams. Funding allocation solutions are diverse to meet each field's needs, with some challenges commissioning Māori research teams to address gaps in scope (Ministry of Business, Innovation & Employment 2018b), whereas others have allocated half of their funding to address research priorities co-developed by Māori communities, service providers, end users (e.g. kaumātua and/or Māori businesses) and Māori researchers.

Nationally a larger pool of excellent Māori scientists is needed who cover social sciences, life sciences and physical sciences, who have expertise in kaupapa Māori, qualitative and/or quantitative methods to meet opportunities that NSCs and other science-funding agencies offer. Important to note is that:

Te Kupenga o MAI: The National Programme for Māori and Indigenous Postgraduate Advancement exceeded its original target of supporting 500 Māori students to complete their doctoral qualifications and this is an extraordinary feat. However, if those graduates are unable to secure work that allows them to practice their disciplines and if universities are not actively committed to building and retaining a critical mass of indigenous researchers, then the outcome will be a lot of very highly qualified unemployed or under-employed Māori graduates, many of whom have high levels of student debt to repay (Kidman et al. 2015, p. 91).

The opportunities are significant. Between 2019 and 2024, the Government has committed \$422 million to fund NSC research programmes (Ministry of Business, Innovation & Employment 2018b). Given current trends, it is likely that more opportunities will arise for Māori scholars throughout other science funding streams.

Research agencies are commended for increasing the expectations of VM implementation. Given that the VM policy was developed in 2010, it needs to be refreshed to acknowledge standard practice in 2019, and also raise VM requirements to better meet Māori aspirations. MBIE and Marsden score VM sections, and an application must obtain a good score (4 out of 7) to be awarded funding. The HRC utilises a similar scoring process, but has a distinct Ranga-hau Hauora Māori strategy and investment stream (Health Research Council of New Zealand 2010). The next step is to ensure that funded researchers annually report VM progress. This is essential for researchers to ensure that adequate Māori personnel, expertise and time are included in research teams. The VM section is sometimes addressed by saying the team will recruit a Māori postgraduate student. However, when no recruitment and support strategy is detailed and

there is no evidence that the team has supported a future Māori scholar through to thesis completion, this statement is meaningless. Similar issues relate to PhD graduates being employed at a lower status, such as Research Assistant or Assistant Research Fellow. Reporting on VM progress will mean that both successes and failures will be identified, enabling funding agencies to reward teams that positively implement VM and better manage those who do not.

Aotearoa needs to increase Māori science capacity and capability, but the current academic situation presents significant challenges to achieving this goal (McAllister *et al.* 2019). Māori academics must balance diverse and competing calls on their attention, in ways that are specific to the post-colonial context for these academics. Māori researchers often find their time divided into small FTE allocations on many projects that cover diverse methods and subject matters. Often, they are low-FTE co-investigators whose role is to help other researchers make their projects more competitive for funding rounds. This service reduces the amount of time that these individuals can devote to honing their own research skills and programme, building an experienced team, and being recognised as a science leader of a specific discipline. The only remedy is to build capacity within research communities. Māori scholars need to be appropriately resourced financially and given appropriate time allocations for the leadership roles that they fulfil and the essential additional skills they bring to the research team. Māori scholars mentor tauira Māori (Māori students) into the research team that are essential for capacity building, a key component of VM and Te Koronga's vision.

Māori researchers also face specific economic challenges. Kidman *et al.* (2015) highlight the change in circumstances for Māori academics for early career academics compared to their older colleagues, e.g. previous familial attendance at university but also the possibility of higher student debt which impacts decisions to have children or buy houses. There is also less certainty surrounding employment prospects, permanent academic contracts, and a sense of isolation in departments where there is only one Māori academic; even though there is a growing number of Māori PhD graduates completing their study. These issues are supported by Ministry of Education figures in 2018 that demonstrate that there were only 495 Māori academics compared to over 10,000 non-Māori (<https://www.radionz.co.nz/news/national/366304/maori-academics-isolated-and-lacking-in-numbers>). There are also frequent requests for Māori academics to support other projects beyond their normal workload. This often leaves Māori academics at a crossroad; despite it being outside their normal requirements, there is often an inherent obligation to ensure that the mātauranga shared is tika (correct).

Māori academics also have a parallel set of priorities (Kidman *et al.* 2015, p. 11) that focus on whānau, hapū (sub-tribal) obligations and 'these relationships are frequently disregarded or unseen within the academy but they are a critical element of the 'invisible' intellectual labour of Māori researchers who require these networks and alliances in order to do their work' (Kidman *et al.* 2015, p. 84). Kidman *et al.* (2015) argue that 'this situation reflects a wider structural

dysfunction within the institutions of higher education in New Zealand that, to date, has only been partially addressed by formal mission statements and institutional strategies aimed at recruiting and retaining Māori and Pacific faculty' (p. 13).

All of these challenges derive from Māori researchers' unique and vital roles in two worlds. For Māori academics to thrive, these worlds must be brought together in academically and culturally meaningful ways that are holistic in focus on indigenous science; rather than subdivide attention. An indigenous science curriculum would nurture the next generation of Māori scientists who have the skills and knowledge to work at the interface between Te Ao Māori and Western science approaches.

University of Otago policies and strategies for Māori research in sciences

The University of Otago is the academic institution that hosts Te Koronga so this section provides context for the recent state of the host institution's policies and strategies for Māori research in sciences. The University of Otago's Strategic Direction is guided by a set of 10 core values and 7 strategic imperatives (University of Otago 2013). Commitment to Treaty-based partnership, with Ngāi Tahu as its principal partner and with other iwi and Māori groups as appropriate, is among the core values. The University's Māori Strategic Framework (University of Otago 2017) sets goals that elaborate how Divisions and Departments should respond to the University Imperatives in ways that support Māori and Māori ambitions.

Delivering on University and Māori goals is challenged by the low number of Māori academic staff in the sciences. In the Division of Sciences in 2018, of the 77% of staff who disclosed their ethnicity, 3.3% identify as Māori. In the Biomedical Sciences the number is even lower; of the 74% who disclosed their ethnicity, 1.8% identify as Māori. Viewed by job family, these percentages represent 7 Māori academics engaged in some form of teaching across the 22 departments, centres and schools that make up both the Division of Sciences and Biomedical Sciences. Not all of these people are employed full-time in these roles. Kidman *et al.* (2015) highlight that 'formulating equity and diversity plans is a good start but unless there is a serious and genuine commitment to working in partnership with under-represented groups to create inclusive institutional structures, little will change' (p. 92).

Coordinated intra- and inter-Divisional effort across is required to respond to University Imperatives and to meet the MSF goals. There are two reasons for this. First, Māori ontology is grounded in interdisciplinary science. Deepening and broadening the Māori curriculum and supporting Māori students in culturally resonant ways is necessarily an interdisciplinary activity. Second, the small number of staff with the knowledge and experience to support this kaupapa are dispersed across the divisions. Facilitating connections among Māori staff, and others with an interest in diversifying their knowledge and teaching practice, is a culturally meaningful and expedient approach to growing the curriculum and supporting both student and staff success.

Realisation of potential opportunities (unlocking innovation potential)

Meeting its MSF goals requires the University of Otago to grow its capacity and capability to deliver Māori content across its diverse science curricula. Doing so will create new opportunities for staff and students. Recruiting, training and graduating new generations of Māori and non-Māori students who are prepared to work respectfully and responsively in indigenous, interdisciplinary contexts will position the University as leader and innovator in science education.

At Otago, Te Koronga provides a framework for mātauranga Māori (Māori epistemology) in the sciences, through its paired focus areas of Graduate Research Excellence and the Indigenous Science Research Theme. Within Te Koronga, students are mentored to express tikanga Māori in their work and to develop their own interdisciplinary kaupapa. Researchers make connections that help them to connect across traditional disciplinary and epistemological boundaries. This is the ideal framework in which to develop new courses that meet the needs of students who want to learn in an indigenous, interdisciplinary context. Otago's Ecology and Applied Science programmes, in which a core set of papers are augmented by electives that allow students to specialise in ways that are meaningful to them, are examples of the interdisciplinary approach to science education.

Many essential ingredients are already in place but connecting and growing them are a significant challenge. Māori science could be taught in two ways: in explicitly Māori science papers and as Māori science content integrated into other papers. The latter category includes papers that cannot be correctly taught without Māori content and papers where such content would strengthen a course. New Māori staff will be required to better support existing teaching and mentoring, to training current staff to engage with mātauranga Māori in new ways and to offer new papers. We continue with the specific solution in the companion paper in the second Special Issue.

Conclusion

Te Koronga aims to provide a space within the academy that privileges Māori research excellence. One of the strategic aims of Te Koronga is population parity for Māori academics/increasing Māori research capacity and capability, and to address the significant needs within Māori communities in relation to sciences. While there are national and locally based policies and strategies, in reality, these are yet to be translated into academic institutions with any increase in Māori academic staffing numbers nor expertise in Māori research in sciences. There are significant challenges for iwi, hapū, whānau and Māori communities which can be supported through a deliberate and intentional focus on growing Māori academic excellence within sciences. The academy is in a state of crisis for Māori staffing and there is no short-term reprieve from this reality. Many of the authors are Māori researchers and researchers with expertise in working alongside Māori and we are determined in our collective approach in undertaking science and research in a different way; in ways that reflect the aspirations of our communities in the pursuit of mauri ora.

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Whāia ngā pae o te māramatanga: our horizons of pursuit

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Abstracts

Kei te tipu haere te whakaaro i Aotearoa Niu Tīreni he tino iho tonu tō te huihanga ki te Māori me te whakarangatira i a ia puta noa i te ahunga o te pūtaiao me te rangahau kia whakaraetia ai ngā taunahua ā-motu, kia pūrangiaho ai hoki te whakaaro ki ngā āhuatanga motuhake ka taea anahe e te mātauranga Māori te takoha atu ki te puna auaha me te waihanga mōhiotioranga. (Ministry of Education 2013a). E riro mai ai ngā hua o te huri haerehanga o te motu rohanga tangata, e tū ai hoki te Tiriti o Waitangi hei poutokomanawa i te hapori whānui, me tino karanga te Māori kia whaiwāhi mai ia ki ngā rangahau me ngā whakataunga puta noa i ngā akoranga me ngā ahunga katoa. Ka whakaarohia e tēnei tuhinga, pēhea tonu nei ngā takohanga a Ngā Pae o te Māramatanga (NPM) ki te whakaraetia o ngā taunahua me te whakawhanakehia o ngā āheinga kei waengarahi

i te mātauranga Māori me te pūtaiao. E kitea nei e te tuhinga nei, he pai ā NPM takohanga, ā, nā aua takohanga e huri pai nei ngā momo rangahau i Aotearoa Niu Tīreni, otirā i te ao whānui.

