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Research and development absorptive capacity: a Māori perspective

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ABSTRACT

This paper presents a view of research and development absorptive capacity from a Māori perspective. The assessment is part of a case study of a longitudinal programme – Science for Technological Innovation: Kia kotahi mai – Te Ao Putaiao me te Ao Hanagarau that aims to increase Aotearoa New Zealand's capacity to use sci-tech for economic benefit. The paper finds that while Aotearoa New Zealand's macro policy and meso institutional levels have become more responsive to Māori research and development demands, at the micro level of the individual or the firm there are still constraints given the small numbers of Māori in science, technology, engineering and mathematics. In response to this, a novel model of Māori sci-tech capacity is under development that considers not only research and development technical capacities, but also the human and relational capacities required to accelerate absorptive capacity to respond to Māori social and economic aspirations.

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Introduction

Māori make up only a small proportion of New Zealand's academic and research workforce (Kidman et al. 2015). Despite strategies and frameworks developed over time, participation and achievement rates for Māori in mainstream tertiary education organisations remain lower than anticipated (Jahnke and Te Wiata 2016). Latest figures from the Ministry of Education (MoE) show there were 495 Māori academics compared with more than 10,000 non-Māori in 2018 (Hurihanganui 2018), with even lower numbers of Māori in science, technology, engineering and mathematics (STEM) disciplines. Recent media attention has highlighted a need for more academic capacity in the university and research and science sectors. Given the implications of National Science Challenges (NSC) such as the case study presented here, this paper examines Māori STEM capacity in Aotearoa New Zealand and the programmes trying to address this issue.

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Recent evidence suggests that academic barriers can be reduced by culturally responsive policies and strategies, integrated support services, support staff and programmes, and improved institutional practice (Theodore et al. 2017). Science for Technological Innovation: Kia kotahi mai – Te Ao Putaiao me te Ao Hanagarau (SfTI-TAPTAH), one of Aotearoa's 11 NSCs, is developing an approach that seeks to translate such evidence into its programmes. With a mission 'to enhance New Zealand's capacity to use physical sciences and engineering for economic growth' (Science for Technological Innovation 2015a), SfTI-TAPTAH has reframed the research and development notion of 'absorptive capacity' (AC) to incorporate a Māori perspective. The case study presented here reflects on the first years of SfTI-TAPTAH, a 10-year national programme focussing on the High Value manufacturing sector with research that includes IT and data analytics, additive manufacturing, medical technology, virtual reality, robotics, and 'internet of things'.

While SfTI-TAPTAH research involves the development of novel and leading edge science and technology, the broader mission is 'capacity building' so that 'science will not be left stranded in the lab' (Science for Technological Innovation 2015b). Such a mission implies that scientists require additional skills apart from their technical proficiency to ensure that their leading edge science finds an economic or social use. These non-technical human and relational capacities have become the focus of both research and a SfTI-TAPTAH development programme that explicitly incorporates Māori needs and demands (kaupapa), Māori preferred ways of engaging (tikanga) and Māori knowledge (mātauranga). This approach is novel for two reasons. First, most capacity building research in the research and development (R&D) sector focuses on firm level capacity or absorptive capacity (Cohen and Levinthal 1990), and only more rarely (Lane and Lubatkin 1998) considers the capacity of the organisation external to the firm – in our case study, the research institution and its scientists. Second, considering AC from an Indigenous perspective is likewise novel, given that most capacity building is considered from a developmental rather than R&D perspective. Combining both the focus on scientists and science institutions' AC in relation to incorporating Indigenous notions of AC is therefore breaking new ground.

The paper proceeds as follows. First, there is a brief overview of AC as defined in the R&D innovation and developmental academic literature. These AC definitions are then reviewed to provide context to policy developments that have sought to address Māori science, technology, engineering and mathematics (STEM) technical capacity. To assess the success or otherwise of these policies, the third section provides an analysis of a scoping review of current Māori STEM capacity. In response to these findings, a human and relational capacity development programme and model is described that seeks to accelerate scientist's capacity to work with Māori on Māori-derived sci-tech projects. The paper concludes by offering some comments on next steps.

Redefining absorptive capacity

The concept of capacity is familiar within the R&D and innovation literature. It is most often associated with the notion of absorptive capacity, or the mechanism by which a firm, as a consequence of its own R&D efforts and internal capacities, is able 'to recognize the value of new external knowledge, assimilate it, and apply it to commercial ends' (Cohen and Levinthal 1990, p. 128). This is particularly important for knowledge-intensive High Value Manufacturing industries in the context of 'open innovation' (Chesbrough 2003)

whereby such industries open up their internal innovation processes to interaction and collaboration with external expertise to solve their complex science and technology problems (Tacke 2010; Belderbos et al. 2016). Increasingly, open innovation is widespread, with innovative ideas garnered from many sources, including universities (van de Vrande et al. 2009; Chesbrough and Brunswicker 2014). However, unlike in other Organisation for Economic Co-operation Development (OECD) countries, New Zealand firms have low levels of collaboration with universities and research institutions with low expenditure on R&D by OECD standards (Ministry of Business, Innovation and Employment (MBIE) 2016; OECD 2017). Given this, a key rationale for programmes like SfTI-TAPTAH is to contribute to the processes that accelerate uptake and use of leading edge science.

While most open innovation and AC research is on the firm (Perkmann 2007; Miller et al. 2016; Mascarenhas et al. 2018), SfTI-TAPTAH research mostly focuses on the micro level of the research scientist and team. A particular focus is technical 'knowledge creation and its dissemination' (Bartling and Friesike 2014, p. 5) through scientists' interaction, collaboration or co-creation with businesses and Māori enterprises. The technical capacities of leading edge research scientists derive from 'years of training, reward systems, rules of competition and collaboration between and within different [science] groups' (Geib 2017). Such science knowledge is both explicit and tacit (Polanyi 1967), with tacit knowledge being that which is 'incommunicable' because it is 'experience performed in the pursuit of knowledge' (Nahapiet and Ghoshal 1998, p. 245). Technical capacity is the sum of society's investment in training through the higher education system and the opportunity to collaborate or compete in the 'closed community' (Harding 2011, p. 367) of the science system. Yet, science is increasingly 'open', with speedy dissemination of results, cross-institutional collaborations financed from both private and public sources, and inter-disciplinarity (Friesike et al. 2015). Such openness is a function of both scientific curiosity and the need to address globally common 'wicked problems' (Rittel and Webber 1973) such as climate change or the spread of infectious disease. These globally complex issues require scientists to operate across borders: geographic, disciplinary, social and cultural. That is, scientists' human and relational capacities are as necessary as their technical capacities if they are 'to talk [to] and work with their partners in order to progress co-innovation efforts' (Daellenbach et al. 2017, p. 456). From a Māori perspective, these latter capacities are vital given the constrained nature of current Māori sci-tech capacity, a result of past impediments to Māori development. The Māori experience of colonisation in Aotearoa New Zealand parallels that of other indigenous communities and for well over one hundred years, statistics have indicated that the Māori population occupies the lower socio-economic realm in New Zealand society, illustrated by poor education and health statistics, as well as higher rates of incarceration (Walker 1990; Durie 2001). While current government policy aims to rectify such impediments, the strategies needed to accelerate sci-tech capacity for the benefit of Māori are largely scattered and unfocussed. Before exploring this, we examine the prior context that has given rise to the current need to address sci-tech AC from a Māori perspective.

