Enduring competencies for designing science learning pathways

Rosemary Hipkins, Sara Tolbert,
Bronwen Cowie, and Pauline Waiti

UC University of Canterbury
Te Whare Wānanga o Waitaha
Christchurch New Zealand

NZCER
Rangahau Mātauranga o Aotearoa

The University of Waikato
Te Whare Wānanga o Waikato
Te Wānanga Toi Tangata
Division of Education

Rangahau Mātauranga o Aotearoa | New Zealand Council for Educational Research
Te Pakokori, Level 4, 10 Brandon St
Wellington
New Zealand

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Contents

1. Introduction

The framework outlined in this document was collaboratively developed by a group of science curriculum experts. It is not intended to supplant the design work of the Science Curriculum Refresh team, or the science Subject Expert Groups (SEGs) for the Review of Achievement Standards (RAS). Its purpose is to inform current thinking about science learning, curriculum, and assessment, and to build a conceptual foundation that will help both the curriculum and SEG teams keep their work aligned and coherent as their different work streams unfold and evolve.

Our proposed strategy centres around the concept of “enduring competencies”. This term is adapted from the idea of “enduring understandings”, which originated in the much-cited “Curriculum by Design” model developed some years ago by Wiggins and McTighe.[1] The concept of “big ideas” originates from the same research group’s work. This concept should already be familiar to both the Curriculum Refresh team and the National Certificate of Educational Achievement (NCEA) SEG teams.

It is also likely that team members working in this design space have encountered the work on big ideas in science education (including ideas about science) carried out by a European science education team, led by Wynne Harlen.[2]

The use of “competencies” in place of “understandings” creates an explicit link to the key competencies in *The New Zealand Curriculum* (*NZC*),[3] and signals that learning is about what students can do with what they know and understand. In this way, the idea also creates an implicit connection to the “understand/know/do” framework that has been used to structure the recently-published Aotearoa New Zealand Histories curriculum,[4] and subsequently the new draft for the Social Sciences learning area.[5]

1 Wiggins, G., & McTighe, J. (2005). Understanding by design (expanded 2nd ed.). ASCD.
2 Harlen, W. (Ed.). (2015). *Working with big ideas of science education*. https://www.interacademies.org/publication/working-big-ideas-science-education
3 Ministry of Education. (2007). *The New Zealand Curriculum*. Learning Media. https://nzcurriculum.tki.org.nz/
4 https://aotearoahistories.education.govt.nz/
5 https://nzcurriculum.tki.org.nz/The-New-Zealand-Curriculum/Social-sciences

2. What are enduring competencies?

The adjective "enduring" signals something important about the purposes envisaged for learning. Put succinctly, enduring learning is "the learning that will stay with you" beyond school.[6] David Perkins recently described such learning as "lifeworthy".[7] To the concept of "big understandings" he added the concept of "big questions", which take learners beyond what is settled and known in profound ways. Big questions address "particular themes about humanity, our world, and the universe" (p. 74). Perkins suggests you can take any recent event and quickly think of big questions about it, but he also noted that any list of such questions would quickly grow very long. Conscious of the crowded curriculum, he argued the big understandings and big questions tend to come bundled together. Big questions are the "inquiry partner to big understandings" (p. 24). It is this sort of bundling (or we might say "weaving")[8] that we had in mind when we centred our framework on enduring competencies.

The term "competencies" signals that what we have in mind is *something more than* a set of ideas, no matter how "big" these may be. *NZC* defines key competencies as "capabilities for living and lifelong learning" (p. 12) and says they draw on knowledge, skills, attitudes, and values, combining these in ways that lead to action, and to ongoing learning. Importantly, the *NZC* definition on page 12 also notes the contextually bound nature of competencies. They come to life in specific contexts, combining with all the other resources available to students in those contexts. Again, a type of bundling or weaving is implied.

Enduring competencies in the Science learning area of *The New Zealand Curriculum*

The focus on enduring competencies can be linked to the short version of the purpose statement in *NZC* about what science is for. This statement says that "in science, students explore how both the natural physical world and science itself work, *so that* they can participate as critical, informed, and responsible citizens in a society in which science plays a significant role" (*NZC*, p. 17, emphasis added). There is a strong signal here that building competencies that endure and have value beyond school should be seen as the overarching purpose of science learning for all students.

This intention is reflected in other commentary about the reasons that all students should come to appreciate the role that science plays in society and gain an understanding of the contribution it makes to our lives and wellbeing. For example, *Inspired by Science*, a report commissioned by the Royal Society,[9] pointed out that all students are citizens, but only some will become scientists. The report suggested that, even this latter group, who are achieving well by international measures, are

6 These words come from this blog: https://iteachu.uaf.edu/enduring-understandings/
7 Perkins, D. (2014). Future wise: Educating our children for a changing world. Jossey-Bass.
8 This idea references "weaving" approaches to integrating NZC key competencies with content; for example: https://www.nzcer.org.nz/system/files/Weaving%20a%20coherent%20curriculum_0.pdf
9 https://www.nzcer.org.nz/research/publications/inspired-science

not being well served by the current traditional science curriculum.[10] The report recommended a curriculum focus on socio-scientific issues in the middle school years. It also recommended that this focus should be continued into the senior secondary school for all students who choose science, supplemented by specialist courses for some students, as needed. Using a small set of enduring competencies as a framework for both curriculum and assessment planning would provide a practical way to accommodate this challenging recommendation.

Four science competencies that we hope will endure

Having briefly sketched the concept of enduring competencies, we now turn our attention to the selection and justification of a small set of enduring competencies that students need in the short term and that are also "lifeworthy". We acknowledge that both the selection and justification involve value judgements about the kinds of people we hope our education system will nurture. Here we have taken our cue from many respected science educators around the world, drawing on their wisdom and insights to underpin our own decision making. We have also endeavoured to maintain other links with *NZC*; for example, to the high-level intention of the four strands of the Nature of Science (NOS) overarching strand of the Science learning area. We have also introduced the Mana ōrite initiative, which is an important element in both the Curriculum Refresh and the NCEA review. We brought back one element that seemed to get lost between the 1993 curriculum and *NZC*: namely, the close interconnection between new technological advances and new science ideas. We have also been conscious of the need to bundle/weave multiple curriculum elements together, while keeping open the design space for the teams whose work will follow ours.

10 The authors note that organising school science as a preparation for science careers is flawed in a number of ways. "It does not provide a balanced, or even particularly effective, education for the minority who do go on to pursue STEM careers; it results in the majority of students seeing themselves as science failures, and science itself as the boring, esoteric preoccupation of a few; and, it seems to engage only a few in wanting to know more science simply for its own sake." (*Inspired by Science*, p. 8). They attribute this lack of effectiveness to acquisition of many "pieces" of knowledge that cannot necessarily be assembled into a coherent big picture—a pile of bricks rather than a finished wall.

3. Enduring competency: Drawing on different knowledge systems

The broad parameters of this competency

As they take their learning out into the world, young people will be able to understand and interpret events and experiences through at least two different knowledge lenses: they will understand their place and identity in the natural world through the lens of science, and through the lens of mātauranga Māori, as well as other relevant cultural–historical knowledge systems. They will know how and when to draw on the contributions and strengths of science, mātauranga Māori, and other cultural–historical ways of knowing nature, to live as ethically and responsibly as possible.

An overview of the multifaceted nature of this enduring competency

Facet 1: Science as a knowledge system

- Science can be explored as a knowledge system. It has "rules" for building new knowledge and for validating and communicating knowledge claims made by scientists. The "inquiry" competency explores these rules and practices more thoroughly, including exploring similarities and differences within different science disciplines.
- A particular set of values underpins science as a knowledge system. These include: parsimony (looking for the explanation that best fits all the facts); open-mindedness (being prepared to replace an explanation when a better one is established and validated); transparency (sharing all information vital to understanding a knowledge claim); objectivity; scepticism; and so on. These values are ideals. Scientists do not always live up to them; depending on the context and question, they may prioritise different values.
- Science is an evolving knowledge system, not a static one. Newer areas such as complexity science can be brought into the curriculum once it is agreed that there is a clear benefit for doing so.
- History of science stories illustrate ways science seeks to self-correct when explanatory accounts are supplanted by better ones.