In Aotearoa New Zealand there is a growing recognition that Māori engagement and leadership across the science and research sector is essential for addressing national challenges and realising the distinctive contribution of mātauranga Māori to innovation and knowledge creation (Ministry of Education 2013a). To reap the benefits of the nation's changing demographics and to centre Te Tiriti o Waitangi in society, it is critical that Māori are engaged in research and decision making in all disciplines and in all sectors. This article considers how Ngā Pae o te Māramatanga (NPM), New Zealand's Māori Centre of Research Excellence, is contributing towards addressing and developing challenges and opportunities at the interface between mātauranga Māori and science. The article traces the contribution of NPM as a positive transformative contributor to research in Aotearoa New Zealand and internationally.

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Professor Ruru's research has focused on exploring Indigenous peoples' legal rights to own, manage and govern land and water including national parks and minerals in Aotearoa New Zealand and overseas, and she has led, or co-led, several national and international research projects.

Her research interests include: Indigenous Peoples comparative law (including rights to own, govern and manage water, land, marine area, minerals and national parks); Māori land law including Te Ture Whenua Māori Act 1993; Treaty of Waitangi; Family law and Māori; Environmental Law and Māori, Law and landscapes; Aotearoa New Zealand's legal history, Law and Society; and Law and Geography.

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Professor Nikora's specialities are in community psychology, applied social psychology, ethno-psychology and Maori development.

Her research in recent years has focused on Tangi: Māori ways of mourning; traditional body modification; ethnic status as a stressor; Māori identity development; cultural safety and competence; Māori mental health and recovery; social and economic determinants of health; homelessness; relational health; and social connectedness.



Tracey McIntosh (Tūhoe) is Professor and Co-Head of the School of Te Wānanga o Waipapa, the University of Auckland and a past Co-Director of Ngā Pae o te Māramatanga. She previously taught in the sociology and criminology programme, and has also lectured at the University of the South Pacific in Fiji. She was a Fulbright Visiting Lecturer in Washington DC in 2004, and has served on Fulbright selection panels and as a Fulbright student advisor since then.

Professor McIntosh's recent research focuses on incarceration (particularly of indigenous peoples), inequality, poverty and justice. She also sits on several external research assessment panels, such as the Marsden Fund Social Science Panel, and on a number of boards, particularly in the area of social harm reduction. In 2012 she was the co-chair of the Children's Commissioner's Expert Advisory Group on Solutions to Child Poverty.

Introduction

Ngā Pae o te Māramatanga (NPM), New Zealand's Māori Centre of Research Excellence, is committed to realising Māori aspirations for positive engagement in national life, providing solutions to major challenges facing humanity in local and global settings, and fostering excellence in Indigenous scholarship both nationally and internationally. NPM's entire research programme is now designed and led by Māori. This may now seem unremarkable but such a vision was barely implementable less than two decades ago, in part because of research capability and capacity issues borne from enduring and substantial inequities, and, in part because the science sector did not proactively foster and, at times, actively impeded, Māori research leadership. This article traces the contribution of NPM as a positive transformative contributor to research in Aotearoa New Zealand and internationally.

Centres of Research Excellence

In 2001, the Government established the Centre of Research Excellence (CoRE) Fund 'to encourage the development of excellent tertiary education-based research that is collaborative, strategically focused and creates significant knowledge transfer activities (Tertiary Education Commission 2018, p. 28). In announcing the most recent suite of 10 CoREs that are funded through to 2020 (Table 1), the immediate past Minister for Tertiary Education, Skills and Employment Steven Joyce remarked: 'CoREs provide an excellent collaborative environment for the delivery of world-leading, innovative and strategically focused research' (Joyce 2015). Prior to the CoRE Fund, there were no large inter-institutional research networks in Aotearoa New Zealand, and certainly no Māori-led national research network of any kind. The CoREs 'compensated for the lack of critical mass in a small country with a widely distributed population by creating research networks' and 'led to a distinct lift

in New Zealand universities' share of the world's indexed research publications and citations' (Crawford 2016, p. 9 citing Smyth 2012).

NPM was founded in the first CoRE round in 2002 under the central leadership of Professor Linda Tuhiwai Smith and Professor Michael Walker. While NPM, along with some of the other CoRES, were formally declined CoRE status in early 2014, a new re-bid process emerged which included a specific stand-alone competitive process for a single Māori CoRE. In 2015, NPM was announced as the country's Māori CoRE for the current round of CoRE funding: 2016–2020 (Table 2).

NPM is unique. It is Māori-focused and has a broad disciplinary engagement from the humanities, social sciences to law, health and the natural and physical sciences unlike the strongly focused science models of the other CoRES. Today, NPM has 21 Research Partners that enables a deliberate national collaboration of diverse research organisations to embrace the spectrum of Māori research strength across New Zealand (eight Universities, two tertiary Wānanga, two Institutes of Technology, a Crown Research Institute, two museums, three Iwi-based research institutions, two independent Māori research institutes, and New Zealand's largest independent research institute: Cawthron Institute).

The contribution of NPM at the interface

The development of NPM's research programme is world-leading (Royal Society 2017), making a significant contribution to 'arguably one of the newest research fields on the block, albeit with ancient veins' (Smith, L.T. 2018, p. 22). Indigenous research is new in a tertiary education sense simply because tertiary institutions for the most part have been a hostile place for Indigenous students and staff (Kidman *et al.* 2015; Potter & Cooper 2016; Henry *et al.* 2017; Chauvel & Rean 2012; Universities New Zealand 2016; Tertiary Education Commission 2015; Pihama *et al.* 2018).



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Daniel Patrick is Executive Director at Ngā Pae o te Māramatanga. Previously he was Centre and Research Manager of the Centre of Methods and Policy Applications in the Social Sciences (COMPASS) at the University of Auckland, which he co-founded, and before that he developed and established the New Zealand Social Statistics Network (NZSSN), New Zealand Social Science Data Service (NZSSDS), and a Survey Research Unit. He also managed the Centre for Health Services Research and Policy and led national programmes of research in primary health care, health services and household whānau wellbeing using New Zealand Census Data.

He has extensive experience in the fields of research planning, business development, data analytics and management, programme management, and strategic planning. With a background in laboratory models, pathology and microbiology, hospital epidemiology and social statistics he now has a focus and interest in Māori and Indigenous research and connection of knowledges.



Table 1. CoREs in Aotearoa New Zealand

CoRE name	Duration of CoRE status	Host University
Allan Wilson Centre for Molecular Ecology and Evolution	2002–2015	Massey
Bio-Protection Research Centre	2003–2020	Lincoln
Brain Research New Zealand Rangahau Roro Aotearoa	2015–2020	Auckland/Otago
The Dodd-Walls Centre for Photonic and Quantum Technologies	2015–2020	Otago
Gravida: National Research Centre for Growth and Development	2003–2015	Auckland
MacDiarmid Institute for Advanced Materials and Nanotechnology	2002–2020	Victoria
New Zealand Institute of Mathematics and its Applications	2002–2011	Auckland
The Maurice Wilkins Centre for Molecular Biodiscovery	2002–2020	Auckland
The Medical Technologies Centre of Research Excellence	2015–2020	Auckland
Ngā Pae o te Māramatanga New Zealand's Māori Centre of Research Excellence	2002–2020	Auckland
Quake CoRE: Centre for Earthquake Resilience	2016–2020	Canterbury
Te Pūnaha Matatini: Data Knowledge Insight	2015–2020	Auckland
Riddet Institute: Food Innovation Health	2008–2020	Massey

Thus, while other Centres of Research Excellence were likewise in creation mode, they were embedded in established science infrastructure, in many cases dating back hundreds of years (Ministry of Education 2013b).

By contrast, NPM has had to develop and implement new processes and structures to support Indigenous research in an adverse environment. In building this infrastructure NPM has helped enable the formation of a new scholarly community as well as national and international confidence in Indigenous-led research. Laying this groundwork was an immense task enabled by many Indigenous researchers. Collectively they helped to rapidly increase the number of Māori researchers that could design and lead critical research projects, extend the breadth and significance of Kaupapa Māori research, develop transdisciplinary research methods and theories to respond to national and community need, and ensure appropriate and multiple outlets for the research.

In 2002 there were probably fewer than a dozen Māori researchers who were Principal Investigators in their own right in nationally contested, externally funded research. Or, as commented by Linda Tuhiwai Smith, Māori Principal Investigators then: 'could probably have squeezed into a red telephone box' (Smith, L.T. 2016). Confounding the problem was that many Māori researchers were locked into perennial Associate Investigator positions which stifled their

ability to build and lead comprehensive and cohesive research programmes even while their research contributions added real, often critical, value to the projects. While it did mean that many Māori researchers had the opportunity to gain real breadth of experience, it was mainly in service to mainstream research and supporting non-Māori research careers and aspirations. Seventeen years later (2002–2019), it is now commonplace for Māori-led teams to have designed and implemented *every* part of the design process, drawing on mātauranga Māori, kaupapa Māori and other Indigenous research methodologies. Māori researchers have always served Māori communities but NPM has further strengthened their ability to determine the research questions as the fundamental core of a research project. Today, Māori Principal Investigators, of research projects funded externally to their home institutions, would likely fill an Air New Zealand Airbus A320.