Absorptive capacity and Indigenous people: macro factors

Indigenous people are amongst the worlds' poorest even if they live in industrialised countries (United Nations 2009; Hall and Patrinos 2012). To support developing nations, institutions like the UN or the World Bank supply the capital or technical

expertise which such nations then 'absorb' (Berger 1982; Lamb 2013). Thus, in the economic literature, AC is seen as a form of developmental capacity. While innovation AC and developmental AC differ theoretically and in practice, the juxtaposition is useful. First, as in the R&D (OECD 1997, 2015a, 2015b) and social innovation literature (Centre for Social Innovation 2003; Krlev et al. 2014), developmental AC points out that *macro* level factors (management, economic, social and human) provide the underpinning infrastructure for *micro* (firm level) or *meso* (community/institutional) level outcomes (Heffernan 2013, p. 13). Second, the developmental AC literature notes that external prescriptions or 'borrowed ideas, [utilized] borrowed experiences and funds and [engaged] borrowed hands', do not necessarily lead to benefactors' planned for social or economic outcomes (Heffernan 2013, p. 14). Rather, indigenous-sourced *collective* understandings and practices need equivalent or greater consideration. In respect of this, innovation AC needs to be aware of its normative leanings. Privileging individual enterprise divorces organisations from their historic and ideological context and obviates the macro level constraints – structural, political, resource or ideological – that inhibit or prevent enterprises from 'developing' in the first place (Kenny and Clarke 2010) *and* misunderstands or ignores Indigenous collective cultural arrangements and preferences.

For many Indigenous people, the macro level constraint is colonisation, which along with its historical and many would argue ongoing ideological impacts (such as ethnocentrism), has impeded Indigenous sci-tech capacity (Scott 2011). Because of this capacity 'deficit' or 'gap', development agents often apply narrow technical solutions. Such 'deficit thinking' first, overlooks the fact that all communities have capacities, and second, that capacity developers may themselves have much to learn. In other words, capacity development or AC is a 'two-way' street. As Indigenous advocates have emphasised, Indigenous peoples are not just recipients of development but agents contributing to transformational change through 'traditional knowledge systems and innovations developed over generations' (Balawag 2016). For Māori, this knowledge system is *mātauranga Māori* (translated as knowledge, wisdom, and ways of knowing), and how the sci-tech system in Aotearoa New Zealand accommodates and uses this knowledge is important to Māori social and economic development.

In acknowledgment of these historical impediments, over the last thirty years there have been policy efforts to address persistent Māori under-representation in the meso-level institutions that enable sci-tech capacity. Such initiatives, in line with the changing view of capacity approaches as described earlier, are exemplars of the Māori 'potential' ideology, that aims to fulfil 'Māori aspirations for optimal quality of life' (Te Puni Kōkiri 2007) so that Māori 'make choices for themselves' (Barcham 2012, p. 64). At the policy level, Māori education strategies such as *Ka Hikitia – Managing for Success* focus on education system performance and Māori education achievement (Ministry of Education 2013). Increased educational attainment is seen as a crucial enabler of Māori economic aspirations in policies such as *He Kai Kei Aku Ringa,* the Māori Economic Development Strategy (Te Puni Kokiri 2013). In turn, the science and innovation policy *Vision Mātauranga* (VM), expects to 'unlock the innovation potential of Māori knowledge, resources and people to assist New Zealanders to create a better future' (Ministry of Research, Science and Technology 2005). Such policies influence the institutional level, with an 'indigenous dimension' embedded within higher education (Frawley 2017, p. 71). Similarly, most if not all research institutions (eg. Crown Research Institutions

and Universities) and many central government agencies in Aotearoa New Zealand have attempted to address the VM policy in some way with statements relating to 'mātauranga Maori' or Vision Mātauranga.

While the macro and meso level framework appears to be in place, Māori micro level firm and individual sci-tech capacities still appear to be lagging. This matters for a number of reasons. First, moving 'up the value chain' in an economic sense requires greater Māori engagement and alignment with science and innovation (BERL 2011, p. 4). Second, increased Māori technical capacity positions Māori to contribute to, create and lead advances in science and technology rather than react to or become passive end-users of products or processes that may or may not meet Māori economic and social objectives. Third, and as has been recognised internationally, diversifying the research cohort diversifies the science and technology knowledge domain itself (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2011; O'Brien et al. 2015). Opening space for Māori foci (kaupapa), explicit and tacit knowledge (mātauranga) and processes (tikanga) present an R&D opportunity unique to Aotearoa New Zealand.

To conclude this section, while innovation AC is a normative concept privileging firm/individual capacities, application to the Māori context needs to consider the macro condition of colonisation that has influenced meso level institutions that in turn has enabled or constrained R&D innovation at the micro level of the Māori firm or individual. In the next section, we discuss a scoping project that deconstructs this complex web of interactions. While focussing on the technical capacities of individuals, the project has implications for how to accomplish an acceleration of the human and relational capacities needed to talk to and work with Māori partners.

Māori STEM scoping project – objectives, methodology and results

In 2016, the Kāhui Māori, SfTI-TAPTAH's Māori advisory group, whose role is to ensure that Te Ao Māori (the Māori Maori world-view) is embedded across the SfTI NSC and to guide researchers to help them incorporate VM into their research, instigated a scoping project, the results of which were to be used to guide the Kāhui Māori to 'creatively address capacity development' (Science for Technological Innovation 2015, p. 32). While methodologically the project cannot be described as a scoping review (Levac et al. 2010; Peterson et al. 2017), the project does share a scoping review's 'aim to map rapidly … the main sources and types of evidence available' (Arksey and O'Malley 2005 p. 21). A limited review of the Māori sci-tech landscape during the development of the SfTI-TAPTAH proposal showed there were substantial gaps in Māori technical capacity noting a 2010 IPENZ report that Maori made up only 4.6% of architects and engineers and 6.4% of physical science and engineering technicians (IPENZ 2010). Despite this, there were aspirations to include Māori PhD students with the requisite technical capacities in the research projects.

In order to build on this early analysis, the Kāhui Māori sought answers to three key questions: (1) what was the current landscape of Māori STEM; (2) what were the causes of the landscape; and (3) were there public or private sector initiatives making a difference to that landscape. Section two provides explanation to Māori sci-tech development as implied in question 2, hence, the following describes the methodology for questions 1 and 3.

Question 1 was divided into two sections: Māori student participation and attainment in STEM subjects; and capacity of the Māori STEM workforce. Sources of data included secondary literature, reports and publicly available data from the Ministry of Education (MoE). Data was also requested from the Tertiary Education Commission (TEC). This information was then analysed to identify Māori student and academic workforce participation and/or retention trends in STEM subjects relevant to SfTI-TAPTAH (defined as: Natural Sciences, Mathematics, Engineering, Information and Computer Science).

