NOT GOVERNMENT POLICY

An initial exploration of curriculum levels in Science and Mathematics and Statistics

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1. Key insights

In March 2019 the Ministry of Education commissioned NZCER to conduct an exploratory study of curriculum levelling in the Science and Mathematics and Statistics learning areas of *The New Zealand Curriculum* (Ministry of Education, 2007) (*NZC*). The following is a summary of the key insights to emerge from the programme of work. The programme was comprised of four interrelated components that involved:

- identifying what we know about the difficulty of the curriculum, using existing evidence from the National Monitoring Study of student Achievement (NMSSA)
- considering insights from recent comparisons of *NZC* with curricula from other jurisdictions
- consulting curriculum expert groups for their advice about the appropriateness of curriculum expectations
- eliciting teachers' experiences and views about curriculum levelling at a series of focus groups.

This section begins by describing insights from the study that were common to both learning areas, followed by those that relate only to Science, then those that relate only to Mathematics and Statistics.

Insights relating to both Science and Mathematics and Statistics

Studies by the National Monitoring Study of Student Achievement (NMSSA) in both Science and Mathematics and Statistics have shown "persistently low levels of achievement at year 8 relative to year 4" (Ministry of Education Statement of Work). These results raise questions about the comparative difficulty of curriculum expectations at these two levels. Is level 2 (Year 4) pitched too low? Is level 4 (Year 8) pitched too high? Does some combination of both influences apply? What other factors might contribute to this difference?

Patterns of achievement across a learning area, for instance across different strands, can inform judgements about the appropriateness of curriculum levels. However, it is important not to assume that comparatively weaker performance in some areas provides unequivocal evidence of lower curriculum expectations. It might, for example, signal areas where teacher pedagogies need strengthening, or where the curriculum as written could benefit from clarification and exemplification.

The findings outlined in this report suggest that lack of clarity may contribute to achievement patterns, but it is not possible to quantify the size of this impact relative to the level at which expectations are pitched. Teachers involved in the primary level focus groups indicated that a lack of confidence amongst their peers in teaching both Science and Mathematics and Statistics could also be a contributing factor.

With these caveats in mind, we did find evidence that curriculum levels need some adjustment, particularly in Mathematics and Statistics. Judging the appropriateness of the curriculum expectations for Science was problematic because the learning area generally lacks the clarity needed to be able to tell.

Insight 1: The achievement objectives for Science and, to a lesser extent for Mathematics and Statistics, lack clarity as guides to curriculum levels

The curriculum experts and focus group teachers were in broad agreement that the *NZC* achievement objectives (AOs) in Science, and to a somewhat lesser extent in Mathematics and Statistics, lack the necessary clarity to guide teachers' decisions about the curriculum levels at which their students are working. It is necessary to read the AOs against relevant curriculum support material to get a clear picture of what is expected at each curriculum level. The Australian Curriculum, Assessment and Reporting Authority (ACARA, 2019) also found this to be the case when they compared *NZC* to the Australian curriculum.

Lack of clarity about levels is very problematic in Science

Both the science curriculum experts and the teachers in the science focus groups said they could not readily make judgements about curriculum levels based on the science AOs.

- The teachers said they "just made up" criteria to allocate levels—if they used levels at all. They said that the allocation of science topics to different levels seems to represent an arbitrary chunking of content into AOs. The secondary teacher group discussed use of the SOLO taxonomy for allocating grades, but it was not clear how the examples they showed related to actual curriculum levels. The primary group said they allowed students to pursue questions that opened up in their inquiries, regardless of which level of the curriculum a specific emergent topic might be located at.
- Both the science experts and the teachers in the science focus groups said that the Nature of Science (NoS) strand was the more useful guide when making decisions about levels, compared to the four contextual strands. They thought this even though the AOs in this NoS strand are chunked into two-level bands (with a few small exceptions).

The thinking of the science experts, and the teachers in the primary science focus group, has been strongly influenced by the science capabilities, developed post-*NZC*.

- The experts said the capabilities provide tangible evidence about what students can do with their learning. Once teachers are aware of these possibilities, they are better prepared to notice student demonstrations of these capabilities.
- The primary teachers said the capabilities fit more readily with the inquiry approach they typically take in science.
- Some secondary teachers said they were interested in the science capabilities but found them "too confusing" in their relationship to *NZC* and so have reverted to using the NoS strand to write their own levelling criteria.

Some achievement objectives in Mathematics and Statistics also lack clarity

While clarity appeared to be a comparatively greater challenge in science, it was also raised as an issue by the mathematics and statistics curriculum experts. Three features that could obscure meaning were as follows.

- The variable grain size of AOs: The experts said some AOs are very large and need to be carefully broken down into their parts. Other AOs address just one important idea. It can be difficult for teachers to judge the relative emphasis to give to each one.
- The use of technical and dense language: This challenge is seen to be more acute from Level 4 upwards. The focus group teachers said that lack of understanding of the intent of the AOs above this level can generate real anxiety for primary teachers in mathematics (and to some extent in science).
- The positioning of the pedagogical statement: All the Mathematics and Statistics AOs at each level are prefaced by the umbrella statement "In a range of meaningful contexts, students will be engaged in thinking mathematically and statistically. They will solve problems and model situations that require them to …". Because this statement is separated from the individual AOs, it can be overlooked. This hinders clarity about pedagogical expectations. ACARA identified this as a problem when making determinations about the rigour of expectations in *NZC*.

Insight 2: Poor visibility of the development of big ideas

In both learning areas, the curriculum expert groups described a lack of visibility of the development of big ideas.

- The experts contrasted the cryptic nature of the AOs in Science with the clear narrative development of a small set of big ideas developed by a European expert group (see Appendix 1). In this alternative model, each big idea is sequentially expanded from simple foundations to the fully-fledged set of interrelated concepts.
- As well as recommending greater specificity in the Mathematics and Statistics learning area to build clarity and support teachers' understanding, the curriculum expert group called for clearly expressed progressions of big ideas, such as fractions.

Insight 3: There is an association between high expectations and areas of comparative achievement strength

In both learning areas, some association between high expectations and areas of comparative achievement strength was evident.

The Nature of Science strand of the Science learning area conveys high expectations relative to other jurisdictions. This is an area of strength for New Zealand students in the Programme for International Student Assessment (PISA) testing. (The Trends in International Maths and Science Study [TIMSS] does not directly assess NoS understandings.) This is the aspect of science in *NZC* about which focus group participants and experts spoke most positively. If they do make decisions about the curriculum level at which students are working, the NoS strand is the one that teachers are more likely to use.

Statistics is also an area of mathematics in which our students perform strongly in international tests. Compared to curricula from other jurisdictions, it also stands out as the strand of the mathematics curriculum that conveys high expectations for student achievement. Compared to other curricula it is also more obviously differentiated from other aspects of mathematics. The experts and the primary and secondary teachers were all in agreement that statistics is a real strength in *NZC*. The primary teachers said that the use of familiar contexts—in the statistics strand in particular—fosters mathematical thinking and makes it possible to meet these high expectations in statistics.

These patterns suggest that achievement can be lifted when challenging expectations are clearly conveyed. Comments made by the focus group teachers add the proviso that high expectations need to be understood as such and be well supported with resources that model indicative achievement at each level.

Science insights

Insight 4: The Science learning area lacks clarity and detailed learning progressions

The strong message was that the Science learning area lacked clarity, which also contributed to a lack of visibility of detailed learning progressions. Given the lack of clarity about curriculum expectations for Science, it was more difficult to identify specific issues and recommendations at the AO level than was the case with Mathematics and Statistics. Instead, the insights here tended to focus on the structure of the learning area and how this is linked with challenges in enacting it.

Insight 5: The ways in which science learning is structured contributes to the sense that AOs at different levels hinder rather than support teacher decision-making

Primary teachers typically use “inquiry” as the vehicle that brings science into the learning programme. When this is genuinely student-driven, topics at different curriculum levels can arise. There were some indications in both the expert and the focus groups that primary teachers can feel “guilty” when students’ interests lead them to higher levels of *NZC* than expected for their age. There was a sense that the curriculum “holds them back”. Secondary teachers also experience frustrations with the AOs when designing programmes of work around a specific topic, such as climate change. The experienced teachers in the focus group tend to ignore the contextual strands and levels at the planning stage, matching AOs retrospectively for record-keeping purposes rather than using them to guide teaching and learning.

Insight 6: More up-to-date resources are needed to support teachers’ levelling decisions in Science

Secondary science teachers use and value the ARBs but are concerned that these are no longer being regularly updated. Similarly, the teachers in the primary science focus group use and value the Building Science Concepts (BSC) booklets and would like to see these updated and made freely available online.

Mathematics and Statistics insights

Insight 7: Adjustment is needed to the curriculum expectations around Level 4

Although the overall message was that Mathematics and Statistics learning area is broadly appropriate, there are indications that some levelling adjustments would be helpful. These adjustments are in the nature of “fine-tuning” rather than wholesale change. On-balance indications are that level 4 could be a good place to begin any such discussions, with implications for adjustments to both higher and lower curriculum levels.

Some of the Mathematics and Statistics curriculum experts would like to see “unrealistic” expectations at level 4 adjusted by moving more complex number and algebra AOs to level 5. An alternative suggestion interprets the problem at level 4 as overcrowding. In that case, the solution could be to introduce some concepts earlier. Strengthening teaching at earlier levels was also recommended.

Insight 8: Some concepts in mathematics could appear earlier in the curriculum

To adjust the current level 4 expectations, one option is to introduce some concepts at earlier levels. The ACARA study found that level 2 of NZC specifies fewer mathematical ideas compared to the Australian curriculum but has a greater emphasis on number. This finding would appear to support the suggestion that additional concepts could make an earlier appearance, even if they are not assessed until higher curriculum levels. International benchmarking carried out for the TIMSS programme has also identified some areas of lower expectations at levels 2-3, compared to other jurisdictions. TIMSS results show comparatively weaker performance of Year 5 NZ students in algebra/pattern recognition, geometry, and measurement. Again, earlier introduction of foundational concepts in these areas could be indicated. Specific suggestions from the curriculum expert group were that integers, variables in number contexts, and spatial patterns could be introduced at level 2 but not assessed until level 4.

Insight 9: Primary teachers notice a "big jump" in expectations from level 3 to level 4

The focus group teachers discussed what they saw as a big jump in expectations from level 3 to level 4. Teachers in this group said that some of their colleagues are too far out of their own comfort zones to be able to confidently teach mathematics at this level. TIMSS has reported that many Year 9 students are still being taught at level 4 when they should be working at level 5. While we cannot make direct links between these two different observations, it could be that some catching up is perceived to be necessary as students move into secondary school. This suggests that teaching at senior primary/intermediate levels could also benefit from being strengthened.

Insight 10: There are multiple resources to support teachers' levelling decisions in Mathematics and Statistics

Compared to Science, more resources are available to support decision-making about curriculum levels in Mathematics and Statistics.

- Overall, the maths expert group believed that the performance expectations associated with the Progress and Consistency Tool (PaCT)[1] at curriculum levels 1 to 5 reflected the intent of *NZC*, providing teachers with a practical guide to curriculum expectations at the different levels.
- The primary teachers in the focus group identified a wide range of freely available resources that they access when making judgements about student achievement. They

[1]https://curriculumprogresstools.education.govt.nz/lpf-tool/

were, however, reluctant to use PaCT because it required making a judgement about every strand at the same time.

- The secondary teachers said they still access the 1992 curriculum document for making judgements and several use NZCER's Progressive Achievement Tests (PATs). None mentioned PaCT tools or Assessment Resource Banks (ARBs).
- Both sectors use NZMaths, but the secondary teachers said they did not find it easy to navigate. They said the same about NZQA's online resources.

2. The context for this work

In March 2019 the Ministry of Education commissioned NZCER to conduct an exploratory study of curriculum levelling in the Science and Mathematics and Statistics learning areas of *NZC*. The study was prompted in part by a desire to probe possible reasons for patterns of achievement reported by NMSSA. Results from NMMSA have shown "persistently low levels of achievement at year 8 relative to year 4" (MOE Statement of Work). These results raise questions about the comparative difficulty of curriculum expectations at these two levels.

This section of the report outlines the study questions and describes how we addressed them.

The study questions

The questions driving the study fall into two clusters, each with a different analytical basis.

