

# The Impact of the Numeracy Development Project on Mathematics Achievement

Gill Thomas  
*Maths Technology Ltd*  
<gill@nzmaths.co.nz>

Andrew Tagg  
*Maths Technology Ltd*  
<andrew@nzmaths.co.nz>

The central focus of the Numeracy Development Project (NDP) is to raise student achievement in mathematics by improving the professional capability of teachers. This paper reports on the mathematics achievement of year 4, 5, and 8 students in 31 schools that participated in the NDP prior to 2003. The findings suggest that the project has had a positive impact as the NDP students performed better on TIMSS items than did their same-age peers in 1995.

## Background

### *The Numeracy Development Project*

Much of the impetus for The Numeracy Development Project (NDP) came from the results of the 1995 Third International Mathematics and Science Study (TIMSS), which showed that New Zealand students performed poorly when compared to other education systems. Garden (1997), in the report on New Zealand performance, stated that “the most direct influence on student achievement in mathematics and science is the teacher” (p. 250). The government’s Review of Teacher Education Green Paper (Ministry of Education, 1997a) further linked the relatively poor performance of students in the TIMSS mathematics assessment to their teachers’ lack of knowledge in mathematics. In 1997, the Ministry of Education established the Mathematics and Science Taskforce in response to the reported difficulties of teachers (especially primary teachers) in implementing effective mathematics programmes. The report of the taskforce expressed concern about the professional skills and knowledge of teachers. They argued that “satisfactory learning of mathematics and science is strongly influenced by a teacher’s own confidence” (Ministry of Education, 1997b, p. 3).

The focus of the NDP is to “improve student performance in mathematics through improving the professional capability of teachers” (Ministry of Education, 2004, p. i). The NDP was first implemented in New Zealand schools in 2001, following a 2000 pilot study of Count Me In Too, a numeracy initiative of the New South Wales Department of Education and Training. Since then, more than 300 000 students and 14 000 teachers have participated in the project. The project has been informed by annual evaluation reports that have examined the impact of the NDP on students’ learning, as well as exploring the experiences of the numeracy facilitators, teachers, and principals. Findings from the evaluations indicate that the project has had a positive impact on the quality of teaching and learning in mathematics (Christensen, 2003, 2004; Higgins, 2003, 2004; Irwin, 2003, 2004; Thomas, Tagg, & Ward, 2003; Thomas & Tagg, 2004; Young-Loveridge, 2004).

### *Trends in International Mathematics and Science Study*

TIMSS collects educational achievement data at the fourth and eighth grades to provide information about trends in performance in mathematics and science. Approximately 50 countries from all over the world participate in TIMSS. TIMSS is designed to help countries improve student learning in mathematics and science by identifying and monitoring areas of progress or decline in achievement. One of its most important features is that it has enabled the collection of information on the nature of teaching and learning at both international and national levels. Conducted on a four-year cycle, the first round of TIMSS was in 1995, the second in 1999 (eighth grade only), and the third in 2003. Preparations are underway for the next round of TIMSS, which will take place in 2007. TIMSS assesses the mathematics and science achievement of students in two target populations. Population 1 was defined as “all students in the two adjacent grades that contained the largest proportion of students in the age 9 cohort ...” (Garden, 1997, p. 10). In New Zealand, this translated to students in years 4 and 5. Population 2 was defined as “all students in the two adjacent grades that contained the largest proportion of students in the age 13 cohort...” (Garden, p. 10). In New Zealand, this translated to students in years 8 and 9.

### **NDP Longitudinal Study: Overview and Methodology**

As the impetus for the NDP was a desire to improve mathematics achievement, it is necessary to quantify such improvement. The student achievement data has predominantly come from the results of the Numeracy Project Assessment (NumPA) interview. The NumPA data has consistently shown that the project is successful in improving the number profiles of students (Young-Loveridge, 2004). To investigate the impact of the NDP on students’ overall performance in mathematics, tests developed using 1995 TIMSS items were given to year 4, 5, and 8 students in 31 schools that first participated in NDP from 2000 to 2002. This paper reports on the performance of the students on these tests.