The development of two internationally peer-reviewed journals is an example of this research infrastructure development: *AlterNative: An International Journal of Indigenous Peoples* and *MAI Journal: A New Zealand Journal of Indigenous Scholarship*. Critical, robust, culturally informed peer-review processes and dissemination have been crucial for the development of conceptual, foundational and applied Indigenous research. Other flagship foundation activity of

Table 2. NPM leadership 2002-2019

Period (Contract)	Board Chair	Directors	International Research Advisory Panel/Board Chair	Research Committee Chair
2002–June 2008	Prof. Michael Brown (2002–2005); Sir Tīpene O'Regan (2006–)	Prof. Linda Smith (2002–2007); Assoc. Prof. Michael Walker (2002–); Assoc. Prof. Tracey McIntosh (2007–)	Est. in 2006 with Prof. Sir Mason Durie as Chair.	Assoc. Prof. Michael Walker
July 2008–2015	Sir Tīpene O'Regan	Assoc. Prof. Michael Walker (–2010); Assoc. Prof. Tracey McIntosh (–2010); Prof. Charles Royal (2010–2014); Assoc. Prof. Tracey McIntosh (2014–)	Prof Sir Mason Durie (2008–2013); Prof. Harald Gaski (2014–2015)	Assoc. Prof. Michael Walker (–2010); Assoc. Prof. Tracey McIntosh (–2010); Prof. Charles Royal (2010–2014)
2016–2020	Tā Tīpene O'Regan (–2018); Kerensa Johnson (2019–)	Prof. Jacinta Ruru (2016–); Assoc. Prof. Tracey McIntosh (2016–Oct 2017); Prof. Linda Waimarie Nikora (Oct 2017–)	Prof. Linda Smith (2016–)	Prof. Huia Jahnke (2016–)

NPM included the bold creation of a national network of Māori postgraduate students with the now well surpassed vision of 500 Māori PhDs (designed and instigated initially by Professor Graham Smith) (Smith, L.T. 2017; Smith, G.H. 2016; Ormond & Williams 2013); a suite of grants and awards to support Māori research and researchers (including supporting Māori to study and research in the United States with the Fulbright Ngā Pae o te Māramatanga Awards) and the biennial International Indigenous Research Conference.

NPM has emerged as an international benchmark with an international profile in Māori and Indigenous research. The New Zealand Institute of Economic Research (2014) independently assessed the economic and social impacts of NPM research and found that:

- NPM has established an unprecedented and extensive network of cooperation between its partner research institutions
- 80% of NPM research projects are designed and shaped by home communities
- A majority of NPM's projects improved the practices, processes and policies of end-users
- The impacts of NPM projects are localised and highly relevant to the communities involved
- NPM researchers are highly engaged with Māori communities
- Almost half of NPM's projects received additional direct funding
- NPM is a unique organisation, where the assessors were not aware of any international benchmark with which it could be compared.

The legacy of NPM has been immense for fostering the carving out of a space for mātauranga Māori, te reo and tikanga Māori within science research leadership in Aotearoa New Zealand. As Professor Angus Macfarlane, a NPM Principal Investigator has stated:

What we at the University of Canterbury like is the collaborative spirit that exists between a CoRE such as Ngā Pae, and the academy. We like the fact that Ngā Pae invites research partners to 'reach in', to peruse and consider the opportunities that they offer emerging and experienced researchers working within the Māori and Indigenous paradigms. More importantly, Ngā Pae is proactive, that is they 'reach out' to academics and members of the broader research community that have cultural diversity as a central focus. (Macfarlane, A. pers. comm. 2017)

NPM's research vision

NPM articulates a strong research vision of Māori leading New Zealand into the future; this vision is demographically grounded (Māori are a youthful and fast-growing population) and solutions-focused (Māori can contribute evidenced-based, culturally informed and novel solutions for many of our societal issues and challenges). NPM's research programme is activist-driven, which is unsurprising given that societal transformation is part and parcel of Indigenous research. As L.T. Smith observes: 'Indigenous research aims to make positive transformations for indigenous nations and

communities that overturn colonial paradigms of thinking and working and that create new spaces for indigenous knowledges, cultures and peoples to thrive' (2018, p. 28). NPM's research programme is also foundation building. In the absence of the infrastructure that long-established disciplines such as physics, history or botany enjoy, NPM research and researchers have had to create the lexicon and literature for base theories and methods. Mātauranga Māori is embedded within NPM's research programme because many solutions for transformative societal change lie within the ancestral knowledge systems and practices, and because mātauranga provides a means to study the universe from a Māori worldview (Waitangi Tribunal 1999, 2011). By valuing mātauranga Māori, te reo me ngā tikanga Māori, the NPM research programme uses dual knowledge systems (Indigenous and discrete disciplinary knowledge) and is a leader in research design, outputs and impact. There is now a burgeoning literature on the mātauranga-science interface (Smith, L.T. *et al.* 2016; Leonard & Mercier 2016), much of it contributed by past and present NPM researchers.

An important component that gives life to mātauranga Māori embedded research is the development of the wānanga, not just as a meeting practice but as a critical research method. At a pragmatic level NPM is determining and exploring 'spaces of integrity' for mātauranga Māori to facilitate a process of Māori exploring and understanding mātauranga enabling creation of new knowledge and answers to critical questions. In these circumstances wānanga on the marae provide a framework for how, why and where we meet together, including how we listen to one another and how we engage with the kaupapa at hand. Not only is this underpinning NPM's activist-driven research, but wānanga also establishes a space to explore and express our mātauranga in creative and innovative ways (Royal 2009; Adds *et al.* 2011; Edwards 2013).

NPM's research programme prioritises wānanga as a significant research practice and method. For example, in 2018, NPM Principal Investigators spent three days at Wakatū Marae (in Nelson) to great effect. Associate Professor Māmari Stephens (Victoria University of Wellington), one of NPM's Principal Investigator's, commented:

I got a far clearer sense of belonging to the Ngā Pae whānau, and of where my own work fitted in amongst the work being done by others. It is a powerful feeling having a 'place', so I was very grateful to be able to develop that. I was challenged in my thinking. I felt invigorated and more purposeful as a result of this wānanga. ... I was so grateful to be in the house that was so much the expression of the mana of its people, but also of the vision and genius of Auntie Pubanga Tupaea. Man, what a whare. I'm a bit hard to prise out from under my rock, but I was so glad I came! ... (Stephens, M. pers.comm. 2018)

Spotlighting some of NPM's research

NPM has developed a holistic integrated research programme grounded in mātauranga Māori, Māori science, kaupapa Māori, and tikanga Māori approaches and methods, additionally utilising all appropriate other science knowl-

edge and techniques. NPM has directly enabled more than 160 research projects many of which continue to live on and deliver outputs and impact for the Māori researchers and the Māori communities they work with. Many have been leading-edge projects that have demonstrated next-stage potential impact.

One example is the work of NPM Principal Investigators Professor Rawinia Higgins (Victoria University of Wellington) and Professor Poia Rewi (University of Otago) where their NPM research developed the innovative ZePA (Zero Passive Active) right-shifting Māori language revitalisation model (Higgins & Rewi 2014). This research has now been incorporated into policy throughout many of the Government Departments and has clearly informed replacement legislation: *Te Ture mō Te Reo Māori* (Māori Language Act) 2016.

Another example is the work of NPM Principal Investigator Professor Rangi Matamua (University of Waikato and Fulbright Ngā Pae o te Māramatanga Scholar Awardee) where his research project developed into a successful Marsden Fund project 'Te Mauria Whiritio: The sky as a cultural resource – Māori astronomy, ritual and ecological knowledge' (2014, \$710,000). Professor Matamua's international profile acknowledges his world-leading work on how astronomy is embedded within the cultural practices of Indigenous peoples. At a national level he disseminates his knowledge in academic and community settings including annually at free public Matariki talks at museums around the country engendering considerable media interest (Matamua 2017a, b). He credits NPM as being '...central in the development of my career' (Matamua, R. pers comm. 2017).

A further example is the work lead by Dr Shaun Ogilvie (Eco Research Associates and Cawthron Institute) whose NPM research 2010–2012 (Ogilvie *et al.* 2010, 2012) led onto a MBIE programme 'Ka Hao te Rangatahi: Revolutionary Potting Technologies and Aquaculture for Scampi' (2013–2019, \$8.9million) (Ogilvie *et al.* 2018). This world-first research that values mātauranga Māori at the interface with science 'all started with my NPM project' (Ogilvie, S. pers. comm. 2017).

Succession planning and mentoring is hugely important to NPM. Dr Anne-Marie Jackson (University of Otago) reflects on how critical her NPM Summer Internship was as a 25-year-old student who wanted to do Māori research for her career: 'I had next to no experience in my training of working with Māori and it was such an important part of my own development' (Jackson, A.-M. pers. comm. 2016). She went on to complete her PhD, be employed as an academic and now mentors and supervises a large contingent of Māori postgraduate students on NPM summer internships in Māori communities all over the country.

These are just a few of the many NPM stories of transformative research.

Conclusion

In less than two decades NPM has contributed strongly to changing the research landscape. Moreover, the tertiary research academy and broader community research capability has grown to recognise the value of Māori leadership in research design and delivery. Māori are championing the

dynamic interface between mātauranga Māori and science domains. With hundreds of Māori researchers across the country, and many iwi, hapū and community partners, NPM is proud of the contribution it is making to our national and local research futures. But there is an acute need to do much more. As Professor Juliet Gerrard, the new Chief Science Advisor to the Prime Minister, acknowledged when taking up her role, 'There's lots of old white guys, not many women, and no Māori voice' in the science advisory roles. Furthermore, with 'only 2% [of Māori and Pasifika] represented in the science workforce' this is 'a really urgent thing to address' (Manhire 2018). We agree.

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Teaching the next generation of scientists to support communities in their restoration of ecosystems and ways of life

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Abstracts

He uaua te whāriki i te mātauranga me te mōhio whānuitanga ki te whakamahi ā-ringa nei i te tukanga pūtaiao, engari, he pitomata tōna e takatū ake ai ngā pia ki ā rātou ake mahi ā haere ake nei. Mō te taha ki ngā kaipūtaiao whakarae, ko te mea nui kia mārama rātou ki tā te kaipūtaiao mahi i roto i te pāpori, ki ngā matatika, ki te ngākau tapatahi, ki ngā āhuatanga ōrite o te mahi kōkiri me te pūtaiao matua, ki te whakatau puehu, ki te horopaki ā-hītori, ki te mahi hoki a te whakaturehanga me ō te marea whakaaro. Ko te AQFI 301 Field Methods for Assessment of Fisheries and Aquatic Habitats tētahi kōhi tōpū kaha i te Whare Wānanga o Ōtākou e arō pū ana ki ō te rohenga mahi, e hora nei i te āheinga ki te taura kia whakamahia te pūtaiao hei rongoā i ngā tino take, me te tautoko mai a te hāpori. Ko te tūāpapa o te kōhi ko te houruatanga mauroa ā-rangahau, ko Te Tiaki Mahinga Kai, nā, e kōrero nei mō te whakangungu i ngā wāhi e kīia nei e te tikanga he wāhi kōhi kai. I tēnei houruatanga ka mahi tahi te hāpori me ngā kairuruku kia tautokohia te whaka-haere i te mahinga kaimoana tuku iho, ka mutu, ina whānui ake te titiro, te whakarauora i ngā pūnaha ā-pāpori, ā-hauropi anō hoki. Mā te tautoko i a Tangata Tiaki/Kaitiaki¹ (ko ngā kaitiaki/kaiwhakahaere ā-mahinga kaimoana tuku iho kua whakamanahia ki te whakaturehanga) ka tūhono atu te kōhi ki te hāpori whānui (p.m. ngā kaipāmu, ngā rōpu whāomomo rānei), ki ngā mahi iho pū a te marae, a te hapū, a te whānau anō hoki i ngā hāpori taiwhenua. Kua poua te kōhi rohenga ki te marae o Ngāi Tahu, ko tāna hoki he whakapuaki i ngā tikanga me ngā kawa o te marae, o te mahinga kaimoana anō hoki. Ka whakaakona houruatia te AQFI 301 me te hāpori, nā, e hora nei ngā hua ki ngā taura, ki te Whare Wānanga, ki ngā kaiuru anō hoki o te