Descriptive questions

How do the current curriculum statements for Science and for Mathematics and Statistics:

- signal the difference between levels in each learning area
- indicate the comparative difficulty of each level?

Questions that require on-balance judgements (expert and/or research-based evidence)

How well do the current curriculum levels:

- detail learning expectations that are appropriate at each level
- describe what is both desirable and feasible learning for New Zealand students, schools, and society more broadly?

How the questions were investigated

We briefly describe how we investigated the study questions by drawing on the following interrelated components: existing evidence, international comparisons with *NZC*, curriculum expert group workshops, and teacher focus groups.

Existing evidence

For each of the learning areas, we summarised some of the key evidence that has prompted this study. For Science, this included students' achievement in NMSSA and PISA 2015. For Mathematics and Statistics, data from NMSSA, PaCT, e-asTTle, and PAT: Mathematics contributed to the evidence base.

International comparisons with *NZC*

We looked at published commentary about curriculum expectations in *NZC* as compared with those of other jurisdictions. This aspect of the study drew heavily on ACARA's recent comparative study of the New Zealand, Australia, and British Columbia curriculum documents (ACARA, 2018, 2019). It is important to note that when making judgements about *NZC*, ACARA drew on multiple sources in addition to the actual curriculum documents. These included the following sources.

- The Learning Progression Framework for mathematics and statistics that underpins the PaCT and the National Standards (the latter are no longer in use).
- The science matrices developed to support the 1990s science curriculum,[2] the science capabilities developed after NZC was published,[3] and the *Connected* journals that exemplify intended science learning at different curriculum levels.[4]

We also drew on published analyses of international tests in which New Zealand students have recently participated (specifically PISA and TIMSS). The question at issue was what these studies might tell us about curriculum *expectations*. Patterns of achievement can inform such judgements but it is important not to assume that comparatively weaker performance in some areas is, ipso facto, evidence of lower curriculum expectations. It might, for example, signal areas where teacher pedagogies need strengthening, or where the curriculum as already written could benefit from clarification and exemplification. We invited Robyn Caygill from the Ministry of Education to confirm our reading of the literature and provide a critique of our conclusions.

Curriculum expert group workshops

Two curriculum expert group workshops were held in the last week of April 2019. The first was with a group of science curriculum experts. The second was with experts in the Mathematics and Statistics learning area. Some members of the NZCER team were able to attend all or part of both meetings, so that similarities and differences could be noted.

The main purposes for these meetings were for the curriculum experts to:

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2 http://www.tki.org.nz/r/assessment/exemplars/sci/matrices/index_e.html
3 https://scienceonline.tki.org.nz/Science-capabilities-for-citizenship/Introducing-five-science-capabilities
4 https://literacyonline.tki.org.nz/Literacy-Online/Planning-for-my-students-needs/Instructional-Series/Connected

- provide a general comment on the appropriateness of curriculum expectations at levels 2, 3, 4, and 6 of *NZC* and the extent to which these expectations are clearly articulated
- identify aspects of the curriculum statements that they believe are not well levelled or generally problematic—including identifying outcomes that might be relatively more demanding for priority learner groups
- make judgments about the expectations of *NZC* at levels 2, 3, 4, and 6 against curricula from at least one other jurisdiction.

Teacher focus groups

Four teacher focus groups (one primary and one secondary for each of the two learning areas) were held in Wellington in the last week of May and the first week of June 2019. A total of 17 teachers from 11 schools attended (one teacher attended two focus groups). Those who attended had previously indicated their willingness to complete a survey, but now accepted the invitation to discuss curriculum levels face-to-face.[5] All participants were engaged and interested in the question of curriculum levels, with one describing the lively conversation as: "the best PD I have had this year".

After brief introductions, participants discussed their responses to four questions.

- How do you use/what is your main purpose for using the curriculum levels for Science/Mathematics and Statistics?
- What resources do you draw on when you're making judgements of students' achievement?
- How clearly do the AOs convey expectations at a level? (Photocopied sets of the relevant AOs were provided for this part of the conversation.)
- What is your top recommendation about curriculum levels for the Ministry of Education?

The remainder of the report

Chapter 3 of the report outlines findings for the Science learning area, and Chapter 4 outlines findings for the Mathematics and Statistics learning area. Each of these chapters begins by summarising what we know about achievement in the respective learning area. It then considers what can be learned about the difficulty level and appropriateness of curriculum expectations from each of the remaining sources of evidence: international comparisons; curriculum expert

5 Given the clear insights and level of consensus that emerged from the expert group workshops, further work to gather teacher insights via a survey was put on hold part-way through the project at the Ministry's request. The other activities were carried out as planned.

groups; and teacher focus groups. In Chapter 5, we present some overall conclusions and comment on additional considerations.

3. Science

Existing evidence of student achievement in Science

The most recent NMSSA study in Science (EARU & NZCER, 2018) showed that the majority (94 percent) of Year 4 students were achieving at or above curriculum expectations. However, only a minority (20 percent) of Year 8 students were achieving at or above curriculum expectations.

The 15-year-olds in New Zealand who participated in PISA 2015 showed strong achievement in science. However, the difficulty of the assessment items was not necessarily representative of the expectations in *NZC* for students of this age (this will be discussed more in the section, *Are the learning expectations in Science appropriate?*).

International comparisons with *NZC*: Science

Desirable and feasible learning in Science

We drew heavily on ACARA's recent comparative study of the New Zealand, Australia, and British Columbia curriculum documents (ACARA, 2018, 2019) to examine the extent to which NZC describes learning expectations that are desirable and feasible. The evidence we gathered suggests that the current science curriculum does *broadly* specify "desirable and feasible" learning—assuming the curriculum specifications of other nations provide an appropriate yardstick for this exercise. We base this on the following.

- Around three-quarters of the science topics assessed in the Year 9 TIMSS international test are also specified for *NZC* level 5 (Caygill et. al., 2016).
- Overall, both the New Zealand and Australian science curriculum objectives provide a comprehensive breadth of coverage of science concepts (ACARA, 2019).
- Aspects of all the "big ideas" developed by a consortium of European science education experts (Harlen, 2015) are directly stated or are implied in *NZC*.

There are several caveats to the positive finding of appropriate breadth. ACARA posed a key challenge as follows:

> … curriculum depth should be prioritised over breadth (Masters, 2015). For some time, there has been concern that providing students with some knowledge about a range of topics can lead to a mile-wide, inch-deep curriculum, and that while the mastery of factual and

> procedural knowledge is deemed essential in all school subjects, this knowledge should be organised around core concepts or 'big ideas' of the discipline. (ACARA, 2018, pp. 39–40)

ACARA's comparison between the Australian and British Columbia curricula suggests that "the theoretical framework that underpins British Columbia's new curriculum arguably privileges depth over breadth" (ibid, p. 40). Since the New Zealand and Australian science curricula are judged to be broadly similar in breadth and depth, we can assume that this judgement would also hold if *NZC* science was directly compared with British Columbia science—i.e., there are more appropriate signals of depth in the British Columbia science curriculum compared to *NZC* science.

The ACARA analysis identified several features of the British Columbia curriculum design as encouraging depth. These include sets of big ideas and the specification of curricular competencies for each learning area (in contrast to the generic key competencies of *NZC* and capabilities of the Australian curriculum).

A direct comparison of *NZC* with the set of big ideas developed by the European consortium noted earlier, further suggests that the concepts covered in *NZC* are not organised in such a way that big ideas can be readily discerned or given greater attention than the mass of supporting detail. ACARA similarly noted that the science achievement objectives in *NZC*:

> … give only broad directions regarding the knowledge and skills students are expected to learn. On their own they provide insufficient information for giving an accurate estimate of the expected level of depth. (ACARA, 2019, p.102)

One further notable difference between the British Columbia science curriculum and those of Australia and New Zealand is that British Columbia "emphasises First Peoples knowledge and perspectives of science and the importance of *place* in human perception and experience of the world" (ACARA, 2018, p. 80).

Are the learning expectations in Science appropriate?

Evidence suggests the specification of difficulty levels in *NZC* is broadly similar to those of other comparable curricula, *at least as far as we can tell*. ACARA noted that the broad nature of the *NZC* achievement objectives makes it impossible to judge expected difficulty levels without also examining curriculum support materials that exemplify the learning anticipated.

The science expert group added another important caveat: the same concept can be more, or less, accessible to students depending on the *context* in which it is introduced. Since *NZC* does not specific contexts for learning, further analysis again rests on support materials that exemplify the intended learning.

Given these caveats, ACARA's analysis of rigour found the following points.

- Level 1–2 *NZC* (Australian curriculum Year 2): both curricula specify a "moderate" level of rigour. In the Australian curriculum, "the content descriptions and elaborations do not reveal a level of abstract thinking or critical analysis and evaluation that would justify the classification challenging" (ACARA, 2019, p. 103.) It should be noted that the judgement of *NZC* was based on science matrices from 2010. In our view, the more recently developed science capabilities would have provided a better comparison and could well have shifted the expectation to "challenging" (see discussion about the Nature of Science strand below).

- Level 3–4 *NZC* (Australian curriculum Year 6): the rigour of science objectives is judged to be "moderate" at level 3 (as is the Australian curriculum) and "challenging" at level 4. In the Australian curriculum, "relatively few examples provide evidence for engaging students in abstract thinking and reasoning, or a level of individual planning, critical analysis and evaluation of investigations that would justify a higher classification of rigour at this year level" (ibid, p.107). It follows that the expectation of *greater independence* in investigations at *NZC* level 4 is one characteristic that was used to identify *NZC* as challenging at this level. The other difference identified was that at *NZC* level 4 students are expected to draw on some science knowledge as they shape explanations, whereas at level 3 they are mainly still drawing on their own understandings.
- Level 5–6 *NZC* (Australian curriculum Year 10): the rigour of science objectives is judged to be "moderate" at level 5 (as is the Australian curriculum) and "challenging" at level 6. The judgement of "challenging" at level 6 is justified by the expectation of "quantitative analysis and mathematical application of scientific concepts" (ibid, p. 111). It seems that the expectation of quantitative analysis for some of the NCEA Level 1 achievement standards is what made the difference at level 6.

One aspect of PISA's 2015 assessment programme provides an insight into the relative difficulty of the achievement objectives in the Nature of Science strand. A subset of science questions probed students' epistemic beliefs in science. Table 1 shows an estimation of closest matches between the statements in the PISA instrument and the achievement objectives in the Nature of Science (NOS) strand of *NZC*.

New Zealand made a comparatively strong showing on this international index (Kirkham, with May, 2016). Note that four of the six statements align with *NZC* levels 3–4 rather than levels 5–6 that might be expected given that PISA is administered at age 15.

Table 1 **A comparison of AOs in *NZC* with statements in PISA**

***NZC* "Understanding about science" achievement objectives**	**PISA Likert-scaled survey items**
Appreciate that science is a way of explaining the world and that science knowledge changes over time (level 3–4)	Ideas in science sometimes change The ideas in science books sometimes change
Understand that scientists' investigations are informed by current science theories and aim to collect evidence that will be interpreted through the process of logical argument (level 5–6)	Sometimes scientists change their minds about what is true in science
***NZC* "Investigating in science" achievement objectives**	
Ask questions, find evidence, explore simple models, and carry out appropriate investigations to develop simple explanations (level 3–4)	A good way to know if something is true is to do an experiment It is good to try experiments more than once to be sure of your findings
Begin to evaluate the suitability of the investigative methods chosen (level 5–6)	Good answers are based on evidence from many different experiments

The mismatch begs the question of whether we expect too much of our students, or whether PISA sets the international benchmark for NoS understandings too low. The science expert group (see Section 3) was of the view that Year 3–4 children can cope well with the specified NoS achievement objectives—as translated into the science capabilities—provided that their learning is supported with appropriate experiences in well-chosen contexts. An informal analysis of TKI resources intended to support the development of science capabilities reveals many potential contexts that make these epistemic ideas accessible to students at levels 3–4. The science teachers also expressed a preference for using the NoS strand to determine curriculum levels, which again suggests they are not troubled by expectations being too high.

Analysis of achievement patterns in PISA 2015 science suggests that "design and evaluate scientific enquiry" is another area of relative strength for New Zealand students (May, with Flockton & Kirkham, 2016). This is also congruent with comparatively high expectations related to the Nature of Science strand and the science capabilities.

