MINISTRY OF EDUCATION
TE TĀHUHU O TE MĀTAURANGA

# Progress and achievement and the context of mathematics and statistics learning in New Zealand (English-medium education)

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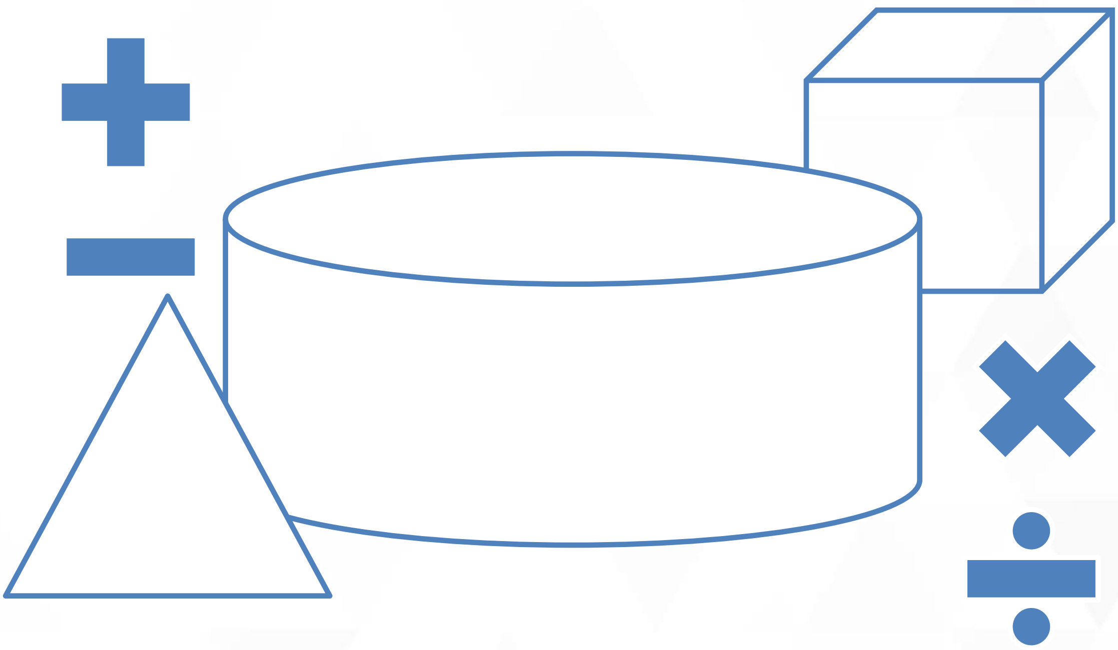

New Zealand Government

# Contents

# Executive Summary

## Introduction

Mathematics and statistics play an important role in our everyday lives, allowing us to make sense of the world around us and to manage our lives. This paper has been developed to provide an overview of the latest key findings across a range of large national and international sources. These findings give us a broad picture of student achievement and progress in mathematics and statistics learning in English-medium early learning and schools. It also presents information from these studies about teachers' knowledge and experiences and common practices in teaching mathematics and statistics. Throughout the paper when we use the term mathematics we are often referring to mathematics and statistics.

### Data sources

This paper draws primarily on national sources to provide information about students' achievement and progress in mathematics, from an Aotearoa New Zealand context. References are at the end of this paper. These sources included:

- ***Growing Up in New Zealand (GUiNZ)*** study at age 4.5
- ***National Monitoring Study of Student Achievement (NMSSA)***, conducted with Year 4 and Year 8 students, their teachers, and their schools
- ***The electronic assessment tool for teaching and learning (e-asTTle)***, developed primarily for learners in Years 5 to 10, and
- Data from the ***National Certificate of Educational Achievement (NCEA)*** for secondary students.

We've also included international sources to give us a view on the characteristics and performance of our system against the systems of other countries. These international sources were:

- ***Trends in International Mathematics and Science Study (TIMSS)***, conducted with Year 5 and Year 9 students, their teachers, and their schools
- ***Programme for International Student Assessment (PISA)***, conducted with 15-year-old students.

### Scope and limitations

There was limited data and research available on mathematics education in early childhood and in the beginning school years. More information is available from middle primary years onwards but is still limited in scope. More research is needed for the early years and about what happens in classrooms from middle primary onwards.

Data on differences across population groups has been included in this paper. However, much of the evidence represents associations and does not constitute causations. The paper does not present much evidence that considered the intersection between various home, school, and classroom factors. Further research is currently underway to explore the role of wider social context in students' academic outcomes.

Finally, further research about mathematics and pāngarau teaching and learning would also be useful to understand what works for learners and teachers in kura.

## Summary of findings

### Overall

In general, many of our learners perform well against national and international benchmarks of mathematics achievement. Many are making good progress at an expected pace throughout year levels. However, the range of achievement in maths at each year level is wide and many students are achieving lower than either expected or desired. There is also a significant variation in the amount of measured progress students make over a school year. Evidence about mathematics lessons suggests that many children and young people are not getting an opportunity to learn all the material that would help them succeed.

The wide variation in achievement was also found within the ethnic groupings and socio-economic categories as well as special education needs learners, with advanced achievers and very low achievers in all groupings. The analysis shows there is further work to be done to close the gaps.

Positive attitudes towards learning maths are commonly associated with higher achievement. Data indicates that many students, particularly those in primary schools, enjoyed learning maths and secondary students valued learning maths. Many of them also felt confident in their mathematical abilities. However, on a global scale, there were more New Zealand students who were negative about maths than their international counterparts.

Teachers' confidence and preparation, along with their teaching methods, have an impact on students' opportunity to learn and academic outcomes in mathematics. Most primary teachers enjoyed teaching maths, but many lacked the mathematical ability to teach Year 7 and 8 students and expressed negative views towards doing mathematics, though this didn't necessarily negatively impact their attitude to teaching maths.

Many New Zealand students reported teachers were clear and easy to understand in mathematics lessons. However, the methods and strategies used by teachers in lessons varied greatly across New Zealand classrooms.

### Achievement

- Commonly, children aged 4.5 can count to 10, but find it harder to count backwards from 10. Fewer children from poor homes demonstrated these counting skills.
- The mathematics achievement of Year 5 students is relatively low internationally, but that of secondary students is about the middle internationally (compared to international averages). Note that mathematical literacy of 15-year-olds in PISA appeared to be slightly better than the maths achievement of Year 9 students in TIMSS (based on relative rankings).
- There were a lot of New Zealand students who did well both in an international and national context. However, there was also a relatively large proportion of lower achievers and a relatively wide range of achievement compared with other countries, though this was around the middle compared to other countries at the lower secondary level (from both TIMSS and PISA).
- Fewer students meet curriculum expectations in the latter years of primary schooling compared with the earlier years, though a significant proportion don't meet them in the earlier years. Few students are working at the appropriate curriculum level in lower secondary school.
- In recent years, there hasn't been much change in mathematics achievement at the middle primary level, but a decrease in average achievement at the lower secondary level. There have also been some increases in the proportions of lower achievers over the past 20 years.
- Many learners achieve at least some level of mathematical credential prior to leaving school. Changes over time in NCEA reflect changes in standards and there is large variation in the proportions of students sitting each standard.

### Achievement among different groupings of students

- In many analyses, there is no difference between girls' and boys' average mathematics achievement and progress, though some studies show boys scoring higher on average.
- Although there were high and low achievers in all groupings, learners in homes with many economic resources had higher average achievement than those in homes with fewer economic resources. The gap between learners in economically affluent schools and those in economically disadvantaged schools was large compared with other countries.
- Some of the difference between different ethnic groupings can be explained by socio-economic status. Evidence shows that ethnic grouping and socio-economic status need not determine outcomes of education. One piece of evidence that supports this is that year-to-year progress is the same across different deciles and ethnic groupings.
- Many students identified by their schools as having special education needs achieved at or above curriculum expectations but there is still work to do to help many of these learners succeed.