hāpori. He rerekē tā AQFI 301 titiro ki te whakaako i te pūtaiao koiora moana ki ngā whare wānanga auraki, he aronga nōna ki ngā hiahia me ngā wawata o ngā ahikā Māori o te hāpori, he whakamārama hoki nōna ki te taura me pēhea te whakamahi i te pūtaiao i ngā horopaki mātinini. He whakahirahira nei te taiao waimāori me te taiao moana ki te Māori, koia pū tā mātou titiro ki te whakatipu i ngā pia e taea ai e rātou te mahi tahi ki te Māori, ki hāpori kē atu rānei, i runga i te kauanuanu, i te whai take anō hoki. Ko tēnei tuhinga, e whakatakoto nei i ngā tau-nahua o te whāngai i te taura ki ngā pūkenga whai tikanga o te whakaako i te pūtaiao mātauranga matua, e whakamahuki nei i te houruatanga me te hāpori hei whakaako i te pūtaiao ā-ringa, e whakamārama nei i ngā whakaritehanga mō te kōhi rohenga, e whakamahuki nei hoki i te kōhi rohenga ā-noho marae me te kōrero i ngā pānga ki ngā rōpū kaiuru, i ngā ngoikorehanga me ngā whakatau anō hoki.

¹ Local guardian or trustee of a specific area. Tangata Kaitiaki/Tiaki means any person appointed as Tangata Kaitiaki/Tiaki under the Fisheries (Kaimoana Customary Fishing) Regulations 1998 or the Fisheries (South Island Customary Fishing) Regulations 1999, being a member of the Tangata Whenua or a tangata whenua organisation or their notified representative. A Tangata Kaitiaki/Tiaki appointed under the Fisheries (Kaimoana Customary Fishing) Regulations 1998 or the Fisheries (South Island Customary Fishing) Regulations 1999 may authorise any individuals, in accordance with these regulations, to take any fish, aquatic life, or seaweed for customary food gathering purposes from within the whole or any part of the area/rohe moana, for which the Tangata Kaitiaki/Tiaki has been appointed. This term is defined in various Fisheries notices. Source: <https://fs.fish.govt.nz/Page.aspx?pk=78&dk=1806>

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Providing expertise and high-level understanding in the practical application of the scientific process is challenging but has the potential to better prepare graduates for future careers. The key for frontline scientists is to understand the role of a scientist in society including ethics and integrity, the interface between advocacy and primary science, conflict resolution, historical context, and the role of legislation and public opinion. AQFI 301 Field Methods for Assessment of Fisheries and Aquatic Habitats is an intensive field-focussed course at the University of Otago that provides students with an opportunity to apply science to real issues with the support of the community. The course is built on the long-standing research partnership Te Tiaki Mahinga Kai, which means, guarding the customary food gathering areas. In this partnership communities and researchers work together to support customary fisheries management and, more broadly, the restoration of social-ecological systems. By supporting Tangata Tiaki/Kaitiaki¹ (legislatively empowered customary fishery managers/guardians) the course connects to the broader community (e.g. farmers, conservation groups) through the central role the marae (ancestral meeting house), hapū (subtribe) and whānau (families) play in many rural communities. The field course is based at a Ngāi Tahu marae (communal or sacred place) and provides an introduction to tikanga (custom) and kawa (protocol) at the marae and around fisheries. AQFI 301 is taught in partnership with the community, providing benefits to the students, the University and community participants. AQFI 301 takes a unique approach to teaching marine science in mainstream tertiary institutions as it is based on the needs and aspirations of local Māori communities and allows students to understand how science can be applied in different contexts. Freshwater and marine environments are of significant importance to Māori and this is our approach to building graduates who can work alongside Māori and other communities respectfully and in meaningful ways. This article outlines the challenge of providing practical skills to students in tertiary science teaching, describes a partnership with the community for teaching applied science, details the preparation for the field course, describes the noho marae-based field course and discusses the impacts on the participant groups, with limitations and conclusions.

The challenge: Providing practical skills to students in tertiary science teaching

Providing practical skills that underpin the more theoretical aspects offered in tertiary science programmes can be challenging (Linn *et al.* 2015). Training in the practical application of the scientific method from observation and question development through to reporting and delivery of findings to end-users (Figure 1) should be provided throughout tertiary science programmes (Windschitl *et al.* 2008; Corwin *et al.* 2015). For many students practical activities are key in providing the motivation to apply themselves in more theoretical parts of the degree programmes (Jackson *et al.* 2017). Practical aspects of courses can also help identify pathways for students to future study and improve their understanding of what they want to do for the first steps of their career – and importantly what they don't want to do.

In our experiences, laboratory and field-based aspects of courses are useful in teaching the practical aspects of science but sometimes lack wider context or purpose. Basic hands-on laboratory and field skills are important – they are fundamental in science careers – but some key skills have been completely lost from the scientific teaching toolbox (Windschitl *et al.* 2008). This 'activity without understanding' (Windschitl *et al.* 2008) can reduce authentic science

experiences which promote scientific inquiry and create connections between concepts learnt in the classroom to everyday life (Oberhauser & LeBuhn 2012; Mitchell *et al.* 2017). Such experiences have been identified as lacking in New Zealand (Haigh *et al.* 2005), Australia (Mitchell *et al.* 2017) and the US (Oberhauser & LeBuhn 2012; Fukami 2013; Shah & Martinez 2016) resulting in students entering university with limited exposure to this way of learning (Oberhauser & LeBuhn 2012; Shah & Martinez 2016). Participating in research-based projects in undergraduate studies can increase the likelihood of students pursuing science-related careers or postgraduate studies (Linn *et al.* 2015; Mitchell *et al.* 2017; Corwin *et al.* 2015). Student learning experiences with a community relevance also make it more likely for students to engage with communities in the future (Oberhauser & LeBuhn 2012).

In the third and final year of undergraduate University science courses, many students want to apply skills developed on real issues and problems. Today, science students have strong interests in sustainability, conservation and new ways of managing the environment and natural resources. Empowering and encouraging future professionals to be on the front line of environmental and natural resource management will provide broader benefits to the wider community. Graduates must, however, understand the general process that underpins decision making, the limitations of what can be achieved and the advantages and disadvantages of advocacy *v.* primary research to inform decision making.

AQFI 301: A partnership with the community for teaching applied science

Here we offer an example of an undergraduate course that exposes students to fishery and environmental sciences, Aquaculture and Fisheries 301 Field Methods for Assessment of Fisheries and Aquatic Habitats also known as AQFI 301. This course provides the practical applications of the scientific process through developing and applying research questions that are based on problems faced by communities. Students then report their work back to community members and respond to feedback from end users. The challenges and benefits of this approach are shared through the experiences of the AQFI 301 teaching. The team includes Tangata Tiaki/Kaitiaki, community members, freshwater and marine scientists working for iwi, academic staff and former students. This multi-sectoral partnership team has its origin in the establishment of marine Customary Protected Areas (CPAs) by Te Rūnanga o Ngāi Tahu. The management committee of these CPAs are often made up of representatives from iwi, recreational & commercial fishers, community environmental groups and scientists. Balance must be maintained when delivering teaching programmes of this type so that benefits flow to all members of the team. The partnership developed between university academics and the community allows a course like AQFI 301 to exist and also provides general lessons for the development of sustainable research and educational programmes with the wider community (Figure 2). To be successful, AQFI 301 must provide useful information to help Tangata Tiaki/Kaitiaki in their primary role of supporting the restoration of local ecosystems. That is the foundation of the partnership and the engine room for both teaching and learning.

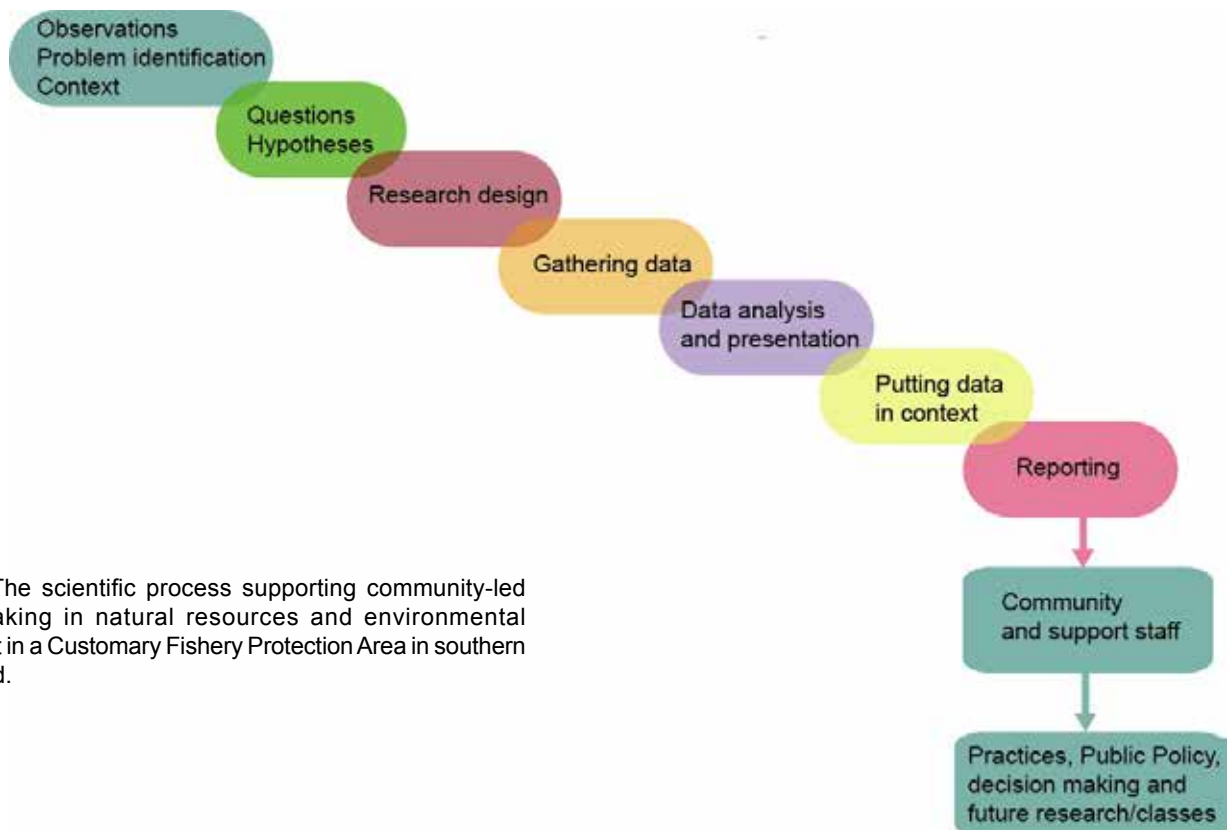


Figure 1. The scientific process supporting community-led decision making in natural resources and environmental management in a Customary Fishery Protection Area in southern New Zealand.