Facet 2: Mātauranga Māori as a knowledge system

- Mātauranga Māori and science are distinct yet intersecting knowledge systems.
- Mātauranga Māori is an evolving knowledge system, not a static one. Mātauranga Māori knowledge is developed by careful and prolonged observation of natural processes, and the identification and interpretation of patterns in nature.
- Some mātauranga Māori knowledge is generalisable (across iwi) but some is specific to the local contexts in which it is generated.
- Mātauranga Māori determines the ways that Māori interact with the environment with specific reference to ngā kōrero tuku iho (the knowledge handed down through generations) and this in turn determines the nature of the continued interaction.

- Ngā kōrero tuku iho is an oral tradition, situated in context. Important aspects of memory reside in mental maps of specific places and relationships. For example, "the Polynesians and their navigators had an ocean and a sky in their minds".[11] They did not need a drawn map on paper, or measurement instruments, to help them find their way.
- In mātauranga Māori accounts of natural systems, people are typically positioned inside the system as one interconnected part. Science accounts typically position people outside the system, looking in.

Facet 3: Science, as a knowledge system, is historically and socioculturally embedded

- Science is part of a larger system of power relations. Both now and in the history of science knowledge development, social systems and societal mores have influenced how scientists conceptualise their new explanations (e.g., via the metaphors and analogies on which they can draw).[12] Power dynamics also influence the nature of research that gets funded or overlooked.
- Both now and in the past, science subjects are deeply interconnected with other STEM subjects, and with other learning areas such as the social sciences. Science is in the foreground for this learning area, but students need to learn to think beyond its traditional content to understand its reciprocal relationships with other knowledge areas.
- Technological advances open up new ways of "seeing" which, in turn, enable different types of science discoveries to be made. In this way, science and technology are inextricably interconnected.

Facet 4: Relationships between knowledge systems, worldviews, and identity

- The ideas we "think with" influence how we "see" the world, understand our experiences, and envision possibilities For example, mātauranga Māori as a knowledge system provides a world view and an identity for those who have whakapapa Māori and engage with the knowledge system.[13] For those who do not have whakapapa Māori, engagement with mātauranga Māori provides an opportunity to explore and understand the Māori world view; however, it does not provide identity. It is important that this subtlety is carefully considered in a diverse classroom.
- The learning experiences of ākonga in the context of mātauranga Māori, as the knowledge and understandings of our tūpuna, can be shown to be relevant today and in the future, and will provide a strength to explore wider and further in validation of the knowledge base.
- Science learning experiences need to be designed to foster a continuing sense of open-mindedness and curiosity. Opportunities to "play" with ideas and be creative, understanding the boundaries of the knowledge system yet also thinking beyond these, is at the heart of innovative activity.
- Being uncertain, confused, or learning from productive failure, can all be part of purposeful engagement with science, although accounts of such failures "are seldom considered desirable or worth publishing".[14]

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11 Smith, K. (2022). *Navigation: Kupe and Cook.* There is an informative overview of the book here: https://www.nzbooklovers.co.nz/post/navigation-kupe-cook-by-kingsley-smith. Navigators from all around the Pacific held these mental maps. They thought of the world as a "sea of islands" rather than "islands in the sea". This quote is from Rimoni, F., Glasgow, A., & Averill, R. (2022). *Pacific educators speak: Valuing our values* (pp. 3–4). NZCER Press.

12 Stephen Jay Gould's book *Wonderful Life* is a comprehensive exploration of this point. He documented two very different interpretations of relationships between the ancient fossils of the Burgess Shale in Canada and today's animals. Each classification reflects metaphors of its time (e.g., the "Great Chain of Being" influenced the original interpretation). New technologies also allowed the more recent group of scientists to "dissect" the fossils.

13 This paper provides a useful follow-up to this point: Barnes, H. et al. (2019). Noho Taiao: Reclaiming Māori science with young people. *Global Health Promotion*, 3, 35–43. https://pubmed.ncbi.nlm.nih.gov/30964403/

14 This quote is from Mansfield, J. (2021). When failure means success: Accounts of the role of failure in the development of new knowledge in the STEM disciplines. This is a chapter in a book titled *Education in the 21st century*: https://link.springer.com/chapter/10.1007/978-3-030-85300-6_9

Why this competency?

Honouring our commitments to Te Tiriti o Waitangi

The Aotearoa New Zealand school curriculum was initially built on knowledge valued by the settler population at the time that New Zealand was colonised. The knowledge of the Indigenous people, and their ways of doing and being over many centuries of living in Aotearoa, and closely observing the natural world they found there, were largely ignored. Commitments to Māori made at the time Te Tiriti was signed were not upheld. That continues to be the case. When the 2007 *NZC* framework was developed, our commitments to Te Tiriti were acknowledged in the Vision (p. 8), the Principles (p. 9), and the Values (p. 10). However, it was not clear how these high-level signals should, or could, shape the contents of the learning areas. The current refresh of the curriculum, and the associated mana ōrite initiative, provide the next opportunity to continue to honour our commitments to Te Tiriti, but to do so with greater clarity of intent.[15]

The growth in the understanding and relevance of mātauranga Māori began in response to the recognition and revitalisation of te reo Māori in the 1970s. It is important to note that, as with any language, the language and the knowledge base from which it derives cannot be separated, they are inextricably intertwined. This eventually led to the claim that Māori had the right to be educated fully immersed in te reo Māori and therefore with mātauranga Māori. Engagement with mātauranga Māori became of major importance for Māori and involved researching, exploring, contextualising, and analysing the many bodies of Māori knowledge from hapū and iwi. This continued development of understanding mātauranga Māori positioned it to be a knowledge base that hapū and iwi are continually engaging with, and has been growing and developing as our world changes.

Including mātauranga Māori alongside their science education enables ākonga Māori to be “knowers”, “understanders”, and “doers” for their future. Mātauranga Māori is a body of knowledge informing a person’s worldview: their interpretation of what they see is based on what they already know and understand, and impacts their future knowing, learning, and doing. This can be expressed in their decision making. For example, mātauranga Māori provides guidance for decisions made about te taiao (the environment). One topical example might be a proposal to redirect the flow of an awa by mechanical force, with the aim of preventing erosion of banks on which houses are built. The local mātauranga Māori will suggest solutions other than redirecting the awa by force, because the awa will always find its own way to flow into the sea. The long-term solution may have to be about the houses and not the awa.

Respecting the increasing diversity of students in schools

New Zealand’s population has become much more diverse over time. In the 20th century, many people from different Pacific nations settled here, bringing other knowledge traditions with them. New Zealanders immigrating from Asian countries are currently the second largest minority ethnic group, after Māori.[16] Immigration from Middle Eastern, African, and Latin American countries have also continued to rise in the past decade, and New Zealand is home to a growing number of former-refugee students and families.

15 We note that parallel conversations are taking place in the research science community, and in many other government settings. The link here is to a paper that provides that big-picture framing: http://www.rauikamangai.co.nz/wp-content/uploads/2021/06/CB_TePutahitanga_A4_2021_inner_Digital_final.pdf

16 All demographic trends reported here were sourced from the 2018 census: https://www.stats.govt.nz/2018-census

These demographic shifts, and associated increasing cultural and linguistic diversity, are important for science educators to understand. We know that learning to which students can relate is more likely to "stick", but it is impossible for any one teacher to address this much diversity, increasingly referred to as "superdiversity",[17] without some sort of guiding and organising framework. The flip side of this dilemma is that students should not have to leave who they are at the classroom door.

Superdiversity also offers important opportunities. For example, students who can take different perspectives, thinking critically and creatively across different knowledge systems (a type of a "meta-understanding") are also more likely to become change makers who are more comfortable with uncertainty and more able to think in the new ways needed in times of runaway change.[18] The goal is to understand how each knowledge system works. It is explicitly NOT about taking it apart or trying to knock it down. Jane Gilbert explains that we need a process to:

> … break out of, and see beyond, the conceptual categories that, at a deep level, structure the way we think. The aim is to look below the surface to see how these conceptual categories work together as a system, and how this system becomes possible by excluding or disallowing certain other categories. (See footnote 18.)