### Student confidence and interest

- International evidence suggests mathematics anxiety starts before school.
- Generally primary students liked learning mathematics, and many felt confident in their mathematics abilities. However, older children and young people were less positive than younger children. More New Zealand students were negative about maths than their international counterparts, but lower secondary students valued mathematics learning more.
- Liking maths, being confident in doing maths, and valuing maths were all associated with higher achievement in maths. But confidence was more strongly associated with achievement than liking or valuing, particularly for older learners.
- More boys were confident in their maths ability than girls. There was no consistent pattern when confidence and attitude to maths were examined for each ethnic grouping. For all ethnic groupings, students who had more confidence tended to have higher achievement but there was no consistent pattern for other attitudes.
- Year 4 and Year 8 students with special education needs liked learning mathematics less, and felt less confident in their ability to do maths, than those with no special education needs
- Learners' mathematics self-concept has been shown to be negatively impacted by socialisation of stereotypical gender beliefs, social comparison, and the impact of teachers

### Teachers' confidence and preparation

- International evidence shows that many early childhood teachers have low levels of confidence in their mathematical ability.
- Few primary teachers had specialised in mathematics or mathematics teaching. More secondary mathematics teachers had a maths specialisation, but over a third of maths teachers did not (and this latter proportion was high compared to other countries).
- Some principals felt that student instruction was hindered by a lack of teachers with a specialisation in mathematics, and this was borne out in the achievement data.
- Primary teachers felt better prepared to teach some topics than others and this appeared to impact students' opportunity to learn and outcomes. Some Year 9 teachers also expressed feelings of being unprepared, even though they were more likely to have a mathematics specialisation. Again, at the Year 9 level, teacher preparedness appeared to impact opportunity to learn. This lack of opportunity to learn was confirmed by 15-year-olds in PISA.
- Most primary teachers liked teaching maths, but many primary teacher trainees could not correctly do the maths they needed to be able to teach to Year 7 and 8 students and many

expressed negative views towards doing mathematics. However, being negative about doing mathematics didn't necessarily negatively impact their attitude towards teaching maths.

- New Zealand teachers had high levels of professional development compared with other countries though fewer teachers experienced these opportunities in 2018 than in 2014.

### Teaching

- Maths learnt in ECE has positive impacts on academic outcomes further down the track. Teaching mathematics can be either a deliberate action or based on finding teachable moments in ECE settings – a balance of the two is recommended. Research has shown even very young children have the potential to engage with mathematical thinking but often don't get the appropriate opportunities. In the early childhood years, learning happens at home and home activities in partnership with ECE services was shown to be effective.
- Many New Zealand students reported teachers were clear and easy to understand in mathematics lessons, but the proportions were lower than their international peers. Greater clarity of instruction and better student-teacher relationships were associated with higher achievement
- Instructional techniques and activities differed between middle primary and lower secondary teachers. New Zealand teachers were less likely to explain things to students or ask them to memorise things compared to their international peers. Some teachers had students explain solutions regularly. Setting challenging activities for students was not as common
- Compared with other countries, more New Zealand primary teachers use same ability grouping regularly for mathematics instruction, though this use had decreased since 2014, while the use of mixed ability had increased. Regular use of same ability grouping has been associated with lower achievement, but mixed ability grouping has the potential to increase learners' self-concept and achievement.
- Computer availability for maths lessons was higher in New Zealand than in other countries and they used computers for practising maths and to support learning. Calculators were not used as much as computers.
- Assessment methods teachers used in middle primary classes differed from both their international peers and their lower secondary counterparts. Around one-quarter of schools were found to use achievement information well at the upper primary level and few schools were found to be highly effective at gathering and using achievement information at the lower secondary level to improve practice.

## Curriculum

Te Whāriki[1] is the curriculum for the early learning sector. Under the strand of communication, it sets an expectation that children will '[recognise] mathematical symbols and concepts and [use] them with enjoyment, meaning and purpose'. Expanding this, it includes familiarity with numbers and their uses and describing patterns and relationships related to quantity, number, measurement, shape and space. Under the strand of exploration, opportunities for mathematics context occur in exploring, puzzling over and making sense of the world, using such strategies as setting and solving problems, looking for patterns, classifying, guessing, using trial and error, observing, planning, comparing, and explaining.

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[1] Ministry of Education. (2017). Te Whāriki. Retrieved from https://tewhariki.tki.org.nz/en/te-whariki-foundations/early-childhood-curriculum-document/

The New Zealand Curriculum[2] is the curriculum for the schooling sector. It has the learning area *mathematics and statistics*, bringing to the foreground the discipline of statistics, indicating that it is different but as important as the discipline of mathematics. Within New Zealand, when we talk about mathematics, we are usually incorporating statistical ways of thinking. Mathematics includes the areas of number, algebra, geometry, measurement, and in later years, calculus.

[2] Ministry of Education. (2015). The New Zealand Curriculum. Retrieved from https://nzcurriculum.tki.org.nz/The-New-Zealand-Curriculum

# Progress and Achievement

## Early learning (at home and at a service)

### Commonly, children aged 4.5 can count to 10, but find it harder to count backwards from 10

There are very few studies that assess mathematics progress and achievement of learners before they begin school. The Growing Up in New Zealand study (GUiNZ) includes counting skills in its assessment.[3] About three-quarters of children (78%) aged 4.5 could count up all the way to 10 correctly, but fewer could count down and about a quarter (27%) could not count down correctly at all[4]. English was not the first language for the children or their parents[5].

### Children from poorer homes were less likely to demonstrate these counting skills

While many children across all deprivation groups could count up from 1 to 10 correctly, children living in homes with a higher level of economic deprivation were less likely to complete the task (66%) than children in homes with the lower economic deprivation (88%). Māori and Pacific Island children were over-represented among homes with a high level of economic deprivation[6].

## Primary schooling

### The mathematics achievement of Year 5 students is relatively low internationally

The average maths achievement of New Zealand Year 5 students in TIMSS in 2018 was relatively low compared to the other 58 countries who participated. Although the mean achievement was significantly higher than 15 countries, it was lower than 38 countries, including all the other predominantly English- speaking countries, Asian countries and most European countries who participated at the middle primary level.

### There are a lot of New Zealand students who do well but also a relatively large proportion of lower achievers and a relatively wide range of achievement compared with other countries

One-quarter of New Zealand Year 5 learners (25%) were considered high performers in an international context in TIMSS, meaning they could apply their knowledge and understanding to solve problems. However, seventeen percent of Year 5 learners did not demonstrate the ability to reach the low benchmark, meaning they didn't demonstrate much of what was considered to be basic mathematical knowledge (correctly completed less than half of the low benchmark questions).

Compared with other countries, New Zealand was around the middle when considering the proportion of advanced performers (6% in NZ and 7% on average internationally), but had a high proportion of lower performers (17% in NZ compared with 8% on average internationally). High performing countries, Singapore, Hong Kong Special Administrative Region (SAR), the Republic of

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[3] https://www.educationcounts.govt.nz/__data/assets/pdf_file/0011/195185/He-Whakaaro-What-developmental-resources-do-our-pre-schoolers-have.pdf

[4] Counting down helps demonstrate that the children have a sense of the ordinal nature of numbers and is a potential indicator that they haven't just learnt the numbers by rote but also understanding the meaning of the numbers.

[5] English was spoken by almost all the children (99%), followed by te reo Māori (10%), Samoan (5%), Tongan (4%), Mandarin (3%), and Hindi (3%);

[6] For example, almost 10% of Māori children and over 10% of Pacific children experienced severe material hardship. See Figure 50 page 77 of the Now We Are Eight report from the GUiNZ study https://www.growingup.co.nz/sites/growingup.co.nz/files/documents/GUINZ_Now_We_Are_8_ONLINE.pdf

Korea (South Korea), and Chinese Taipei, had more than one-third of their middle primary students classified as advanced performers, and one percent or fewer classified as below low performers.

The range of achievement among New Zealand learners was also relatively wide and wider than nearly all countries with higher achievement than New Zealand (the one exception was Turkey).

### In recent years, there hasn't been much change in mathematics achievement, although the range has widened over time

After showing an increase in achievement through the 90s, there was a significant decrease in average mathematics achievement between 2002 and 2011[7]. While the 2014 achievement appeared to signal a turnaround of the downward trend, the 2018 mean achievement, while not statistically different from the achievement from 2006, 2011 or 2014, was significantly lower than in 2002. The mean achievement of Year 5 students in 2018 was significantly higher than in the first cycle in 1994.