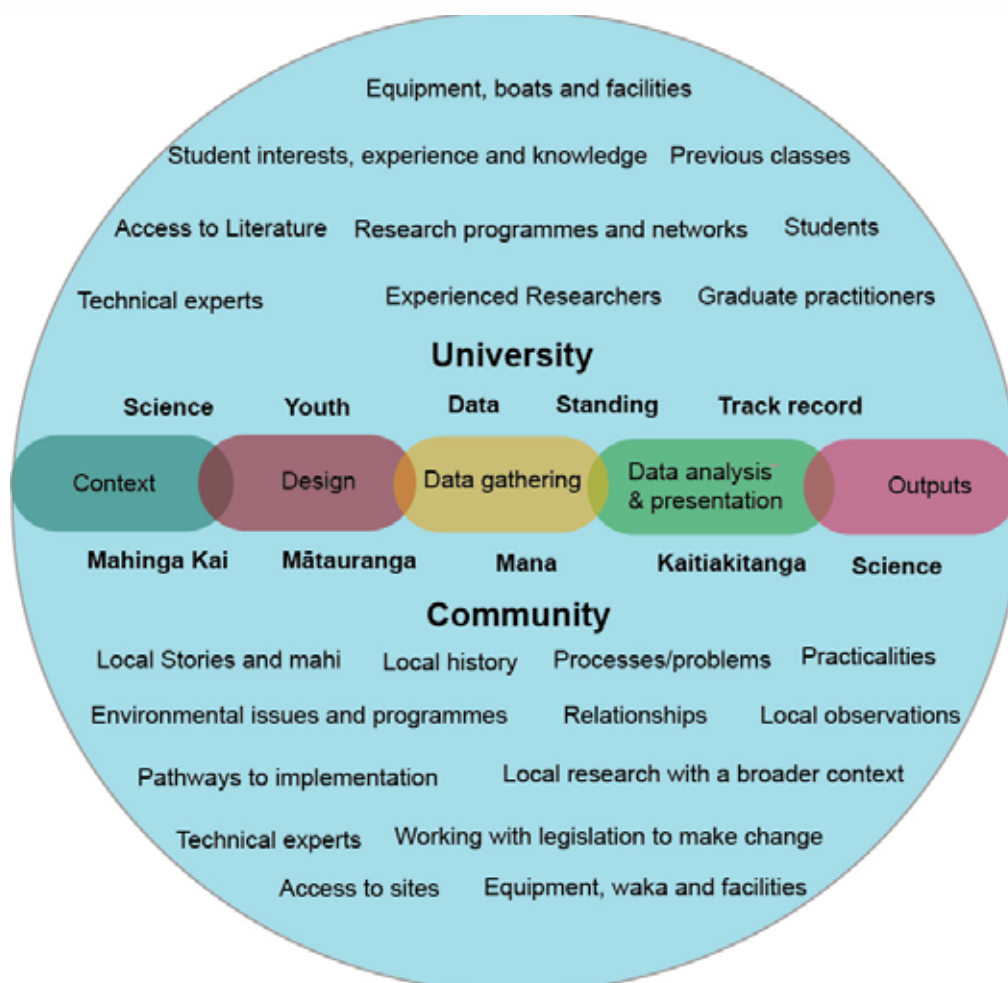


Figure 2. The partnership becomes blurred. Resources and strengths are provided by each side of the support team for AQFI 301. As each partner learns and builds capability, more and more aspects are provided by both sides of the partnership. Mutual respect is key, benefits are shared, and relationships and trust built – kanohi-ki-te-kanohi (face-to-face) and together through ongoing struggle to restore what has been lost and to build something new.

AQFI 301 enables holistic learning of the scientific process and helps students understand the role and limitations of science in society. The course is based within the East Otago Taiāpure and Waikouaiti Mātaimai CPA, and the broader cultural landscape of Kāti Huirapa ki Puketeraki on Otago's northern coast on New Zealand's South Island (Jackson *et al.* 2018; Hepburn *et al.* 2019). Alongside academic staff, Tangata Tiaki/Kaitiaki and their support staff, freshwater and marine scientists who work for the Te Rūnanga o Ngāi Tahu Mahinga Kai Monitoring and Enhancement Unit and other members of the community (e.g. conservation groups and farmers) support teaching. The course has a broad focus extending from rivers, estuaries and into coastal seas, consistent with the kaupapa of kaitiakitanga as applied locally as '*ki uta ki tai*' (mountains to the sea) (Hepburn *et al.* 2010). This is built from Te Tiaki Mahinga Kai (TMK), a long standing partnership programme between researchers and kaitiaki surrounding CPA (www.mahingakai.org.nz). Puketeraki Marae and its community are integral to the success of this course. The marae provides a base from which to conduct research and opportunities for formal and informal engagement with the community. Without the support of Kāti Huirapa Rūnaka ki Puketeraki the programme of research and learning would not be possible. The course has two distinct component parts. One is the University-based preparation for the noho marae and post-field workshops. The other is the noho marae encompassing the field work and community-based learning. Each of these two parts have activities that are best suited to the two distinct learning environments. These will be detailed in the following two sections.

Preparing for the course

The course begins with a series of seminars and workshops on campus. The initial learning phase is best suited to the University campus environment as students are not yet equipped to go straight onto the marae as a roopu. This preparation provides some historical, geographic, and cultural understanding of the area in which students will be working and living. Spanning almost 1000 years of history, there is a lot of material for students to consider. An introduction to what it is like to work with communities as a researcher and what to expect when living and working on the marae is provided. Aspects of Te Ao Māori (the Māori world), history, political boundaries, tribal and family units, tikanga and kawa on the marae are introduced. Aspects of local geography and history and the legislative processes that surround management of customary fisheries in New Zealand along with aspects of the Treaty of Waitangi as it applies to fisheries is also covered. This is very important as most science students do not have this background, many have not stayed on a marae and have little understanding of the Treaty of Waitangi. Students are prepared for their stay on the marae by learning about the pōwhiri (welcome ceremony on the marae), through a step-by-step process so they are more comfortable. Students develop a basic pepeha (who they are and where they are from), practise waiata (songs), and learn the importance and significance of karakia (incantation) in Te Ao Māori. The goal is enable students to be confident and comfortable when working with Tangata whenua² (local people).

Instructions and guidance on developing research questions, experimental design and the practical aspects of gathering and managing data are provided. Students learn about and are assessed on animal welfare ethics before they can handle animals in the course. Broader ethical questions around how to deal with sensitive fishery data are also discussed, e.g. what can it be used for? can it be shared? The answers are often found in doing the research and kōrero (conversation) in the field and on the marae. Questions and problems from the community and past research in the area are shared as a frame for the design of student projects and the research process and structure is guided by the teaching team. This design process is enabled by having students attend hui with the community such as East Otago Taiāpure Management Committee meetings. However, ultimately students have flexibility and can decide the direction of their projects. From this, students present a research question, preliminary plan and provide a list of equipment they need. Feedback is then provided from community members, scientists and academic staff to focus the project, give context and suggest alternative approaches.

Noho Marae

Most learning occurs when staying (noho) at the Marae, during the pōwhiri, mihi mihi (introductions) and doing the fieldwork, sharing the findings and reflection on the experience in the poroporoaki (farewell speeches). The marae is the best environment for this form of learning, as it brings the work, the issues and the people together in one place. The Tangata Tiaki/Kaitiaki involved with the programme also whakapapa to the marae. They provide an understanding of the kawa of the Marae and whaikōrero (formal speeches). A Māori academic staff member supports the class as kaikaranga (woman who makes a ceremonial call in a pōwhiri). Without these key people, engaging in the correct way on the Marae would be challenging. Leaders of the teaching staff are kaikōrero and speak on behalf of the students and the University. Students support speakers through waiata. The kōrero primarily surrounds the history of the people of the area, intrinsic connections of the people to te awa (river) and te tai (the coast), the relationship between Kāti Huirapa and University academics and students. A key theme is the foundational importance of education and knowledge. The message is that students should not be afraid to try, as everyone is learning and all are on different stages of that journey (Jackson *et al.* 2017).

Data collection

Once on the marae, learnings are less formal. Kōrero; during data entry, meal times, down time in the evenings, on the river or coast and working with people are learning experiences that are valuable, even if this value is difficult to quantify. Students work in small groups and are supported by experienced practitioners (e.g. scientists, Tangata Tiaki/Kaitiaki, academics). Often other members of the community come out to see field work, look at the methods being used and talk to students about their project. At all times

² Tangata whenua, in relation to a particular area, means the iwi, or hapu, that holds mana whenua over that area. Mana whenua means customary authority exercised by an iwi or hapu in an identified area, (Iorns Magallanes 2011).

of the day and night students and their supporters are on the local rivers, estuaries and coasts. Students direct their projects and are supported by a willing team of technicians from all the supporting groups involved in the course.

Once the field research is complete students give short (< 5 minutes) presentation on their work to the community, provide preliminary fresh results, images and videos of them at work. This presentation is key as it allows students to share their work while it is still fresh in their mind, allows feedback before the final reports are written and allows the community to see the human side of science that has been conducted. This also gives community members a chance to thank the students for their hard work – and to encourage them to be active ‘voices’ in their own communities for good science and community life.