### *Sample*

The Longitudinal Study began in 2002 with the participation of 20 schools that first implemented the NDP in either 2000 or 2001. In 2004, the number of schools in the Longitudinal Study was increased to 31 through the inclusion of 16 schools that first participated in 2002. Five of the original 20 schools withdrew from the Longitudinal Study at the start of 2004. The three tests generated from the TIMSS items were used to assess 2995 students at years 4, 5, and 8. Tables 1 and 2 show the breakdown of students by year level and gender and by year level and decile band. The low-decile band includes decile 1 to 3 schools, the medium-decile band includes decile 4 to 7 schools, and the high-decile band includes decile 8 to 10 schools.

Table 1  
*Analysis of Students by Year and Gender*

Year	Female	Male	Total
4	663	684	1347
5	678	674	1352
8	148	148	296
Total	1489	1506	2995

Table 2  
*Analysis of Students by Year and School-decile Band*

Year	Low	Medium	High	Total
4	392	405	550	1347
5	421	417	514	1352
8	103	106	87	296
Total	916	928	1151	2995

Table 3 compares the ethnic profiles of the TIMSS sample with the students in the Longitudinal Study. The ethnicity information for the longitudinal sample was obtained from the ethnicities given for students whose data was entered onto the numeracy website in 2004. For the 12 schools that did not enter data in 2004, the ethnicity information was taken from the most recent year they entered data. The proportion of Pasifika students in the longitudinal sample is higher than in the TIMSS 1995 sample for both populations. The difference is primarily balanced by a decrease in the proportion of New Zealand European students.

Table 3  
*Comparison of Ethnicities*

	Population 1 (years 4 and 5)		Population 2 (years 8 and 9)	
	TIMSS	Long.	TIMSS	Long.
NZ European	63%	55%	68%	56%
Māori	26%	23%	19%	28%
Pasifika	6%	9%	7%	12%
Asian	3%	7%	5%	3%
Other	2%	5%	1%	1%

### *Methodology*

Tests for each of the three year levels were developed from the pool of items released from the 1995 TIMSS. The tests comprised 24 items, which were selected to give coverage of all strands of the mathematics curriculum. The tests were piloted in a non-longitudinal school to check that they took approximately 40 minutes to administer. Tables 4 and 5 show the number of items by strand contained in the three tests. Each test was designed so that the average score in each test would be 50%, based on the percentage of New Zealand students answering each item correctly in TIMSS 1995.

Table 4  
*Analysis of Items in the Year 4 and 5 Tests*

TIMSS Content Category	Year 4	Year 5
Data Representation, Analysis, and Probability	2	2
Fractions and Proportionality	2	5
Geometry	5	2
Measurement, Estimation, and Number Sense	3	3
Patterns, Relations, and Functions	5	4
Whole Numbers	7	8
	24	24

Table 5  
*Analysis of Items in the Year 8 Tests*

TIMSS Content Category	Year 8
Algebra	1
Data Representation, Analysis, and Probability	6
Fractions and Number Sense	11
Geometry	4
Measurement	2
	24

Test scripts were sent to each of the participating schools in July. The classroom teachers administered the tests, following instructions adapted from those used with TIMSS. The tests were sent back to the researcher for marking during August. Once the scripts had been marked, a report was compiled for each of the participating schools. This report included details on the item responses of each student and their overall test score. The schools' average performance by item and overall was compared to the TIMSS 1995 performance for the same age peers.

### NDP Longitudinal Study: Results and Discussion

All reporting of results in this section is based on the average percentage of items answered correctly by students in the stated sub-groups. For each question, the 95% confidence limits for the difference in mean proportion between the longitudinal sample and New Zealand TIMSS 1995 sample were calculated. This is the criteria used to define significant differences in the results reported below.

As shown in Table 6, the performance of boys and girls in the longitudinal schools was very similar at all three year levels.

Table 6  
*Average Score by Year and Gender*

	Year 4	Year 5	Year 8
Male	56%	58%	53%
Female	56%	59%	52%
Total	56%	58%	53%

As shown in Table 7, year 4 and 5 longitudinal students performed significantly better overall than the New Zealand students in TIMSS 1995. The year 8 students performed at a similar level. The lack of improvement by the year 8 students may be explained by the fact that the earliest exposure they could have had to NDP practices was in 2001 as year 5 students. More than 50% of the year 8 students did not encounter these practices until 2002 or 2003 as year 6 or 7 students.