To answer Question 3 an internet search was undertaken to identify Māori-focussed STEM programme initiatives or funding. The search was deliberately broad in order to be able to capture the niche programmes or projects that, in particular, had been evaluated. Five main categories of search data across organisations (including universities; Wānanga and Polytechnics; Research Institutes and Groups; Trust and scholarships; and schools) restricted to years 2000–2017 were established. A 'lookup' syntax of 'Māori + STEM + Science + Engineering + Mathematics + Technology' was applied until there were a sufficient number of 'hits' to conclude there were no additional STEM initiatives or groups promoted within the target category website (note where the initial lookup term failed to located an initiative, the lookup was broadened e.g. Māori + Science + Engineering + Mathematics + Technology and so on. Once the systematic approach had been concluded, additional websites were identified through consultation). For the University sector, the level of STEM initiatives for each category was then assigned a relative score ranging from groups with obvious Māori STEM initiatives or funding, to those that provided support for Māori students or researchers, although not specifically focused on Māori STEM.

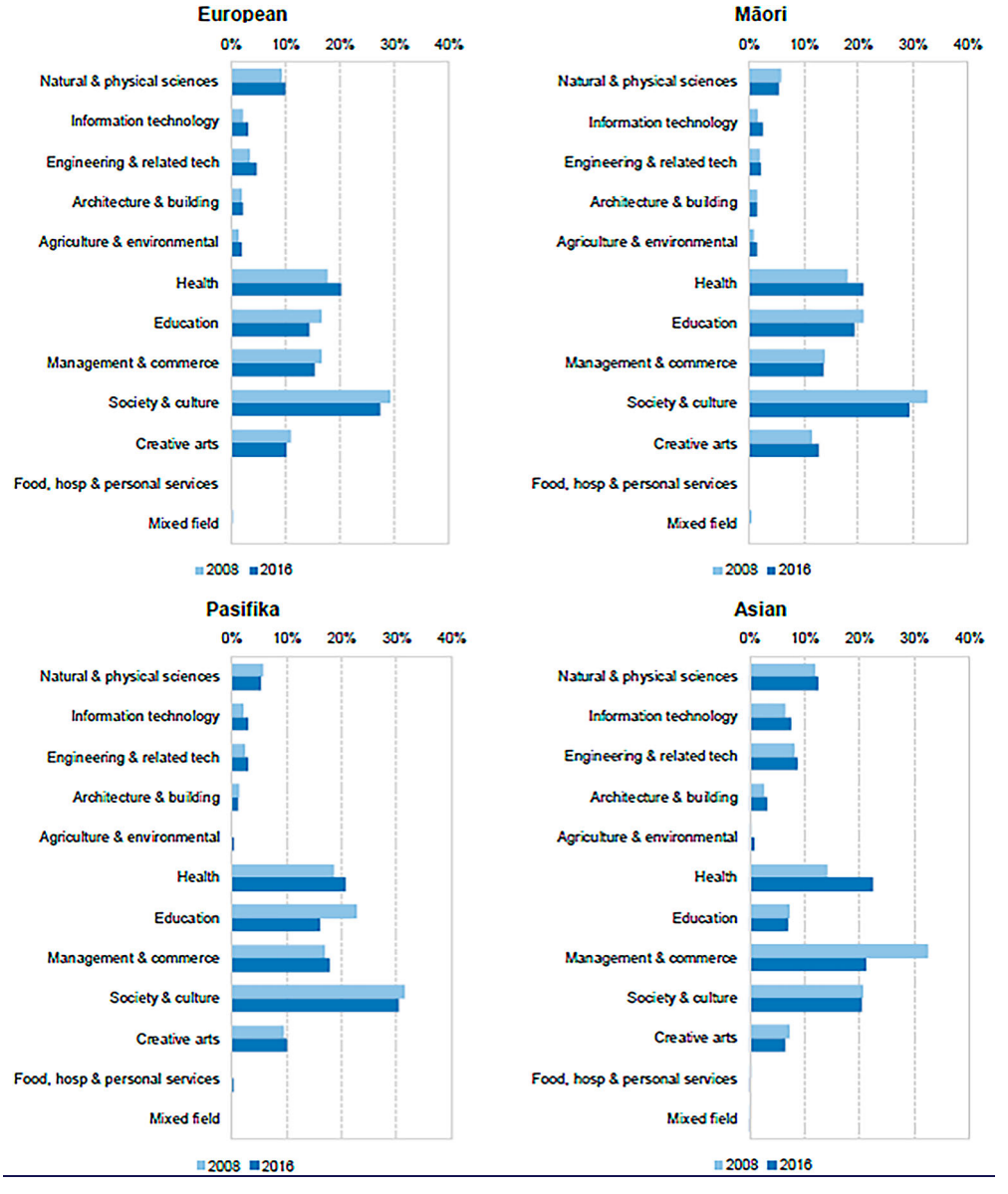
Māori student and workforce STEM capacity

The period 2008–2016 saw a general increase in the numbers of students graduating in STEM subjects at Bachelor's degree or higher. In comparison to OECD students, New Zealand students were on average more likely to study natural sciences, mathematics and statistics at tertiary level (10% vs 6%), although for engineering, manufacturing and construction it was the opposite (8% vs 16%). Enrolment in ICT subjects was 7% (OECD 5%). Therefore, overall STEM enrolment rates were about the same as most OECD countries (Norgrove and Scott 2017; OECD 2017). When broken down by ethnicity, the general trend is likewise apparent for Māori graduates, with 62% completing qualifications at bachelor degree level or above within five years of starting full-time study (Theodore et al. 2017). However, in comparison to European and Asian students Māori were about half as likely to be studying STEM subjects as a proportion of overall enrolments (Table 1).

When one investigates Māori STEM enrolments at Bachelors and above (MoE 2017a, 2017b), a stark picture emerges. A snapshot of Māori 2016 enrolments and graduates in STEM forms of research (FoR) (Table 2) shows *no* Māori graduate with a STEM PhD and small proportions graduating with Masters or bachelors and postgraduate qualifications. Enrolment data for 2016 indicates the potential for more Māori STEM graduates in future years, particularly PhDs. This needs to be tempered with the fact that about half of STEM graduates and enrolees were in biological sciences, mostly associated with Health Science, hence less likely to move into FoR associated with SfTI-TAPTAH research.

This student data has a 'flow-on' impact into the Māori STEM workforce. In 2010, an academic workforce planning report suggested that attracting and retaining Māori in

Table 1. 2008–2016: Distribution of domestic graduates by ethnic group and broad field of study – bachelors or higher in New Zealand tertiary institutions.



