34th Australasian Association for Engineering Education Conference
3 - 6 December 2023 – Gold Coast, QLD

Wai Water? Growing bicultural literacy in water-related STEAM for a country co-governed with indigenous peoples.

[a] Aisling O'Sullivan and [b]Angela Pratt
University of Canterbury, NZ[a] and Jacobs NZ Ltd [b]
aisling.osullivan@canterbury.ac.nz

ABSTRACT

CONTEXT

Aotearoa New Zealand is biculturally governed, and healthy water (wai mauri) is core to the identity and social wellbeing of its indigenous Māori people. The water industry has therefore refocused on including indigenous perspectives, and associated benefits, to restoring the health of our water (wai). To meet the escalating needs of the water profession with this mission, it is critical to engage, enthuse and empower a diverse next generation of biculturally-literate water engineers, at an early age, while their appetite for learning is fresh and flexible. An education-engineering partnership involving teachers, academics, water professionals and students with indigenous knowledge, can help achieve this. Partnerships aiming to enrich schools' ecological awareness or confidence in STEAM, are mostly reported in the US and target the senior years or teachers. Furthermore, they are prescribed from a western-science perspective so may not provide inclusive and fit-for-purpose upskilling of all parts of the community. Despite the increasing global scarcity of healthy freshwaters, there is no reported framework for upskilling younger students | Ākonga in STEAM-related water literacy through using a practitioner-educator model that meet the needs of a biculturally co-governed nation.

PURPOSE OR GOAL

A framework (Wai Water Literacy Programme (WWLP)) was developed to help teach bicultural water-literacy in the primary school years, implemented through a practitioner-educator partnership. It is delivered through STEAM-based activities. The goal is that students will be more biculturally confident and competent in fundamental water-related engineering problem-solving upon completion of the programme. This 'upskilling" is helping to excite and prepare generation alpha for a career in the water engineering industry that meets the needs of a biculturally-governed nation.

APPROACH OR METHODOLOGY/METHODS

The WWLP maps lesson concepts, bicultural perspectives, driving questions and practical-based learning activities, both within and outside schools, to the National Curriculum Te Marautanga o Aotearoa objectives, learning outcomes and achievement aims, for school years 1-8 (aged 5-13). It is based on contextual learning, aligned to current and anticipated industry needs and spearheaded by educator-practitioner partnerships. The programme started in late 2022, is iterative and evolving and, informed by reflective lessons learnt and best international pedagogical practice. It is providing a framework for other industry-educator partnerships to adapt and implement within their communities.

ACTUAL OR ANTICIPATED OUTCOMES

Successful implementation of the WWLP requires personnel, pedagogical and technical resources. Incorporating field-based activities at the school makes it contextual and empowering for children. Using "real" engineering solutions to solve water pollution makes it relatable and transferrable. Targeting language and concepts at the right curriculum level is essential and including indigenous mentors in the programme design and implementation is critical for ensuring bicultural competence.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

Cross-disciplinary partnerships between engineers, educators and students provide early socialisation of and feed the natural curiosity of younger students about STEAM careers. These partnerships can help stimulate and sustain the diversity and pipeline of STEAM talent destined for the water profession.

KEYWORDS

Indigenous peoples, water literacy, STEAM enrichment, practitioner-educator partnership

Introduction

The general population is typically unaware of how water quantity and quality are managed, typically by engineers, what pollutants (sometimes invisible) water carries and the impacts of those pollutants on the receiving environment. Furthermore, there is limited understanding of managing water from a bicultural perspective, but the appetite and demand for this understanding is growing in Aotearoa New Zealand, spearheaded by the national Three Waters Reforms and the associated Te Mana of Te Wai principle of prioritising the health of the water over the needs of people (e.g., drinking water) as well as their social, economic and cultural wellbeing (MfE, 2020). Radical water management changes are needed to reverse catastrophic flooding/water quantity impacts, water quality degradation and the resulting community devastation, such as those impacts from Cyclone Gabrielle in 2023. It will take a generation to reverse the devastation of our freshwaters have experienced during the past decade. These changes require behavioural and technical solutions, sustained by educating and upskilling a diversity of emerging talent attracted into the water profession. Meeting the escalating needs of the water industry to better manage our freshwater resources in a biculturally-competent manner, requires increasing water literacy of the next generation. Upskilling students from the primary school years is essential to build up this talent base. It requires active engagement, contextual learning, aligned to the National Curriculum Te Marautanga o Aotearoa, leveraged from educator-practitioner partnerships.