The Science curriculum expert group

The tenor of the Science curriculum expert group's discussion was markedly different to that of the mathematics group. Rather than engaging with the current curriculum at the level of fine detail anticipated, the group expressed a desire for substantive curriculum change.

Appropriateness of the curriculum expectations for Science

The expert group was of the view that the achievement objectives for the four science contextual strands (Living World, Material World, Physical World, Planet Earth and Beyond) are not clearly and consistently articulated *at any level* of *NZC*.

According to the expert group, as currently written, the AOs do not adequately differentiate between the eight curriculum levels. The following Physical World AOs were selected by one participant to highlight the nature of the problems canvassed. Notice that these are matched AOs from the highest and lowest of the eight levels, and hence, in theory, represent the developmental extremes.

- Level 1–2: *Explore everyday examples of physical phenomena such as movement, forces, electricity and magnetism, light, sound, waves, and heat.*
- Level 8: *Investigate physical phenomena in the areas of mechanics, electricity, electromagnetism, light and waves, and atomic and nuclear physics, and produce qualitative and quantitative explanations for a variety of complex situations.*

The qualifications in the second half of the level 8 AO do suggest that much more depth is expected. The point being made, however, was that the phenomena per se are not conceptually differentiated in the wording of the AOs. It is not apparent how exploration of waves (say) at level 1 or at level 8 should be differentiated by either depth or breadth. As they stand, these are essentially lists of potential topics.

The curriculum expert group's view was that several factors contribute to this lack of clarity.

- Expectations of progress are not conceptually differentiated in the wording of the achievement objectives at each level. They are mostly written as inquiry activities (e.g., "explore and describe natural features and resources"). The lack of specificity about either ideas or depth renders them cryptic on both counts.
- Most substrands name a broad overarching phenomenon intended to focus conceptual development (examples include ecology, Earth systems, the structure of matter). Titles for the substrands in the Physical World strand are not consistent with this pattern. They either canvass the whole discipline (physical concepts) or describe a type of learning activity (using physics) or combine both of these with some repetition (physical inquiry and physics concepts).
- The achievement objectives were intended to be referenced back to overarching achievement aims for each strand and substrand. However, the achievement aims are not

included in *NZC* and can now only be accessed in fold-out documents that are out of print.

The following achievement aim and two of its accompanying AOs illustrate this lack of clearly differentiated expectations. They are from the ecology substrand of the Living World contextual strand.

Achievement aim: Understand how living things interact with each other and with the non-living environment.

AO for this aim at Level 1/2: Recognise how living things are suited to their particular habitat.

AO for this aim at Level 6: Investigate the impact of natural events and human actions on a New Zealand ecosystem.

The concept of interdependence between living and non-living elements of ecosystems is implied in these AOs but it is not explicit. Neither is it clear that what is required at level 6 will be more sophisticated conceptually than what is required at level 1/2.

The group noted that the bullet-point nature of the contextual strand achievement objectives cannot convey the richness of meaning that can be gleaned from a narrative account of how an important idea develops over time. This format also implies that any one bullet point might be developed via one discrete set of learning activities, rather than needing to be revisited over time.

There was a consensus view that the achievement objectives for the Nature of Science strand currently provide a better basis for documenting students' learning progress than do the contextual strands. Most members of the group were active users of the science capabilities. Because capabilities must be actively demonstrated by students, they provide more readily accessible markers of progress than content-based tests which are the traditional means of assessing science learning.

It is important to note that idea of science capabilities, while referenced to *NZC*, post-dates the curriculum. For this reason, these expectations can only be found in support materials. They are not in the curriculum document itself. The group was of the view that many teachers are more confident that they can recognise evidence of progress in the contextual strands, because content-based tests are their familiar experience of assessment. This was not what we found in the focus groups (see next section) but participants were all highly experienced, confident teachers.

Suggestions and recommendations from the curriculum expert group

- Focus future curriculum work that articulates ideas about making progress on the Nature of Science strand and the associated idea of science capabilities.
- Redevelop the conceptual content as sets of "big ideas". The group expressed a preference for narrative development of these, as in the example of the work of a European expert group of science educators (Harlen, 2015).

- Reorganise the content to support development of energy as a big idea. At the moment the concept of energy is too diffuse in its sporadic distribution across the different contextual strands.
- Include other important big ideas that are missing from the current set of achievement objectives. Students should have opportunities to begin to learn about complex systems as early as possible. Learning about uncertainty and risk are other big ideas that are currently missing.

Aspects of the Science curriculum expectations that are problematic

The expert group agreed that many science concepts per se are not *inherently* more or less accessible to students of different ages and stages of development. They can be introduced in simple terms, with their complexities being gradually added over time. The comparative difficulty of the learning is also impacted by the contexts that teachers select and the scaffolding of ideas that they orchestrate. This was why the group strongly supported the narrative development of big ideas that has been modelled by the consortium of European science education experts (Harlen, 2015). The whole conversation was framed by a wish to rethink the way in which the science achievement objectives are organised and divided into curriculum levels.

Given this desire for change, there are issues with the way the learning expectations are currently articulated. As in the Mathematics and Statistics learning area, there is:

- an uneven grain size across achievement objectives: in some instances, multiple concepts are subsumed by single bullet points while in other instances quite fine-grain detail is specified
- a lack of detail and clarity: as already noted, many AOs are cryptically worded and seem to assume knowledge that teachers might not have
- a lack of coherence: this is a particular issue when "big ideas" integrate concepts from the different contextual strands rather than sitting neatly within one of them—for example, "energy" is a big idea that is too diffuse in its treatment.

Suggestions and recommendations from the curriculum expert group

The group expressed a strong desire for a thorough redevelopment of the whole learning area.

Comparing the Science expectations of *NZC* to those of other curricula

As already noted, the group was drawn to the set of big ideas produced by a group of European science education experts (Harlen, 2015). In this, each overarching big idea is accompanied by a page-length narrative that elaborates on how the idea might be developed at different stages of schooling, mostly beginning at age 5–7. (The narratives for several of the ideas do not begin until age 7–11.) The group felt that the *NZC* achievement aims probably correspond quite closely to the big ideas of the European group's work. After the expert group, we tested the match and found that with two exceptions, *NZC* does indeed address these ideas. Appendix 1 shows the detail of the analysis. Note that the blank boxes do not mean that the idea is totally missing. Rather it is scattered (in the case of energy) or addressed in the science essence statement but not in the AOs (in the case of science as a knowledge system). Clearly, coverage per se is not the key difference—rather it is the developmental and conceptual clarity.

These big ideas do not come from one jurisdiction and we have no knowledge about how they a have been taken up (if they have) in different European nations. The group looked at several examples of other national curricula. Those from Scotland, British Columbia, Australia, and Singapore were provided for this exercise. Overall, the group noted pluses and minuses in these various curricula.

The critique of *NZC* carried over into the examination of the curriculum documents of other selected nations. The experts were critical of what appeared to be semi-random parcelling out of chunks of content across different curriculum levels. For example:

- the curriculum of British Columbia introduces electromagnetism at Grade 7 yet students do not encounter electrical circuits until Grade 9
- Scotland's curriculum takes students straight to atoms, seemingly with no preceding conceptual development of the idea of particles.

The inclusion of First Nations perspectives in the British Columbia curriculum was viewed positively by some in the group but seen as problematic by others. While the intent to be inclusive was clear, some of the experts were concerned that the juxtapositioning of two quite different knowledge systems could lead to disciplinary confusion and work against developing insights about the nature of science, unless teachers can be given much stronger support for their own epistemic thinking.

The group commented positively on the discipline-specific development of science competencies in the British Columbia curriculum, and on the inclusion of "big ideas" at each level. However, detailed traditional content is also included, and this was seen as having the potential to work against the general intent of the more novel features.

Some members of the group mentioned the work of a Government Commission in the UK which has suggested strong benefits for "removing curriculum levels". On further investigation, we found that the levels removed in this initiative were actually *assessment* levels that had been traditionally used in the UK. They were replaced with an emphasis on formative assessment, referenced to the four broad-banded "key stages" of the actual UK curriculum documents (Commission on Assessment without Levels, 2015).

Suggestions and recommendations from the curriculum expert group

No suggestions or recommendation about specific curriculum expectations were made. This could have been because the group was strongly drawn to the work of the European science experts (Harlen, 2015) which is not, per se, a national curriculum document.

Teacher focus groups for Science

The primary teacher focus group: Science

Four teachers attended the primary teacher science focus group. All were highly experienced in teaching primary science: one held a science degree; one was a senior leader in the school; two had completed the Science Teacher Leadership programme; and one had taken part in a recent Teaching and Learning Research Initiative (TLRI) project with a focus on adapting Citizen Science programmes for school science learning. Given this mix of backgrounds, all were passionate about meaningful inclusion of science in primary school programmes of learning.

Use of curriculum levels

The primary teacher group said that curriculum levels are not used for reporting science learning and achievement to parents. In fact, there was a sense that they are not really used much at all, with one teacher describing *NZC* as a "dead document".

One teacher said they looked for "cool stuff" that would excite the students' interest and then went to the AOs to see where the potential learning might fit best. In this context, the AOs from the contextual strands were seen as limiting rather than enabling. The NoS AOs are more useful but not sufficiently detailed. Both these points are explained in more detail in the next paragraphs.

In this conversation, there was a strong focus on curriculum integration. Science is typically included in the curriculum as part of an inquiry topic that follows students' interests. For example, two of the group said they combine science with social studies for inquiry learning. However, they worried that teachers who are less confident in their own science understanding tend to make social studies the main focus of their inquiries. By contrast, in their own classrooms the science ideas explored are those that unfold to follow students' interests. What the students want to learn about may take them well beyond the specified curriculum AOs for students of their age. In the Citizen Science project, students worked with a programme where participants help find exoplanets in space. The teacher said these intermediate-age students ended up exploring and understanding concepts that are more typically introduced in senior physics.

The group also noted that progression is typically non-linear and uneven. For example, autistic students might be working far ahead of the level of the class in topics where they have a personal passion.

Resources used for making judgements

NZCER's Science Thinking with Evidence (STwE) and Science Engagement survey were both mentioned as resources used to make judgements against curriculum levels. However, the group felt that many schools "make stuff up" by creating their own rubrics because there is not one specific "go to" resource. In any case, assessment of reading, writing, and mathematics still takes precedence and science is often not assessed at all.

These teachers were all familiar with science capabilities. Working with these was their strong preference when it comes to determining the level at which their students are working. Students can be following different lines of inquiry, but the capabilities focus can still be much the same. (They were aware that their strong science knowledge gave them an advantage when responding flexibly like this.) Compared to the detail provided in capabilities resources, the actual NoS strand of the curriculum was seen as lacking specifics, especially when contrasted with the detailed AOs in the contextual strands. They would like to see the NoS strand more fully developed, to ensure it captures the capabilities.

The group mentioned the Building Science Concepts (BSC) series as a resource that provides a helpful guide to curriculum levels. They like that many of the concepts are developed across levels 1–4. This can help meet needs of students working at different curriculum levels in the same topic. Alternatively, the guides can be useful for ensuring students do not explore ideas with which they are already familiar—they can start at a higher level if this proves to be more appropriate to their needs. They dipped into the series for good ideas, but also felt the series provided useful support and guidance for those who are less experienced at teaching science. They would like to see this series updated and provided electronically. They said that the booklets can now be hard to find in some schools.

The group noted that the science kits provided by Hutt Science[6] have "no rhyme or reason" in terms of curriculum levels and conceptual development. They can be useful to encourage teachers who are not confident to dip a toe into the water, but that was as far as their usefulness went. They did not mention using ARBs to determine curriculum levels.

How clearly AOs convey expectations

None of this group was aware of the existence of the achievement aims before they looked at the curriculum fold-outs during the focus group. They really liked the achievement aims and found them enlightening. They said they could be a great guide to "big ideas" to explore in inquiry topics. (This was a different sense of the usefulness of big ideas than that conveyed by the secondary science teachers, who saw them as a basis for working out progressions.) However, they found the elaboration of each achievement aim as a series of AOs much less helpful. They said that some of these sequences seemed rather contrived and like "semantic incrementalism" rather than conveying informative insights into potential progressions.