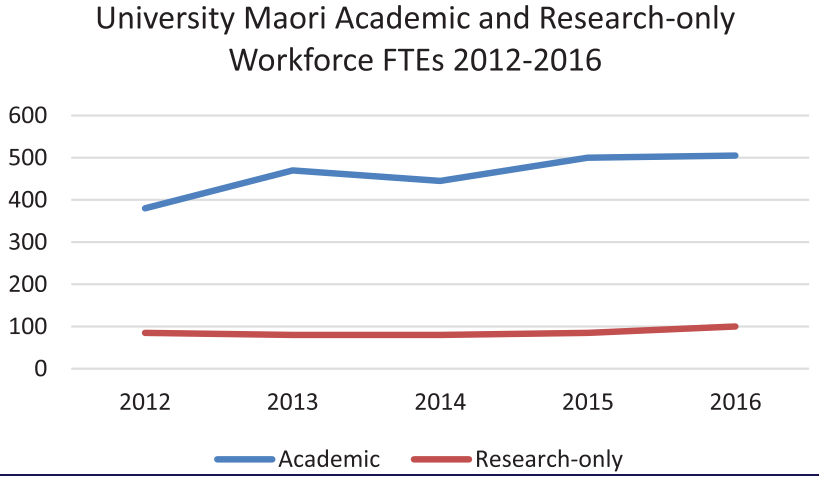
academia was an issue, with proportions of the Māori academic workforce remaining static over the 1991–2006 period (BERL 2010). An analysis of 2012–2016 University Māori data (Table 3) shows that there was a 25% increase in the number of Māori staff employed as academics with a 15% increase in research-only staff. However, the increase as a proportion of all staff was more a modest 12% for Māori academic staff and a decrease of 20% for Māori research staff (Table 4). In both cases, Māori made up only about 5% of the overall University academic and research workforce.

Table 2. New Zealand University Maori enrolments and graduates in STEM FoR 2016[a]

	Graduates			Enrolled		
Level	PhD	Masters	Bachelor/Postgrad	PhD	Masters	Bachelor/Postgrad
Number	0	40	465	65	130	3,215
%	0	4	6	4	5	7

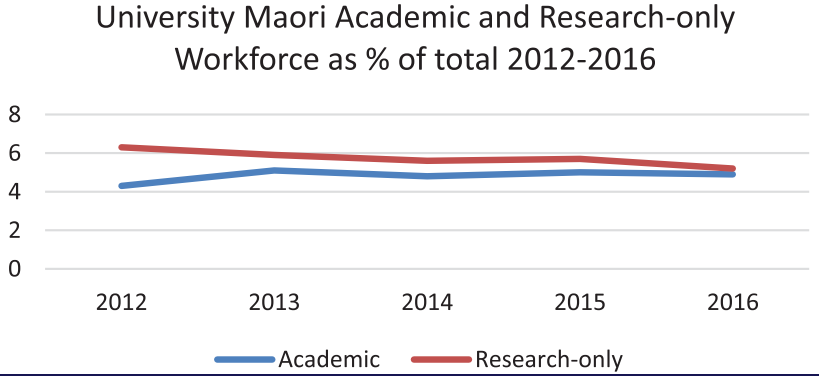
[a]Note that multi-responses can be given to ethnic identity. Hence, percentages in Table 2 reflect total ethnicities rather than student numbers.

Table 3. New Zealand University Maori Academic and Research-only Workforce FTEs 2012–2016



To ascertain STEM staffing levels, the TEC provided customised data on the 2012 Performance-based Research Fund (PBRF) assessment. There were some limitations to this data relating to self-reporting of ethnic status and, being multi-response, some individuals' results will be included in more than one category. Additionally, the PBRF assessment does not apply to Crown Research Institutes (CRIs). Given these caveats, the PBRF data revealed that 36 Māori researchers were in STEM FoR. A total of 660 Māori researchers undertook the PBRF assessment, with a total of 7356 researcher Evidence Portfolios (EPs) submitted of which 6758 EPs have been awarded funded Quality Categories

Table 4. New Zealand University Maori Academic and Research-only Workforce as % of total 2012–2016



(TEC 2013). Given the trajectory of overall Māori staffing subsequent to the 2012 PBRF assessment, the percentage of Māori STEM researchers is unlikely to have increased to any significant degree.

Public and private sector STEM initiatives

Category 1: Universities (See Appendix 1)

A total of 11 STEM initiatives for Māori, 9 for Māori and Pacific students, and one for general STEM students were identified. It is expected that all Universities provide Māori students with support, however only seven websites were located using the search syntax and look-up method. Only Victoria University of Wellington appeared to have an evaluated initiative targeting Māori STEM retention to degree completion, with other Universities supporting STEM students at various levels. While not strictly a STEM initiative as defined for the purposes of this paper, both the Universities of Auckland and Otago have evaluated their Māori Health Sciences workforce development programme (Jones et al. 2010; Baxter 2015). Hence, these programmes are included for comparative purposes.

Category 2: Wānanga and Polytechnics' STEM Initiatives (See Appendix 2)

A total of 24 organisations were investigated, none of which had obvious STEM Māori or Pasific initiatives, albeit 16 indicated some STEM content. Of those, 13 had STEM courses or curricula including a range of Sciences (e.g. Health, Environmental and Applied Science), Engineering (e.g. Electrical and Automotive Trades) and Information and Communication Technology.

Category 3: Crown Research Institutes (CRIs) and other groups' STEM Initiatives (see Appendix 3)

Seven CRIs, one Crown entity, and eight 'other' groups were investigated. Of the CRIs, each had clear general STEM initiatives with some offering STEM support specifically for Māori, such as offering internships, scholarships or fellowships. The Crown entity Callaghan Innovation offered a range of support for Māori students involved in STEM. Of the 'other' groups, none were specifically offering specific STEM initiatives but were aimed at general Māori academic development (eg. Te Kāhui Amokura – a sub-group of the Universities New Zealand sector group) or postgraduate student academic acceleration (eg Ngā Pae o Te Māramatanga – a national Centre of Research Excellence).

Category 4: Trusts and Scholarship providers STEM funding (see Appendix 4)

Forty-one Trusts and two online scholarship databases were investigated. Around nine indicated they might provide STEM related scholarships with a subsequent manual check revising that number down to seven providers. For example, in 2016, the Māori Education Trust offered two undergraduate and two postgraduate STEM scholarship, with Te Putea Whakatipu Trust offering one STEM scholarship. Given the number of providers, a more extensive analysis was unable to be undertaken.

Category 5: Schools STEM initiatives (see Appendix 5)

Seven school-based Māori STEM initiatives were located, however given the large volume of information using the 'look-up' method, the most relevant for the project was not able to be reliably determined. A screenshot sample of STEM school outreach initiatives is shown in Appendix 4 to give a 'flavour' of the nature of activity.

Analysis of results

A number of trends can be identified from the data. To start, while absolute numbers of Māori students taking STEM subjects has increased, proportionately these remain low, particularly in comparison to European and Asian students, where Māori are about half as likely to participate in STEM FoRs. In fact, Māori numbers over the period have slightly declined in Physical and Natural Sciences. While it is uncertain as to what proportion of the 2016 Bachelors and Postgraduate Māori students will translate into completed Masters and PhDs, 2016 enrolments reflect four per cent of Māori undertaking PhDs. Unsurprisingly, this historically modest proportion of Māori students has translated into low numbers of Māori academics and researchers, at least in the tertiary sector. While the 2010 BERL report noted static Māori staffing, the current analysis shows only very modest growth overall. From a research supply perspective the implication of both these data sets is that the sector will struggle to find Māori researchers to contribute to and lead STEM initiatives as technical experts, given their very low numbers. There may be other factors at play such as those highlighted in previous research (see Kidman et al. 2015; Potter and Cooper 2016), the findings of which point to the need for greater institutional and government investment in and commitment to Māori student success and Māori staff more broadly.