Goals

A framework entitled the Wai Water Literacy Programme (WWLP) was developed to help teach bicultural water literacy in the primary school years and is being implemented through a practitioner-educator partnership. It maps lesson concepts, bicultural perspectives, driving questions and practical-based learning activities to the national curricula objectives and learning outcomes, with the goal of upskilling and enriching students | Ākonga in water literacy using STEAM-based concepts and activities. At the end of the programme, run consecutively and progressively from school years 1-8, the goal is that students will be more literate in water-related concepts and have experienced enrichment in associated STEAM activities that will upskill the next generation to be enthused and motivated to enter the water profession.

STEAM Literacy Programmes

Cross-disciplinary partnerships between engineers, educators and their students (e.g. Figure 1) are critical in upskilling the next generation of STEAM (Science, Technology, Engineering, Arts and Mathematics), including water-STEAM, literate students. These partnerships can help stimulate the pipeline and diversity of students | Ākonga necessary for the profession. Teachers | Kaiako (in Schools) have the knowledge and training to effectively deliver learning objectives of the national curricula. Water Engineering Leaders | Mātāmua Kaipūkaha (Water Profession) provide contextual and practical knowledge of current and future needs, as well as serving as role models. Engineering Professors | Ahorangi Kaipūkaha (Education, Research and Innovation) and their engineering students | Ākonga, at the educational-engineering nexus, help inform and support the partnership based on international best practice in engineering education research. They also provide contextual experience in applied engineering research and in designing innovative solutions. `

Figure 1: Participants of a STEAM-Water Literacy Partnership

These collaborations help provide primary teachers with new knowledge, real-world activities and the confidence to engage students in science and engineering design problem-solving, thus ultimately enhancing student achievement (Dailey et al., 2018). Colston et al. (2017) found significant gains in students' understanding with such a collaborative approach. Informal science opportunities, facilitated by such a partnership model, provide authentic experiences to stimulate students' interests in STEAM and foster their natural curiosity through problem-based investigations (Dailey et al., 2018). Moreover, students' spatial visualization - the ability to visualize various configurations of objects in space, has been linked to academic success in STEAM disciplines, particularly engineering (Maeda & Yoon, 2011). Research has also shown that factors influencing women and other minorities decisions about career choices often relate to early socialization about STEAM fields (Mbamalu, 2001). Of particular significance to bicultural Aotearoa New Zealand, is that Harris et al (2013) found an observation-based learning to be more authentic than a traditional (western-only) science approach by understanding more than one of the ways scientists gather data about the world around them. This aligns with Te Ao Māori (indigenous world view) and mātauranga Māori (indigenous knowledge) and can support more effective engagement and endorsement from a wider diversity of talent with bicultural perspectives.

Internationally, there have been a small number of industry-education partnership programmes implemented in the primary school years specifically to enhance student STEAM and environmental literacy, and concurrently support teachers to deliver these goals. Harris et al. (2013) built a 3-year environmental literacy programme with a guiding principle of ecosystems thinking (inputs-outputs, changes), contextualizing the concepts by mapping the school's Ecological footprints, but they didn't include engineering literacy. Conversely, Colston et al. (2017) designed a programme "Engineering is Everywhere" to connect science inquiry and mathematical reasoning to engineering practices and to engage students in hands-on engineering activities, yet this was not tailored to include environmental wellbeing or indigenous world views. Other programmes have focused on upskilling gifted and talented (GATE) students only e.g., STEMulate Engineering Academy (Dailey et al., 2018) or teachers only, such as the I-STEM Programme (Hodges et al., 2016). Most of the programmes were developed in response to the Next Generation Science Standards (NGSS Lead States 2013), which aims to expand preschool through high school (P-12) engineering education in the US. These standards were specifically set because of:

1. inadequate numbers in the engineering profession and an increasing need for more talent,
2. few programmes focused on primary school level and where they do, are relegated to add-on activities and,
3. to help overcome the misconceptions and stereotypes about engineering careers and engineer persona.