The proportions of Year 5 students reaching each TIMSS classification benchmark (low, intermediate, high, and advanced) in 2018 was higher than in 1994. However, compared with 2002/03 (the TIMSS cycle with the best results), fewer achieved at or above the low and intermediate benchmarks (83% and 56% respectively compared with 86% and 62% in 2002). The range in achievement, measured by percentiles, has also increased since 2002.

### Fewer students meet curriculum expectations in the latter years of primary schooling compared with the earlier years, though a significant proportion don't meet them in the earlier years

To be able to meet curriculum expectations, learners need to be exposed to teaching and learning at the appropriate level. New Zealand teachers were asked in TIMSS at which level(s) of Mathematics and Statistics in the New Zealand Curriculum most of their Year 5 students were working for each of the strands: number and algebra, geometry and measurement, and statistics. The proportion of students working at Level 3 of the curriculum varied across strands and many classes were working across levels of the curriculum. Less than a third of students were in classes where the majority of students were working at Level 3 of the curriculum (29% on the number and algebra strand, 26% on geometry and measurement, and 25% on statistics). Nearly two-thirds of the classes were working across levels 2 and 3 (61% on number and algebra, 65% on geometry and measurement, and 64% on statistics).

In terms of outcomes, NMSSA showed that 81 percent of students in Year 4 and 45 percent of students in Year 8 achieved at or above curriculum expectations (Levels 2 and 4 respectively). Given that TIMSS shows that by Year 5 many classes are still working with some material at Level 2 of the curriculum, despite most Year students achieving at or above Level 2, there may be indications that students are not being given challenging enough material in Year 5.

In TIMSS, the intermediate benchmark is considered the desired minimum expectation for Grade 4 or, in New Zealand's case, Year 5 students. While the description of this benchmark aligns well with Level 3 of our curriculum, Level 3 is expected to be covered over Years 5 and 6, so not all students will have had the opportunity to learn all concepts. Nevertheless, just over half (56%) of Year 5 students achieved at or above the TIMSS intermediate benchmark.

e-asTTle showed that average (mean) mathematics achievement for students at Years 4 to 6 align with the expectations set by the New Zealand Curriculum but for later years the average achievement is lower than the level expected by the New Zealand Curriculum. Close to a third of students at the end of Year 8 are achieving scores lower than the expected level. Mean annual progress decreases as students move from Year 4 to Year 10.

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[7] Note that the 2011 study was conducted out of the 4-year sequence to reduce the pressure on primary schools who were being asked to conduct PIRLS in 2010.

All of these studies demonstrated that there is a large spread of achievement at each year level. e-asTTle showed there is also a wide variation in the amount of measured progress students make over a school year, with some students progressing a whole curriculum level while others show no progress.

## Secondary schooling

### The mathematics achievement of secondary students is about the middle internationally (compared to international averages) though better in PISA than in TIMSS

The average maths achievement of New Zealand Year 9 students in TIMSS in 2019 was in the middle grouping compared to the other 39 countries who participated, though lower than the scale centre-point (482 in NZ c.f. the centre-point of 500). The mean achievement was significantly higher than 14 countries and lower than 20 countries, including all the other predominantly English-speaking countries who participated at the lower secondary level.

In PISA 2018, the average maths achievement was significantly above the OECD average (but only by 5 scale score points) and similar to nine other countries. Average maths achievement was also above 50 countries but significantly below 19 countries (75 scale score points lower than Singapore for example).

Comparing TIMSS and PISA rankings is complicated. TIMSS is a grade-based study, while PISA is an age-based study. Countries in TIMSS test students who are, on average, the same age or older than New Zealand students; some would have had about the same number of years of formal schooling (though some have had fewer years of formal schooling). However, in PISA, New Zealand students have had more years of schooling that students in most other countries (who start in the academic year they turn 6 or 7 rather than on their 5$^{th}$ birthday).

### The range of achievement in New Zealand at lower secondary level was around the middle compared with other countries

Compared with other countries, New Zealand was around the middle when considering the proportion of advanced performers in TIMSS at Year 9 (6% in NZ and 5% on average internationally). At this level, students can apply their understanding and knowledge in a variety of relatively complex situations and explain their reasoning. However, 18 percent of Year 9 learners (13% on average internationally) did not demonstrate the ability to reach the low benchmark, meaning they didn’t demonstrate some knowledge of whole numbers and basic graphs (technically they correctly completed less than half of the low benchmark questions – easier questions).

High-performing countries in TIMSS, Singapore, Chinese Taipei, the Republic of Korea (South Korea), and Japan had more than one-third of their lower secondary students classified as advanced performers, and three percent or fewer classified below the low benchmark.

In PISA, the proportion of high-performing New Zealand 15-year-old students (12%) who were at Level 5 or above was similar to the OECD average (11%). Students at Level 5 and above are capable of advanced mathematical thinking and reasoning. In PISA there was a significant proportion of learners who did not demonstrate the competencies that were considered necessary to enable them to participate actively in life situations which require mathematical skills. Within New Zealand this proportion was 22 percent, which was similar to the OECD average (24%).

### In recent years, there has been a decline in mathematics achievement and increases in lower achievers

In TIMSS 2019 there was a significant decrease in the achievement of Year 9 students, 11 score points lower than in 2014 and 19 score points lower than 1994. However, in PISA, there was a significant decrease in mathematics achievement between 2009 and 2012, though this average has remained stable since then (2015 and 2018).

The proportions of Year 9 students reaching each benchmark classification in TIMSS in 2019, apart from the advanced benchmark, has declined since previous cycles. There has been a steady increase in lower achievers since 1994, with only 11 percent below the low benchmark in 1994, compared with 15 percent in 2014 and 18 percent in 2019. There was also a significant decrease in the proportion of intermediate and high achievers (from 64% and 28% respectively in 1994 to 53% and 22% respectively in 2019).

The distribution of students at each proficiency level in PISA in 2018 was the same as in 2015. The proportion of students who were below the baseline (proficiency level 2) for mathematics proficiency rose significantly from 15 percent in 2003 to 23 percent by 2012; this proportion has remained stable since and was 22 percent in 2018. This increase occurred at the same time as a reduction in the proportion of students who were high achievers (at or above proficiency level 5), from 21 percent in 2003 to 12 percent in 2018.

### Few students are working at the appropriate curriculum level in lower secondary school

As mentioned in the primary section of this paper, to be able to meet curriculum expectations, learners need to be exposed to teaching and learning at the appropriate level. New Zealand teachers were asked in TIMSS at which level(s) of Mathematics and Statistics in the New Zealand Curriculum most of their Year 9 students were working for each of the strands: number and algebra, geometry and measurement, and statistics. The proportion of students working at level 5 of the curriculum varied across strands, and many classes were working across levels of the curriculum. Less than one in ten students were in classes where the majority of students were working at level 5 of the curriculum. Around one third of the students were in classes working across levels 4 and 5, the rest (over half) were working at level 4 or lower.

As mentioned earlier, 45 percent of students in Year 8 achieved at or above curriculum expectations (level 4) in NMSSA. This could help explain why many Year 9 teachers were still working with students at level 4 of the curriculum.

e-asTTle showed that nearly half of students at the end of Year 10 are achieving scores lower than the level expected by the New Zealand Curriculum (44%).

All of these studies demonstrated that there is a large spread of achievement at each year level. e-asTTle showed there is also a wide variation in the amount of measured progress students make over a school year, with some students progressing a whole curriculum level while others show no progress.

### Many learners achieve at least some level of mathematical credential prior to leaving school

Under the current method[8] for gaining numeracy credits, 83 percent of learners in 2019 met the NCEA Level 1 Numeracy requirements, although only 69 percent attained 14 credits at Level 1 in mathematics and statistics. As is the pattern across all learning areas, fewer learners attain at least 14 credits at Levels 2 and 3 (43% and 27% respectively).