On balance, the group liked the strand-based structure of the learning area. However, they did also speculate about the impact of this on cross-discipline integration. They noted that STEM inquiries are a popular means of curriculum integration in many primary schools. They also noted that topics such as climate change involve several strands. (They also said that it was too late to

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[6] https://www.huttscience.co.nz/

introduce this at Level 6, and that many primary schools are beginning to explore this highly topical issue.)

Like the primary mathematics and statistics teachers, this group worried that many of their colleagues are really only confident working with levels 1 and 2 of the science curriculum. They said that teachers who should be working with levels 3 and 4 will often not move beyond the comfort zone of level 1 and 2, and they saw this as the likely reason that so many primary students did not achieve level 4 in the NMSSA assessments.

Suggestions and recommendations from the primary teacher focus group

The group would like to see the digitised curriculum linked to curated resources that teachers can follow through. They like what is already available but want resources to be easier to find and more plentiful. They requested that money be invested in free and accessible professional learning if there is a plan to revamp the curriculum. This is especially needed by teachers for whom science is not their "thing".

There was a clear preference for an emphasis on the capabilities. This could be done through the NoS strand, or the capabilities could stand alone, with more examples provided. They said that teachers don't understand how to put the capabilities into a science lesson even if they understand what the capabilities are. More specific and actionable examples are needed. They asked that any assessment emphasis be moved "away from levels and towards skills" that can be applied in different contexts.

Like the primary mathematics and statistics focus group, the absence of any reference to mātauranga Māori in the science curriculum was raised. The group noted that such a focus is becoming increasingly important for a lot of schools: "We are a bicultural country—it should be front and centre." As one example, they noted that kaitiakitanga is not mentioned in the Living World strand: "It's a very white document." They felt that inclusion of mātauranga examples would help to integrate more te ao Māori concepts into their teaching. One school was exploring space because Matariki was approaching. This teacher said it would be easier to include science concepts if the links were more obvious.

The secondary teacher focus group: Science

Seven teachers from four schools attended the secondary teacher focus group. Their specialist subject expertise was spread across the science disciplines. All were experienced teachers who held additional responsibilities (Head of Department (HoD), Assistant HoD etc.)

Use of curriculum levels

Most of the group said that NCEA achievement standards determine levels of achievement in the senior secondary school, rather than *NZC*. In the junior secondary school, reporting is based on the Nature of Science (NoS) strand, even though these AOs are broad and span two curriculum levels. Asked how levels of achievement are determined from the NoS strand, one teacher said "We just made them up," to which there was general agreement. It was the teachers' observation that every school has to do the work of creating their own levels. Once a focus has been determined, the Structure of Observed Learning Outcomes (SOLO) taxonomy[7] is often used to differentiate actual levels of achievement within one group of students. One person mentioned a NoS-based scheme from another secondary school, which they were adapting. This was "a work in progress".

It was clear from the conversation that the AOs from the four contextual strands are not seen as sufficiently clear and useful for decision-making about achievement. At best, they are used as broad guides to topics to be taught. The teachers were not necessarily bothered about this—they liked the freedom to "put our own flavour" on the learning they planned.

The group mostly agreed that the front half of *NZC* is inspirational but the back half (i.e. the sets of achievement objectives) is no longer useful. One described it as "belonging to another era". In one school, the curriculum came out once, on the teacher-only day at the beginning of the year. However, at the other end of a continuum of engagement with *NZC*, one HoD described it as a "living document" for planning units of work. Nevertheless, her team used SOLO to determine actual levels of achievement.

Resources used for making judgements

Several teachers said they used the Assessment Resource Banks (ARBs) to support them in making judgments against the curriculum. The focus on the *meaning* of levels led them to ponder how the ARB developers had themselves determined the levels for items.[8] (This appeared to be a question they had not previously considered.) Some concern was expressed that new items are no longer being added to the science bank—it needs to be kept fresh (see recommendations to the Ministry of Education).

The only other resources mentioned were the Senior Subject Guides on TKI, but their usefulness was related to the big ideas they convey, rather than for determining levels. The teachers were aware that other science resources can be found on TKI but none were mentioned by name. One school had previously used Science Thinking with Evidence (STwE)[9] but was no longer doing so.

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[7] See, for example, http://pamhook.com/solo-taxonomy/

[8] The ARB team develops items to support assessment of specific AOs. Items are piloted and trialled in classrooms to check their fit with the target AO(s). From students' responses and teacher feedback, the team develops information to support teachers with next learning steps and how to address misconceptions that are evident. In NMSSA, a curriculum alignment exercise is used to determine achievement expectations (cut-scores) on the achievement scale for the learning area concerned, associated with achievement at different curriculum levels. This is undertaken by a committee of experts in that learning area. Further explanation can be found in the technical reports available at https://nmssa.otago.ac.nz/ .

[9] https://www.nzcer.org.nz/tests/science-thinking-evidence

How clearly AOs convey expectations

The photocopied sets of AOs from the science learning area were perused with interest. Some participants had forgotten about, or were never aware of, the achievement aims. The lack of clarity of the contextual strand AOs was a predominant theme in this part of the conversation. One physics expert paraphrased the levels in the Physical World contextual strand as "Just do some physics [at Year 9], do some more [at Year 10], now do some hard stuff [in senior secondary]." The Earth and Space Science strand was not seen as conveying a sense of progression: "It doesn't seem harder, just different."

There was some discussion about the uneven distribution of the levels across the years of schooling. One teacher likened the spread to the "hockey stick" shape of an exponential graph. The group speculated about whether the 1:1 correspondence of years and curriculum levels in the senior secondary school reflected a more academic cohort in years past (when many students did not stay at school for these years). There was general agreement that the expectation that all students will make progress at this rate in senior secondary is "way too ambitious".

The group also discussed the content of the current sets of AOs. The Living World strand was seen as out-of-date (for example, there is no reference to new gene-editing technologies such as CRISPR).[10] The lack of opportunity to study human biology in senior secondary was seen as a significant omission. The "lack of cross-over" between the disciplines was also noted and seen as out of date. Climate change was discussed as a topic that students must learn, yet it is not evident in the current organisation of knowledge. The lack of any reference to mātauranga Māori was also noted. However, one teacher said that any change must "Keep the rigour. We can't just become social scientists."

A desire for change/simplification was evident, although this was not expressed directly. For example, one participant likened this exercise to an archaeological dig. The AOs represented "accretions over time, but never taken back to a systems or learning viewpoint". Looking across the whole set, another participant said, "I wish we had about 10 big ideas to work with." It was at this point that the big ideas in the senior subject guides were mentioned.

Suggestions and recommendations from the secondary teacher focus group

Any change should proceed slowly and be well supported. (The lack of time to get to understand the science capabilities was the reason they had been dropped in one school.)

There was a clear desire for common resources to support curriculum decision-making.

- The group wanted the ARBs to be "kept up-to-date" with new additions.
- The Building Science Concepts (BSC) booklets were mentioned as one possible model for additional resources.

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[10] See, for example, https://en.wikipedia.org/wiki/CRISPR

- “Ten big ideas” would provide a useful focus. It should be clear what students need to know by the end of Year 10, when many drop the sciences, as well as what should be achieved by Year 13.

One person suggested colour-coding the curriculum document to show pathways through the different strands.

4. Mathematics and Statistics

Existing evidence of student achievement in Mathematics and Statistics

What we know from NMSSA results and the PaCT

NMSSA assessed the mathematics and statistics learning area in 2013.[11] The study's results indicated that about 41 percent of students from Year 8 were meeting or exceeding curriculum expectations (curriculum level 4). This compared with about 81 percent of students in Year 4 (curriculum level 2).

Since the NMSSA study, data stored in the PaCT has also indicated fewer students achieving at level 4 in Mathematics and Statistics, compared with the proportions of younger students achieving their expectations for their year level (see Appendix 2 for more information about what the PaCT can tell us about the difficulty associated with the Mathematics and Statistics learning area).

Other system-wide assessments of New Zealand students

Students from New Zealand schools take part in two international studies of achievement in mathematics: the Trends in International Mathematics and Science Study (TIMSS), and the Programme for International Student Assessment (PISA). Both studies involve the assessment of nationally representative samples.

The TIMSS programme is focused on students in Year 5 and Year 9, and assessments are administered in a 4-year cycle. Looking at changes over time, there has been little significant change in Year 5 and Year 9 students' scores over the past 20 years.[12]

The PISA project, an initiative of the Organisation for Economic Co-operation and Development (OECD), looks at the mathematical, reading and scientific literacy of 15-year-old students. Assessments of mathematics have been undertaken on a three-yearly cycle since 2003. In mathematics literacy, the PISA scores of New Zealand students have fallen from an average of

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[11] Educational Assessment Research Unit and New Zealand Council for Educational Research (2015). *National monitoring study of student achievement: Mathematics and statistics 2013.* University of Otago: Educational Assessment Research Unit.

[12] Ministry of Education. (nd). Mathematics achievement: What we know from New Zealand's participation in TIMSS 2014/15 and PISA 2015. Retrieved from Education Counts: https://www.educationcounts.govt.nz/publications/series/2571/timss-201415/mathematics-achievement-what-we-know-from-new-zealands-participation-in-timss-201415-and-pisa-2015

523 scale score units in 2003 to 495 in 2015. Most of the decline occurred between 2009 and 2012[13].

International comparisons with *NZC*: Mathematics and Statistics

Desirable and feasible learning in Mathematics and Statistics

ACARA make the following observation about the way in which *desirable* learning in mathematics is signaled in the Australian curriculum (shortened to AC here):

> The AC [mathematics] aims to be *relevant and applicable to the 21st century* by equipping students with the capacity to think, solve problems and respond to challenges. The inclusion of the proficiencies of understanding, fluency, problem-solving and reasoning in the curriculum enables students to respond to familiar and unfamiliar situations by employing mathematical strategies to make informed decisions and solve problems efficiently. The proficiencies define the range and nature of expected actions and applications in relation to the content descriptions. The proficiencies are an integral part of Mathematics content across the three content strands … (ACARA, 2018, p. 59, emphasis added)

"Curricular competencies" in the British Columbia curriculum are broadly equivalent to the proficiencies of the Australian curriculum. In mathematics these curricular competencies include reasoning and analysing, understanding, problem solving, communicating, and representing. Sample inquiry questions are included in the curriculum to illustrate what students are expected to do (ibid, p. 60).

A direct comparison of the Australian, British Columbian, and New Zealand mathematics curriculum specifications related to mathematical proficiencies highlights the difference between these explicit expectations in the Australian and British Columbian curricula, and the more implicit signals given by *NZC*. In *NZC* these signals are embedded in the statement that precedes each level's achievement objectives: "In a range of meaningful contexts, students will be engaged in thinking mathematically and statistically. They will solve problems and model situations that require them to…". In contrast to the explicit weaving of proficiencies in Australia's and British Columbia's curricula, it is up to teachers to do this weaving when teaching mathematics in New Zealand (ACARA 2019, pp.84–85).

The evidence we found points to some more specific differences between what the Mathematics and Statistics learning area of *NZC* specifies as desirable and feasible learning, and the specifications of curricula elsewhere.

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[13] As above.

- Compared to the Australian curriculum, *NZC* makes a clearer distinction between mathematics and statistics (ACARA, 2019).
- At level 2, *NZC* specifies fewer key ideas than the equivalent level of the Australian curriculum. The AUSTRALIAN CURRICULUM is classified as having "comprehensive" breadth, whereas *NZC* is classified as having only "fundamental" breadth. The ACARA report notes that the lack of breadth at level 2 makes room for a greater emphasis on number, which is fundamental to the development of other aspects of mathematics (ibid, p. 83).
- The depth at level 2 for the *NZC* is judged to be "challenging", particularly for the number and algebra strand. New Zealand students working at level 2 are also expected to show a higher level of statistical reasoning and critical thinking than students working at the equivalent level in Australia (ibid).
- *Both* curricula show comprehensive breadth and "challenging" depth at Year 6 and Year 10 (ibid).

Are the learning expectations in Mathematics and Statistics appropriate?

In discussion with the Ministry of Education, we agreed that "appropriate" in this question means, in essence, "at the right level of difficulty". ACARA used the term "rigour" to investigate this aspect of curriculum.

Evidence from our international comparison work suggests that *NZC* signals somewhat lower expectations than those indicated by international benchmarks, with the notable exception of the statistics strand.