Similar drivers are present nationally in Aotearoa New Zealand (The New Zealand Productivity Commission, 2020), including evidence that career aspirations, biases and misconceptions start from an early age (TEC, 2020), highlighting the importance of mitigating these challenges in the early school years. Despite the benefits reported from STEAM partnerships and in increasing global scarcity of healthy freshwater resources, there are no internationally reported programmes to upskill young children in water-STEAM literacy that can be supported through a practitioner-educator model.

The Wai Water Literacy Programme

Framework

The Wai Water Literacy Programme (WWLP) aims to provide a national framework for engaging and upskilling the next generation of water-STEAM -literate students that is contextualized for a country in which natural resources are co-governed by indigenous peoples and those communities who followed. The partnership programme is tailored to the primary years to enable progression from the fundamental concepts in a sequential and scaffolded approach. Table 1 summaries core lesson concepts, driving questions, hands-on-activities, key learning objectives and anticipated outcomes mapped to the Ministry of Education (MoE) curricula.

Table 1: Outline of the Wai Water Literacy Programme (WWLP) Framework mapped to the Ministry for Education (MoE) Curricula

When	What			How	Why		
NZ MoE Curriculum Level Year(s)	**Lesson concepts**	**MoE Science Curricula focus areas**	**Bi-cultural perspectives**	**Activities examples**	**Driving Question(s)**	**Key Learning Objective(s)**	**Anticipated Outcomes**
All	**Engineers are diverse** and can have numerous other roles		Include terminology specific to topic being covered	**Game** – match photos of diversity of actual engineers to different roles (engineer, mum, dad, dancer, volunteer, sports coach etc.)	What does an engineer look like and what do they do? Where is engineering around us.	Understand engineers are diverse with a common interest in solving technical problems. Awareness of engineering in the world all around us.	Dispel early stereotypes about engineers and see anyone can become an engineer
Level 1 *Years 1 to 3*	**Types of water** - freshwater, seawater, wastewater **Where we find water** - streams/rivers, lakes, wetlands, oceans, underground in rocks and pipes **Water moves** between locations	**Earth Systems:** Students explore and describe natural features and resources	Ngā momo wai *The types of Water* Ki uta ki tai *Mountains to Sea*	**Exploring** the school to identify different water types. **Classify** the different water types at school and at home. **Water play** with pouring, sieves, funnels, tubes, straws, water runs	What are the different types of water? Where do we find water? How can water move?	Understand different types of water in bicultural terms and where we find each type. Understand water moves between locations; sometimes by humans	Appreciate different types of water are found in various locations and move between locations
Level 2 *Years 2-6*	We are each part of "The Environment". **Everyone needs clean water.** **We all have a responsibility** to use water wisely to make sure there is enough clean water for us all and that the environment does not become polluted.		Kaitiakitanga *Guardianship*	**Game** – teams are allocated different amounts of red ("unhealthy") resources including toycars, old cellphones and plastic bags and blue ("healthy") resources including push bikes/scooters, colourful books and reusable lunch containers. Each resource is worth different amounts. Students are supported to work in teams negotiating trading their allocated resources across teams.	Which of our things are good for the environment and which ones cause it harm? What happens when everyone wants all the best resources? How can we share (trade-offs) for the benefit of everyone?	Understand we all own the environmental (including water) resources we need to live well. If one person is greedy, it is worse for us all. "Trajedy of the Commons" Understand that we can all help our environment for the benefit of everyone	Understand that we can choose to do and own things that are good (or bad) for our environment. We all collectively own the environment.
		Interacting systems - Describe how natural features are changed and resources affected by natural events and human actions	Ka ora te wai, ka ora te whenua, ka ora ngā tāngata *If the water is healthy, the land is healthy, the people are healthy*	**Experiment** – using water, salt/sugar, clay and food colouring to see how pollutants get entrained in water. **Make** sock filters (old socks, sand, peatmoss/other) to show how some pollutants can be removed from water and others are "dissolved" (difficult to remove).	How do pollutants get into water? What damage might pollutants do to us and critters that live in our waterways? How can we help solve water pollution?	Understand where pollutants originate and how they can be transported in water.	Pollutants can be visible (sediment) and invisible (salt) in water. Designing things to solve water pollution problems is a type of engineering
Level 3 *Years 4-6*	Water Cycle | Te Hurihanga Wai	**Earth Systems:** Appreciate the water, air, rocks and soil, and life forms make up our planet and recognise that these are also Earth's resources.	Te Hurihanga Wai *The Water Cycle* Te Mana o te Wai *Priority of Water Uses* Wai-o-nuku (Papatūānuku) *Connecting water back to the land* Ki uta ki tai *Mountains to Sea*	**Visit** your local wastewater treatment plant (Be warned it will be a bit smelly!! **Create** dioramas of the water cycle from both western and Āo Māori lenses	What does the Water Cycle | Te Hurihanga Wai look like?	Understand key components and processes of the water cycle from bicultural perspectives. Appreciate the dynamics of the Water Cycle and that the cycle is a "closed system".	Understand the fundamentals of mass conservation, forces moving water and how society impacts water quality.
				Water Quality **Testing**- House of Science Te Wai Kit	How do we measure pollutants in water?	Appreciate pollutants are measured differently.	
				Track stormwater from source (school) to sea via GIS and on the ground.	What happens during a small storm vs a big storm/flood? What contaminants get entrained?	Understand how stormwater and wastewater are generated and where it goes	Understand stormwater happens when rain runs off paved surfaces and moves until it finds a place to settle.
	Mountains to sea	**Interacting sytems:** Students will investigate the water cycle and its effect on climate, landforms and life		**Investigate** stormwater treatment systems at the school/nearby and/portable stormwater education demo trailer	What designs can help remove pollutants from stormwater, stormwater or drinking water? How do they work? How could we reduce the amount of water we use at school/home, stormwater discharged at our school (e.g. rain barrels, raingardens), wastewater discharged at school/home (e.g. quick showers, buying low water usage appliances?	Understand that one solution doesn't solve all pollution problems. We need a toolbox of solutions.	Ākonga/students become curious and engaged in technical solutions to water problems
Extension *(e.g. faciltated via University open days)*				**Construct** and **install** mini weirs and dams Help build your own mini stormwater treatment device	What does stormwater engineering involve?	Diversity of water engineering roles	Continuity of engagement and upskilling in water literacy