### Changes over time reflect changes in standards

There was a large drop in the proportion of learners attaining 14 credits in Level 1 mathematics between 2012 and 2014 (nearly 10 percentage points). This was due to a review of the standards that retired some of the low credit value standards; the proportions have been pretty stable since then.

[8] At the time of writing, in 2020, the method for gaining numeracy credits was under review. Data obtained from https://www.nzqa.govt.nz/assets/About-us/Publications/stats-reports/ncea-annual-report-2019.pdf

### There is large variation in the proportions of students sitting each standard[9]

Some standards are more ‘popular’ than others. In 2019, many more learners sat the internally assessed Level 1 credit ‘apply numeric reasoning in solving problems’ (52,274) compared with the externally assessed credit ‘apply geometric reasoning in solving problems’ (12,095) or the internally assessed credit ‘apply measurement in solving problems’ (20,022). Interestingly the popularity of those standards has changed over time with more students sitting the numeric reasoning standard in 2019 than in 2014 and fewer sitting the other two credits (though numeric reasoning was still the most popular)[10].

## Differences across population groups

### In many analyses, there is no difference between girls’ and boys’ average mathematics achievement and progress, though some studies show boys scoring higher on average

There were both high and low achieving girls and boys[11] across all studies.

Both TIMSS (both Year 5 and Year 9 except for the 2010/11 cycle for Year 9) and e-asTTle showed similar average mathematics achievement for boys and girls. In contrast in NMSSA and PISA the average mathematics achievement for boys was higher than for girls (with the exception of the 2009 cycle of PISA).

In contrast, proportionately more girls attained 14 credits in mathematics and statistics in NCEA at each level compared with boys in 2019. The difference in 2019 was about 5 percentage points at each level and has grown since 2009.

e-asTTle analyses found no difference in annual progress between boys and girls.

### Although there were high and low achievers in all groupings, learners in homes with many economic resources had higher average achievement than those in homes with fewer economic resources.

Regardless of the measure of socio-economic status and the study, there were high and low achievers in all population subgroups. All studies also showed that those who were more economically advantaged had higher mathematics achievement, on average, than those who were more economically disadvantaged.

TIMSS and PISA show that students in homes with many resources (including resources for learning)[12] had higher maths achievement, on average, than those whose homes had fewer resources. Similarly, at a school level, TIMSS, NMSSA, PISA and e-asTTle found that maths achievement was higher, on average, for students in schools with more affluent students than those in schools with more economically disadvantaged students.

Depending on the measure used, the difference between average mathematics achievement in schools in more economically advantaged communities and those in economically disadvantaged communities was at least one year of schooling (for example e-asTTle). NMSSA estimated the difference was more than two years of schooling[13].

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[9] Numbers retrieved from excel spreadsheets found at https://www.nzqa.govt.nz/studying-in-new-zealand/secondary-school-and-ncea/find-information-about-a-school/secondary-school-statistics/data-files-for-3/

[10] 2014 figures were numeric:34,970; geometric: 22,701; measurement: 14,757.

[11] At this age group there is only binary gender identification collected.

[12] For example, the resources Year 9 students in TIMSS were asked about were: internet connection, computer or tablet, study desk/table, own mobile phone, own room, bicycle, clothes dryer, dishwasher, heat pump or air conditioner, gaming systems, musical instruments, two or more bathrooms, television in own bedroom, boat.

[13] This estimate is based on actual progress, rather than expected progress.

NCEA shows a similar pattern, with more learners in higher decile schools attaining 14 credits in mathematics and statistics than in lower decile schools. The difference is most marked at NCEA Level 3 where only 15 percent of learners in decile 1 and 2 schools (combined) attained 14 credits in 2019 compared with 44 percent in decile 9 and 10 schools (combined).

### The gap between learners in economically affluent schools and those in economically disadvantaged schools was large compared with other countries

In TIMSS, the difference in maths achievement between New Zealand Year 5 students in economically advantaged and those in disadvantaged schools was higher than in nearly all other countries. At the Year 9 level the difference was higher than the international average, but there were several other countries with significantly higher differences.

In the most recent cycle of PISA, reading was the main domain and so they didn't perform this analysis with mathematics. But previous cycles of PISA have found the maths achievement difference between students with high levels of socio-economic advantage and those with low levels was large in New Zealand compared to other countries.

### Some of the difference between different ethnic groupings can be explained by socio-economic status

In all studies, there are high and low achievers in all ethnic groupings. We also know that experiences of racism, bias, and discrimination contribute to differences in achievement between ethnic groups. This is demonstrated by the finding that in all studies of mathematics Māori had lower average maths achievement than non-Māori and similarly, Pasifika students had lower average maths achievement than non-Pasifika. Analyses using TIMSS data show that this average achievement gap narrows markedly when the contribution of socio-economic factors is taken into account. That means that somewhere between a third and nearly a half of the differences can be explained by the differences in socio-economic status. Neither socio-economic status nor experiences of racist teaching practices are the fault or the responsibility of learners.

### Evidence shows that ethnic grouping and socio-economic status need not determine outcomes of education

There was a wide variation in maths achievement within ethnic groupings and socio-economic categories, with advanced achievers and very low achievers in all groupings. This demonstrates that ethnicity and socio-economic disadvantage doesn't necessarily determine the outcomes of education and effective teaching practices that reduce experiences of racism, bias and discrimination can have positive benefits.

### Year-to-year progress is the same across different deciles and ethnic groupings

e-asTTle found that students at higher decile schools have similar levels of annual progress on average to students at low decile schools in mathematics. Similarly, there was no clear systematic difference in progress for different ethnicity subgroups in mathematics. This similarity in progress was only among averages and some students were making little or no progress while others were making lots of progress. The authors of the e-asTTle report concluded that the differences in achievement by school decile and ethnicity observed reflect different starting points rather than differing progress.

### Many students identified by their schools as having special education needs achieved at or above curriculum expectations

Within the broad special education needs (SEN) category, there is a wide range of achievement and a wide range of learning needs including sensory needs (such as low vision, blind, or deaf), physical, social, emotional as well as behavioural difficulties. Many Year 4 SEN students achieved at or above curriculum level 2 (53%); some (10%) achieved at level 3 or level 4. As mentioned earlier, in NMSSA there were a significant proportion of learners who achieved lower than level 2 of the curriculum in Year 4. Among the SEN students, this was nearly half (47%). By Year 8, 12 percent achieved at or above curriculum expectations (curriculum level 4). Many (61%) achieved at level 3 and some (26%) were at or below level 2.

## Key takeaways about achievement

Lots of students are doing well in their mathematics progress and achievement, but lots are not. The proportion of students working and attaining at curriculum level reduces as they get older. There are indications that many students are doing enough to pass by the time they sit NCEA but there are still improvements that could be made here too. There are serious inequities observable in the data which will require concerted effort to reduce and eliminate. The trends over time generally do not show a positive picture, which adds to our concerns.

# Student confidence and interest

### International evidence suggests mathematics anxiety starts before school

Geist (2015) found that mathematics anxiety was present even in pre-school and first grade students. The research showed that teacher behaviour was a prime determinant of mathematics anxiety in children and teacher behaviour was affected by their own confidence and anxiety. In a New Zealand context, the Competent Children study found that early childhood education staff's interactions with children had impacts on mathematics learning throughout their schooling, even through to when they were 14 years old (Wylie and Hipkins, 2006).

### Generally primary students liked learning mathematics

Three quarters of New Zealand Year 5 students in TIMSS liked learning mathematics (index created from responses to 9 questions on enjoyment and liking – 40% very much like, 35% somewhat like, 25% do not like). A similar proportion of Year 4 students in NMSSA 'agree quite a lot' or 'totally agree' that they like learning maths at school (51% and 24% respectively).

### And many felt confident in their mathematics abilities

Findings from TIMSS show that while the majority of New Zealand Year 5 students felt confident in their mathematics abilities (20% very confident; 49% somewhat confident), almost one third (31%) were not confident. Using different questions, NMSSA found similar proportions of Year 4 learners felt confident in their maths ability (35% totally agree and 34% agree quite a lot that they are good at maths; 18% agree a little and 5% disagree; 8% didn't respond).