Low-decile students at all year levels performed not only lower than the medium- and high-decile schools, but also slightly lower than the New Zealand TIMSS 1995 sample (50%). There is no decile information available on the New Zealand TIMSS 1995 sample so no comparisons can be made by decile. The differences between high- and medium-decile students were not significant.

Table 7  
*Average Score by Year and Decile Level*

	Year 4	Year 5	Year 8
Low deciles (1–3)	48%	47%	42%
Medium deciles (4–7)	59%	61%	58%
High deciles (8–10)	61%	65%	59%
Total	56%	58%	53%

Table 8 shows the average performance of students on items classified by mathematical content. The items classified as number for the year 4 and 5 tests included the categories of whole number; fractions and proportionality; and measurement, estimation, and number sense. The items classified as number for the year 8 test included: fractions and number sense; and algebra. The results show that the year 4 and 5 students performed significantly better than the New Zealand TIMSS 1995 sample on both number and non-number items. The year 8 students performed at a similar level on both categories of items.

Table 8  
*Performance of Students on Number and Non-number Items*

	Year 4		Year 5		Year 8	
	Number	Non-number	Number	Non-number	Number	Non-number
TIMSS 1995	47%	53%	49%	53%	47%	53%
Longitudinal	55%	58%	56%	63%	49%	56%

### *Results of the Year 4 Students*

Of the 24 questions in the year 4 test, longitudinal students performed better on average than the TIMSS 1995 New Zealand sample on 16 questions, and equally well on six questions. The two questions on which longitudinal students performed significantly lower than New Zealand students in TIMSS 1995 were question 3 (38%, compared with 47%), in which students were presented with the sum  $6971 + 5291$  in vertical form, and question 13 (43%, compared with 67%), in which students were asked to identify which of a set of shapes was “made with straight lines only”. As shown in Figure 1, the numbers presented in question 6 are too large and, with three columns adding to greater than 10, too complicated to be readily added using a mental strategy. As written forms are not introduced until the higher stages of the Number Framework, few year 4 students would be expected to answer this question correctly.

6	Add	6971 <u>+5291</u>		
a	11 162			
b	12 162			
c	12 262			
d	1 211 162			

	Percentage
Longitudinal	38%
NZ 1995	47%
TIMSS 1995	67%

Figure 1. Item 6

The poor results for question 13 can possibly be explained by the quality of the reproduction of the question in the test. Although the image in Figure 2 was taken directly from the released items published on the TIMSS 1995 website, the corner at the top of the shape D appears slightly curved (<http://timss.bc.edu/timss1995.html>).

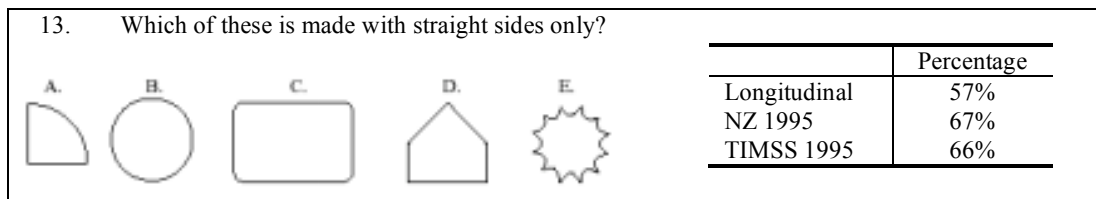


Figure 2. Item 13

Of the 15 questions on which the longitudinal students performed better than the New Zealand students in TIMSS 1995, there were 13 in which the difference in percentage of correct answers was greater than 5% and 10 in which the difference was greater than 10%. The largest difference was on question 22 (Figure 3), in which students were asked to draw the shape produced when a piece of paper that had been folded and then cut was opened out. Seventy-three percent of longitudinal students answered correctly, compared with 48% of New Zealand students in TIMSS 1995 and 45% of the TIMSS international sample.