The lesson concepts and MoE curricula focus areas are set within the Framework and anchor the chosen (sub)topics to the overall pedagogical aims, irrespective of the topic and its associated driving questions and related activities. For instance, the chosen topic may be stormwater, rural runoff or other water challenges, each which would have specific driving questions and related activities to meet the intended learning outcomes and achievement aims. Table 1 shows, as an example, the activities and driving questions of learning plans that focussed on stormwater during the initial student engagement trials. Stormwater is a sub-discipline of water and a topic with which the authors have expertise so was selected to trial initially. Concurrently, there is an escalating need to manage the increased frequency and magnitude of stormwater-related problems, exemplified by the 2023 Cyclone Gabrielle that devastated many communities in Aotearoa New Zealand. However, the lesson plans and, associated driving questions and activities, can be easily adapted to any specific water topic that a community feel is most relevant to them. The framework is therefore sufficiently flexible to be responsive to individual and evolving community needs and as science discoveries emerge, yet the goal of enriching water-literacy in a bicultural context, is still maintained.

The programme starts in the junior years with understanding fundamentals of water sources and forms, how we use and impact water, our shared critical resource and then leads into details of The Water Cycle | Te Hurihanga Wai from both western and indigenous Māori perspectives (e.g. Figure 2). Building on this in the more senior primary school years, it progresses into engineering and community solutions with a strong STEAM focus that encompasses bicultural perspectives.