### But older children and young people were less positive than younger children

NMSSA found that students in Year 8 tended to be less positive about mathematics and, overall, expressed lower levels of confidence in mathematics than students in Year 4. For example, 51 percent of Year 4 students 'totally agree' 'I like learning maths at school', while only 33 percent of Year 8 students 'totally agree'. Similarly, 35 percent of Year 4 students 'totally agree' 'I am good at maths', while only 20 percent of Year 8 students totally agree.

In TIMSS, nearly half of New Zealand Year 9 students (47%) did not like learning mathematics (c.f. 25% of Year 5 students), and about the same proportion (45%) were not confident in mathematics (c.f. 31% of Year 5 students).

### More New Zealand students were negative about maths than their international counterparts

Compared to the TIMSS international average, more New Zealand Year 5 students were negative about mathematics (25% do not like c.f. 20% on average internationally). New Zealand had more 'not confident' and fewer 'very confident' Year 5 students in mathematics, compared with international averages (on average internationally 23% not confident c.f. 31% in NZ; on average internationally 32% very confident c.f. 20% in NZ).

New Zealand had similar proportions of not confident lower secondary students (45%) as the international average (44%); however, more New Zealand Year 9 students did not like learning mathematics (47%) than their peers internationally (41%).

### But they valued mathematics learning

Despite big proportions of students not liking and not being confident in mathematics, only 14 percent of Year 9 students did not value mathematics. New Zealand had slightly more lower secondary students who valued mathematics, compared to the international average (50% somewhat value, 37% strongly value c.f. 47% and 37% respectively internationally).

### Liking maths, being confident in doing maths, and valuing maths were all associated with higher achievement in maths

Students had higher mathematics achievement, on average, if they were confident in their mathematics ability, liked mathematics, or valued mathematics. This relationship held for TIMSS and NMSSA at both year levels in each study. PISA 2012 also found a similar relationship between confidence and maths achievement.

### But confidence was more strongly associated with achievement than liking or valuing, particularly for older learners

The mathematics achievement of Year 5 students had a stronger relationship with their confidence in mathematics (100 scale score points (SSP) difference between top and bottom of scale) than how much they liked learning mathematics (liking was far less predictive in NZ – only 34 SSP difference between top and bottom of scale).

NMSSA also found that overall, the relationship between confidence and achievement was stronger than the relationship between attitude and achievement. The relationship between confidence and achievement was stronger for Year 8 students than for Year 4 students.

Similarly, at the Year 9 level in TIMSS, the difference in mean mathematics achievement between the most positive and least positive students was larger with respect to confidence (124 SSP), than liking (68 SSP), or valuing (33 SSP).

Students need to experience success to be confident; therefore it is perhaps not surprising that achievement and confidence have a strong relationship.

### More boys felt confident in their maths ability than girls

TIMSS, NMSSA, and PISA 2012 found that proportionately more boys felt confident in their maths ability compared with girls. For example, at the Year 5 level, 35 percent of girls were not confident compared with 27 percent of boys. At the Year 9 level in TIMSS, in addition to being more confident, more boys liked maths and more valued maths compared with girls.

Confidence was more strongly associated with achievement for boys than for girls. For example, the difference between Year 5 boys who were very confident and those who were not confident (110 scale score points) was larger than the same difference for girls (89). Similarly, at the Year 9 level, the difference for boys was 128 compared with 118 for girls.

### There was no consistent pattern when confidence in and liking of maths were examined for each ethnic grouping

Across TIMSS and NMSSA, more Pacific learners than non-Pacific learners said that they liked mathematics. In NMSSA, at the Year 8 level, more Māori than non-Māori learners liked maths, but in TIMSS the relationship was the other way at Year 9. In the older age groups, more Asian learners liked maths than non-Asian, but the difference was smaller at the younger age groups. Fewer Pākehā/European learners liked maths in TIMSS and at Year 8 in NMSSA than non-Pākehā/European (on average they liked it the least of all the ethnic groupings).

However, there were few differences between ethnic groupings when it came to confidence. The only reported differences were at the Year 9 level in TIMSS and in PISA 2012 where more Asian students were confident in their maths ability compared to non-Asian.

### For all ethnic groupings, students who had more confidence tended to have higher achievement

Consistently across all ethnic groupings, those who were very confident, on average, had higher mathematics achievement than those who were not. Although the relationship was not as strong for liking maths it was still evident to some extent among all ethnic groupings.

### Year 4 and Year 8 students with special education needs liked learning mathematics less, and felt less confident in their ability to do maths, than those with no special education needs

Fewer students with special education needs (SEN) liked maths according to NMSSA and scored lower on the Attitude to Mathematics scale on average than those with no special education needs (by 4 scale score units at Year 4 and by 10 scale score units at Year 8). They were also less confident on average than those with no special education needs (at Year 4 by 5 scale score units and at Year 8, the difference was 10 scale score units).

### Learners' mathematics self-concept has been shown to be negatively impacted by socialisation of stereotypical gender beliefs, social comparison, and the impact of teachers

Given this relationship between student confidence and achievement, it is useful to consider what can positively influence this. Watson, Rubie-Davies, and Meissel (2019) identified three factors that have been shown to influence learners' mathematics self-concept: socialisation of stereotypical gender beliefs, social comparison, and the impact of teachers. By social comparison they mean comparing performance or attainment with that of peers and by the impact of teachers they mean teacher's expectations, beliefs and subsequent behaviours.

We have a reasonably large body of evidence now that shows some teachers have lower expectations for Māori and Pacific learners based on race. The following sections on teachers and teaching will discuss the impact of teaching on outcomes for learning.

## Key takeaways about student confidence and interest

There are many students who like maths, are confident in their ability and value maths. However, there are a significant proportion who don't like maths or are not confident in their mathematical ability. This is important because there is an association between achievement and attitudes. This is exemplified by research that shows the negative impact of stereotypical gender, ethnic, and socio-economic beliefs and social comparison.

# Teachers' confidence and preparation for teaching mathematics and statistics

### International evidence shows that many early childhood teachers have low levels of confidence in their mathematical ability

International evidence shows that many early childhood teachers have high maths anxiety, aren't confident in their ability to teach mathematics, aren't sure why they need to be able to teach maths, or elected to teach early childhood because they thought maths was not part of the curriculum (see for example Cohrssen and Tayler, 2016; Dunekacke et.al., 2016; Geist, 2015; Wenig, 2016).

### Few primary teachers had specialised in mathematics or mathematics teaching

Over three-quarters of New Zealand Year 5 students in TIMSS (79%) had teachers who had trained as primary teachers but did not have a specialisation in mathematics and only fourteen percent of Year 5 students had teachers who had specialised in mathematics.

Similar to TIMSS, NMSSA found few Year 4 or Year 8 teachers who had maths related qualifications or training, though if they did, they were slightly more likely to be teaching at the Year 8 level.

### More secondary mathematics teachers had a maths specialisation, but over a third of maths teachers did not (and this latter proportion was high compared to other countries).

Over one-third of Year 9 students in TIMSS had mathematics teachers who had specialised or majored in a subject other than mathematics (37%). Internationally, more of the lower secondary students had teachers with a specialisation in mathematics (on average 10% had a different specialisation).

Although they asked principals, rather than teachers directly, PISA found a similar proportion of teachers with a qualification in maths.

### Some principals felt that student instruction was hindered by a lack of teachers with a specialisation in mathematics

Both at the primary and secondary level, in both TIMSS and PISA, there were principals that reported that a shortage of teachers with a maths specialisation hindered learning.

In primary schools, almost one-third of students had principals that indicated this shortage hindered learning some or a lot (26% some and 4% a lot). In TIMSS at secondary schools, the proportion was just under one-fifth (9% some and 10% a lot). There has been a small increase in the proportion of students whose principals said that learning was hindered a lot by a shortage of maths teachers between 2014 and 2018/19 (7 percentage points at Year 5 and 2 at Year 9). In PISA 2012, 16 percent of principals reported that learning was hindered to some extent, and 5 percent reported that learning was hindered a lot, by a shortage of qualified maths teachers.