Increasingly, scientists are working with Indigenous scholars to rethink challenges and potential solutions, in areas as diverse as conservation, land management, fisheries, and public health issues such as obesity.[19] Learning about knowledge systems as systems that generate different perspectives on complex issues will support students to understand these shifts that are already taking place in professional science communities.

Navigating the interface between mātauranga Māori and science

Acceptance of the value mātauranga Māori has in informing the world view of the "knowers and understanders and doers" of the mātauranga is implicit in the act of negotiating the interface between mātauranga Māori and science in the Aotearoa New Zealand education sector. Students need to understand that both knowledge systems are valuable on their own terms. It is important that they do not develop pejorative comparisons that favour one over the other, or try to assimilate one into the other.

For this competency to be *enduring*, students need to develop a strategy for bringing the two knowledge systems into a meaningful and respectful dialogue that works for them personally. Various models potentially support and enhance engagement at the interface between mātauranga Māori and science, showing how this might be done in the classroom. Models using metaphors such as braided rivers,[20] and two-eyed seeing,[21] provide the opportunity to consider other ways of viewing the world, and to weave the ways of knowing together to develop new and deeper ways of knowing

17 New Zealand is now home to over 200 ethnic groups and over 150 different languages: https://theeducationhub.org.nz/how-to-use-a-superdiversity-approach-to-work-with-migrant-families-in-early-childhood-care-and-education-settings/

18 This idea is drawn from a conference paper that will shortly be included in an open access book: Gilbert, J. (30 September 2019). *Re-balancing science education for the Anthropocene era*. Paper presented at the NZARE Science Education SIG Seminar: Post-normal science education—What might it look like? The book will be titled *Reimagining Science Education for the Anthropocene* and will be published by late 2022 or early 2023.

19 See, for example, Heke et al. (2019). Systems thinking and indigenous systems: Native contributions to obesity prevention. *AlterNative: An International Journal of Indigenous Peoples*, 15(1), 22–30. https://doi.org/10.1177/1177180118806383

20 Macfarlane, A., & Macfarlane, S. (2019). Listen to culture: Māori scholars' plea to researchers. *Journal of the Royal Society of New Zealand*, 49(sup1), 48–57.

21 For teaching implications, see: Zeyer, A. (2022). Teaching two-eyed seeing in education for sustainable development: inspirations from the science|environment|health pedagogy in pandemic times. *Sustainability*, *14*(10), 6343. For an example of how New Zealand scientists have used this way of bringing knowledge systems together, see: Rayne, A., et al. (2020). Centring indigenous knowledge systems to re-imagine conservation translocations. *People and Nature*, 2(3), 512–526. https://doi.org/10.1002/pan3.10126

and understanding the world. For ākonga Māori, weaving mātauranga Māori and science together can suggest another way of doing science and perhaps a better understanding of science. For other ākonga, it provides an opportunity to consider other ways of seeing that enhance their perspective and attitude to their world. For every ākonga, it places value on mātauranga Māori.

Specific issues for science education to address

It is likely that some aspects of this enduring competency will not be familiar for many teachers, and they could be confronting. While science has enjoyed a relative position of power (i.e., viewed as generating "truth claims"), mātauranga Māori has been devalued and deliberately disrupted by colonisation. Mana ōrite in science means recognising that both mātauranga Māori and science are valuable, rigorous, and reliable knowledge systems for understanding the natural and physical world, and particularly for understanding how to live sustainably together in Aotearoa New Zealand.[22]

Both knowledge systems have norms for vetting the validity of knowledge claims, though these norms differ culturally. As a knowledge system, science aspires to produce one authoritative version of how the various aspects of the natural world function, with the proviso that what is taken as authoritative changes over time. Traditional science explanations are deliberately lacking in context, so that they are generalisable across multiple circumstances. They are as factual as possible, and do not directly reference social issues. These features are not shared by many other knowledge systems, which tend to present explanations about the world in a more holistic, interconnected way.

Context is critically important in mātauranga Māori and in other Indigenous knowledge systems. Therefore, local variations on centrally important ideas can be a characteristic that differentiates these knowledge systems from science. This difference also means that a mātauranga Māori programme will be locally based, drawing on the knowledge and understanding of the iwi and hapū of the locality where the schooling is located. For an interface between mātauranga Māori and science to be successful, a science programme should also be locally derived.

It is important that students have opportunities to learn about knowledge systems and their differences, but we do not want to leave them with the impression that "anything goes", depending on what you choose to believe. That is why this competency takes a "meta-level" view of what science is and what it is not.[23] Other knowledge systems have the potential to become a treasure in this context because they help students to see what might be invisible to them if they hold the view that science is the one and only "true" way of thinking about the natural world.[24] The aim is to enrich their worldview as their enduring competencies are built.

22 We note here that this is one of the goals in the draft vision statement developed by the Youth Advisory Group as part of the Curriculum Refresh process: https://www.education.govt.nz/school/student-support/youth-advisory-group/

23 A useful reading here could be https://www.nature.com/articles/450033a

24 This paper might be a useful resource for those who can access it: Bang, M., & Medin, D. (2010). Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science Education*, *94*(6), 1008–1026.

4. Enduring competency: Enacting a range of science inquiry practices

The broad parameters of this competency

When asking curious and critical questions, and making judgements and choices relevant to their lives, young people can draw on their awareness and understanding that scientists use a range of disciplinary inquiry practices to produce defensible explanations of natural phenomena.

An overview of the multifaceted nature of this enduring competency

Facet 1: The inquiry practices of science disciplines

- Scientists make careful, systematic observations and measurements of natural phenomena, drawing on inquiry practices that are relevant to their discipline.
- Inquiry practices are diverse and contingent. Examples include pattern seeking, modelling, or testing predictions.
- Measuring scales and classification categories are based on existing understandings / theoretical ideas about how the world "is". This means that all observation is actually "theory-bound".[25]
- The specifics of a practice evolve over time as scientists solve problems and create methods for answering their questions.
- There can be contextual differences in the way a practice is applied. These differences will reflect the context and goals of the inquiry, including the specific discipline in which the inquiry is located.
- Technological advances open up new ways of observing and measuring.

Facet 2: The theory-building practices of science

- Scientists construct explanations that combine evidence with what is already known, including existing science theories and concepts.
- They also review and critique other scientists' explanations.
- Finding and acknowledging counter evidence helps scientists remain open to the possibility that there might be a different explanation from the one that is currently supported.
- Theories can change if sufficient evidence builds up to support a different explanation (a so-called paradigm shift).

Facet 3: The social nature of science practices

- Scientific knowledge construction is a social process.
- Scientific findings undergo rigorous peer review before they are accepted as valid.
- Scientists often collaborate within and across research communities and disciplines to refine what is known or generate new insights.

25 This classic paper makes the point well: Millar, R., & Driver, R. (1987). Beyond processes. *Studies in Science Education*, *14*(1), 33–62. https://doi.org/10.1080/03057268708559938

Facet 4: The thinking practices of science

- A disciplined blend of critical and creative thinking is integral to all science practices.
- Scientific inquiry is often fuelled by intuition, imagination, and empathy.
- Working collaboratively and inviting peer review are practices that can help avoid the well-known thinking trap of “confirmation bias” (where we see what we expect to see and, in the process, overlook counter evidence).
- Being uncertain or confused can be a productive part of the inquiry process if it opens up new ways to think about a question or a challenge such as unexpected results from an inquiry.
- Uncertainty is integral to complex systems thinking: the behaviour of complex systems cannot be fully predicted.
- There is considerable overlap between some science inquiry practices and mathematical reasoning practices.

Why this competency?