The Water Cycle (Western Science) **Te Hurihanga Wai (Indigenous Science)**

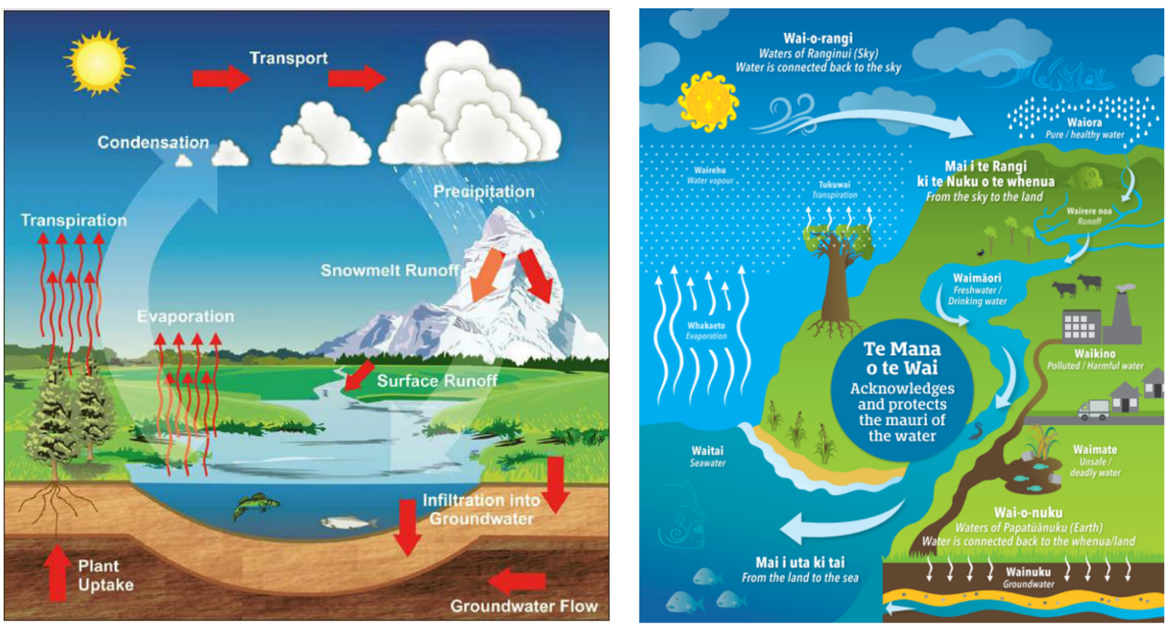

Figure 2: The Water Cycle (US NWS) and Te Hurihanga Wai (Water New Zealand)

The WWLP specifically aligns to the key science focus objectives of the National Curriculum Te Marautanga Aotearoa thereby helping to achieve several learning outcomes. It builds confidence and competence in understanding water from a bicultural lens while upskilling students | ākonga in water literacy and related STEAM careers through contextual (place-based) learning within their community. Another benefit of the framework is that it can easily integrate into existing science, mathematics and bicultural instruction so doesn't require 'extra space' in the curriculum.

Precursor Trials

A precursor application of the WWLP was implemented at one primary school in late 2022, with a second application occurring in May 2023. Further applications are scheduled for the latter half of

2023 and beyond. Reflecting on these lesson plans, field-based activities and, informed by international best practice, the WWLP is evolving in response to lessons learned, key community aspirations and growing needs of the water engineering profession.

During 2022, a series of three stormwater-topic focussed education sessions were undertaken in Years 3-4 (aged 7-8 years) at a school in Ōtautahi | Christchurch. The sessions included discussion of concepts and related field-based exercises, including making use of a proprietary treatment device (SW 360 Littatrap) installed within the school grounds that captures gross pollutants from stormwater runoff. This activity provided for contextual understanding of students' actions (littering) and natural processes (e.g., leaves falling from trees, decaying and getting washed into the treatment system) through hands-on investigations. The sessions were supported by a range of other activities and discussions led by the teacher during other class-time to reinforce the concepts and enhance learning outcomes. The stormwater focus areas and key content of the precursor sessions are provided in Table 2, with supporting photographs in Figures 3 and 4.