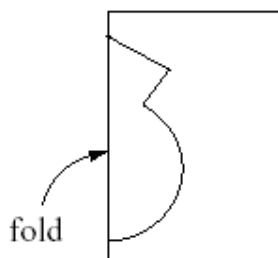


Figure 3. Item 22

The next three largest differences were for questions 9, 15, and 24, with differences in percentages of correct responses of 20%, 20%, and 18% respectively. These three questions are all based in the number strand, on which students in NDP schools have had a greater focus. Their strong performance on these questions is encouraging. Question 9 asked the students to write a fraction that was larger than  $\frac{2}{7}$ . Fifty-eight percent of the longitudinal students gave a correct answer, compared with 38% of the New Zealand and 41% of the international samples from TIMSS 1995. Question 15 asked the students to identify the missing number from a segment of a hundreds chart (see Figure 4). Seventy-seven percent of the longitudinal students answered this correctly, compared with 57% of the New Zealand and 64% of the international samples from TIMSS 1995. Question 24 asked the students to write the addition fact  $4 + 4 + 4 + 4 + 4 = 20$  as a multiplication fact. Sixty-three percent of the longitudinal students answered this correctly, compared with 45% of the New Zealand and 63% of the international samples from TIMSS 1995.

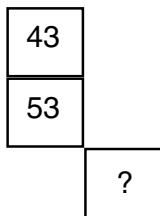


Figure 4. Hundreds chart (item 15)

### Results for the Year 5 Students

The pattern of results for the year 5 students is very similar to that of the year 4 students. The year 5 students performed better on average than New Zealand students in TIMSS 1995 on 19 of the 24 questions and equally well on two questions. The three questions for which the percentage correct for longitudinal students was significantly lower than that for New Zealand students in TIMSS 1995 were questions 2, 5, and 19c.

Question 2, illustrated in Figure 5, was similar to the vertical form question found difficult by the year 4 students. Twenty-five percent of the longitudinal students identified the correct response, compared with 30% of the New Zealand students and 71% of the international sample in TIMSS 1995. It is confusing that the year 5 students performed relatively poorly on question 5 as this was the same hundreds chart problem (Figure 3) that the year 4 students performed well on. Fifty-six percent of the year 5 students answered this correctly, compared with 70% of the year 4 students and 73% of the New Zealand students in TIMSS 1995. Question 19c required the students to compare two rates (3 kilometres in 10 minutes with 1 kilometre in 3 minutes). Although significantly fewer of the longitudinal students (71%) answered this correctly, compared with the New Zealand students on TIMSS 1995 (75%), it was still one of the highest scoring items.

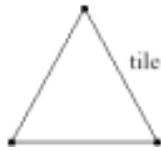
2.	Subtract	6000	
		<u>-2369</u>	
a	4369		
b	3742		
c	3631		
d	3531		

	Percentage
Longitudinal	25%
NZ 1995	30%
TIMSS 1995	71%

Figure 5. Item 2

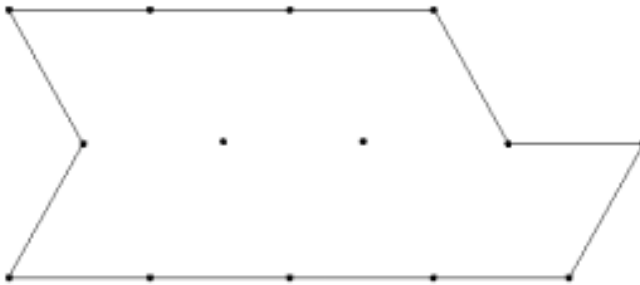
Of the 19 questions on which the longitudinal students performed significantly better than the New Zealand students in TIMSS 1995, there were 10 on which the difference was greater than 10%. The two questions for which the difference was the greatest were question 17, the same folded paper question on which year 4 students also performed well (see Figure 3), and question 18, in which students were asked to identify the number of triangles required to fill a given shape (Figure 6). Eighty-four percent of the year 5 students answered the paper fold question correctly, compared with 64% of the New Zealand students and 59% of the international sample in TIMSS 1995. Sixty-three percent of the longitudinal students correctly answered the tiling problem, compared with 37% of the New Zealand students and 50% of the international sample in TIMSS 1995.

18. The triangle represents one tile in the shape of a triangle.



	Percentage
Longitudinal	63%
NZ 1995	37%
TIMSS 1995	50%

How many tiles will it take to cover the figure below?