In a world awash with misinformation, and deliberate disinformation, all students need to develop a sense of the veracity of knowledge claims, informed by their knowledge of science practices. Disinformation communications are cleverly crafted to mimic features of rigorous science, and to cast doubt on vital understandings that most scientists accept as the best explanations for now (e.g., specific, evolving understandings of the dynamics of climate change). To help guard against such deceptive practices, students need first-hand experiences of the practices that scientists actually use, and these experiences need to be as authentic as their curriculum level allows.

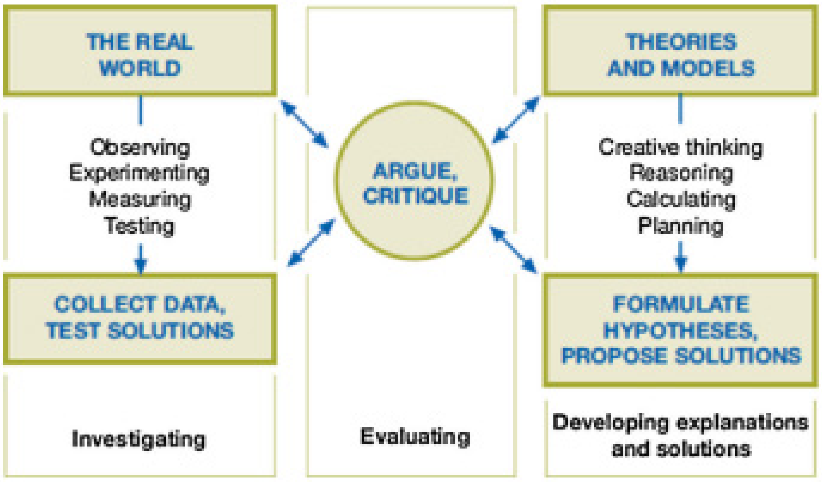
The use of the word “practices” originates from the research field of “science studies”.[26] This research aims to describe what scientists actually do. Interest in this area was partly prompted by the assertion that published science accounts tend to strip out the contextual detail, including the challenges that inevitably precede successful knowledge claims. A related concern is that null or negative results are not usually published, which means a significant chunk of the knowledge “landscape” is missing. Offering rich inquiry experiences of all the types of practices that scientists undertake helps put contexts, contingencies, and messiness back and gives students a first-hand opportunity to experience the challenges of knowledge building.

There is a growing body of research on the teaching, learning, and assessment of science practices in school settings. Science educator Jonathon Osborne distilled this research to arrive at the model shown in Figure 1. He used this model to make a very important point—critique is the centrally important practice that applies to all science activities, whatever their specific differences. Yet critiquing investigations (their own or others’) is something that many students do not get to do in a meaningful way.[27]

26 This paper is a useful survey of how the research field came to be applied to school science education and underpinned the transformative move to a focus on science practices: Ford, M., & Forman, E. (2006). Redefining disciplinary learning in classroom contexts. *Review of Research in Education*, *30*(1), 1–32. https://www.researchgate.net/publication/250185413_Chapter_1_Redefining_Disciplinary_Learning_in_Classroom_Contexts

27 Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education*, *25*(2), 177–196. https://doi.org/10.1007/s10972-014-9384-1

FIGURE 1: **Modelling the relationships between science practices (Osborne, 2014, p. 181)**



The first three facets we have proposed for this competency broadly follow Osborne's model. They can also be readily linked to three of the five science capabilities,[28] which were created as a practical strategy for weaving the various components of *NZC* science into purposeful bundles.

Many of the facets of this competency will not be fostered by carrying out traditional recipe-style practical work. All students need opportunities to directly experience the messiness, uncertainty, and creativity that actual science practices support.

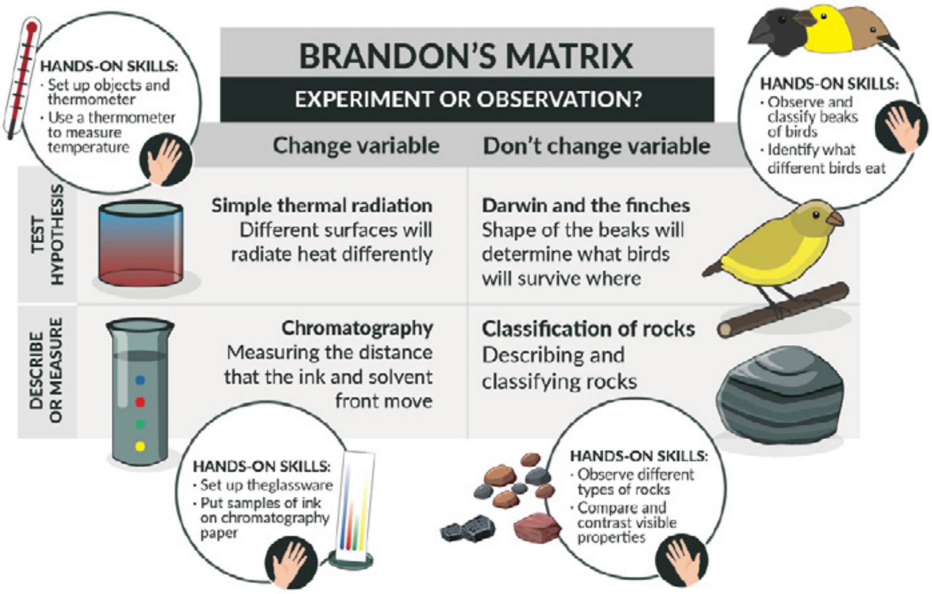
Discipline-specific similarities and differences

The model in Figure 2 shines a critical spotlight on the widespread misunderstanding that there is one "scientific method" and that this inevitably involves carrying out a "fair test". Brandon's Matrix[29] highlights the existence of discipline-specific methodologies that can help bring the facets to life in different ways in different science subjects. Put another way, the subject itself is one critical aspect of the inquiry context. Carefully controlling variables is a central practice in physics but does not feature in many types of biological and earth science inquiries.

28 At the time of writing, these are hosted at: https://scienceonline.tki.org.nz/Science-capabilities-for-citizenship/Five-science-capabilities. They are named as: Gather and interpret data; Use evidence; Critique evidence; Interpret representations; and Engage with science.

29 Figure 2 was sourced from Erduran, S. (2021). *Enhancing summative assessment of practical science: A systematic approach. Final report.* https://ora.ox.ac.uk/objects/uuid:3e3640c2-cbb9-4fca-8664-3cf6fbaab202

FIGURE 2: **Brandon's matrix: A model for classifying diverse science practices (Erduran, 2021)**



Science changes over time as models are tested and revised. Just as there are multiple ways of carrying out science investigations, there are also different ways to model ideas and to use models as part of science investigations. Scientists can draw on a wide range of types of models as part of their inquiry repertoire. Literal models can be created and tested in some instances, but metaphors and analogies are also models, as are diagrams, matrices, formulae, explanations, and thinking supports such as concept maps.

Models can be used to: make complex and abstract ideas easier to conceptualise; make predictions and generate new inquiry questions; help decide what data to collect; surface assumptions and make them explicit; and explore trade-offs and efficiencies when there is no obvious "right" way to proceed.[30] Again, there are discipline-specific differences in the "rules" for use of models: this point overlaps with the "literacy in science" competency which we introduce next.

There is overlap between science practices and mathematics practices. Many scientists use numerical techniques and computational thinking to define and measure quantities and look for relationships between them. Measuring scales devised for this purpose may be updated if necessary by the community of practising scientists who use them.[31] The OECD has recently identified the ability to find and describe patterns in big data sets as an inquiry practice that is becoming increasingly important in this century.[32]

30 For an extended discussion, see Epstein, J. (2008). Why model? *Journal of Artificial Societies and Social Simulation*, *11*(4). https://www.jasss.org/11/4/12.html

31 There is an example amongst the resources to support the science capabilities: https://scienceonline.tki.org.nz/Science-capabilities-for-citizenship/Five-science-capabilities/Interpret-representations/Mercalli-Intensity-Scale

32 OECD. (2020). *PISA 2024: Strategic vision and direction for science.* https://www.oecd.org/pisa/publications/PISA-2024-Science-Strategic-Vision-Proposal.pdf

Probabilistic reasoning is an important area of overlap between the sciences and the subject of statistics in the mathematics curriculum. This is relevant to explanations of stochastic phenomena (e.g., diffusion and osmosis)[33] but also applies to ways in which scientists manage uncertainty and risk when inquiring into complex, dynamic phenomena such as climate change.