Post-field workshops

After a reflection on the learning and experience of the noho marae at the poroporoaki, students return to campus for a statistics and data management workshop. Students are supported to develop reproducible data workflows. A benefit of this approach is that it demonstrates the importance of separating data collection, entry and validation (the ‘raw data’), from data analysis. Separation of these concepts, which students often conflate, is introduced with a discussion that the raw data and supporting documentation (e.g. a README file) is an output from their projects that will be used more than once. Raw data from AQFI are treated as operational datasets within TMK and are stored for use by the community to support projects in the future. Students are encouraged and supported to use open-source statistical (e.g. R) and mapping software (QGIS). This means that practical skills developed in AQFI are immediately transferable to the workplace, even if graduates move to small- or medium-sized organisations that cannot provide access to expensive software licences for more popular tools. In many instances, the AQFI statistics and data management workshop is the first application of theory learnt at an undergraduate level to a ‘real world’ problem and the first experience of end-to-end data science.

Course assessment

The primary means of assessment for the course is an end-user focused scientific report. While other work in the course is conducted as a group (emphasising concepts of collaboration and team work), the final reports are produced individually. This provides an opportunity for students to extend themselves through additional background reading, literature review and/or data analysis. Students with outstanding final reports are often invited to present to the East Otago Taiāpure Research Evening, held annually in November on the marae and well attended by members of the community.

Impact

The partnership approach to teaching in AQFI 301 provides mutual benefits. This programme has been run annually since 2014. The faculty and students have benefited from being part of the local community and the community has gained invaluable information about local ecosystems. It has created learning opportunities for the community, students, and University staff and has allowed the sharing

of knowledge of all types in a respectful way. Locally the research conducted in AQFI 301 has provided for input in many processes to date and provides a diverse data set to track the recovery of local systems over the 200-year vision for restoration held by Kāti Huirapa ki Puketeraki. The value of this data will only grow with time. This model closes the loop – ideas and problems from the community, provided to students, and returned back to the community with new knowledge that might allow action.

Students

Students learn how to be respectfully involved as a scientist in helping communities regain their roles as guardians of their local natural resources. The AQFI 301 course also allows science to be taught within a New Zealand context. Learning about fisheries management in a way that is useful for a community not only highlights the importance of relationships between communities and scientists to students, but also uncovers the need for multiple forms of knowledge in order to manage a place that is significant to multiple members of the community. From both formal course evaluation and informal feedback students appreciate being able to do ‘real science’ that is useful for the community. They like the freedom to pick their own topics, making their research more interesting. They value learning about ‘pretty cool ecosystems’, working with different people and understanding the dynamics of group projects. AQFI 301 provides a unique opportunity to fully participate in the planning, gathering and presenting of scientific data that is of relevance to a local community. Being able to collect information that was not only important for their own education but also was of interest to the local community was key. Research was done in a collaborative and supportive environment allowing access to knowledge from a range of experts. This experience provided insight into what it was like to work in science as well as introducing tools that would be invaluable in postgraduate studies.

Academics

Academics gain the benefit of working directly with Tangata Tiaki/Kaitiaki and other end users of the research. This helps build trust and relationships leading to further research. Academics also gain practical skills working alongside scientists from Te Tiaki Mahinga Kai who are experts in their field and have practical skills that can only be learned in a field setting. There are few examples of tertiary curriculum that are focused in a Māori context in sciences and certainly even fewer within the University of Otago. For academic staff this paper has provided a meaningful training ground for future scientists and researchers as well as providing real benefit to local community aspirations. Through the partnership approach, we have been able to create positive change for local issues, and furthermore train a new generation of scientists who are advocates for local, and local indigenous issues. The approach we have taken in this teaching has meant that we gain significant enjoyment and purpose in our work.

Community

From the community’s perspective the student research has provided scientific results, data, information, and facts to support community ‘voice’ in interactions with territorial authorities. These mechanisms for reporting back demonstrate real respect for the community and acknowledge to

students that their research is valued and useful. It provides 'alerts' about what is happening in the research sites. It has boosted confidence in the community for advocating for improved regulation, practices, monitoring and compliance of resource consents affecting coastal waterways. This helps working with regional and city councils, non-government groups (e.g. Fish and Game) and landowners regarding best practice to maintain and enhance biodiversity and healthy waterways. It also informs and guides community conservation projects (science-based conservation). The 'snapshot science' provided by the student researchers has built up over time. Some of the subjects have been refined over time to develop into stronger longitudinal studies. This approach to teaching brings scientists and community members together to understand what's happening in our marine, estuarine and river environments in order to make better decisions around local responsible stewardship.

Kaimahi

For kaimahi (employees) scientists for Te Rūnanga o Ngāi Tahu, supporting the AQFI 301 course aligns closely with their primary role of supporting Tangata Tiaki/Kaitiaki and whānau. AQFI 301 provides a framework for students to understand the role of science in this kaupapa (purpose) and it is satisfying for kaimahi to support them in this journey. The key strength of AQFI 301 is its focus on linking science to community. Immersing students within the local community allows for a much deeper level of understanding of values, aspirations, and tikanga, which not only serves to guide the direction of their studies, but gives them an opportunity to contribute to an intergenerational kaupapa. The sense of worth generated by this connection has been a significant contributor to many students choosing to remain engaged with this kaupapa long after the field course is completed. This, in turn, has fostered lasting relationships among the students, community, organisations, and individuals who support this kaupapa and has achieved something that is much greater than the sum of its parts.

Tangata Tiaki/Kaitiaki

The benefit to Tangata Tiaki/Kaitiaki and Mahika Kai³ (places and practice associated with wild food gathering) is greatly enhanced by the ongoing science and scientific knowledge willingly shared with this role and the need to be more fully educated as a community, in areas of significance for both. Understanding of the role that science and its application offers Tangata Tiaki/Kaitiaki as recipients allows a clearer knowledge exchange through science and mātauraka (knowledge held by practitioners and within practices) partnerships. That knowledge exchange uplifts and enhances our customary roles through these interactions. The ability to collaborate with science experts and their students continues to build understanding of our wai tai (seawater) and wai māori (freshwater) and how science and scientists treasure equally the ecosystems in which our kaimoana (seafood) live and grow. Going forward we are more fully able to live as the Iwi whakatauaki (proverb) intends; Mā tātou, aianeī, me a muri ake. This takiwā will

be a place where our mokopuna (descendants) will benefit from this significant and valued partnership and how we as kaitiaki (guardian) whether as scientists or as Tangata Tiaki/Kaitiaki, are better able to maintain ecosystems and steadily regenerate the health of the awa and moana (sea) over time as we encourage better management of whenua practices in our rohe (territory). This is what customary practitioners are charged with doing as kaitiaki and are aided by the ways in which science is better able to acknowledge the importance of science necessary to complete our kaitiakitaka (guardianship) and is where scientists (as students or professionals) are willing to share and apply their knowledge aided to through the combining of mātauraka with science.

Limitations

The relatively short timeframe of this course provides some limitations to the questions that students are able to address, especially in relation to some of the larger issues that the community is grappling with. This is well managed, however, by supporting students to design projects that are able to be integrated into a long-term narrative and be woven into a larger picture along with the work of past and future AQFI students. This course has been an entry point for students into community-based postgraduate research enabling longer-term projects to be conducted. The main limitation for rolling this type of course out in a wider context is that relationships and trust need to be developed first. This takes time and needs to happen at a tempo that all are comfortable with. Post-course evaluations are conducted to provide formal feedback from students in order to aid future improvements.

Conclusions

Scientists must consider cultural and historical context, how communities operate (relationships and conflict) and be able to conduct research in a respectful manner. They must walk the line, avoiding bias, to strengthen the value of their data in decision making but focus on questions relevant to local issues and receive input and support from end users to maximise utility. Noho marae provide a unique opportunity for students to learn what is expected when working with communities and to be open and ready to explain what the work is about and what underpins the approach used. Working with Tangata Tiaki/Kaitiaki who are legislatively empowered to change public policy and who possess relationships in the community to influence what people do strengthens the impact of research conducted on this course and also shows students how their research is used. This course supports the responsibility of mana whenua as they continue the task of active customary management in a modern landscape. The relationship between Mātauranga Māori and current science is as relevant now as it has ever been. The relationships that allow this approach are built and maintained through hard work on both sides and a shared commitment to the management of the fishery for everyone. AQFI 301 is really a celebration of the partnership and provides inspiration and hope that a generation of scientists will have some understanding of local context, history, and the importance of place when they are in a position to make a difference.

³ This paragraph is written in the voice of the Tangata Tiaki/Kaitiaki for Kāti Huirapa ki Puketeraki, so the southern dialect of Kāi Tahu (Ngāi Tahu), where K is substituted for Ng, is used.

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Mātauranga Māori and the high-tech interface

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Abstracts

E tino whai nei a Science for Technological Innovation (SfTI): Kia Kotahi Mai - te Ao Pūtaiao me te Ao Hangarau - kia whakanuia ngā pūkenga i Aotearoa ki te whakamahi i te pūtaiao, i te pūhanga, i te hangarau hoki hei whakatipu ake i te ōhanga. Ahakoa te tokoiti o te hunga Māori e tautōhito pū ana ki tēnā, ki tēna o ngā momo hangarau, kua waihangaia mai e SfTI tētahi mahere whakamahinga – ko Te Tihi o te Maunga – e whakanui nei i te rite ā-hiranga o te āheinga whakawhanaunga me te āheinga tangata e pā ana ki te pūtaiao hou, hei arumoni, hei whakamahinga hoki mā te iwi Māori, me te iwi Māori anō hoki. Mā roto mai i tēnei tuhinga, ka tirohia whānuihia te whakawhana-ketanga o te mahere me ngā whakaaroaro o muri, ka tahi; ngā whakamahinga o te mahere kia ākina te huringa o te whakaaro e taea ai te mahi tahi ki te hunga Māori kia āta panoni rā pea, kia kanorau rā pea te pūtaiao me te hangarau, ka rua; ka mutu, ko te anga whakamua a SfTI.

Science for Technological Innovation (SfTI): Kia Kotahi Mai - te Ao Pūtaiao me te Ao Hangarau - has a mission to enhance New Zealand's capacity to use science, engineering and technology for economic growth. Despite the small numbers of Māori with domain-specific technical expertise, SfTI has developed a model - Te Tihi o te Maunga (Mountain Summit) - that emphasises the equal importance of relational and human capacities to commercialise and use novel science for and with Māori. This paper provides an overview of the model's development and the theory behind it; how the model is being used to assist the mental shift required to work with Māori in a way that may transform and diversify science and technology; and, finally some future directions for SfTI.