Table 2: Precursor Trial Session Contents- Stormwater Focus

Session	Focus area	Driving Question(s)	Activities	Learning Outcomes
1	Storm(water) Concepts	What is an engineer / What I do as a job"- discussion about engineering as a career to link the session content to a potential career. What does the Water Cycle | Te Hurihanga Wai and Te Mana o te Wai (Figure 2), look like? How does the water cycle differ in an urban and non-urban context, how urban stormwater is generated and its pathway to the ocean. How and what sort of contaminants become entrained in stormwater from various surfaces in our school (roads, the playground, roofs) and are conveyed to our awa/stream (Figure 3). What can we can all do to prevent these contaminants polluting our waterways, e.g. not littering, picking up rubbish, not washing cars on the road or driveway.	How water moves from the school to our local awa/stream using CCC's GIS viewer as a visual aid Introduction to Session 2 – Viewing Littatrap Youtube Video (LittaTrap: Protecting the future of our waterways - YouTube	Students gain an understanding of what the water cycle means in the context of stormwater specifically.
2	Littatrap Visit – following a couple of rain events	What do stormwater contaminants look like? Where and what is our stormwater system?	Investigating the Littatrap stormwater treatment device. Discussion of H & S requirements (fall risk, contaminants found).	Students gain an understanding of the types of contaminants that enter our streams, their origin and impacts
3	Field-based exercise – Stream Habitat and Water Quality Assessment	Where do our stormwater systems discharge into the natural environment? What lives in our streams and rivers that we should be protecting? What types of environment do these things like to live in? How does stormwater pollution and modifications to our natural environment	In this session the House of Science's Te Wai kit was used as a resource. Viewing the outlet of the stormwater network connecting the school stormwater to the awa, including seeing if we could see any contaminants that shouldn't really be in the stormwater system and stream. Observing the awa from a bridge to see the various in-stream environments present (riffles, runs, pools), shading provided by trees, stream bed type (rocky, sandy etc). Using nets at a nearby kayak launch ramp (accessible to the waters edge) to catch and analyse the types of fish and invertebrates present in the water (Figures 7a and 7b). At the same location we undertook measurements of stream velocity, pH, temperature, nitrates, clarity, to help us understand the quality of the water (Figure 7c). Reflecting on how the various stream environments and stormwater contaminants would impact the types of fish and invertebrates present.	Students see the different types of instream habitats that occur in their local area. Students understand what sort of habitats would support certain types of instream life Students develop a connection to their local river/awa which can enhance their desire to act in ways which protect this environment.

Figure 3: The path of pollutants to the river | awa

Figure 4: (a) Students | Ākonga using nets to catch invertebrates and minnow fish, (b) Investigating their catch and (c) measuring water clarity, a measurement of sediment in water.

At another school (with the same age group), the precursor activity involved an exploration and investigation of living creatures in a local freshwater reserve and was delivered in a bicultural context. The activity was led by professional science outreach coordinators and supported by one of the authors of this paper and two teachers. It included hands on water sampling of a lake, classifying the invertebrates that students caught, discussion of what the invertebrates needed to keep them safe and healthy and the interdependency of animals and humans. It ended with a very engaging role modelling game that reinforced how our choices and use of everyday products impacts water quality and how these can kill our freshwater biota. Both English and Te Reo (Māori, indigenous language) terms were used throughout. Importantly, it ended with the students identifying actions we can all take to sustain life in and around our waterways, empowering them to be able to help solve global challenges at a local level. Students subsequently received instruction (literacy, science, categorisation) on the life cycle of water animals and in appreciating how water quality is critical to all our survival. Their enthusiasm for the learning was infectious.

Lessons Learnt

Key lessons learnt during these precursor activities that are being integrated into and enhancing the future WWLP programme sessions include;

• Targeting language at the appropriate year and curriculum level.

• Practicing explaining abstract/intangible concepts like pH, mass balances and dissolved pollutants as things we can "see with our eyes" (rubbish, sediment) and things we can't see (dissolved metals, salinity). A helpful analogy for "invisible" pollutants is how when we add sugar to hot water it dissolves ("invisible") but is still there and has changed the quality of the water.

• Walking to and from site visits helps facilitate more enquiry and Q&A with the children at an individual level.

• School teachers have escalating administrative and counselling demands on their time so the lesson plans need to be well mapped out in advance.

• Other curricula areas can be incorporated into sessions including mathematical concepts (counting, sorting, graphing data) and the importance of using bilingual (indigenous and English) terms.

• To prevent eco-anxiety of young children, it's important to discuss and end on what we can all do to help solve the problems explored so that students are empowered and optimistic about their future and excited to become part of the solution.

Future WWLP goals are to include:

• Formal partnership with indigenous landowners | mana whenua (local tribes) to enrich the programme's bicultural competency.

• Greater engagement of University engineering students to enhance the modelling experience for children and build up new intergenerational relationships.