Imagination and empathy, though under-recognised as dimensions of scientific practice, are integral to making sense of and engaging with complex socio-scientific phenomena. As Albert Einstein has famously stated, "I am enough of an artist to draw freely upon my imagination. Imagination is more important than knowledge. Imagination encircles the world." Imagination is essential for "outside-the-box" thinking that characterises scientific innovation.

Empathy also fuels scientific understanding. For example, Nobel laureate and geneticist Barbara McClintock's "feeling for the organism" led to significant shifts in our understanding of DNA.[34] Empathy as a dimension of scientific practice can catalyse social and political change, as demonstrated by the renowned work of biologist Rachel Carson. Empathy, when made explicit as a dimension of socio-scientific practice, enhances students' motivation to put science ideas and practices into action.[35] There are overlaps here with the fourth of our set of enduring competencies: Using science for decision making and action.

33 A recent systematic analysis of the many diverse fields of biological research identified three "integrating conceptual frameworks" that apply across multiple areas of biological knowledge. One of the three is "randomness, probability, contingency". The author stresses that lack of mathematical understanding can create difficulties for learning biology, right up to the university level. Nehm, R. (2019). Biology education research: Building integrative frameworks for teaching and learning about living systems. *Disciplinary and Interdisciplinary Science Education Research*. https://diser.springeropen.com/articles/10.1186/s43031-019-0017-6

34 Keller, E. F. (1984). *A feeling for the organism, 10th anniversary edition: The life and work of Barbara McClintock*. Macmillan. McClintock's own words provide insight into the power of empathetic reasoning when new data cannot yet be explained by any directly observable cytological evidence: "I was down there. I was part of the system. I was right there with [the cells], and everything got big. I even was able to see the internal parts of the chromosomes—actually everything was there. It surprised me because I actually felt as if I were right down there and these [cells] were my friends … the main thing is that you forget yourself" (p. 117).

35 See, for example, Zeyer, A., & Dillon, J. (2018). The role of empathy for learning in complex science/environment/health contexts. *International Journal of Science Education*, *41*(3), 297–315. https://www.tandfonline.com/doi/full/10.1080/09500693.2018.1549371

5. Enduring competency: Working with literacy practices of science

The broad parameters of this competency

When communicating their ideas and accessing texts that provide, or purport to provide, scientific accounts of phenomena, young people can draw on their awareness and understanding of the ways in which scientific knowledge is constructed and communicated with the intention to be as generalisable as possible across all the contexts in which it is applicable.

An overview of the multifaceted nature of this enduring competency

Facet 1: Science communications are characterised by protocols

- Scientists aim to communicate their practices, findings, and explanations as clearly and unambiguously as they can (at least to their peers).
- The strategies they use to communicate their work include: consistent use of specialist science vocabulary; following agreed protocols for visual communications (diagrams, graphs, tables, etc.); and following grammar conventions for science texts (formality/provisionality/use of conditional clauses etc.).
- There are discipline-specific communication protocols for different types of publications (experimental reports; information reports; explanations of new insights; syntheses of ideas already published, etc.).
- Contexts are usually left out of formal science explanations, though they might be included in accounts written for a more general audience.
- Science communications are typically multi-modal. Different modes are used to convey different insights. When these modes come together, they "multiply meaning" by addressing different aspects of the same phenomenon.[36]

Facet 2: Disinformation mimics these practices to confuse/obfuscate

- Any of the above features can potentially be manipulated to create false authority for disinformation that seeks to undermine established science or create doubt in people's minds.
- Scientists often make statements about the degrees of confidence they have in their knowledge claims. Disinformation strategies might be less successful when students can interpret this particular nuance of science claims within a broader understanding of science as a knowledge system.
- Disinformation dressed up to look like science can be difficult for lay people to detect. Locating online knowledge claims within the meaning-making ecology that surrounds them has proved to be a more reliable strategy than traditional critical reading.[37]

36 Lemke, J. (1998). Multiplying meaning: Visual and verbal semiotics in scientific text. In J. Martin & R. Veel (Eds.), *Reading science*. Routledge.
37 Weinberg, S., & McGrew, S. (2019). Lateral reading and the nature of expertise: Reading less and learning more when evaluating digital information. *Teachers College Record*, 121(11). https://doi.org/10.1177/0161468119121011

Facet 3: Mātauranga Māori accounts of the natural world are communicated in different ways

- Authoritative mātauranga Māori accounts of the natural world are typically conveyed in the form of contextualised stories or pūrākau. As well as conveying explanations, these are intended to build a shared sense of meaning and hence identity within the audience.
- Wisdom about phenomena and patterns observed in nature can also be conveyed via karakia, whakataukī, and many other customary practices (e.g., rāhui). In this way, a sense of "being" in, and part of, the natural world is integral to daily life (see also the fourth enduring competency, facet 1).
- Over the past 50 years, Māori experts in this area have provided insight and analysis to ensure mātauranga Māori has a written record and justify the depth and breadth to the knowledge of our tūpuna, to further position mātauranga Māori as a valid and enduring body of knowledge. These written resources are discoverable and deserve to be engaged within the context of the knowledge base itself.
- Kupu (individual words) in te reo can convey many layers of meaning that cannot easily be captured in a single word or phrase in English. There is a risk that a straightforward substitution "romanticises and dilutes the word's many complex and profound meanings".[38] Science seeks to condense meanings into single words too; for example, turning a whole process into a single word (e.g., evaporation, diffusion, fossilisation, evolution, and so on). In this case, the aim is to make the meaning as concise as possible, which is the very opposite of adding deep layers of meaning to kupu in te reo.

Facet 4: Building awareness of how we, as individuals, make sense of communications

- Both science and social science perspectives are needed to interpret and understand accounts of the dynamics of complex issues.
- When reading science accounts, many social factors influence our sense making. These are likely to include: motivated reasoning (we are more likely to believe what we want to be true); familiarity (fake news grows in power the more often it is repeated); the influence of our social relationships, including a bandwagon effect and the echo chambers created on social media; a "backfire" effect (e.g., where retracted science papers take on a life of their own on social media).[39]
- Making sense of mātauranga Māori cannot be achieved by finding out the meaning of one Māori word or phrase. It requires an understanding of the development and context of this body of knowledge, which will have different meanings for Māori and non-Māori.
- There are developmental differences in causal reasoning processes.[40] Understanding the thinking strategies that we use is an important facet of metacognition in general.

38 https://e-tangata.co.nz/reo/taking-care-of-our-kupu/

39 Marangio, K., & Gunstone, R., (2020). Science as "just opinion"—the significance for science education of emerging social media. In D. Corrigan, C. Buntting, A. Fitzgerald, & A. Jones (Eds.). *Values in science education: The shifting sands*, pp. 69–89. Springer. https://link.springer.com/book/10.1007/978-3-030-42172-4

40 Kuhn, D. (2012). The development of causal reasoning. *Cognitive Science*, *3*(3). https://www.researchgate.net/publication/264213251_The_development_of_causal_reasoning. and Kuhn, D. (2020). Why is reconciling divergent views a challenge? *Current Directions in Psychological Science*, *29*(1), 27–32. https://doi.org/10.1177/0963721419885996

Why this competency?

Some years ago, Jonathon Osborne noted that "a core feature of science is that it is a cultural activity undertaken through the medium of language".[41] Even though literacy practices are integral to science inquiries, we did not include them in the inquiry practices competency above because they are so multifaceted that these practices need to be considered as a discrete enduring competency. The developers of the Science learning area of *NZC* must have made a similar call: Communicating in Science is one of the four NOS strands.