What efforts, then, have been made to increase and retain the supply of Māori STEM researchers? As the desk-top analysis shows, there have been or are initiatives that aim to increase Māori participation and success, to reach out to Māori communities and to fund Māori students. Unfortunately, there is very little evaluation of the success of these specifically STEM initiatives, apart from the now discontinued VUW programme (Richardson et al. 2018). This does not mean that such initiatives have not been evaluated, only that such evaluations were not easily accessible using the search criteria. What is apparent, is that there have been and continue to be a number of initiatives aimed at increasing STEM supply, however, the overall impression is that these 'are not connected or evaluated for cost-effectiveness' (Office of Auditor General 2016, p. 6). To this we would add neither have these initiatives been assessed for their effectiveness to increase Māori STEM capacity over time.

Overall, many of the initiatives might be classified as 'consciousness raising' such as school and community outreach programmes, along with targeted individual support (scholarships and internships) and a handful of collective initiatives, such as Ngā Pae o Te Māramatanga's general postgraduate support. Māori taking STEM courses has increased, however, unlike in the Māori Health workforce development programmes (Curtis & Reid 2013) where there is a very clear link between training and employment, there is no initiative aimed at shepherding Māori STEM graduates into STEM careers. Neither, apart from the VUW STEM evaluation, could we find any evidence of programmes making a material difference to Māori STEM cohort success.

Given this landscape, the KM has begun to lay out an acceleration pathway that includes the other two sides of the capacity development triangle – human and relational capacity.

Te tihi o te maunga – implementing a Māori absorptive capacity programme

As outlined in the opening section of this paper, AC has been conceptualised as consisting of three components: technical, human and relational. Given the paucity of Māori

researchers with the technical capacities to contribute to the research domains aligned to the SfTI-TAPTAH programme, the Kāhui Māori has supported a programme of human and relational capacity development. The objective of this programme is to expand human and relational skills so that the almost exclusively non-Māori technical specialists can connect and co-innovate with industry and Māori to create new, high-value, high-impact products and services. The programme has four features:

- Whakawhanaungatanga (connecting) to learn how to make and maintain relationships with Māori organisations.
- Whakawhitiwhiti korero (communicating) to learn the values and perspectives that resonate with Māori.
- Auaha-ā-rōpū (co-innovating) to draw on creative, best-practice teams with diverse skills and perspectives to develop high-tech innovations with the needs of Māori in mind.
- Aronga Pakihi (commercialising) to understand the process, priorities and timelines of commercialisation, and how to work with Māori to advance their ideas into the commercial market place.

The human capacity programme has developed a number of activities, ranging from researchers attending specially developed workshops on the Māori economy to participation at Māori-organised business, community or science events. For many of the sci-tech researchers, this is a first 'taste' of the Māori world as can be seen from comments such as, 'The University never put on a course to engage with Māori. You don't know what you don't know'; or, '"Māori model" – I don't know what that is. Asian I know'. The workshops proved popular and effective, with two-thirds of the first cohorts rating them as being extremely beneficial (the top 'grade') and with scientists from outside the SfTI-TAPTAH programme asking to participate. Additionally, a specialised resource of simple Māori language greetings, invocations and songs has been developed for the researchers to help facilitate relationships with Maori stakeholders and improve insight to the concept of a Maori knowledge system.

Such activities are important precursors to relationship building with Māori. However, they are in and of themselves just that, precursors or consciousness-raising activities. Recognising this, the Kāhui Māori has developed the 'Te tihi o te maunga', or 'mountain summit' implementation model (Figure 1) to focus on where to accelerate capacity development effort for maximum outcome and to assesses technical capacity in light of its contribution to and incorporation of Māori people and knowledge. The model is conceptualised as a journey. First, the sci-tech researcher is ignorant of or sees no relevance in connecting with the Māori world, represented in the model as the researcher being offshore. This represents a state where no Māori knowledge is incorporated, where Māori are not involved and where there is no direct Māori benefit. Then the researcher lands on the developing shores of understanding, perhaps through undertaking some of the human capacity development activities.

However, there is a further journey to reach the summit where the technical capacity incorporates a high degree of Māori knowledge, where Māori participation is likewise high and where the benefits are Māori focussed.

As shown in section three, Māori technical experts are few in the sci-tech sphere and in the absence of any specific Māori STEM workforce development, an organic workforce approach

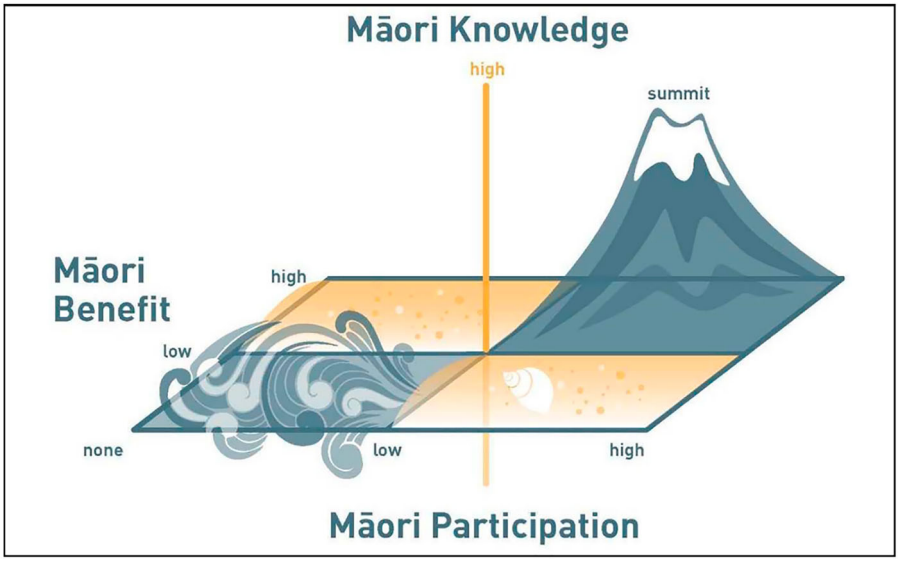


Figure 1. Te tihi o te maunga.

will take many years, and perhaps never seriously impact on Māori sci-tech research capacity. Rather than waiting for the organic approach, the Kāhui Māori is focussing on a tikanga-approach to building sci-tech relational capacity with Māori community and business. Through the human capacity development programme, the 'closed community' of the scientist is opening up to mātauranga Māori, tikanga Māori and kauapapa Māori. Through this, the scientists then have to reframe their science to incorporate this new learning.

To date, this has led to:

- a machine learning project to identify Māori landholders for a large Māori land trust with applications more broadly to the traceability of Māori land;
- a robotics project using the concepts of 'whānau' and Māori intergenerational communication based on non-written information exchanges using icons and symbols for communication of complex situations; and
- a project to develop, amongst other things, a te reo 'engine' integrating block-chaining to assist with indexing, traceability and control of content, integrated text and voice recognition for te reo Māori.