Introduction

In 2014, the first group of what would be 11 National Science Challenges (NSCs) was launched. Designed to 'take a more strategic approach to the Government's science

investment by targeting a series of goals, which, if achieved, would have major and enduring benefits for New Zealand' (Joyce 2013), the NSCs will receive almost \$1.6 billion of government funding over 10 years.

The NSCs initially met with some scepticism from scientists and Māori. In a 2014 New Zealand Association of Scientists 'snapshot' survey, 80% of the 280 respondents disagreed that the NSCs were the best way to organise research to deliver benefit to New Zealand (Ray 2014). Likewise, Māori were disgruntled with lack of representation within the challenges, with claims of being shut out from the process (Prussing & Newbury 2016). However, five years on, such positions have changed, with one commentator noting that there had been 'some great wins from the Challenges' and another stating that 'the most successful NSCs may be those that have learned to cooperate most effectively with other research organisations' (Science Media Centre 2018). Māori too have partially revised their position, with NSCs having Māori as independent advisors (Kāhui), in governance, as researchers and with projects or programmes specifically focussed on Māori concerns. However, some Māori still have reservations. In a 2016 panel discussion (Ruckstuhl *et al.* 2016) participants saw both opportunities and challenges for Māori in the NSCs. While some saw the NSCs as a new research paradigm requiring collaboration with Māori communities leading to transformative outcomes, others questioned the difficulty of mixing science outcomes with social outcomes, given this would require a 'mental shift' of researchers.

This 'mental shift' is the area that has been the focus of Science for Technological Innovation (SfTI): Kia Kotahi Mai - te Ao Pūtaiao me te Ao Hangarau. SfTI's mission is to

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Willy-John Martin (Ngāti Wai, Ngāti Whātua, Ngāti Tamaterā) is the Manager Vision Mātauranga and Capacity Development at the Science for Technological Innovation (SfTI) National Science Challenge. His scientific work in New Zealand and Australia incorporates both western science and indigenous perspectives, and has included research on rongoā Māori, inflammation, gouty arthritis, rheumatic fever, omics and genetics, and cellular-based technologies. His current work involves the strategic development and implementation of Vision Mātauranga in the technology and innovation sector, and oversight of the capacity development programme deployed to scientists across the SfTI community.



enhance New Zealand's capacity to use science, engineering and technology for economic growth. Despite the small numbers of Māori with domain-specific technical expertise, SfTI has developed a model, Te Tihi o te Maunga, or Mountain Summit, that emphasises the equal importance of relational and human capacities to commercialise and use novel science for and with Māori. Previous research (Ruckstuhl *et al.* 2019) has provided a brief description of the model in the context of broader Māori science and technology capacity. This paper expands on that research, giving a more detailed assessment into the theory behind the model's development and an analysis of how the model, along with SfTI's changes in process, are supporting the 'mental shift' of scientists to work with Māori. The study draws on longitudinal research undertaken by one of SfTI's research streams, Building New Zealand's innovation capacity (BNZIC). Using a multi-method approach suitable for the investigation of complex phenomena (Hunter & Brewer 2015), the researchers present an overview that emerged (Creswell 2005) through analysis of SfTI documents, observations on SfTI organisational activities and practices, and surveys of SfTI researchers. To conclude, some future directions for the SfTI challenge are indicated, as it applies and refines the model in a way that has potential to diversify New Zealand's science and technology knowledge domain (O'Brien *et al.* 2015).

Aims of Science for Technological Innovation: Kia Kotahi Mai - te Ao Pūtaiao me te Ao Hangarau

Framed within the concept of 'open innovation' (Chesbrough, 2003), the SfTI challenge focus is on 'the processes and relationships needed to acquire, assimilate and exploit knowledge from both internal and external sources' within 'co-created partnerships' (Science for Technological Innovation 2015). The challenge proposal argued that it was the lack of connection between New Zealand's researchers and industry that was undermining the ability to benefit from public spending on physical sciences and engineering. Hence, the SfTI challenge should focus on 'understanding in greater detail how co-innovation actually happens specifically in New Zealand's indigenous Māori context' (Daellenbach *et al.* 2017).

To understand the detail of co-innovation, SfTI has been operating under a three-tier model, to bring into closer alignment researchers' technical, human and relational capacity (Figure 1).

As defined within the SfTI challenge, *technical capacity* is the ability to deliver 'stretch' or novel science and technology; *human capacity* includes understanding business, entrepreneurship skills, and ability to communicate research to industry or end-users; and, *relational capacity* is how researchers and research teams engage with industries, including Māori enterprises and their knowledge systems or mātauranga Māori (Science for Technological Innovation 2015).

An advantage of the three-tier model is that, in line with broader literature on science innovation (Leydesdorff & Etzkowitz 1998; Rogers 1983; Garud *et al.* 2011), it has articulated the dimensions of innovation capacity as more

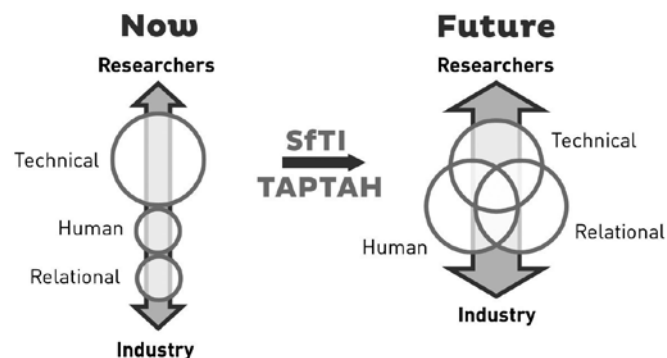


Figure 1: Relationships between the three capacities: current and future trajectory

than just technical science expertise. However, programme implementation that supports Māori innovation aspirations in areas as diverse as sensors, robotics and automation, IT, data analytics and modelling, and materials, manufacturing and design, has required creativity, and 'buy-in' from researchers and the leaders of the Challenge. Through analysis of the role of the Kāhui in leading development of a new theoretical model, Te Tihi o te Maunga, the next section explains how this was achieved.

Setting SfTI's direction: Te Ao Māori

The Kāhui Māori was established to ensure that Māori world views and principles were embedded across the Challenge with members drawn from Māori business, community and academia. The Kāhui Māori terms of reference identified six foci that would cover SfTI's strategic, operational and scientific activities:

- F1 – Strategic direction of SfTI from a te ao Māori lens;
- F2 – Identifying research and engagement opportunities for Māori;
- F3 – Project assessment to ensure due consideration to the Vision Mātauranga policy throughout a project's development and planning;
- F4 – Capacity and capability building for Māori and non-Māori in the NSC;
- F5 – Knowledge translation, ensuring that there were processes in place to ensure that SfTI delivers tangible benefits for and with Māori; and
- F6 – Gap and risk analysis to anticipate and remove barriers of delivery to Māori.

In the first year, the large science and technology projects were investigator-led, hence incorporating a Māori lens (Focus 1) was not key to the science strategy at that point. However, with development of the 'seed' projects in year two, Focus 3 came to the fore, with 20% of funding assigned to small 2–3 year Māori-specific projects such as:

- development of a low-cost sensor network that provides real-time monitoring of the quality of freshwater supply in the Waikato River, drawing knowledge from western science and Te Ao Māori;
- formulating a framework for next generation Indigenous data and knowledge management in eResearch;
- digitisation of whakapapa into a secure, easily shareable, unalterable form;
- Māori researchers supporting women to cease smoking

during pregnancy by developing 3-D software to model the impacts of smoking on the developing fetus;

- research with iwi to give accurate estimates of kiwi population densities using machine learning algorithms and acoustic microphone arrays and mathematical and statistical methods to estimate the location of kiwi from their calls.

Focus 4, capacity building, has also seen successful implementation. Given that the majority of science researchers were largely new to anything Māori, introductory human capacity development workshops were organised that explained the Māori economy and how science and technology could contribute to it. Feedback from the first year of workshops indicated that of the 29 participants giving feedback, 93% reported that the workshop had provided them with new knowledge and skills, with 79% feeling confident they could apply it. Additional opportunities for knowledge and skill development have included encouraging scientists to attend Māori focussed events such as: the Federation of Māori Authorities annual meeting; the Ahuwhenua (Māori farming) awards; Matariki X – a Māori technology event; and Te Matatini, the national biennial kapa haka competition. Additionally, a wallet-sized guide, He Ritenga, developed by the Kāhui Māori to incorporate appropriate karakia, waiata and greetings within science meetings was provided to all SfTI researchers (Science for Technological Innovation 2018a).

While these might be considered helpful initial steps, Focus 5 – Māori knowledge translation into the science and innovation itself – has required a different approach. To help theorise this, the Kāhui developed a three-dimensional model – Te Tihi o te Maunga, or Mountain Summit (Figure 2) – to assess the extent to which Māori resources, knowledge and talent were being incorporated and utilised for innovation.

The first dimension, is the extent to which mātauranga Māori (Māori knowledge) was being utilised. Encompassed within this axis are Māori values, principles, processes, approaches, knowledge of history and resources, relationships, language and technical knowledge (see for example: Cram *et al.* 2002; Pihama *et al.* 2004). The second dimension is the extent to which Māori participate in the project, with inclusion from inception and co-leadership of the project the most desirable approach. The third dimension is the potential to deliver benefit for Māori: new products, increased efficiencies, positive impacts, training and capability gains, with a higher emphasis on priority areas identified by Māori. It was also viewed that research incorporating all three dimensions in technical innovation – Tihi or summit research – would lead to innovation and new Māori knowledge. The Kāhui Māori used the term tino mātauranga to describe working at the forefront of Māori knowledge generation through the interface of mātauranga Māori with emergent technological innovation.

Te Tihi o te Maunga allows the Kāhui Māori to map projects, from having little or no Māori innovation (viewed as landing on the shore), to incorporating some Māori potential (arriving at the base of the mountain), to high levels at the summit. The model owes much to earlier Māori science and innovation frameworks (Cunningham 2000) which have been adapted by others (Ministry of Business, Innovation and Employment 2019; New Zealand's Biological Heritage 2019).