There is an obvious overlap between literacy in general and science learning. Foundation literacy is necessary but not sufficient to read accounts of science in information books, textbooks, or science papers. Disciplinary literacy in science should be the focus of literacy learning in science. The specific practices of literacy/communication in science are the focus of this enduring competency.

- Science ideas are typically presented in multi-modal formats: the words are supported by tables, diagrams, graphs, and so on. Each of these has been created by following a specific set of cultural practices that need to be understood to comprehend the full meaning of the text. Research has shown that integrating meaning from across these modes is difficult and should not be taken for granted.[42]
- Science texts are also characterised by specific grammar conventions, and specialist vocabulary. Both these features can also make them harder to read than narrative accounts.
- Context is really important to comprehension. Some science terms convey different meanings when used in different disciplinary contexts. Some words have highly specific meanings in science contexts but different meanings in everyday life. "Energy" is an example of both challenges. It has a specialist meaning and an everyday meaning, and it is used in somewhat different ways in different science disciplines.[43]

An additional type of literacy challenge comes to the fore when accessing accounts of science in news media and social media. In these contexts, recognising disinformation at work becomes an important facet of this enduring competency, and so does growing self-awareness of our personal meaning-making habits.[44]

There is an important area of overlap between this enduring competency and the competency of being able to draw on different knowledge systems. Just as science has its own culturally located set of communication practices, so does mātauranga Māori. Learning about what is similar and what is different regarding how knowledge is communicated in each system is important to a full appreciation of how each knowledge system makes meaning in the world. A lack of understanding of these systemic differences is one of the factors that has been used in the past to misguidedly promote science knowledge as more authoritative than mātauranga Māori, or to make the power-laden accusation that mātauranga Māori is pseudo-science.[45]

41 Osborne, J. (2002). Science without literacy: A ship without a sail? *Cambridge Journal of Education*, 32(2), 203–218, p. 204.
42 Two classic foundational texts are: Lemke, J. (1990). *Talking science: Language, learning and values*. Ablex; and Kress, G, Jewitt, C., Ogborn, J., & Tsatsarelis, C. (2001). *Multimodal teaching and learning: The rhetorics of the science classroom*. Continuum.
43 Examples for both the second and third bullet points are included in Osborne's paper (fn 41).
44 See, e.g., Marangio & Gunstone (2020), as in fn 39.
45 After some debate as a writing group, we decided to use the term "disinformation" when communications intended to obfuscate are dressed up to look like science. Some people call these efforts pseudo-science, but we have only used this term in contexts where it is intended as a pejorative judgement against other legitimate forms of knowledge.

Making a clear distinction between scientific literacy and the literacies of science

Curriculum designers face the challenge that the word “literacy” can connote a whole range of meanings. The facets we have elaborated above are intended to highlight the complex meaning-making demands involved in building students’ literacies in science and in science communications. These practices need to be explained, illustrated, and then practised by students. They will not understand and deploy the literacy practices of science simply by reading and using various types of science texts.

The term “science literacy” has a more expansive, overarching meaning. This is well illustrated in the following quote, from a paper that makes the case for a more pluralistic science education, in which students from many different backgrounds work together to make meaning of their science learning:

> Scientific literacy cannot be pre-packaged in books or delivered to students away from the lived-in world. It must be understood as a community practice, undergirded by a *collective* responsibility and a social consciousness with respect to the issues that threaten our planet. We need to treat scientific literacy as a recognizable and analyzable feature that emerges from the (improvised) choreography of human interaction, which is always a collectively achieved, indeterminate process. (Roth & Calabrese Barton, 2004, p. 3)[46]

We make this point here to encourage the design teams to think about how to weave/bundle literacy practices in science together with facets of the other three enduring competencies. As Roth and Calabrese Barton make clear, all the practices of science need to be experienced in contexts that matter in students’ lives, and for living responsibly on planet Earth. We come back to this challenge in the fourth and final competency in this set.

46 Roth, W-M., & Calabrese Barton, A. (2004). *Rethinking scientific literacy*. Routledge.

6. Enduring competency: Using science for decision making and action

The broad parameters of this competency

When young people are confronted with real-life events, opportunities, and challenges, or issues of concern and interest to them, they know how and when to draw on their science knowledge and skills, or their mātauranga Maōri knowledge and skills, to act in the world. They are prepared to act responsibly and ethically on these issues with an awareness of the interconnectedness of things and events in both the natural and social world.

An overview of the multifaceted nature of this enduring competency

Facet 1: Acting with an awareness of interconnectedness

- Although the sciences are organised into sub-disciplines, phenomena in the natural and physical world are intricately interconnected.
- Mātauranga Māori reaffirms relationships between people and the natural world, and the practice of people is determined by this.
- In science, students often study parts but not necessarily the whole. Part/whole thinking can help students see how the parts are inseparable from the micro-, meso-, and macro-systems in which they are located.
- Connections always exist within and between parts of a whole, amongst individuals, across groups, over time, and across contexts. Acting on one part can often have unanticipated effects as change ripples across the whole.
- Many natural systems and problems are complex. Complexity concepts and dynamics have not been part of a traditional science curriculum but should be considered as an important new element, given the complex nature of many urgent issues that face us.[47]
- Complex systems[48] are characterised by uncertainty and emergence.

Facet 2: Ethical thinking and doing for responsible action

- Scientific research can cause harm and/or be misused when conducted or applied without careful consideration of its potential impacts.
- Doing responsible science necessitates an in-depth understanding of relationship and interconnectedness (see facet 1 above), as well as consideration of multiple perspectives, with particular attention to mātauranga Māori. (A focus on personal responsibility is implied here and makes a strong link to the first of the four enduring competencies—see facet 4, in Section 3 .)

47 This argument is elaborated in: Hipkins, R. (2021). *Teaching for complex systems thinking*. NZCER Press.
48 A very small sample of the diversity of natural systems might include: weather and climate systems; insect colonies (many species), gene/environment interactions (epigenetics), the nervous system, and the brain as a complex organ; food systems (and many other systems with integral social components).

- Acknowledgement of relationships between all living organisms, as reflected in mātauranga Māori, impacts the practices of being ethical and responsible.
- At the community level, ethical thinking and doing requires thoughtful analysis of power dynamics in science, as well as careful deliberation over the potential short-term and long-term impacts of scientific study, scientific findings, and/or scientific innovations (see also the enduring competency Drawing on different knowledge systems, facet 3—see Section 3).

Facet 3: Science and mātauranga Māori as tools for personal and collective decision making and action

- For all students, scientific knowledge can enhance personal as well as collective wellbeing—it can be a source of agency. Learning science through the lens of mātauranga Māori is an important source of wellbeing and agency for ākonga Māori.
- Science on its own is insufficient to understand many of the challenges and opportunities facing society today (see also first bullet point of facet 4 of the enduring competency Working with the literacy practices of science in Section 5). However, science can support more robust understandings of social, political, and environmental dilemmas, particularly when used alongside other disciplinary tools and cultural knowledge systems.
- Science can help illuminate dimensions of an issue or phenomenon that may be otherwise undetected within other disciplines, and vice versa. For example, science can help identify contaminants within a soil, and their health effects, where history can help us understand how and why the contaminants were introduced in the soil in the first place.[49]
- Learning about aspects of mātauranga Māori encourages all ākonga to reflect on rich contextual knowledge in their local context, and to see themselves as part of natural systems and not separate from them.

Facet 4: Science for innovation and problem solving

- Science has transformative potential.
- Thinking outside the box and taking risks are part of innovating in science inquiries.
- Engagement with mātauranga Māori, and therefore understanding the value and depth of knowledge about the natural world, provides opportunities to innovate and problem solve by considering other ways of thinking, knowing, and doing. Similarly, those engaged primarily with mātauranga Māori are able to innovate and problem-solve by engaging with science.
- Innovative thinking and problem solving support the development of important life and work skills like collaboration, motivation, resilience, and agility.
- Innovation and problem solving are enhanced through meaningful collaboration and community partnerships.

49 Morales Doyle, D. (2021). *Disciplining equity: Studying science teachers' work at content area boundaries.* Paper presented at the annual meeting of the National Academy of Education, USA, online.