These are the first, but by no means last research projects intended to be implemented. Future initiatives include an Indigenous data sovereignty project, and explorations of how to incorporate Māori design concepts or indigenous biological materials for use in additive manufacturing (3-D or 4-D printing).

Conclusion

This paper has considered the notion of absorptive capacity and the way that the concept is being reframed to focus on the sci-tech institution and researcher rather than the firm. While firm capacities and the ability to absorb external knowledge for commercial

advantage are key ingredients in an open innovation context, how sci-tech knowledge is conceptualised, co-created and communicated in the first place is the flipside of the knowledge exchange/AC coin. As our research has indicated, Māori capacity has been impeded due to past historical forces that have current consequences for Māori firm, individual and organisational sci-tech capacity. While there have been and continue to be policy and institutional initiatives to address these past impediments, these appear to be unfocussed, uncoordinated and un-evaluated. This organic approach is unlikely to accelerate Māori sci-tech capacity within the near future. As a consequence, the SfTI-TAPTAH Kāhui Māori is developing its own sci-tech acceleration programme, 'Te tihi o te maunga', focussing on consciousness-raising kaupapa in the first instance and then instigating targeted projects that develop tikanga relationships between Māori and scientists and that embed mātauranga Māori as a priority within each project.

While it is early days for approach, this novel model is under development to assess these projects' impact and potentially to act as exemplars for a richer and deeper engagement by Māori with the sci-tech system as a whole.

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Appendices

Appendix 1: Universities' STEM initiatives

University	Clear Māori STEM	Māori & Pacifica STEM	General STEM	Māori Research Support	Total Initiatives
Victoria University of Wellington	Te Rōpū Āwhina Te Putaiao Maori/Maori Science*	Expos to boost Māori and Pasifika science learning* Māori and Pasifika students Te Rōpu Āwhina*			4
University of Auckland		Tuākana Outreach Tuākana Mentoring Programme Tuākana Maths The Tuākana Engineering Programme South Pacific Indigenous Eng Students (SPIES) Network			5
Auckland University of Technology		STEM-TEC STEM-TEC Bridging			2
University of Waikato	Te Pūtahi o te Manawa*		TEMS Education Research Centre		2
Massey University				Massey Science Academy - Pūhoro Kaitautoko (Maori Student Advisory) service.	2
University of Canterbury	Science, Māori and Indigenous Knowledge			Ngāi Tahu Research Centre (NTRC) Māori Research Centre He Puna Pūtaiao	4
Lincoln University				Poutama Whenua	1
University of Otago	Māori at Health Sciences* Kaiāwhina Network for Sciences* Te Ara Hauora: Māori Health Sciences Outreach* Tū Kahika: A Health Sciences scholarship for Māori* Science Wānanga* Manutaki Tuarua Māori*			Te Poutama Māori	7
Total	**11**	**9**	**1**	**7**	**28**

Appendix 2: Wānanga and Polytechnics' STEM initiatives

ID	Wānaga or Polytechnic	URL link	# Hits	STEM?	Content Description
1	Aoraki Polytechnic	http://www.aoraki.ac.nz/			
2	Bay of Plenty Polytechnic	http://www.boppoly.ac.nz/	15		
3	Ara Institute of Canterbury (ARA)	http://www.cpit.ac.nz/	31	y	Engineering Trades, Fisheries & Resource Management/Environmental Science
5	Eastern Institute of Technology (Hawkes Bay) (EIT)	http://www.eit.ac.nz/	12	y	Automotive & Engineering
6	Manukau Institute of Technology	http://www.manukau.ac.nz/	7	y	Māori & Pasifika Trades, Engineering, Health Science
7	Nelson Marlborough Institute of Technology (NMIT)	http://www.nmit.ac.nz/	7	y	Engineering & Construction, Bachelor of Aquaculture & Marine Conservation
8	Northland Polytechnic (NorthTec)	http://www.northland.ac.nz/	58	y	Applied Science,Architectural Technology, Automotive Engineering, Health Sciences
9	The Open Polytechnic of New Zealand	http://www.openpolytechnic.ac.nz/	629	y	Applied Science, Engineering
10	Otago Polytechnic	http://www.otagopolytechnic.ac.nz/	43	y	Technology & ICT
11	Southern Institute of Technology (SIT)	http://www.sit.ac.nz/			
12	Tairawhiti Polytechnic	http://www.tairawhiti.ac.nz/			
13	Telford Rural Polytechnic	http://www.telford.ac.nz/	9		
14	Tai Poutini Polytechnic	http://www.tpp.ac.nz/			
15	Te Wānanga O Aotearoa	http://www.twoa.ac.nz/	98	y	Environmental Science, Conservation, Bachelor of Māori Advancement,Certificate in Applied Technology
16	Universal College of Learning (UCOL)	http://www.ucol.ac.nz/	7		
17	Unitec New Zealand	http://www.unitec.ac.nz/	29	y	Science & Technology, Bachelor of Applied Technology - Marine
18	Toi Ohomai Institute of Technology	http://www.waiariki.ac.nz/			
19	Te Whare Wānanga O Awanuiārangi	http://www.wananga.ac.nz/	252	y	Science, Bachelor of Health Science Māori
20	Te Wānanga O Raukawa	http://www.wananga.com/			
21	Wellington Institute of Technology (Weltec)	http://www.weltec.ac.nz/	12	y	Construction & Engineering
22	Whitireia Community Polytechnic	http://www.whitireia.ac.nz/	216	y	Māori & Pasifika Trades, Certificate in Electrical Engineering
23	Waikato Institute of Technology (Wintec)	http://www.wintec.ac.nz/			
24	Western Institute of Technology at Taranaki (WITT)	http://www.witt.ac.nz/	6	y	Māori & Pasifika Trades, Fisheries & Resource Science, Information & Communication Technology
Total number of Wānanga or Polytechnics with potential STEM content			***16***		
Total number of Wānanga or Polytechnics with descriptions of STEM content				***13***	