### And this was borne out in the achievement data

Students in New Zealand schools where PISA 2012 principals reported that instruction is hindered a lot by a shortage of qualified maths teachers scored 26 points lower than students in schools where instruction is not at all hindered by such shortage. The difference was not as large in TIMSS (3 scale score points at Year 9 and 4 at Year 5).

### Primary teachers felt better prepared to teach some topics than others

In 2014 teachers in TIMSS were asked about how well prepared they were to teach topics and whether those topics were covered in class. However, this first question was not continued in 2018/19. Rather a more general question about curriculum areas was included. Most Year 5 teachers in TIMSS 2014 felt very well prepared to teach adding, subtracting, multiplying, and/or dividing with whole numbers (94% of students). Topics like comparing and drawing angles (63% of students) and concepts of decimals, including place value and ordering, adding and subtracting with decimals (68% of students) had fewer teachers agreeing that they were very well prepared to teach them. In general, New Zealand Year 5 teachers felt better prepared to teach data display topics than number and geometric shapes and measures. However, when asked in 2018 about the topic areas in general, more teachers felt very well prepared to teach number (91% of students) than statistics (75%), geometry and measurement (74%) or algebra (56%).

### And this appeared to impact students' opportunity to learn and outcomes

According to their teachers, the mathematics topics covered by the fewest New Zealand Year 5 students in 2018 were:

- comparing and drawing angles (44%);
- parallel and perpendicular lines (55%);
- concepts of decimals, including place value and ordering, adding and subtracting with decimals (60%).

The angles and decimals topics were also the topics that fewer of the 2014 teachers felt well prepared to teach (parallel and perpendicular lines was not a separate topic in 2014).

Those Year 5 students whose teachers felt very well prepared to teach the topics had significantly higher achievement than those whose teachers felt not well or somewhat prepared.

NMSSA produced a resource for teachers based on three focus areas: spatial reasoning, fractions and percentages and collaborative problem solving.[14] The first two align with teachers' relative weaknesses in terms of feelings of preparation.

Specifically, NMSSA recommended that teachers use the language of spatial reasoning from an early age to help students communicate their thinking. They also recommended teachers encourage spatial play and introduce challenges that develop students' visualisation skills. For fractions and percentages they again recommended starting earlier, particularly with introducing simple percentages. Students should be provided with multiple opportunities to work with different representations of fractions and to make connections between these representations.

### Some Year 9 teachers also expressed feelings of being unprepared, even though they were more likely to have a mathematics specialisation

There were quite a few topics that most Year 9 mathematics teachers in 2014 felt very well prepared to teach, the highest of these was simplifying and evaluating algebraic expressions (93% of students). The topics simultaneous (two variables) equations (57% of Year 9 students), concepts of irrational numbers (62%), and congruent figures and similar triangles (62%) had fewer teachers agreeing that they were very well prepared to teach them. However, when asked in 2019 about the topic areas in general, more teachers felt very well prepared to teach number (94% of students) than geometry and measurement (91%), algebra (89%), or statistics (83%).

### Again, at the Year 9 level, teacher preparedness appeared to impact opportunity to learn

The mathematics topics covered by the fewest New Zealand Year 9 students in 2019 were:

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[14] https://www.educationcounts.govt.nz/goto/nmssa/nmssa/all-nmssa-publications/nmssa-2018-insights-for-teachers-maths-and-statistics

- simultaneous (two variables) equations (15%);
- congruent figures and similar triangles (27%);
- solving problems involving the Pythagorean theorem (30%);
- simple linear inequalities (30%);
- theoretical and empirical probability of compound events (33%).

Fewer Year 9 students had covered the first two topics in 2019 than in 2014 (the remaining topics cannot be directly compared). These two topics were also the topics that fewer teachers in 2014 felt well prepared to teach.

### This lack of opportunity to learn was confirmed by 15-year-olds in PISA

Nearly 60 percent of 15-year-olds in PISA reported that they had never heard of congruent figures (59%; a further 19% had only heard of it once or twice). Over a quarter of 15-year-olds had never heard of quadratic functions (27%) and over 40 percent had never heard of cosine (43%) or exponential functions (42%). About a quarter of 15-year-olds reported that they had never heard of rational or complex numbers (25% and 24% respectively).

### On average, New Zealand students perform higher on tasks related to statistics but relatively lower in geometry and measurement

Interestingly, the areas where students achieved relatively better, in general, didn't necessarily align with teachers' feelings of preparation. Across the mathematical content areas, Year 5 students performed relatively better on tasks related to *statistics* (504 points), compared to other content areas including *geometry and measurement* (481 points) and *number* which includes early algebraic thinking (478 points). Year 9 students did relatively better in *data and probability* questions (496 points) but less well on *number* (483 points), *geometry* (477 points), and *algebra* (464 points).

In the PISA context, New Zealand 15-year-old students performed best on questions related to *uncertainty and data* (506 points), which fits with the aspects of *statistics* in the New Zealand curriculum. This is followed by *change and relationships,* covered through teaching the *algebra* strand (501 points) and *quantity*, covered through teaching both *number* and *measurement* (499 points). *Space and shape* (491 points) is an area of weakness, which can be translated to the New Zealand mathematics curriculum as *geometry and measurement*.

For all of these strands, the better performance was only relative to the other strands, not relative to other countries. Students in high-performing countries performed significantly better on these strands, on average, than New Zealand students

### Most primary teachers liked teaching maths

Most teachers in NMSSA agreed or strongly agreed that they liked teaching maths (94% at the Year 4 level and 96% at the Year 8 level with these two categories combined).

### Many primary teacher trainees could not correctly do the maths they needed to be able to teach to Year 7 and 8 students

Young-Loveridge, Bicknell, and Mills[15] (2012) found that many students training to be primary teachers couldn't successfully answer questions at level 4 of the curriculum. In particular they had difficulty with questions using fractions and percentages as the content of the question, with only around a third of students correctly answering these questions.

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[15] Young-Loveridge, J., Bicknell, B., and Mills, J. (2012). The mathematical content knowledge and attitudes of New Zealand pre-service primary teachers. *Mathematics Teacher Education and Development 14.2, 28-49.*

### And many expressed negative views towards doing mathematics

Young-Loveridge et al [16]found that many of these student teachers also expressed either neutral or negative attitudes to mathematics. Fewer than half (48%) of the students expressed positive attitudes to mathematics.

There was a marked tendency for those who scored well (either more than half the tasks correct, or no more than one error) to have a positive view of mathematics.

### However, being negative about doing mathematics didn't necessarily negatively impact their attitude towards teaching maths

The relationship between general attitudes towards mathematics and attitudes towards *teaching* mathematics seems to be complex and nuanced. Some students were positive about mathematics, possibly having experienced success with school mathematics, but were anxious about the responsibility of teaching others, and hence negative about the prospect of teaching mathematics. Others were negative about mathematics because of unpleasant experiences learning school mathematics, but looked forward to teaching mathematics more effectively than their own teachers, so were positive about the prospect of teaching mathematics.

### New Zealand teachers had high levels of professional development compared with other countries though fewer teachers experienced these opportunities in 2018 than in 2014.

A high proportion of New Zealand Year 5 teachers had undertaken some form of mathematics professional development in TIMSS 2014 in the previous two years (across a range of aspects - the highest was 74% on mathematics content; the lowest integrating IT into maths 42%). The proportions having professional development were high in an international context (comparative proportions were 45% and 36% respectively). However, due to changing centrally funded PLD priorities, though still relatively high internationally, fewer teachers in 2018 had had professional development (highest 61% for mathematics pedagogy/instruction; lowest 26% for integrating IT into maths).

At the Year 9 level, the proportions of teachers receiving professional development in the two years prior to the 2019 assessment in some aspect of mathematics education was higher than the international average (range from 40% for mathematics assessment to 66% for mathematics pedagogy/instruction c.f. 35% and 45% respectively on average internationally). The proportion of Year 9 teachers participating in professional development in *improving students' critical thinking or problem solving skills* had increased in New Zealand from 37 percent in 2014 to 54 percent in 2019, while the proportion for *mathematics assessment* had decreased over time (from 51% to 40%).