• Concepts of biomimicry to explain how we can use nature's sustainable designs for solving water quality (and quantity) challenges.

• Modules to be considered in the Children's University certification to strengthen the awareness of and attraction into STEAM careers.

• Inclusion of before and after surveys/knowledge checks to gauge improvement in learning.

WWLP Resourcing Needs

Successful implementation of the WWLP requires committed personnel to champion it locally, on-going pedagogical guidance from primary level educators and some technical resources (e.g. water quality and flow measurement tools) for including engaging and hands-on activities. Endorsement, motivation and enthusiasm from educators, volunteers and the water profession are essential for sustaining the industry-educator partnership. It requires engaged leadership and local advocates. Understanding the target curriculum level is necessary for it to be effectively integrated into existing curriculum requirements without over-whelming schools with another competency requirement. Incorporating field-based activities at the school makes it contextual and accessible for schools. Using "real" engineering solutions makes it relatable and supports transferrable skills. A number of available e-resources (e.g. Figure 5) shows some of the available resources in Aotearoa New Zealand) that can be leveraged to deliver the programme. These can be selected and tailored to a partner school to adapt the framework to the schools' goals and community aspirations.

Figure 5: Possible resources to support the WWLP (in Aotearoa New Zealand)

Conclusions

A new educator-practitioner partnership was established to develop a framework that helps upskill primary school students | Ākonga children in water-literacy with a STEAM-focus to help meet the increasing needs of the water industry. Importantly, the programme was designed and is delivered with a bicultural lens, specifically for a country co-governed by indigenous peoples and those who followed. The programme is aligned to the national primary level curricula and industry needs. It is iterative and evolving, informed by reflective lessons learnt and best international pedagogical practice.

Acknowledgements

We appreciate our partner schools support and our respective workplaces for enabling us to pioneer this bicultural water literacy framework. We also acknowledge our indigenous communities in guiding us with strengthening the framework's bicultural quality. We also acknowledge

Stormwater360's donation of a Littatrap for the precursor study, which provided an invaluable resource for supporting students' active learning and concurrently helping to remove pollutants from entering the local awa Opawaho/Heathcote River.

References

Colston, N., Thomas, J. Ley, M. Tyler, Ivey, T. and Utley, J. (2017*). Collaborating for Early-Age Career Awareness: A Comparison of Three Instructional Formats*. Journal of Engineering Education, Vol. 106, No. 2, pp. 326–344.

Dailey, D., Jackson, N.Cotabish, A. and Trumble, T. (2018). *STEMulate Engineering Academy: Engaging Students and Teachers in Engineering Practices*. Roeper Review, 40:97–107. https://doi.org/10.1080/02783193.2018.1434709

Harris, C., Berkowitz, A., McLean, M. and Notin, K. (2013). *"Beyond Eco-Footprints: Using the STEM Process."* Green Teacher: 100 (18-20), ISSN: 1192-1285.

Hodges, G.,Jeong, S., McKay, P., Robertson, T. and Ducrest, D. (2016). *The American Biology Teacher*, Vol. 78, No 3, pages. 200–207, ISSN 0002-7685.

Maeda, Y., & Yoon, S. Y. (2011). *Scaling the revised PSVT-R: Characteristics of the first-year engineering students' spatial ability*. Proceedings of the American Society for Engineering Education, USA, 118, 22.1273.1–22.1273.19.

Mbamalu, G. E. (2001). *Teaching science to academically underprepared students*. Journal of Science Education and Technology, 10(3), 267–272.

Ministry for the Environment (MfE).2020. *Essential Freshwater: Te Mana o te Wai factsheet,* Reference Number: INFO 968, https://environment.govt.nz/publications/essential-freshwater-te-mana-o-te-wai-factsheet

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

Tertiary Education Commission, Drawing the Future Report. February 2020. https://www.tec.govt.nz/assets/Publications-and-others/TEC-Drawing-the-Future-Report-v3.pdf

The New Zealand Productivity Commission | Te Kōmihana Whai Hua o Aotearoa (2020). *Technological change and the future of work.* https://www.productivity.govt.nz/assets/Documents/0634858491/Final-report_Technological-change-and-the-future-of-work.pdf

Copyright statement