Why this competency?

As we have highlighted, learning about how the natural world works and understanding how scientific knowledge is constructed and communicated are important goals for science education. However, over the past few decades, science educators and policymakers in Aotearoa New Zealand and around the world have increasingly called for a more action-oriented, issues-based approach to science curriculum development.[50] Students need not only to understand scientific knowledge, but also need to be empowered to skilfully and ethically use that knowledge to act upon personal, local, social, and political matters of concern.

This argument for a more action-oriented, issues-based approach has been advanced by several influential international agencies, and already has links to several areas of *NZC*:

- Empowering and Mobilising Youth and Accelerating Local Level Actions have been identified as two of five priority action areas in UNESCO's (2020) Education for Sustainable Development Roadmap,[51] a document that has informed the cross-curricular Education for Sustainability (EfS) component of NZC.[52]
- The OECD's PISA advisory panel made a similar set of recommendations for the 2024 framework.[53] The report noted that the outcomes seen as desirable by the international panel members "could be broadly described as a means to achieving 'social justice' whereby all individuals are able to become active citizens" (p. 23).

The call for a more civically oriented approach to science education is not new.[54] In fact, this call appears as patterns of resurgence throughout history, from Dewey's notions of democratic education and educational pragmatism, through the science–technology–society and science–technology–society–environment education of the 1970s and 1980s, to critical feminist science education,[55] socio-scientific issues education,[56] and science education for socio-political action.[57] A connecting idea amongst all of these approaches is that science education must play a key role in preparing students to be critically reflective and socially engaged.

In addition to understanding scientific concepts—which is certainly part of taking informed action—a future-oriented science education prepares students to develop a civically minded scientific practice: that is, to appreciate the impacts and culturally embedded nature of scientific research and innovation; recognise the relationship between scientific and technological development and the distribution of wealth and power; use scientific knowledge for personal and socio-political decision making and action; and consider ethical dimensions of science (Hodson, 2010; OECD, 2020).[58]

Furthermore, an action-oriented and issues-based approach to science education aligns with Education for Enterprise (E4E), a New Zealand cross-curricular approach and context that spans

50 For example, the *Inspired by Science* report to the Royal Society. https://www.nzcer.org.nz/research/publications/inspired-science
51 https://en.unesco.org/themes/education-sustainable-development/toolbox
52 https://nzcurriculum.tki.org.nz/Curriculum-resources/Education-for-sustainability/Why-EfS#collapsible9
53 https://www.oecd.org/pisa/publications/PISA-2024-Science-Strategic-Vision-Proposal.pdf
54 See Aikenhead, G. (2006). *Science education for everyday life: Evidence-based practice*. Teachers College Press.
55 See Barton, A. C. (1998). *Feminist science education*. Teachers College Press.
56 For example: Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socioscientific issues education. Science Education, *89*(3), 357–377.
57 Examples include: Hodson, D. (1999). Going beyond cultural pluralism: Science education for sociopolitical action. *Science Education*, 83(6), 775–796 and Tolbert, S., & Bazzul, J. (2017). Toward the sociopolitical in science education. *Cultural Studies of Science Education*, *12*(2), 321–330.
58 For example, Hodson, D. (2010). Science education as a call to action. *Canadian Journal of Science, Mathematics and Technology Education*, *10*(3), 197–206. OECD. (2020). *PISA 2024 Strategic direction and vision for science*. https://www.oecd.org/pisa/publications/PISA-2024-Science-Strategic-Vision-Proposal.pdf The OECD 2020 report identifies three components to using scientific knowledge for decision making: 1: Use scientific knowledge for decision making; 2: Take into account ethical considerations; 3: Create new value through problem solving and innovation.

all learning areas.[59] E4E supports students to access multiple pathways for learning, generate new knowledge, and "build learning capacity for an unknown future".

Using science for decision making and action necessitates ethical thinking and doing. Though historically, ethics have been taught separately from science, ethical thinking and doing must become an integral part of learning (and doing) science responsibly.[60] Acting ethically requires an in-depth understanding of the interconnectedness of the world. In te ao Māori, mātauranga Māori guides decision making by reaffirming relationships to therefore determine responsibility to the natural world. Many iwi or hapū personify the natural world, reflecting their relationship with it by using such statements as "Ko koe ko au, ko au ko koe: You are me, I am you" where the "you" can be their tribal maunga (mountain), awa (river), ngahere (forest), repo (wetland), or any part of their natural world. This implies a shared whakapapa which itself requires one to consider any actions taken within the natural world to be an action upon oneself; that is, the impact on one will impact the other in this relationship.

Mātauranga Māori also informs practice by determining the need to look at what has gone before to inform what to do next by sayings such as "Hoki whakamuri kia anga whakamua: Look to what has been done before to inform the way forward." This further elevates mātauranga Māori as a body of knowledge that informs appropriate tikanga or practice.

Design challenges for working with this competency

The careful selection of appropriate and authentic contexts for socio-scientific learning is a design challenge for this competency. In his 2010 paper (see footnote 58), Derek Hodson identified seven key areas of concern that could inform an issues-based action-oriented science curriculum. These included human health; land, water, and mineral resources; food and agriculture; industry (e.g., biotechnology, manufacturing); energy resources and consumption; information transfer and transportation; ethics and social responsibility. The recent PISA 2024 Strategic Vision and Direction for Science (footnote 58) similarly recommended that students learn science within a larger context of socio-environmental systems and sustainability. The report recommended nine possible areas of focus that could be included:

- economics, markets, and institutions
- population, migration, and wellbeing
- ecosystems, natural resources, conservation
- climate change, mitigation, and adaptation
- sustainable food systems, nutrition, food security
- health, environmental health, pollution, and spread of disease
- land use and change; Water, governance, and water security
- energy supply, development of renewables, and
- retirement of carbon-based energy sources.

Personal, local, and global issues served as assessment contexts for measuring students' science competencies in the 2018 PISA science assessment. These contexts were

> ... chosen in light of their relevance to students' lives and because they are the areas in which scientific literacy has a particular value in enhancing and sustaining quality of life and in the development of public policy. (OECD, 2019, p. 103)[61]

59 https://nzcurriculum.tki.org.nz/Curriculum-resources/Education-for-Enterprise#collapsible4
60 Barad, K. (2001). Reconceiving scientific literacy as agential literacy. *Doing Science + Culture*, 221–258. Routledge.
61 OECD. (2019). PISA 2018 assessment and analytical framework. https://www.oecd.org/education/pisa-2018-assessment-and-analytical-framework-b25efab8-en.htm

These include health and disease, natural resources, environmental quality, hazards, and frontiers of science and technology (see Table 1).

TABLE 1: **Contexts for the 2018 PISA scientific literacy assessment**[62]

	Personal	Local/National	Global
Health and disease	Maintenance of health, accidents, nutrition	Control of disease, food choices, community health	Epidemics, spread of infectious diseases
Natural resources	Personal consumption of materials and energy	Maintenance of human populations, quality of life, security, production and distribution of food, energy supply	Renewable and non-renewable natural systems, population growth, sustainable use of species
Environmental quality	Environmentally friendly actions, use and disposal of materials and devices	Population distribution, disposal of waste, environmental impact	Biodiversity, ecological sustainability, control of pollution, production and loss of soil/biomass
Hazards	Risk assessments of lifestyle choices	Rapid changes (e.g., earthquakes, severe weather), slow and progressive changes (e.g., coastal erosion, sedimentation), risk assessment	Climate change, impact of modern communication
Frontiers of science and technology	Scientific aspects of hobbies, personal technology, music and sporting activities	New materials, devices and processes, genetic modifications, health technology, transport	Extinction of species, exploration of space, origin and structure of the Universe

When designed with attention to relevant socio-scientific topics such as those described above, an issues-based and action-oriented science curriculum creates meaningful opportunities for mana ōrite, as referenced in the first enduring competency. For example, when investigating a water pollution issue in their local community, students might engage in the scientific practices of macroinvertebrate sampling and pH testing, while learning about the Māori concept of wairua, that water has a life force which must be respected.[63] As this example also demonstrates, an issues-based approach to the science curriculum facilitates cohesive opportunities for local curriculum design, in which learning is personalised, inclusive, and responsive to whānau and community contexts and interests. Opportunities for local curriculum design are essential, but, as the 2018 PISA framework highlights, connections to relevant global issues should also be emphasised—addressing the need for what has more recently been referred to as a "glocal" approach (i.e., thinking globally and acting locally).