## Key takeaways about teachers

New Zealand teachers have a relatively low level of specialisation in mathematics, with primary much lower than secondary and both lower than on average internationally. They also felt less prepared to teach some mathematical topics than others and this seemed to impact students' opportunity to learn as some topics were less likely to be taught than others. Students in New Zealand performed relatively better on statistical questions than on other areas of the curriculum in international tests, though this was only relative to New Zealand performance not that of other countries. Some teacher trainees had negative views about mathematics, though this didn't necessarily negatively impact their attitude towards teaching mathematics. A relatively high proportion of New Zealand teachers had had professional development recently.

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[16] Young-Loveridge, J., Bicknell, B., and Mills, J. (2012). The mathematical content knowledge and attitudes of New Zealand pre-service primary teachers. *Mathematics Teacher Education and Development 14.2, 28-49.*

# Teaching

## Early childhood settings (ECE)

### Maths learnt in ECE has positive impacts on academic outcomes further down the track

National and international studies have shown the value and long term impacts of mathematical learning in the years prior to school (see for example Stipek, 2013; Björklund, van den Heuvel-Panhuizen, & Kullberg, 2020).

In New Zealand, the Competent Children study found high mathematics scorers at age 14 were likely to have a good level of mathematics when they started school. There were indications that high scorers were more likely to have attended early childhood education that offered good staff-child interaction (including language use), and print-saturated environments (Wylie and Hipkins, 2006). Similarly, the Christchurch Health Development Study found a small but significant benefit from ECE attendance for some aspects of verbal and numerical reasoning, attainment of high school qualifications and academic success up to age 30 even after adjustment for prior social, family and individual factors (Horwood and McLeod, 2016).

### Teaching mathematics can be either a deliberate action or based on finding teachable moments in ECE settings – a balance of the two is recommended

There is debate in the field of early childhood education as to whether teaching of mathematics should be a deliberate action or based on the teacher finding teachable moments in the child's play (see for example Helenius, 2018, Stipek 2013). The debate has often placed these two pedagogies as oppositional (see for example Thomas, Warren, and DeVries, 2011). The debate highlights the impacts on mathematics learning of each pedagogy. Some argue that formalised, deliberate teaching will undermine children's self-confidence and their natural curiosity and intrinsic motivation to learn mathematics. Others argue that children often miss out on any mathematics learning in settings where play-based learning is the focus or that the learning is restricted to very simple concepts such as counting by rote. Finding teachable moments requires teachers with good understanding of mathematics and mathematics education.

ERO (2016) and Thomas et al (2011) recommend a balance of child-initiated learning experiences and deliberately planned activities and ERO provides examples of both these pedagogies happening in a New Zealand context.

### Research has shown even very young children have the potential to engage with mathematical thinking but often don't get the appropriate opportunities

Research has shown that very young children can learn mathematical skills and understandings (Stipek, 2013; Anthony and Walshaw, 2009) and some are surprised by how advanced the maths they can learn is (Helenius, 2018). Yet evidence suggests that many children don't get sufficient or appropriate opportunities to learn maths and this may be related to teacher knowledge and confidence (Anthony and Walshaw, 2009).

### In the early childhood years, learning happens at home and home mathematical activities in partnership with ECE services was shown to be effective

New Zealand and international research found that the home context can have a positive effect on mathematics. For example, "high scorers on numeracy tasks had a wide range of experiences involving numbers, a strong orientation towards numeracy by members of their families, and the opportunity to observe their mothers using numbers to solve everyday problems of their own" (Anthony and Walshaw, 2009). International research has shown that interactions and interventions that connect the work in the ECE with what is happening at home are effective in developing mathematics skills and understandings (Anthony and Walshaw, 2009). In particular, interventions that teach parents and their children how to take advantage of mathematical opportunities for learning have been shown to increase learning and reduce achievement gaps for those from low socio-economic backgrounds (Anthony and Walshaw, 2009).

## Schooling

### Many New Zealand students reported teachers were clear and easy to understand in mathematics lessons, but the proportions were lower than their international peers

According to TIMSS, New Zealand Year 5 students were positive about the clarity of instruction in their mathematics classes (at least 89% of students agreed at least a little with each of the 7 statements, the lowest being *my teacher is easy to understand* with 56% agreeing a lot and 32% agreeing a little). However, fewer Year 5 students reported their mathematics lessons had *high clarity* compared to the international average (74% categorised as having high clarity internationally c.f. 70% in NZ).

Similarly, many New Zealand Year 9 students were positive about the clarity of instruction in their mathematics classes (at least 73% agreed at least a little with each of 7 statements; as for Year 5, the lowest was *my teacher is easy to understand* with 37% agreeing a lot and 36% agreeing a little). As with the Year 5 students, compared to the international average, fewer students reported their mathematics lessons had high clarity (46% categorised as having high clarity internationally c.f. 39% in NZ). Both in New Zealand and internationally, lower secondary students reported less clarity than middle primary learners, possibly because the mathematics was getting more complicated.

### Greater clarity of instruction and better student-teacher relationships were associated with higher achievement

Both in New Zealand and internationally, the clearer and easier to understand the middle primary and lower secondary students found their mathematics lessons, the higher the achievement.

15-year-old students in PISA with more positive reports about teacher–student relations were more likely to achieve higher maths scores than students who were not as positive. The link between teacher–student relations and maths achievement found in New Zealand classrooms was one of the strongest among the PISA participants.

### Instructional techniques and activities differed between middle primary and lower secondary teachers

At the Year 5 level, many New Zealand teachers reported that in every (or almost every) lesson they encouraged their students to express their ideas (82%) and encouraged classroom discussion among students (82%). Year 9 teachers were less likely to use these techniques every lesson (56% and 46% respectively). The most common activities at the Year 9 level were linking new content to students' prior knowledge (62%) and asking students to explain their answers (60%).

### New Zealand teachers were less likely to explain things to students or ask them to memorise compared to their international peers

According to teachers in TIMSS, activities where Year 5 teachers explained new mathematics content (29%), teachers explained how to solve problems (23%), or teachers asked students to memorise rules, procedures and facts (5%) were less likely to be used in every or almost every lesson in New Zealand classrooms, compared with other countries (68%, 61%, and 37% respectively). Although more New Zealand Year 9 teachers used these kinds of activities (50%, 47%, and 14% respectively), these activities were used by fewer New Zealand teachers than on average internationally (68%, 63%, and 36% respectively).

### But some teachers had students explain solutions regularly

One-third of students in NMSSA reported explaining their way of solving a maths problem to other students or the teacher every day or almost every day (33% Year 4 and 34% Year 8). More Year 5 and Year 9 teachers in TIMSS said that they had students explain their answers every (or almost every) lesson (72% and 60% respectively – but note the different wording). In contrast, fewer 15-year-old students in PISA reported that they were asked to explain how they have solved the problem always (35% and 36% sometimes were).

ERO's research (2018) on effective mathematics teaching approaches and strategies reported that having students explain solutions can increase learners' ownership of their learning. Students said that they understood the teacher was there to help them with their learning. They also knew that their peers were there to help them and that they were there to help their peers. Teachers encouraged these mindsets by avoiding immediately offering solutions, asking children to explain their thinking so far, and reminding children to listen carefully to the ideas of others in the group.

### Setting challenging activities for students was not as common

NMSSA asked students how often they do maths problems that make them think really hard. Just over one third of students said this happened daily (37% Y4 and 38% Y8), though quite a few said that this happened weekly (31% Y4 and 44% Year 8).

TIMSS asked teachers how often they ask students to complete challenging exercises that require them to go beyond the instruction. More than three-quarters of teachers had their students do this at least half the lessons (29% every lesson and 50% about half the lessons at Year 5 & 34% every lesson and 42% about half the lessons at Year 9).

A preliminary analysis of a Year 9 textbook undertaken for the Mathematics Curriculum Document Analysis Project run by the OECD found that the textbook contained mostly routine tasks, some word problems, but very few higher-order tasks (those requiring analysis, synthesis, and evaluation). For teaching to be effective learners need consistent experience with higher-order tasks. Teachers need to provide these higher-order tasks if they are using such textbooks.