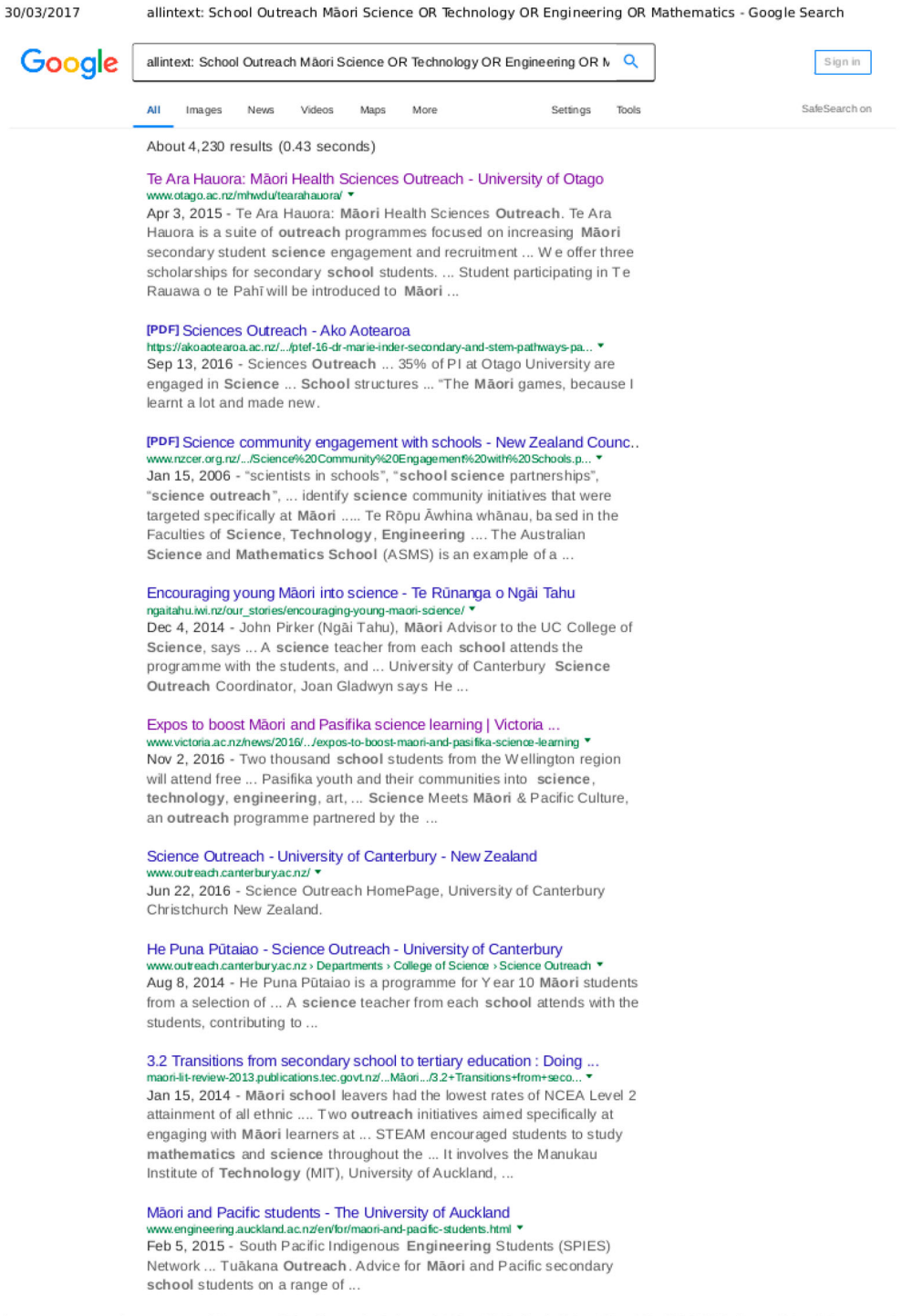
Appendix 3: Crown research institutes (CRIs) and other groups' STEM initiatives

ID	Research Group	URL link	# Hits	STEM?	Examlple Text
1	New Zealand Pastoral Agriculture Research Institute	http://www.agresearch.co.nz/	36	y	Supporting Maori science capability and contribution...
2	New Zealand Institute for Plant and Food Research	http://www.plantandfood.co.nz/	16	y	Te Kete Ahumāra...
3	Institute of Environmental Science and Research (ESR)	http://www.esr.cri.nz/	223	y	Māori Innovation Strategy...
4	Scion (New Zealand Forest Research Institute Limited)	http://www.scionresearch.com/	66	y	Māori are very important stakeholders in forests ...
5	GNS Science, the Institute of Geological and Nuclear Sciences	https://www.gns.cri.nz/	1250	y	Ngā Kura Huna a Papatūānuku combines research, science and matauranga Māori...
6	Landcare Research	http://www.landcareresearch.co.nz/	3060	y	Mātauranga Māori can be defined as 'the knowledge, comprehension, ... Such holistic thinking can be at odds with reductionist science approaches.
7	National Institute of Water and Atmospheric Research (NIWA)	http://www.niwa.co.nz/	195	y	The science communication and outreach programme for NIWAs National Centre of Māori Environmental Research (Te Kūwaha) within which ...
8	Callaghan Innovation	http://www.callaghaninnovation.govt.nz/	348	y	Connect with other Māori businesses and work alongside Callaghan Innovation's Māori Innovation Hub interior ...
9	National Science Challenge	http://www.sftichallenge.govt.nz			
10	National Science Challenge (Vision Mātauranga project)	http://www.mbie.govt.nz/	1300	y	This increased investment in the science and innovation potential of Māori ... to grow skills and capacity for Māori participation...
11	National Science Challenge (Curious Minds)	http://www.curiousminds.nz/	107	y	The Māori Futuremakers website profiles 30 inspirational Māori with ... knowledge intensive and growth science and innovation and ...
12	Nga Pae o Te Maramatanga	http://www.maramatanga.co.nz/	56	y	We invest in integrated, inter-sec toral projects across the research specturm, but which are grounded in mātauranga Māori, Māori science, kaupapa Māori and ...
13	MANU AO Academy	http://www.manu-ao.ac.nz/	1440	y	Accelerating Māori leadership; Strengthening the links between Māori Academics and Māori Professionals and Advancing Māori scholarship.
14	Katoa Limited	http://www.katoa.net.nz/	56	y	Kaupapa Māori Epidemiology · Researching with Whānau Collectives: Māori & Science · Māori Family Wellbeing Māori Family Violence Prevention.
15	Te Kāhui Amokura	http://www.universitiesnz.ac.nz/ aboutus/ sc/ te-kahui-amokura			
16	Universities New Zealand - Te Pōkai Tara	http://www.universitiesnz.ac.nz/	42	y	Universities New Zealand - Te Pōkai Tara is responsible for the quality of university programmes, administers a range of scholarships and represents the universities in the public interest, both nationally and internationally.
Total number with potential STEM focus for Māori			*16*		
Total number with STEM focus for Māori				*14*	