- The TIMSS 2015 international test included questions set at a higher level of difficulty in comparison to curriculum expectations for Year 9 mathematics in New Zealand (Caygill, Hanlar, & Singh, 2016, p. 28). Caygill et al. also noted teachers' indications that many of the students who took part were working at *NZC* level 4, rather than level 5 as might be expected. The analysis did not establish a link between these two findings but it could be inferred as a reason that some students did not perform well in the assessment.
- The same pattern was found when TIMSS 2015 for Year 5 was compared with mathematics in *NZC* (Caygill, Singh, & Hanlar, 2016, p. 29). Again, according to their teachers, many New Zealand students were working at *NZC* level 2, rather than level 3 as might be expected.
- The ACARA analysis described both the Australian and New Zealand curricula as having "challenging" rigour at level 2. Nevertheless, it states that "the expected developmental levels within *NZC*: MS [Mathematics and Statistics] are slightly less rigorous than AC: M [Mathematics] for this age group" (ACARA, 2019, p. 84). The focus on additive thinking at the expense of early multiplication and division is given as the reason for this judgement.

- In ACARA, Level 4 mathematics is judged to be rigorous, with the statistics strand seen as “very rigorous” (ibid, p. 91). The level of sophistication required for statistical inquiry at level 4 *NZC* is not expected in Australia until lower secondary school.
- At level 6, the achievement standards for NCEA Level 1 mathematics were used by ACARA to support the judgement that the expectations of rigour are sufficiently challenging.

Patterns of New Zealand students’ achievements in international tests contributed to the judgements outlined above. For example, both TIMSS and PISA results have shown that statistics is an area of relative strength for New Zealand students, compared to other areas of mathematics (Ministry of Education, n.d.). This is the aspect of mathematics pinpointed in the ACARA study as requiring greater sophistication of statistical reasoning from younger New Zealand students when compared to the Australian curriculum expectations (ACARA, 2019). As earlier sections have shown, there was general agreement from both the experts and the teachers that expectations in statistics are realistic. Young students can cope because familiar contexts are used to introduce the learning.

Results from TIMSS have shown that, at Year 5, number questions, along with geometry and measurement questions, are a relative weakness compared with statistics. At first glance this might seem to contradict the comparatively greater *NZC* emphasis on number in the early years. However, for TIMSS, “number” at this level included simple algebraic concepts, including pattern recognition. The lack of early algebra was one of the reasons the ACARA analysis pointed to comparatively less breadth in *NZC* mathematics compared to mathematics in the Australian curriculum. These strengths and weaknesses have been fairly consistent over time within New Zealand (Ministry of Education, n.d.).

The Mathematics and Statistics curriculum expert group

The Mathematics and Statistics curriculum expert group’s discussion, comments, and suggestions are reported here. Note that, before the business of the meeting got underway, the group identified that further information about how the existing curriculum is being enacted by teachers would be needed to inform future decisions about this learning area. With this caveat in mind, their views and recommendations follow.

Appropriateness of the curriculum expectations for Mathematics and Statistics

There was discussion to clarify the group’s understanding of what constitutes “appropriate” curriculum expectations. They interpreted “appropriate” as considering the following questions.

- Does the progression make sense?
- Does the levelling fit the age?

- Are big ideas introduced at the right level?
- Is there coherence across the strand (i.e., do some concepts tail off, are others introduced early, lie dormant, or get picked up later)?

The overall feeling of the group was that the curriculum expectations are broadly appropriate, and that the document is a very good curriculum statement for the Mathematics and Statistics learning area. There was initial discussion about the arbitrary number of levels in the curriculum document and whether having eight levels was helpful or appropriate.

Statistics was a strand that the group thought is particularly strong and should not be altered, especially at levels 1–4. This is supported by NZ students' statistics performance in international comparative studies (see Section 4). However, the group perceived there is something of a jump from level 5 to level 6, from dealing with simple statistics to making informal inferences about populations. They said that earlier foundations need to be laid for this understanding, particularly in probability, results of experiments, and theoretical models, and in noting variations from expected outcomes.

As reported at the start of this chapter, data from various assessment instruments all point to a challenge at level 4. This level is proving too difficult for a significant proportion of students (around 59% in NMSSA) to achieve by the end of Year 8. Members of the group thought it would benefit from adjustment. They were, however, divided in their views about the root causes of the challenge, and hence suggested different potential solutions. These included the following.

- If level 4 is proving unrealistic, some of the "more complex" level 4 number and algebra AOs could be moved into level 5 and/or 6.
- Alternatively, if students are coping well with existing content but level 4 is too crowded, demands could be reduced by introducing some concepts earlier (see specific recommendations below).
- Some teachers do not fully understand what is needed to build strong foundations below level 4, for example in fractions and initial multiplicative concepts. In this case, a solution could include provision of clearer descriptions of AOs, especially those with larger grain size, accompanied by examples.

These positions were not necessarily as clear cut as the three bullet points suggest. Most experts wanted some combination of these changes. The group also noted that expectations for numeracy at NCEA Level 1 are set at level 5 but include some level 4 outcomes. One member of the group thought *NZC* level 6 is set too high.

The specific term "generalise number properties" seems to be unclear to teachers. Likewise, "additive thinking" might be misunderstood by some teachers as applicable to only addition/subtraction situations; exposure to multiplication/division should be more explicitly stated at both levels 2 and 3.

According to the group, producing a “slimline” curriculum document in 2007 seems to have contributed to a lack of specificity. They asked what mechanisms teachers have for supporting consistent interpretation of the AOs in locally determined curricula. Some countries do this with mandated texts, but NZ has only the non-compulsory NZMaths website. The group agreed that the expectations need to be more clearly articulated and organised in a way that supports a shared understanding of progressions. One member of the group noted that a considerable amount of this clarification work had been carried out “years ago” and is available on NZMaths, which is currently being reviewed and updated.

The group voiced general support of the PaCT and Learning Progressions Frameworks (LPF). One group member commented that a real strength of the PaCT is that it represents the whole curriculum. Another member noted that describing progressions in words is strong when it is accompanied by examples. Overall, the group believed that the performance expectations associated with the PaCT at curriculum levels 1 to 5 reflected the intent of the curriculum document.

Suggestions and recommendations from the curriculum expert group

- Reduce the demands at level 4 in Number by introducing some concepts earlier, at level 3 or even level 2, because evidence suggests that students are coping well with the existing content at these levels. Specific suggestions included introducing integers at level 2, with a view to assessment of understanding coming later; encouraging thinking about variables at earlier levels through number; and introducing spatial patterns earlier.
- Alongside the recommendation above, ensure that teachers fully understand what is expected at the earlier levels so that students can build on sound foundations (e.g., fractions and initial multiplicative concepts).
- Move some of the more complex AOs at level 4 (which were not specified) to level 5.
- Rework AO NA3.8: *Generalise the properties of addition and subtraction with whole numbers* so that it explicitly includes commutative, associative, and other properties.
- Provide further support to unpack the achievement objectives and show progressions of big ideas clearly: e.g., for fractions, show what it looks like at level 1, level 2, level 3 and so on in one place. Resources already available on NZMaths would contribute to this.
- Consider how to use the LPF and the curriculum together (rather than changing one to match the other) and communicate this clearly to teachers.
- Use big ideas that bridge levels to organise the curriculum.

Aspects of the Mathematics and Statistics curriculum expectations that are problematic

According to the group, there are issues with the way the expectations are articulated. These include the following.

- *Uneven grain size across AOs:* Not all achievement objectives are created equal. In some instances, there are a lot of concepts subsumed by single bullet points. This obscures key content. How could the different "weights" of AOs be signalled to teachers?

- *A lack of detail and clarity:* The AOs assume knowledge that some teachers may not have. Clear details that flesh out the AOs are available from other sources (e.g., NZMaths), but are sometimes hard to find.

- A lack of coherence: Clearer links between knowledge and strategy or capability are needed.

The point was made that the curriculum is not an assessment framework, and therefore some concepts could be included at earlier levels in the curriculum statement.

The group were cautious about making comments specifically relating to priority learner groups. One member asked how our English-medium curriculum reflects mātauranga Māori and our place in the Pacific. New research was described that has identified a Pacific nation whose language has no words for fractions—how might that make learning about fractions concepts more difficult?

Suggestions and recommendations from the curriculum expert group

The following recommendations should be read with the caveat, made by one expert, that these are "fundamental issues and not ones that can be addressed with minor tweaks". Specifically, splitting up larger AOs would increase the number of AOs overall, and so should only be considered in the context of a full curriculum review.

- Re-size the AOs where possible to make them more comparable. This could be done by separating concepts listed in the same AO. For example, in the Measurement AO GM2.1, the horizontal list of length, area, volume and capacity, weight (mass), turn (angle), temperature, and time could be broken up into smaller AOs to indicate their equivalent importance. Similarly, the NA4.3 AO Find fractions, decimals, and percentages of amounts expressed as whole numbers, simple fractions, and decimals could be split into three AOs.
- When an AO is necessarily big, this should be differentiated from a small AO. For example, NA3.1 Use a range of additive and simple multiplicative strategies with whole numbers, fractions, decimals, and percentages covers four big ideas, while GM3.5 Use a

co-ordinate system or the language of direction and distance to specify locations and describe paths contains one big idea.

- Some concepts could be introduced earlier, although not an assessment focus until a later level. For example, integers are currently included at level 4 but could be meaningfully introduced to students working at level 2; there is a need to encourage thinking about variables in number at earlier levels through number and spatial patterns.
- Mathematical processes that were included in the 1992 document *Mathematics in the New Zealand Curriculum* (Ministry of Education, 1992) need greater emphasis and incorporation into the AOs in *NZC*.
- Mathematical investigation with a mathematics inquiry cycle into problem solving should be included.
- Mathematical literacy should be explicitly included—see the *PISA 2021 Mathematics Framework* (Organisation for Economic Co-operation and Development, 2018).
- Graphics or colour could be used to help teachers identify where a concept threads through the curriculum (similar to the model in the Cambridge Mathematics project, see (https://undergroundmathematics.org/useful-downloads/map-poster.pdf), and to signal the relative "weights" of AOs.

Comparing the Mathematics and Statistics expectations of *NZC* to those of other curricula

The expert group was asked to make judgements about the expectations set by *NZC* compared to those of other nations' curriculum documents. Overall, the group noted pluses and minuses in all the curricula they looked at or knew about. They seemed reassured that the expectations in *NZC* are at about the right levels and that we have a rich curriculum statement for Mathematics and Statistics. Some key points the group noted about the various curricula are included below.

Singapore curriculum

The group found this to be a narrower and faster-paced curriculum, with NZ's broader and slower. Number and computation is accelerated rapidly in Singapore compared to NZ, but strands such as statistics and algebra are minimal in Years 1–4. Geometry includes no positional orientation and there is limited work on transformations. Neither probability nor problem-solving are included. The organisation by "Content" (AOs) and "Learning Experiences" (Opportunities) could be helpful for improving the clarity of our curriculum. Each group of AOs has a corresponding set of specific learning experiences. Interestingly, the expert group noted that the Singapore curriculum aligns better with TIMSS than the NZ curriculum.

British Columbia curriculum

The British Columbia curriculum includes big ideas, although the group thought that having five big ideas at every level was artificial. The big ideas appeared to be written to support the teacher rather than as statements of content that the students need to be learning. Competencies are not connected to content. (The group had insufficient time to make judgements about the expectations at different levels of the British Columbian curriculum compared with *NZC*.)

Australian curriculum

This curriculum allows teachers to follow a concept through year levels. It includes a financial literacy thread. Overall, the levels and expectations appear similar to those in the *NZC*, with fractions and statistics having less emphasis in the Australian curriculum. This curriculum also includes computational thinking.

Suggestions and recommendations from the curriculum expert group

- Consider the organisation of Singapore's curriculum if ours is to be re-shaped.
- The use of "big ideas" has some merit for structuring a curriculum statement.
- Some of the group suggested including financial literacy in mathematics. However, others pointed out that this idea includes important concepts from other learning areas as well, so debate is needed about where it should best be positioned. (We return to this challenge in the final chapter of the report.)