15-year-olds in PISA were asked how often they worked on problems for which there is no immediate solution; just over half thought that teachers presented these kinds of problems regularly (19% always and 35% often).

### Compared with other countries, more New Zealand primary teachers use same ability grouping regularly for mathematics instruction, though this use had decreased since 2014 while the use of mixed grouping ability had increased

New Zealand Year 5 teachers made less use of whole class teaching compared to other countries (22% daily compared with 41% daily) and used group activities more often. New Zealand teachers had relatively high use of same ability grouping (29% daily; 39% about half the lessons c.f. 15% daily and 28% about half the lessons on average internationally). However, the use of same ability grouping has dropped markedly since 2014 (29% daily in 2018 c.f. 47% daily in 2014). Mixed ability grouping was used more in New Zealand in 2018 than in 2014 (30% daily; 33% about half the lessons in 2018 c.f. 13% daily and 29% about half the lessons in 2014).

Similarly, NMSSA found that of the strategies presented, ability group-based activities were used the most regularly, with 58 percent of teachers at Year 4 and 46 percent at Year 8 reporting they used ability group activities 'every day or almost every day'. Whole class (Year 4 38% & Year 8 39% daily) and mixed ability grouping (Year 4 31% and Year 8 31% daily) were less common.

### Regular use of same ability grouping has been associated with lower achievement

In TIMSS 2014, regular use of same ability grouping (about half the lessons or more frequently) was associated with lower average mathematics achievement at the middle primary level. However, with the reduction in use in 2018, this relationship was no longer evident in the data.

In their 2013 report on teaching mathematics at Years 4 to 8, ERO found that most schools used ability groupings within or across classes. They made this comment as part of looking for how schools were addressing the needs of learners who were below or well below the mathematics standards. This was during the period when schools were required to report on the proportions of learners who were meeting the standards. They stated that many schools continued to use the same strategies for the learners needing extra help that they had always used, with no evidence that these strategies accelerated progress for these learners. Using the 2018 TIMSS data we can see that practices are changing compared to previous cycles. A note of caution, however: simply changing from using same-ability grouping to using mixed ability grouping isn't sufficient to improve outcomes for learners.

### Mixed ability grouping has the potential to increase learners' self-concept and achievement

The Developing Mathematical Inquiry Communities (DMIC) project has collaborative problem solving in mixed ability groups as one of its major pillars. Anthony, Hunter, and Hunter (2016) found that the teachers in their study were anxious about their ability to move from same ability grouping to using mixed ability grouping. But after using mixed ability grouping, they found that learners were more engaged, more saw themselves as capable of doing mathematics and had more voice.[17] The authors questioned whether the improved quality of teaching and the nature of students' interactions would have been possible without the move to mixed ability grouping.

ERO (2018) reported that schools with improved performance had implemented mixed-ability grouping. They found that children in mixed-ability groups had greater understanding of their learning, were better able to recognise achievement and progress, and knew what they had to do to improve. Children who had previously been in 'bottom' groups told ERO how their confidence and enjoyment of mathematics had increased since working in mixed-ability groups.

Watson, Rubie-Davies, and Meissel (2019) found in their study that a move to mixed ability grouping, along with other aspects of class climate, enabled a slight increase in student self-concept during the 3-year intervention. Non-intervention studies have shown a decrease in self-concept as children grow older, so this was an important finding. The other changes to class climate included promoting choice of learning activity, facilitation of a collaborative rather than competitive class climate, teacher positivity, and a buddy-system where students encouraged peer responsibility for the classroom climate. However, girls and Māori still had lower self-concept at the end of the intervention than boys and non-Māori.

### Computer availability for maths lessons was higher in New Zealand than in other countries

In TIMSS New Zealand had a very high proportion of Year 5 students with computers available for use during mathematics lessons (92% - but only 33% had enough computers for each student to have one), compared to nearly all other countries (39% on average internationally; 13% with one-to-one access); only Malta had a higher proportion (95%). At the Year 9 level fewer students were in classes with computers available for use during mathematics lessons (81%), but a higher proportion (61%) had enough computers for each student to have one-to-one access. The proportion of students in maths classes with computers available was higher among lower secondary students in New Zealand than on average internationally (37% c.f. 81% in NZ).

### And they used computers for practising maths and to support learning

In NMSSA around 40 percent of teachers reported that they had students use a digital device or the internet to learn or practise maths daily (38% Y4 & 40% Y8) and another nearly half weekly (47% Y4 and 47% Y8).

TIMSS asked a slightly different question and therefore found slightly different proportions. Just under three-quarters of middle primary teachers used computers to support learning at least

[17] These findings come from the work with three DMIC schools working as a cluster within a low socio-economic Pasifika-based community.

weekly (daily 32% and weekly 40%). At the Year 9 level fewer teachers used computers to support learning at least weekly (21% daily, 41% weekly). Although the percentages include those without access to computers, in an international context, New Zealand students had very high regular usage of computers; at middle primary New Zealand had the highest weekly use. For comparison, around one-fifth of teachers on average internationally used computers to support learning at least weekly (middle primary 7% daily and 14% weekly; lower secondary 5% daily and 10% weekly).

### Calculators were not used as much as computers

According to their teachers, proportionately more Year 5 students had access to calculators (though this was mostly restricted - 65% rather than unrestricted - 9%) than their international peers (on average restricted - 33%; unrestricted 2%). Only about one-third of Year 4 students report using calculators to help solve problems (8% daily[18], 10% weekly, 13% monthly), though it was much more common at the Year 8 level (10% daily, 29% weekly, 32% monthly). Primary teachers reported slightly higher usage of calculators than their students (Year 4: 6% daily, 12% weekly, 29% monthly and Year 8: 13% daily, 35% weekly, 32% monthly).

### Assessment methods teachers used in middle primary classes differed from both their international peers and their lower secondary counterparts

More Year 5 students had teachers who placed a lot of importance on observing students as they work (85% a lot) than on asking students to answer questions during class (62%), short, regular written tests (12%) or longer tests (10%). On average internationally, many more teachers placed a lot of importance on short, regular written tests (56%) or longer tests (51%) than in New Zealand (12% and 10% respectively).

More New Zealand Year 9 mathematics teachers placed a lot of importance on tests for monitoring student progress (23% on short, regular tests and 41% on longer tests), compared to their Year 5 counterparts. Year 9 teachers were similar to their Year 5 counterparts for placing a lot of importance on observing students as they work (81%) and asking students to answer questions during class (66%). As with Year 5, internationally many more of the lower secondary teachers placed a lot of importance on short, regular written tests (52%) or longer tests (62%) than in New Zealand (23% and 41% respectively).

PISA 2012 showed that teachers tended to give students with lower mathematical literacy more regular feedback on their strengths and weaknesses (on average) than those with higher mathematical literacy.

### Around one-quarter of schools were found to use achievement information well at the upper primary level

In their 2013 report on mathematics in Years 4 to 8, ERO found that around one-quarter of schools were using mathematics achievement information well, with a further quarter using it to some extent. Part of using information well included involving students and their families in goal setting.

### And few schools were found to be highly effective at gathering and using achievement information at the lower secondary level to improve practice

ERO (2012) judged that only nine percent of schools were highly effective at gathering and using information to align practices to need. A further 57 percent were considered partially effective. Issues occurred in both the gathering and use of information.

## Key takeaways about teaching

From early learning through to secondary there are areas where New Zealand teaching and instruction differs from international practices, or from what some writers suggest is best practice

[18] Daily refers to 'every day or almost every day'; 'weekly' refers to 'once or twice a week'; monthly refers to 'once or twice a month'.

and evidence shows works. However, this paper does not draw conclusions about which patterns need changing and to what degree. No single strategy change, on its own, will solve the issues identified in this paper, nor is there a silver bullet.

The practices that this evidence suggests might need to be explored include direct instruction, grouping practices (and whole class teaching), techniques that get children to explore their own understandings (through explaining), setting challenging activities, particularly those that require higher-order thinking, and ensuring assessment is used formatively.

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