Appendix 4: Trusts and scholarships STEM funding

ID	Trust	Trust URL link	# Hits	STEM?
1	Te Pūtea Whakatupu Trust	http://www.tpwt.maori.nz/	6	y
2	Hauraki Māori Trust Board Education Grants	http://www.hauraki.iwi.nz/		
3	Kapenga M. Trust	http://www.hultonpatchell.co.nz		
4	Manawapopore Trust Wairarapa Moana Trust	http://www.wairarapamoana.org.nz		
5	Māori Education Trust Scholarships	http://maorieducation.org.nz	8	y
6	Morikaunui & Atihau Whanganui Scholarships	http://www.whanganuitrust.com		
7	Mangaorewa Kahoara Te Taumata Trust	http://mangorewa-kaharoa.org.nz/		
8	Mangatu Blocks	http://mangatu.com/		
9	Maniapoto Maori Trust Board	http://www.educomm.ac.nz/		
10	Nga Manawa Incorporation	http://www.ngamanawainc.co.nz		
11	Ngati Kahungunu Iwi Scholarship	http://www.kahungunu.iwi.nz		
12	Ngati Toa Rangatira	http://www.ngatitoa.iwi.nz/		
13	Ngati Whatua o Orakei	http://www.ngatiwhatuaorakei.com/	2	
14	Ngatiwai Trust Board Education Grant	http://www.ngatiwai.iwi.nz/	2	
15	Parinihinihi ki Waitotara Taranaki	http://www.pkw.co.nz/		
16	Sir James Fletcher 1st Memorial Trust Schlarship/Kawera	http://www.kea.org.nz/		
17	Tangiharuru Apa Trust	http://www.hultonpatchell.co.nz		
18	Taranaki Trust Board Education Grant	http://taranakimaoritrustboard.weebly.com/grants.html		
19	Tanenuiarangi Manawatu Incrporated Scholarships	http://tmi.maori.nz/		
20	Tangiharuru Apa Trust (Ngati Manawa)	http://www.hultonpatchell.co.nz		
21	Taringamotu Otamakahi Trust Taumaranui	http://www.taringamotuotamakahi.co.nz		
22	Taupo Forest Shares	http://www.ltft.co.nz		
23	Tauwhao Te Ngare Trust Grants	http://www.tauwhaotrust.co.nz		
24	Tauranga Moana Scholarships and Grants	http://www.tgamoana.co.nz		
25	Te Arawa Fisheries	http://www.tearawafisheries.maori.nz	2	y
26	Te Runanga o Ngati Awa Scholarship	http://www.ngatiawa.iwi.nz	8	y
27	Te Runanga o Ngati Hine	http://ngatihine.iwi.nz		
28	Te Runanga o Ngati Porou	http://www.ngatiporou.com	11	y
29	Te Runanga o Ngati Ruanui	http://www.ruanui.co.nz		
30	Te Whanau o Waipereira Trust	http://www.waipareira.com		
31	Toitū Kaupapa Māori Mātauranga – Māori Education Trust	http://www.maorieducation.org.nz	7	y
32	Tuauropaki Trust	http://www.tuaropaki.com	1	y
33	Tuhoe Waikaremoana Māori Trust Board	http://www.tuhoe.iwi.nz		
34	Tuwharetoa Maori Trust Board	http://www.tuwharetoa.co.nz		
35	Turirangi Te Kani Scholarship	http://www.tgamoana.co.nz		
36	Tuhoe Waikaremoana Māori Trust Board	http://www.tuhoe.iwi.nz		
37	Waikato Raupatu Lands Trust – Tainui	http://www.tainui.co.nz		
38	Waiomu Lands Trust	http://www.tgamoana.co.nz		
39	Ngati Kahungunu Iwi Scholarship	http://www.kahungunu.iwi.nz		
40	Ngati Whakaue Education Endowment Trust Board	http://www.ngatiwhakaue-eetb.org.nz		
41	Te Runanga o Ngati Ruanui	http://www.ruanui.co.nz		
42	*Break Out Funding Information Service**	http://www.fis.org.nz	26	
43	*Takoa**	http://www.takoa.co.nz		
		Total number Trusts with potential STEM Scholarships	***9***	
		Total number Trusts with STEM Scholarships		***7***

Appendix 5: Sample of schools STEM initiatives



30/03/2017 allintext: School Outreach Māori Science OR Technology OR Engineering OR Mathematics - Google Search

Google allintext: School Outreach Māori Science OR Technology OR Engineering OR M Sign in

All Images News Videos Maps More Settings Tools SafeSearch on

About 4,230 results (0.43 seconds)

Te Ara Hauora: Māori Health Sciences Outreach - University of Otago
www.otago.ac.nz/mhwdu/tearahauora/
Apr 3, 2015 - Te Ara Hauora: **Māori** Health Sciences **Outreach**. Te Ara Hauora is a suite of **outreach** programmes focused on increasing **Māori** secondary student **science** engagement and recruitment ... We offer three scholarships for secondary **school** students. ... Student participating in Te Rauawa o te Pahī will be introduced to **Māori** ...

[PDF] Sciences Outreach - Ako Aotearoa
https://akoaotearoa.ac.nz/.../ptef-16-dr-marie-inder-secondary-and-stem-pathways-pa...
Sep 13, 2016 - Sciences **Outreach** ... 35% of PI at Otago University are engaged in **Science** ... **School** structures ... "The **Māori** games, because I learnt a lot and made new.

[PDF] Science community engagement with schools - New Zealand Counc..
www.nzcer.org.nz/.../Science%20Community%20Engagement%20with%20Schools.p...
Jan 15, 2006 - "scientists in schools", "**school science** partnerships", "**science outreach**", ... identify **science** community initiatives that were targeted specifically at **Māori** ..... Te Rōpu Āwhina whānau, based in the Faculties of **Science**, **Technology**, **Engineering** .... The Australian **Science** and **Mathematics School** (ASMS) is an example of a ...

Encouraging young Māori into science - Te Rūnanga o Ngāi Tahu
ngaitahu.iwi.nz/our_stories/encouraging-young-maori-science/
Dec 4, 2014 - John Pirker (Ngāi Tahu), **Māori** Advisor to the UC College of **Science**, says ... A **science** teacher from each **school** attends the programme with the students, and ... University of Canterbury **Science Outreach** Coordinator, Joan Gladwyn says He ...

Expos to boost Māori and Pasifika science learning | Victoria ...
www.victoria.ac.nz/news/2016/.../expos-to-boost-maori-and-pasifika-science-learning
Nov 2, 2016 - Two thousand **school** students from the Wellington region will attend free ... Pasifika youth and their communities into **science**, **technology**, **engineering**, art, ... **Science** Meets **Māori** & Pacific Culture, an **outreach** programme partnered by the ...

Science Outreach - University of Canterbury - New Zealand
www.outreach.canterbury.ac.nz/
Jun 22, 2016 - Science Outreach HomePage, University of Canterbury Christchurch New Zealand.

He Puna Pūtaiao - Science Outreach - University of Canterbury
www.outreach.canterbury.ac.nz › Departments › College of Science › Science Outreach
Aug 8, 2014 - He Puna Pūtaiao is a programme for Year 10 **Māori** students from a selection of ... A **science** teacher from each **school** attends with the students, contributing to ...

3.2 Transitions from secondary school to tertiary education : Doing ...
maori-lit-review-2013.publications.tec.govt.nz/...Māori.../3.2+Transitions+from+seco...
Jan 15, 2014 - **Māori school** leavers had the lowest rates of NCEA Level 2 attainment of all ethnic .... Two **outreach** initiatives aimed specifically at engaging with **Māori** learners at ... STEAM encouraged students to study **mathematics** and **science** throughout the ... It involves the Manukau Institute of **Technology** (MIT), University of Auckland, ...

Māori and Pacific students - The University of Auckland
www.engineering.auckland.ac.nz/en/for/maori-and-pacific-students.html
Feb 5, 2015 - South Pacific Indigenous **Engineering** Students (SPIES) Network ... Tuākana **Outreach**. Advice for **Māori** and Pacific secondary **school** students on a range of ...

https://www.google.co.nz/search?num=100&safe=active&tbs=cdr%3A1%2Ccd_min%3A1%2F1%2F2000%2Ccd_max%3A1%2F... 1/12