The group was concerned that these or any other changes to the curriculum (or the status quo) in the future must be communicated effectively to the sector as research-based refinements to current best practice. This is likely to require high-quality PLD and resources for teachers to ensure that changes in the curriculum lead to changes in practice and student outcomes. The group also voiced concern that if there was to be an opportunity in future for a review of the curriculum, the Ministry would need to provide sufficient time and opportunities to mobilise the thinking of those in the sector.

Teacher focus groups for Mathematics and Statistics

The primary teacher focus group: Mathematics and Statistics

Three teachers from three schools attended the primary teacher focus group. All were highly experienced leaders of mathematics and statistics in their schools. Note that none of this small group taught at Years 7–8, which meant that the conversation was predominantly focused on the lower levels of *NZC*.

Use of curriculum levels

At the start of the session one teacher described *NZC* as a "treasure". It is valued as a "big picture document" that provides overall guidance about strands and expectations. However, it is not seen as sufficiently detailed for day-to-day decision-making. One teacher said that "most teachers open the curriculum at the beginning of a planning session but that's about it." Another teacher said this was not their experience when their school had been exploring play-based or project-based learning, at which times they had retrospectively mapped sessions to the AOs.

Each school has created its own materials to use for making judgements about achievement and for reporting to parents. The National Standards and the Learning Progressions Framework (LPF) have informed these local versions, which are typically broken down into "little steps" that can guide teaching and learning. The group noted that the curriculum levels have recently been removed from the LPF: they thought these indicators of levels were "really useful" and they would like them reinstated.

All three schools report student achievement to parents against year levels rather than curriculum levels. They do go up to year 9–10 to "cater for high-achieving children".

Resources used for making judgements

A wide range of other resources is used for to support making judgements about achievement. Those mentioned in this small group included NZMaths, ARBs, IKAN, JAM, Gloss, e-asTTle, PATs, Figure It Out series, e-ako (student materials), and textbooks from Caxton Educational. NZMaths was described as a "fantastic" resource for key ideas and elaboration of the AOs in clear, consistent language. E-asTTle is used "higher up the school" but not at junior levels.

None of these schools use PaCT for making OTJs about the level at which students are working. They said that PaCT required them to make a judgement about *every* aspect and they were reluctant to do that if there were some aspects they had yet to work on.

How clearly AOs convey expectations

Teachers thought the expectations for the statistics strand are working well, perhaps because statistics is easier than other strands to present in real-world contexts and include in other learning areas, such as Social Sciences.

There was agreement that the lower levels of *NZC* Mathematics are easier to understand than the higher levels. The group noted a "big jump" between level 3 and level 4 and said that a lot of primary teachers are "terrified" about level 4. They noted that there is a lot more to cover at level 4, and the language changes and becomes quite technical, with some of the AOs expressed in long sentences. This AO was cited as an example of technical language:

> Transformation: *Use the invariant properties of figures and objects under transformations (reflection, rotation, translation, or enlargement).*

This type of pithy statement needs a lot of unpacking if teachers are not confident in their own mathematics knowledge. Despite these reservations, the group felt that the expectations signalled at level 4 are "reasonable", particularly if children have been taught to think mathematically from the early years. They have noticed that some children from other nations can come into New Zealand schools confident in applying rote-learned procedures, but unable to apply their skills to problem-solving in real contexts. The use of familiar contexts to foster mathematical thinking in the early years is seen as a strength of *NZC*, particularly in the statistics strand.

The group wondered if algebra should be given more importance at level 4—and perhaps become a separate strand. They felt this would provide a stronger foundation for the transition to secondary school.

The Venn diagrams at the top of each level are regarded as a helpful feature because they provide quick visual guidance about the relative emphasis to be given to each strand when designing a programme of learning.

Like the Mathematics and Statistics curriculum expert group, the primary teachers were concerned that the statements at the top of each level about using meaningful contexts, thinking mathematically, solving problems, and modelling can get lost. They contrasted this structure with the science curriculum, where there is an explicit NoS strand, and said a "Nature of Maths" strand would be helpful.

Suggestions and recommendations from the primary teacher focus group

The general feedback is that the curriculum is pitched at the right levels, at least up to level 4: "Things are where they should be."

The teachers suggested including a "Nature of Mathematics" strand that would make what were previously called "mathematical processes" explicit at all levels. They said it would change their planning and help ensure the teaching and learning is focused on modelling/problem-solving/mathematical thinking.

The teachers would like to see the curriculum use clear, consistent language and terminology that model ways to talk about mathematical ideas. This should be language that children can also use and that can be shared between schools. They noted the use of clear language as a strength of NZMaths resources. The group would like to see NZMaths kept up to date with current thinking. They find this a valuable resource.

The group also asked for indications of "threshold concepts" that children need at each level. They would like these to be made explicit. This request aligns with the discussion of the need for "big ideas" at key stages, as articulated by the secondary science and mathematics teachers. They said that such ideas would be useful for curriculum integration, particularly when mathematical aspects are only part of a topic (e.g., financial literacy, digital technologies).

Like the secondary teachers, this group wanted more resources that show how to put the AOs to work: "NZC on its own is not enough." They said it would be useful to have resources that model different ways to put areas of the curriculum together (e.g., geometry with statistics) in a real-world context. They felt they were not good at integrating different strands yet doing so could be one possible solution to the amount of content to be covered at level 4.

The secondary teacher focus group: Mathematics and Statistics

Four teachers attended the secondary teacher focus group, representing four schools. Three were heads of departments in their respective schools and the fourth had been teaching for some years.

Use of curriculum levels

The teachers said they used the guidance about levels in *NZC* when the curriculum was new. Once they had referred to *NZC* to ensure that the outline of the work for each year was at the right level, then the document was put away and seldom used Some said they revisited the curriculum levels periodically to "check bits and pieces" but it was evident that teachers did not refer to *NZC* for day-to-day guidance. References to levels on schemes of work were described as a "tick-box approach" (to show compliance) rather than a practical guide to decision-making.

The results of common assessment tasks are used for reporting to parents, as well as for streaming in some schools. The group said that parents would not understand levels. Their comments also implied that they did not necessarily think primary teachers understood them either. They described some feeder schools as "very generous" in their reporting of students' attainment and they said they could often tell which feeder school a student had attended by looking at the skills they did or did not have. They noted that students in Year 8 "can be anywhere between level 1 and level 8". Rather than reporting by curriculum level, their preference was to be given a detailed report of the actual skills that students have attained at the time of transition to high school: "We don't really care about what level they're at, it's about what mathematical knowledge they've got."

Reporting of actual skills also addresses the issue that students can be working at different curriculum levels in different aspects of mathematics: "Children will be all over the place, for example good at statistical things but low on skills."

Like the secondary science teachers, this group said that NCEA achievement standards determine levels of achievement expected in the senior secondary school. As one specific example, the guidelines for the Mathematics Common Assessment task (MCAT) influence thinking about what should be taught at level 6. There was some consternation when changes were made to the MCAT to ensure that students select and use algebraic procedures to solve problems (mandated in 2016 but signalled several years before that). A literal reading of the level 6 AOs does not directly link the specified algebraic skills to problem-solving. Instead, as the expert group and ACARA both noted, the need for a problem-solving approach is signalled via a generic statement that appears at the top of each curriculum level. Given this page layout, the teachers understood the MCAT change as "changing the meaning of the AOs". The impact of NCEA extends down into Year 10, to ensure that "foundation skills" are in place before Year 11. Also related to NCEA, this group of teachers thought that levels 6–8 could actually be left out of the mathematics and statistics learning area, since achievement standards "prescribe" what needs to be taught. Somewhat ironically, they also saw these levels in *NZC* as being "OK," compared to the "waffly" lower levels. They added that levels 1-3 needs to be well supported and resourced, given these levels are taught by non-specialist teachers.

Resources used for making judgements

Mathematics in the New Zealand Curriculum (Ministry of Education, 1992) is still seen as a valued resource to support making judgements. It was more prescriptive than *NZC* and has examples of "things to teach and ways to teach them". The group jokingly referred to this document as the "Red Book" or the "Burgundy Bible" and said that they still need it.

Two of the four teachers said they used PATs in Year 9 to determine students' achievement levels on transition. None of this small group mentioned PaCT or ARBs.

The teachers also said they had access to a lot of online resources, although these could sometimes be hard to find. NZQA's resources and NZMaths were said to be "hard to follow". They also noted that considerable expertise is needed to make the most of well-designed online resources for students such as Nrich.[14] Even a resource like Maths Buddy[15] has to be set up by the teacher, and they need to know the resource well enough to appropriately direct students' attention and practice. Participants alluded to informal resources, such as websites created by other mathematics and statistics teachers, which they also access for curriculum support.

How clearly AOs convey expectations

The lack of clarity of the AOs was a predominant theme in this part of the conversation, as it had also been for the science teachers. One teacher said, "It's a bunch of words but there's no specifics." Another said, "The curriculum isn't really the curriculum until you've read the other documents that tell you what it really means."

The group was concerned that some aspects of the curriculum, such as using bearings and grid references to find locations, had been superseded by the Global Positioning System (GPS) and Google Maps, and the curriculum is out-of-date.

Like the science teachers, the group discussed the uneven distribution of the levels across the years of schooling, which they said appeared to be "very arbitrary". Again, like the science teachers, this group was concerned about the 1:1 correspondence of years and curriculum levels in the senior secondary school, seeing this as a sudden change of pace compared to the years before. They also felt that it needs to be explicitly stated in *NZC* that one level subsumes all previous levels, i.e., assumes fluency with previous levels.

Some aspects of *NZC* were viewed positively. The high-level organisation into strands was "good" and the statistics strand was seen as a particular strength, as it was by the curriculum

[14] https://nrich.maths.org/
[15] https://www.mathsbuddy.co.nz/

experts' group. The curriculum gave a "nice progression" of mathematical knowledge, although perhaps without sufficient clarity of "big ideas". One teacher said they would like to see "concepts" described along the lines used in the Literacy Learning Progressions. (It was not clear whether this small group was aware of the PaCT progressions and the opportunity to go back and clarify did not arise in the flow of conversation.)

The concern about lack of detail and clarity related to *how* the curriculum should be taught rather than what should be taught, at least from level 5 up. One teacher said that Year 8 teachers (working at level 4) are "let down" by the curriculum because there is not enough support and guidance. Below level 4 the group felt that primary teachers needed much more explicit guidance. And at the top end of level 3/4 more support is needed if secondary teachers are required to teach outside their subject expertise because this is when "The teacher skill set starts to fall over."

Suggestions and recommendations from the secondary teacher focus group

The teachers asked for more supporting resources that are easily accessible, and greater clarity about curriculum expectations. They would like to see sets of must-know concepts developed for key transition points, in particular for the end of level 4.

They would like to see more consistency between primary schools, so that the key knowledge students need has been mastered before they come to secondary school.

Some mention was made of conflicting advice from NZQA moderators. In general, the teachers wanted to see better alignment between the agencies that develop the curriculum (MOE), design the assessments (NZQA), and translate both of these into actual teaching and learning plans.

5. Conclusions and additional considerations

In this final section we begin by outlining our main conclusions based on the project's findings. We then turn to several additional matters. As part of the programme of work, the Ministry of Education asked for advice on whether it would be advisable to carry out equivalent curriculum levelling studies in other learning areas of *NZC*. We address this question before briefly outlining a challenge that arose during the field work, namely what to do about some distinct topics that do not fit neatly into either science or mathematics but that include elements of one or both, in combination with other learning areas.

Conclusions from the study

Overall, in both Science and Mathematics and Statistics, if there was to be a full curriculum review in the future, a considered plan would need to allow adequate time and sector involvement, and include reliable up-to-date information about how teachers are currently enacting the existing curriculum.

These are the main conclusions relating to the Science learning area that we have drawn from this study.

- A lack of clarity obscures the extent to which the curriculum expectations might be appropriate.
- There is also a lack of visibility of detailed learning progressions in relation to big ideas.
- The role of appropriate learning contexts is critical and needs updating.
- More elaboration and up-to-date supports are needed for teachers to enact the Science learning area.

In the Mathematics and Statistics learning area, our main conclusions are as follows.

- There was general agreement, supported by achievement data, that the AOs at level 4 need adjustment, and the curriculum experts held diverse (although not necessarily incompatible) views about the best way to address this. Suggested approaches included strengthening teaching at earlier levels, and "smoothing out" the AOs at Level 4 by introducing some earlier and moving others to level 5.
- The AOs vary considerably in their grain size and need clarifying for teachers. At the same time as this detail being important, providing teachers with a set of over-arching "big ideas" could also support their understanding of learning progressions in mathematics and statistics.