One of the more obvious challenges for the Science learning area design teams, when developing curriculum and assessments, is the multidisciplinary nature of these problems and contexts, which warrants a more integrated approach to teaching and learning across the curriculum. Curriculum integration is an area in which teachers have identified that they need substantial support, from professional learning, to developing and implementing a coherent school-wide vision for integrating the learning areas, and physical/material infrastructures. An integrated approach also requires that teachers have an in-depth understanding of the disciplines, so they do not get misrepresented, or lost, in integration. However, balancing student agency and disciplinary knowledge can be a daunting task,[64] as can balancing rigour with responsiveness to student ideas.[65]

62 OECD. (2019). PISA Science Framework, p, 103: https://www.oecd-ilibrary.org/education/pisa-2018-assessment-and-analytical-framework_f30da688-en. Note that we have not yet found an equivalent table for the 2024 PISA framework.
63 Waiti, P., & Hipkins, R. (2002). *Cultural issues that challenge traditional science teaching*. Paper presented at the third annual New Zealand Science Education symposium, Massey University, Wellington. https://www.nzcer.org.nz/system/files/12618.pdf
64 See McDowall, S., & Hipkins, R. (2019). *Curriculum integration: What is happening in New Zealand schools?* New Zealand Council for Educational Research. https://www.nzcer.org.nz/research/publications/curriculum-integration-what-happening-new-zealand-schools
65 Thompson, J., Hagenah, S. et al. (2016). Rigor and responsiveness in classroom activity. *Teachers College Record*, *118*(5), 1–58.

Selecting for global contexts that allow for authentic local curricular opportunities can also present challenges, and vice versa.[66] For example, global issues such as acid rain may not be as relevant to Aotearoa New Zealand but increasing acidification of coastal waters is a critical concern for our coastal ecosystems and fisheries. Teachers and curriculum designers will want to think carefully about how to allow for the inclusion of "glocal" socio-scientific contexts and problems to which ākonga and educators can meaningfully contribute.

Designing for multigenerational learning is also a strength of an issues-based and action-oriented local curriculum, particularly "in a world where learning is truly lifelong" and "the 'beneficiaries' of the system include the learners of all ages, not only children but adults and multigenerational groups such as families as well" (Falk et al., 2015, p. 147).[67] For example, ākonga can learn about the natural world, and how to act with an awareness of its interconnectedness, through the embodied practices (e.g., walking, reading, and storying the land) of whānau, kaumatua and other elders, iwi, community members, in ways that can also enhance Te Tiriti relationships in local communities.[68]

66 See Hancock, T., Friedrichsen, P., Kinslow, A., & Sadler, T. (2019). Selecting socio-scientific issues for teaching. *Science & Education*, *28*(6), 639–667.

67 Falk, J., Dierking, L. et al. (2015). Analyzing science education in the United Kingdom: Taking a system-wide approach. *Science Education*, *99*, 145–173. https://doi.org/10.1002/sce.21140

68 A useful international reference here is: Marin, A., & Bang, M. (2018). "Look it, this is how you know:" Family forest walks as a context for knowledge-building about the natural world. Cognition and Instruction, 36(2), 89–118.

7. Why this idea, at this moment in time?

Mid-winter 2022 was a challenging time for us to be working on this paper. With a global pandemic hopefully on the wane, people were generally tired and "over" uncertainty and constant change. Yet futures thinkers have been warning for years that the intensifying global volatile, uncertain, complex, and ambiguous[69] conditions demand urgent transformation of all our social systems, including education. These conditions are not going to go away, and our sense is that we are at a sort of tipping point. With the consequences of climate change becoming ever more severe, transformation of the way we live on the planet is now urgent and overdue.

Science education has an important role to play in supporting our young people to meet the complex challenges of the Anthropocene.[70] Knowing a lot of science ideas is necessary but insufficient to meet the challenge of change. Students need a curriculum that can prepare them to work collaboratively, competently, and confidently to address the wicked "glocal" problems of our time. The rangatahi involved in drafting the Youth Vision statement for the curriculum refresh have asked for a curriculum that will support them to think and act responsibly together, learn and grow through engaging with multiple perspectives, foster wellbeing, honour Te Tiriti, contribute positively to their communities, and be kaitiaki of their environment.[71] These are all reasons for our focus on the idea of enduring competencies that students will take away from their learning at school.

We are conscious that the term "competencies" could be seen as confusing, given curriculum developments in the recent past. For example, some teachers might ask why we didn't continue with the terminology of "science capabilities". That initiative was designed to model ways to weave the *NZC* NOS strand together with the contextual strands and did not explicitly extend to the senior secondary curriculum. While it was being developed, science educators, in the USA, in particular, were working on the idea of "science practices" with a similar curriculum goal in mind. Our preference now is to adopt the international terminology, which is supported by an ever-growing body of science education research, and clearly puts the focus on what scientists actually do (and hence what students might learn to do too).[72]

69 (VUCA), i.e., Volatile, Uncertain, Complex and Ambiguous. An OECD working paper that explores the critical importance of meta-learning in VUCA conditions can be found here: https://www.oecd.org/education/2030/Preparing-humanity-for-change-and-artificial-intelligence.pdf

70 Gilbert, J. (2016). Transforming science education for the Anthropocene—Is it possible? Research in Science Education, 46(2), 187–201.

71 Ministerial Youth Advisory Group, draft Vision for Young People for the Curriculum Refresh.

72 With hindsight, an earlier attempt to clarify the meaning of the NOS strand by developing a set of "NOS propositions" risked being about what scientists say they do, not what they actually do.

Final thoughts

Like many of you who may be reading this, we are simultaneously excited and overcome by the design challenge ahead. But, like you, we know we owe it to the rangatahi of Aotearoa New Zealand to both set out and achieve a bold vision for science education moving forward. What we have tried to do is lay a foundation for science education that will support learning contexts in which students thrive and grow, rooted strongly in community, and in which they can draw from the knowledge they receive while using their hearts and minds to make informed decisions, toward collective wellbeing for all.

Tūngia te ururua kia tupu whakaritorito te tupu o te harakeke.
Clear the overgrowing bush so that the new flax shoots may spring up.

The authors

Dr. Rosemary Hipkins is a Chief Researcher / Kei Hautū Rangahau at NZCER. In her first career she was a teacher of science and biology before moving into teacher education and then research. Rose has a strong interest in the intersection of assessment and curriculum. She has been involved in studies of key competencies, NCEA, and most recently, complex systems thinking. With Ally Bull, she designed the Science Capabilities for Citizenship.

Associate Professor Sara Tolbert works in the Faculty of Education at the University of Canterbury. Before coming to Aotearoa, she worked at the University of Arizona. In her first career she was a science and ESOL teacher and environmental educator. Sara is interested possibilities for justice through science and education in the Anthropocene(s). Among other projects she leads the UC Learning for Earth Futures research cluster (with UC Professor Ben Kennedy).

Professor Bronwen Cowie is the Associate Dean Research, Te Kura Toi Tangata School of Education, University of Waikato. Prior to joining the university, she was a secondary school teacher of maths and physics. Bronwen's research is focused on classroom interactions, with an emphasis on Assessment for Learning in science and technology classrooms, and culturally responsive pedagogy in science education.

Pauline Waiti is a Director at Ahu Whakamua Ltd. As an experienced science teacher, Pauline was involved in the development of the Pūtaiao curriculum to sit alongside NZC. She has previously worked as Māori Development Manager at Learning Media and as Te Wāhanga Māori Manager at NZCER. Pauline provides a Māori educational perspective and deep understanding of Māori-medium education in New Zealand.

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