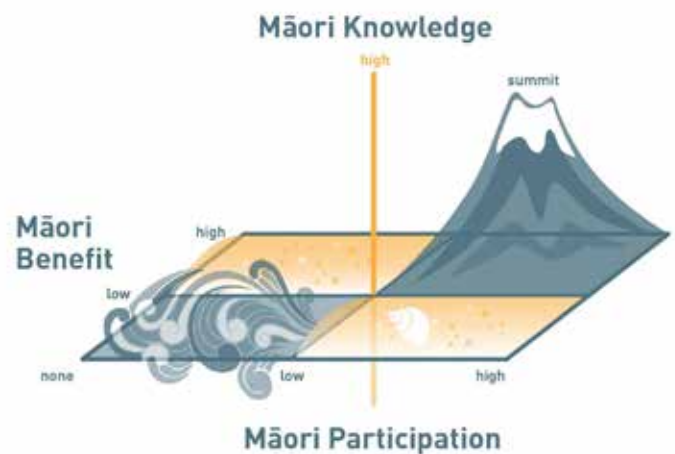


Figure 2. Te Tihi o te Maunga Science and Innovation Model

While the model draws on its predecessors, its novelty lies in its belief that sci-tech innovation and 'stretch' mātauranga will occur when there is an interface at the summit. While this may be a bold approach, there is emergent evidence that this is beginning to occur within the high-tech sphere.

Te Tihi o te Maunga in Operation

This section briefly outlines how the Te Tihi model is being implemented as SfTI research advances into the second tranche of funding. This is exemplified in the convergence of projects under a broader and strengthened mātauranga Māori approach, in the first instance around data analytics. This has involved three concurrent sets of activities:

- Greater engagement with Māori enterprises (iwi, hapū, business organisations);
- Māori-active research design processes – mission lab approach;
- Specific Māori-defined and run programmes.

The first example of greater alignment with Māori derives from a project which was initially the third component of an investigator-led programme under the IT, data analytics and modelling theme. While the two main projects finished, the third – 'Te Tātari Raraunga: Spearheading economic, social, and cultural revitalisation through Māori Data Science' – has been extended to focus on applying data analytics to find Māori land shareholders (Science for Technological Innovation 2018b). This is a problem shared by tribal groups and organisations such as Te Tumu Paeroa that manage Māori land with multiple small shareholding owners. This has required a shift from a science-led research project to one requiring a partnership with one of New Zealand's major Māori enterprise groups, Paraninihi ki Waitotara (PKW). Given that tracing shareholders requires access to and understanding of whakapapa, a tikanga approach has been adopted that is stretching both the science and mātauranga Māori. Along with refocussing of the initial project, new capabilities have been required, including working with linguists and archivists skilled in reading and interpreting Māori text. As well, there has been a need for new analytic tools to analyse the Māori-language archival texts and other data sets, such as whakapapa lists, that form the basis of the project.

The international interest in capturing benefit from large-scale data is both a feature of the Tātari Raraunga

project and the growing awareness amongst Māori of data sovereignty (Te Mana Raraunga, n.d.). As has been identified internationally, data sovereignty is linked with

‘indigenous peoples’ right to maintain, control, protect and develop their cultural heritage, traditional knowledge and traditional cultural expressions, as well as their right to maintain, control, protect and develop their intellectual property over these’ (Tauli-Corpuz 2016, p. xxii).

This is a key concern of a second major project, Ātea, which aims to support Māori, iwi and communities to connect tribal members to mātauranga-ā-iwi, reo, tikanga, histories and knowledge (Science for Technological Innovation 2018c). Owing to a shift in SFTI’s practices from the investigator-led sand-pit approach to the current mission-lab process, this project took 18 months to develop. A research sand-pit, popularised by MBIE to initiate the NSCs (Science Media Centre 2013), is a workshop process that aims to avoid research silos and to encourage multi-disciplinary collaboration (Collins *et al.* 2013). In SFTI’s case, the first sandpits brought together largely business and scientists and led to projects that were investigator-led. The sandpit approach was adapted to bring together Māori researchers and organisations, along with technical scientists, to workshop pre-developed research proposals guided by a taumata (a group of respected Māori experts). While this refined process was useful to give pointers to the direction of a potential research area – a digital marae – the process was further refined to the mission-lab process. In this process industry and Māori define the areas of future research, prior to science input, with these areas then tested through an ‘expression of capability’, whereby ‘through a negotiated process, with industry and Māori still in the room, a multi-disciplinary proposal is formed’ (Science for Technological Innovation 2018c). Ātea required several iterations and refinements with technical experts, including mātauranga experts and community, before being finalised.

The Ātea project (Science for Technological Innovation, 2018c) is ambitious and includes:

- expanding a core digital platform to static and dynamic mātauranga content; integrating block-chaining to assist with indexing, traceability and control of content;
- integrating text and voice recognition for te reo Māori; and
- creating a comprehensive technological, psychological, cultural and socio-psychological model for virtual avatar interactions that incorporate culturally appropriate design features.

The project operates through a collaborative kaupapa Māori approach, which will incorporate the use of wānanga to assess ‘the impact of AI, VR & AR, mixed realities, and machine learning on space, time and place and its effect on culture, language and knowledge’ (Science for Technological Innovation 2018c). According to Royal (2012) mātauranga Māori responds to the ‘great questions in life’ and it is through the process of wānanga and expert discussion about mātauranga Māori that contemporary perspectives can be derived. Thus the process of wānanga creates new knowledge in order to ‘improve the way in which human-kind exists and lives in the world’ (Royal 2012, p. 37).

Wānanga as a facilitative process between the science and Māori spheres has been researched previously (Hudson *et al.* 2012), but it is likely that this will be the first time it has been characterised in the digital sphere. Lessons from that earlier research are likely to inform the Ātea wānanga, particularly how participants negotiate their relationships with: existing and new knowledge; different systems of meaning; and with groups that identify with different knowledge systems (Hudson, *et al.*, 2012, p. 19).

The mission-lab approach has also been successful in seeding another data-focussed project, Māori Data Sovereignty, which is intended to begin early in the second tranche of funded research. Led by experts from the Iwi Leader’s Chairs forum (Iwi Chairs Forum 2018), the aim is to create new technical solutions rather than implement existing technologies. This is because, for Māori, data can be considered a taonga and hence subject to both individual and collective restrictions. Hence there will be a need for novel approaches to how data about, by, or for Māori is collected and shared (data management and integration) as well as data access, security and control (Science for Technological Innovation 2018b). The significance of this area for Māori and others is being tested through hui. To date, two hui in Wellington and at Te Aurere in Northland, have attracted almost 200 participants including iwi and hapū representatives, Māori researchers and practitioners, rangatahi, and data specialists. The intention is to use the new project to act as a catalyst to bring together parallel but disconnected research in this area (Science for Technological Innovation 2018b).

Looking to the future

As can be seen from the previous sections, human and relational capacities have been a focus of the SFTI approach to working with Māori and across the Challenge more generally. Starting with the more traditional investigator-led science of the early programmes, SFTI evolved its approach to a version of MBIE’s sand-pit that brought together individual’s project proposals, to the novel mission-lab approach whereby the areas of research are defined by business and Māori then enabled by science capability. This ‘flipping’ of the research model has worked well for Māori in that projects that are of real concern (axis three of the Tihi o te Maunga model) can be identified and constructed from the beginning (axis two) in order to innovate science and mātauranga (axis one). This has been aided by a deliberate strategy of human capacity building to create the ‘mental shift’ of researchers who are comfortable with working within a mātauranga Māori paradigm.

The Kāhui Tihi o te Maunga model acts as both a guide and as a process for evaluating the opportunities and gaps (Focus 6) for delivery to Māori. For example, how Intellectual Property is assigned and managed between science and Māori partners is still being considered, particularly in light of the Wai 262 report (Waitangi Tribunal 2011). Another issue is how best to include rangatahi in science-led research. Responding to this challenge, a project is being developed spearheaded by three young co-leaders, two of whom are Māori entrepreneurs, including a member from the Kāhui. Other research is also in the development phase, with projects around water and bio-security – both areas of high Māori interest.

Conclusion

SfTI has concentrated not only on technical science but also on the relational and human capacities needed to create innovation that connects to industry and Māori. Within this broader context, the Kāhui Māori terms of reference have provided the framework that has led to a robust model, Te Tihi o te Maunga, that provides operational guidance to SfTI's large and small research projects and capacity development programme. Despite the current small numbers of Māori with technical expertise in the research domains of SfTI, the processes and approaches laid out in this analysis have shown that this need not be a barrier. Rather, these novel approaches have allowed Māori to take a more active role within the Challenge which not only diversifies participation but has the potential to diversify the science and technology knowledge domain itself.

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Congratulations

The primary objective of *Science Review* is to inform and stimulate. This thematic issue entitled 'Mātauranga and Science' is no exception. The New Zealand Association of Scientists (NZAS) is delighted with it and congratulates the many authors involved and especially our distinguished Guest Editors, Ocean Mercier and Anne-Marie Jackson.

Why now and why this topic? This year, 2019, is significant in terms of Māori culture: it is the 250th anniversary of the momentous sudden 'arrival' of a European ship in Aotearoa. Unbeknownst to Māori, the man in charge had instructions from his 'chief', King George III, to search for a putative continent. Hence, he spent some time in Aotearoa, trying to determine its geographic extent. Was this 'new land' a continent, or just an island? Notwithstanding the pivotal role Tupaia¹ played in the voyage, on board were James Cook and a group of men and boys, not a single woman, and they came from a completely different culture.

Most significantly, they were not Māori, and yet they were people. The rest is history, you might say. However, over the past 50 years, since the 200th anniversary of Cook's arrival, there has been a considerable revival of Māori culture within New Zealand and along with it a huge interest in mātauranga, as is clear from the contributions herein.

Science, in its broadest sense, is the exploration of ideas; it comprises ideas that have been explored and discarded, and ideas that have yet to be refuted. Fundamental to science is evidence and repeatability of results. In so-called Western science this requires documentation and publication; it is part of an established written record. Mātauranga is/was different: it is part of an oral tradition.

However, within the past 50 years there has been a sea-change: mātauranga has been documented and committed to written publication, primarily with the advent of legal instruments within the Ministry of Justice, namely the Waitangi Tribunal and the Office of Treaty Settlements. As such, a huge body of Māori knowledge has been captured for posterity.

This special issue is a tribute to where we, in New Zealand, have got to thus far in this endeavour. What has been accomplished is truly remarkable, and NZAS predicts that it is only a matter of time before mātauranga will be 'mainstream' across all New Zealand education providers as part of our unique New Zealand culture.

Hamish Campbell and Allen Petrey
for NZAS Council

¹ See: <https://teara.govt.nz/en/biographies/6t2/tupaia>



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