- Consideration needs to be given to amplifying the capabilities/competencies within and across the content strands (e.g., drawing on the PISA 2021 framework's definition of mathematical literacy and the mathematical processes described in *Mathematics in the New Zealand Curriculum,* 2007).
- The statistics strand was generally seen as a strength by the curriculum experts and teachers.

Should levelling studies be carried out for other learning areas?

There is no straightforward way to answer this question. The issues that arose in the Mathematics and Statistics, and Science learning areas were so different that it is not possible to make any generalisations on the basis of this sample. If anything, the overall findings suggest we should not second-guess what could come up in other learning areas and the only way to find out is to repeat the exercise for each of them.

On the other hand, studies such as this are resource-intensive and should be expected to return value in the form of new insights. Despite the surprising nature of some of our findings (particularly in relation to science), we did find similarities that suggest the same types of issues might be anticipated in other learning areas, even if the specific details differ across them. For example, the lack of clarity of levelling signals provided by many AOs suggests that similar issues could well apply across the curriculum.

There is one source of empirical evidence from the overall NMSSA programme that could be useful for making a decision about whether or not to focus on additional learning areas. This study was prompted in part by the pattern of strong achievement at curriculum level 2 and marked underachievement at curriculum level 4. We have reported on a complexity of interacting reasons for this pattern in Science and Mathematics and Statistics and they are a unique mix of factors in each learning area. If there are similarly problematic NMSSA achievement patterns in other learning areas, it seems reasonable to assume that it would be worth repeating this exercise in those contexts. With this reasoning in mind, the table below shows level 2 and 4 achievement patterns across the learning areas, ranked by the size of the overall achievement difference at level 2 and level 4.

Table 2 **Percentage of students in NMSSA assessments achieving at or above expected curriculum levels across the curriculum for Year 4 and Year 8**

Learning area/year assessed	% at L2 in Year 4	% at L4 in Year 8	Difference %
Science 2017	94	20	74
Health and PE 2013	97	51	46
Mathematics and Statistics 2013	84	41	43
English: Writing 2012	65	35	30
Social Studies 2014	63	38	23
English: Viewing 2015	77	63	14
English: Listening 2015	79	70	9
The Arts 2015	72	63	9

This analysis clearly demonstrates the nature of the problem in Science and Mathematics and Statistics but also suggests that Health and Physical Education might be worthwhile to explore next, if another learning area is to be addressed.

Strategically important topics that cross learning areas

Several strategically important topics arose which include learning areas additional to Science or Mathematics and Statistics. These topics were financial literacy, computational thinking, and a socio-scientific issue. This discussion sits outside levelling considerations per se but could have implications for ongoing curriculum decisions. For this reason, we include them here.

The Mathematics and Statistics expert group and one of the teacher focus groups raised the question of where financial literacy should fit in *NZC*, with some thinking it should have a strong presence in this learning area. However, others argued that it is broader in scope and involves other learning areas such as Social Sciences. The same is true of computational thinking, which currently sits in the digital technologies learning area but has a strong mathematical thinking component. In both the primary and secondary science focus groups, teachers raised the issue of climate change. Not only does it cross the various science disciplines, but it too has social science dimensions.

How to treat these sorts of topics is not a levelling challenge per se, but it does draw attention to some tricky questions that might need to be considered when thinking about levels.

- These are topics where real-world contexts are integral to learning. What impact do such contexts have on expectations at different curriculum levels? (Recall that the teachers thought that accessible contexts made it possible to expect more of young children's mathematical thinking and the same point was made by the primary science focus group.)

- Are expectations consistent across the same level of different learning areas? How would we know?

There is clearly more work that could be done in addressing these and the other questions raised by this study. However, if we were to select just one clear plea from the focus group teachers in both subjects and at primary and secondary levels, it would be to invest more in producing resources that model curriculum expectations at the different levels, and provide the professional learning opportunities that support teachers to make good use of such resources.

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Appendix 1: EU Big ideas vs *NZC* science

Table 3 **Comparison of conceptual big ideas and *NZC* contextual strand achievement aims for science**

Big ideas (European)	**Achievement aims from *NZC* (closest match)**
All matter in the universe is made of very small particles	Interpret their observations in terms of particles (atoms, molecules, ions and sub-atomic particles), structures, and interactions present (**Material World**, the structure of matter substrand)
Objects can affect other objects at a distance	Gain an understanding of the interactions that take place between different parts of the physical world and the ways in which these interactions can be represented (**Physical World**, physical concepts sustrand)
Changing the movement of an object requires a net force to be acting on it	
The total amount of energy in the Universe is always the same but can be transferred from one energy store to another during an event	
The composition of the Earth and its atmosphere and the processes occurring within them shape the Earth's surface and its climate	Investigate and understand the spheres of the Earth system: geosphere [land], hydrosphere [water], atmosphere [air], and biosphere [life] (**Planet Earth and Beyond**, Earth systems substrand) Investigate and understand that the geosphere, hydrosphere, atmosphere, and biosphere are connected via a complex web of processes (**Planet Earth and Beyond**, interacting systems substrand)
Our solar system is a very small part of one of billions of galaxies in the universe	Investigate and understand relationships between the Earth, Moon, Sun, solar system and other systems in the universe (**Planet Earth and Beyond,** astronomical systems substrand)
Organisms are organised on a cellular basis and have a finite life span	Understand the processes of life ~~and appreciate the diversity of living things~~ (**Living World**, life processes substrand)

<table>
<tr><td>Organisms require a supply of energy and materials for which they often depend on, or complete with, other organisms</td><td>Understand how living things interact with each other and with the non-living environment (Living World, ecology substrand)</td></tr>
<tr><td>Genetic information is passed down from one generation of organisms to another</td><td rowspan="2"><s>Understand the processes of life and</s> appreciate the diversity of living things (Living World, life processes substrand)

Understand the processes that drive change in groups of living things over long periods of time and be able to discuss the implications of these changes (Living World, evolution substrand)</td></tr>
<tr><td>The diversity of organisms, living and extinct, is the result of evolution</td></tr>
</table>

Three *NZC* achievement aims from the contextual strands cannot be readily matched to big ideas in science, and two more find a closer match to big ideas about science (see Table 4 below). Those that do not match are as follows.

- Explore and investigate physical phenomena in everyday situations (**Physical World**, physical inquiry and physics concepts substrand)
- Understand and use fundamental concepts of chemistry (**Material World**, structure of matter substrand)
- Investigate the properties of materials (**Material World**, properties and changes of matter substrand).

These achievement aims are not about conceptual ideas per se, but rather about how students come to encounter science knowledge—i.e., they essentially provide *pedagogical signals* about how concepts should be developed. Note also the overlap of two of the Planet Earth and Beyond achievement aims and that that the Living Wold achievement aims required some reorganisation to match more closely to the EU big ideas. These adjustments reflect differences between the organisation of ideas into a coherent narrative and the organisation of ideas into traditional disciplinary silos.

Table 4 **Big ideas about science as a knowledge system vs *NZC* NOS achievement aims**

Big ideas (European)	**Achievement aims from *NZC* (closest match)**
Science is about finding the cause or causes of phenomena in the natural world	
Scientific explanations, theories and models are those that best fit the evidence available at a particular time	Learn about science as a knowledge system: the features of scientific knowledge and the processes by which it is developed~~ and learn about the ways in which the work of scientists interacts with society~~ (**Understanding about Science**, NoS substrand)
The knowledge produced by science is used in engineering and technologies to create products to serve human ends	~~Learn about science as a knowledge system: the features of scientific knowledge and the processes by which it is developed~~ and learn about the ways in which the work of scientists interacts with society (**Understanding about Science**, NoS substrand) Make connections between the concepts of chemistry and their applications and show an understanding of the role chemistry plays in the world around them (**Material World**, chemistry and society substrand) Apply their understanding of physics to various applications (**Physical World**, using physics substrand)
Applications of science often have ethical, social, economic and political implications	Bring a scientific perspective to decisions and actions as appropriate (**Participating and contributing**, NoS substrand)

The first of the EU ideas cannot be directly matched to an achievement aim but it is addressed in the Science essence statement in the front part of *NZC*. Again, we needed to do some reorganisation of the achievement aims to more clearly match them *as ideas* to the EU set.

The big idea about the application of science to technology and engineering matches *three* achievement aims, including one each from the Material World and Physical World strands of the curriculum.

Two *NZC* achievement aims are not addressed by any of the EU set of ideas about science.

- Carry out scientific investigations using a variety of approaches: classifying and identifying, pattern seeking, exploring, investigating models, fair testing, making things, or developing systems. (Investigating in Science, NoS substrand)
- Develop knowledge of the vocabulary, numeric and symbol systems, and conventions of science and use this knowledge to communicate about their own and others' ideas. (Communicating in science, NoS substrand).

This first of these is essentially pedagogical rather than conceptual. The second, with its emphasis on *meaning-making* in science, seems to be an important omission from the EU set.

Appendix 2: What can the PaCT tell us about the difficulty associated with the Mathematics and Statistics Learning area?

Introduction

The PaCT scale has been benchmarked against the mathematics and statistics learning area of the New Zealand Curriculum (NZC). This allows the PaCT to report a 'best-fit' curriculum level associated with scoring at different parts of the PaCT scale.

This document provides background information about the relationship of the PaCT curriculum levels and national 'norms'.

Achievement against the curriculum

In 2018, NZCER used data stored in the PaCT to calculate national distributions of achievement based on PaCT judgments. For Years 4 to 8, the data involved judgments tagged as 'end-of-year' judgments. For Years 1 to 3 the data involved 'anniversary' judgments (completion of one, two or three years at school). The 'average' date associated with the anniversary judgments was early September[16]. The analysis made use of all appropriate judgments recorded since the PaCT was first released for use by schools.

Over 21,000 completed judgments from 228 schools were available for analysis. Table 5 shows the number of schools with data by year level and decile group.

Table 5 **Number of schools with PaCT mathematics data by year level and decile group**

Decile group	School counts								
	Year level 1	**Year level 2**	**Year level 3**	**Year level 4**	**Year level 5**	**Year level 6**	**Year level 7**	**Year level 8**	**All year levels**
Deciles 1, 2 or 3	27	33	30	25	23	22	24	21	**59**
Deciles 4, 5, 6, or 7	56	64	56	45	50	47	38	36	**101**
Deciles 8, 9, or 10	32	47	45	31	34	27	25	22	**68**
All deciles	**115**	**144**	**131**	**101**	**107**	**96**	**87**	**79**	**228**

[16] There were not enough anniversary judgments recorded at the end of the year to conduct an 'end-of-year' analysis.

To ensure the data was as nationally representative as possible, a resampling method was used to construct a data set for the analysis. This ensured that the proportion of students representing each decile matched the appropriate national proportion. The updated data set was used to construct end-of-year score distributions. Table 6 shows the mean and standard deviation at each year level. Figure 1 plots the distributions by year level against the PaCT scale.

Table 6 **Means and standard deviation of PaCT Mathematics scale scores by year level in the synthetic PaCT Mathematics data**

Statistic	Year level 1	Year level 2	Year level 3	Year level 4	Year level 5	Year level 6	Year level 7	Year level 8
Mean	329	394	485	568	626	692	724	784
Standard deviation	65	76	81	76	64	77	93	112

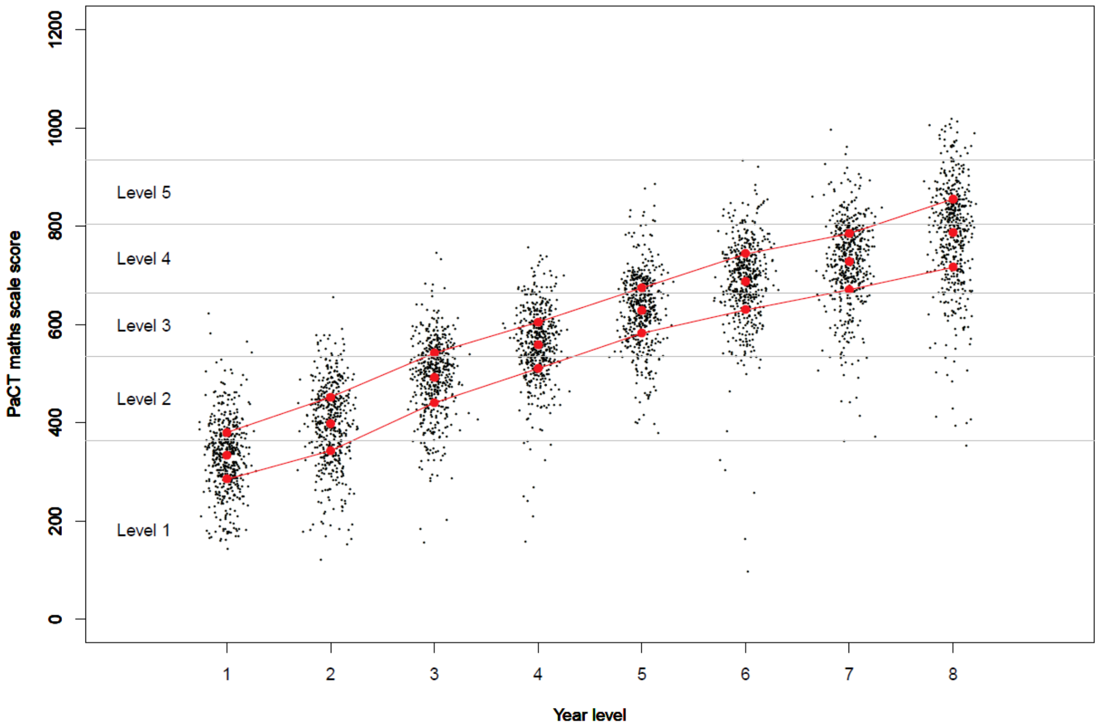

Figure 1 **Distributions of PaCT Mathematics achievement highlighting the 25th and 75th achievement percentiles**

Table 7 shows the estimated percentage of students in Year 1 to 8 working within each curriculum level. The highlighted cells indicate where students are meeting or exceeding curriculum expectations for the year level.

Table 7 **Estimated percentages of students in each year level working within each curriculum level for mathematics, based on PaCT Mathematics achievement**

Curriculum level	Year level 1	Year level 2	Year level 3	Year level 4	Year level 5	Year level 6	Year level 7	Year level 8
Above curriculum level 5	0%	0%	0%	0%	0%	0%	1%	9%
Curriculum level 5	0%	0%	0%	0%	0%	7%	18%	34%
Curriculum level 4	0%	0%	1%	11%	28%	57%	55%	43%
Curriculum level 3	0%	3%	26%	56%	65%	33%	24%	13%
Curriculum level 2	30%	62%	66%	33%	8%	2%	2%	1%
Curriculum level 1	70%	34%	7%	0%	0%	0%	0%	0%

The relationship between PaCT and other assessments tools

During the PaCT trials, a number of students were assessed with the PaCT and then separately assessed using either e-asTTle or PAT: Mathematics. Figures 2 and 3 use scatter-plots to show the relationship between scores on PaCT and e-asTTle, and Pact and PAT: Mathematics respectively.

The graphics can be used to link scores on the PaCT with scores on e-asTTle and PAT. For instance, achieving Level 2 on PaCT, on average, involved scoring at ‘2A’ on e-asTTle (see Figure 2). Similarly, Level 2 on PaCT involved scoring at around the Year 4 (end of year) average score on PAT (see Figure 3).

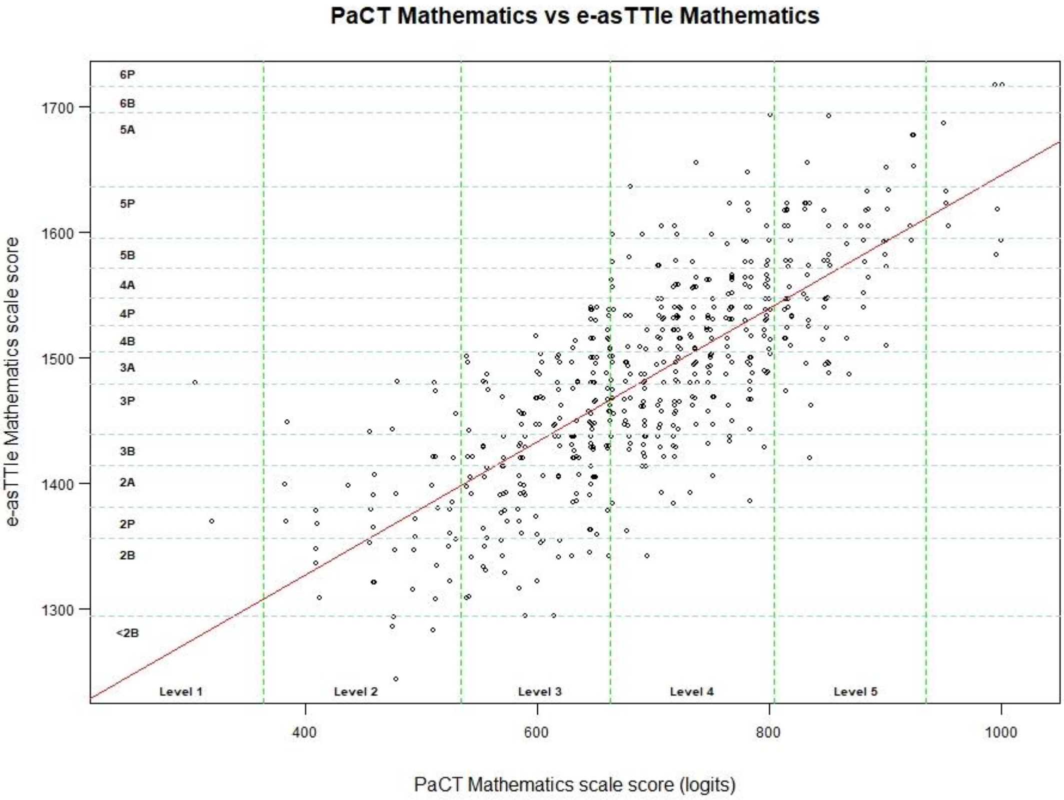

Figure 2 **PaCT Mathematics vs e-asTTle Mathematics**

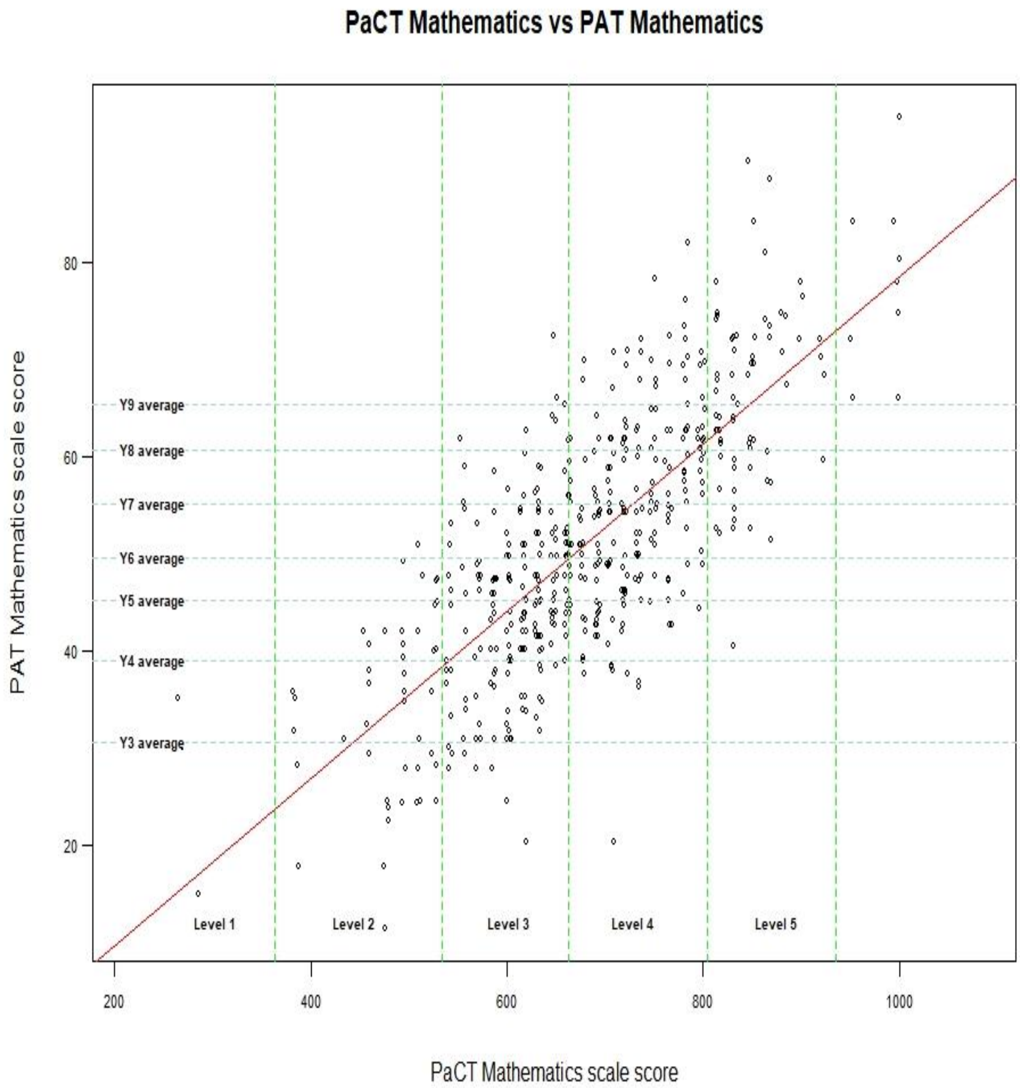

Figure 3 **PaCT Mathematics vs PAT Mathematics**

Further details of e-asTTle Norms and Curriculum Expectation by Quarter: Mathematics

Quarter	Year	Mean Score	Mean Curriculum Level	Curriculum Expectation
1	4	1358	2P	2P
2	4	1364	2P	2P
3	4	1375	2P	2P
4	4	1389	2A	2P
1	5	1400	2A	2P
2	5	1410	2A	2A
3	5	1420	3B	2A
4	5	1430	3B	3B
1	6	1441	3P	3B
2	6	1451	3P	3B
3	6	1460	3P	3P
4	6	1466	3P	3P
1	7	1472	3P	3P
2	7	1479	3A	3P
3	7	1489	3A	3A
4	7	1500	3A	4B
1	8	1512	4B	4B
2	8	1521	4B	4B
3	8	1529	4P	4P
4	8	1535	4P	4P
1	9	1540	4P	4P
2	9	1545	4P	4A
3	9	1554	4A	4A
4	9	1567	4A	5B
1	10	1579	5B	5B
2	10	1590	5B	5P
3	10	1593	5B	5A
4	10	1601	5P	5A
1	11	1608	5P	5A
2	11	1622	5P	5A
3	11	1636	5A	6B
4	11	1650	5A	6P
1	12	1664	5A	6P
2	12	1678	5A	6P
3	12	1692	5A	6A
4	12	1699	6B	6A

Further details of e-asTTle curriculum cut-scores

	Reading		Writing		Maths	
Level	**From**	**To**	**From**	**To**	**From**	**To**
1B	–	–	–	1231	–	–
1P	–	–	1232	1296	–	–
1A	–	–	1297	1360	–	–
<2B	–	1242	–	–	–	1293
2B	1243	1293	1361	1403	1294	1355
2P	1294	1346	1404	1446	1356	1380
2A	1347	1375	1447	1489	1381	1413
3B	1376	1397	1490	1522	1414	1438
3P	1398	1423	1523	1554	1439	1478
3A	1424	1445	1555	1587	1479	1504
4B	1446	1469	1588	1623	1505	1525
4P	1470	1501	1624	1659	1526	1547
4A	1502	1555	1660	1695	1548	1570
5B	1556	1586	1696	1738	1571	1594
5P	1587	1617	1739	1781	1595	1635
5A	1618	1641	1782	1825	1636	1694
6B	1642	1679	1826	1868	1695	1715
6P	1680	1702	1869	–	1716	1738
6A	1703	1733	–	–	1739	1768
>6A	1734	–	–	–	1769	–