Number of tiles: \_\_\_\_\_

Use the figure above to show how you worked out your answer.

Figure 6. Item 18

The next three greatest improvements were recorded for questions 9, 12, and 22, in all of which the longitudinal students outperformed New Zealand students in TIMSS 1995 by at least 15%. Two of these questions are directly linked to the number focus of the NDP. Fifty percent of the longitudinal students were able to correctly identify the pair of numbers in which the second number was 100 more than the first number (Figure 7). This was 17% more than the New Zealand students' performance on this item in TIMSS 1995. The longitudinal students also performed significantly better than the New Zealand cohort in TIMSS 1995 on item 22, which required the students to write the number that is 1000 more than 56 821. Fifty percent of the longitudinal students answered this correctly, compared to 32% of the New Zealand students in TIMSS 1995. It is interesting to note that for questions 9 and 22, whilst the longitudinal students performed considerably better than the New Zealand students in TIMSS 1995, they were within 2% of the international average.

9. In which pair of numbers is the second number 100 more than the first number?

- a 199 and 209
- b 4236 and 4246
- c 9635 and 9735
- d 51 863 and 52 863

	Percentage
Longitudinal	50%
NZ 1995	33%
TIMSS 1995	49%

Figure 7. Item 9



### Results for the Year 8 Students

Although there was little difference in the overall performance of the year 8 longitudinal students and the New Zealand sample in TIMSS 1995, there were significant improvements on six items and significant declines on three. On the items in which the longitudinal students' performance was lower, one was a number item (7% lower), one involved the identification of an angle measure (8% lower), and one involved the rotation of a 3-D object (6% lower). The number item was a word problem that asked the students to find the difference between 61.60 and 59.72 metres (Figure 8). Fifty-nine percent of the longitudinal students answered this correctly, compared with 66% of the New Zealand and 67% of the international sample from TIMSS 1995.

1. In a discus-throwing competition, the winning throw was 61.60 m. The second place throw was 59.72 m. How much longer was the winning throw than the second place throw?	
a. 1.18 m	
b. 1.88 m	
c. 1.98 m	
d. 2.18 m	
	Percentage
Longitudinal	59%
NZ 1995	66%
TIMSS 1995	67%

Figure 8. Item 1

Of the six questions on which the longitudinal students performed significantly better than the TIMSS students, there were four in which the difference was greater than 10%. Three of these items involved an understanding of fractions, so the improved performance of the longitudinal students is encouraging. Two of these items used fractions in relation to probability problems, while the third required the students to shade a fraction of a region (Figure 9). Fifty percent of the longitudinal students shaded the region correctly, compared with 35% of the New Zealand cohort in TIMSS 1995. The fourth item with a substantial improvement (13%) required students to read the temperature off a thermometer.

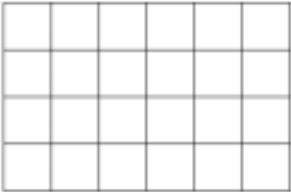
14. Shade in $\frac{5}{8}$ of the unit squares in the grid.	
	Percentage
	Longitudinal
	NZ 1995
	TIMSS 1995
	50%
	35%
	46%

Figure 9. Item 14

The longitudinal students performed similarly to the New Zealand TIMSS 1995 cohort on a total of 15 items, including nine number content items. One of these items was the same 4-digit subtraction posed to the year 5 students (see Figure 5). Sixty-nine percent of the longitudinal students identified the correct answer, the same percentage as for the New Zealand cohort in TIMSS 1995 and 17% lower than the international average. The longitudinal students also performed at a similar level on question 9, which required them to identify a list of equivalent fractions (Figure 10). Given their improved performance on the other fraction items, it is interesting that there was no comparative improvement on these items.

9. In which list of fractions are all of the fractions equivalent?	
a. $\frac{3}{4}, \frac{6}{8}, \frac{12}{14}$	
b. $\frac{3}{5}, \frac{5}{7}, \frac{9}{15}$	
c. $\frac{3}{8}, \frac{6}{16}, \frac{12}{32}$	
d. $\frac{5}{10}, \frac{10}{15}, \frac{1}{2}$	

	Percentage
Longitudinal	55%
NZ 1995	53%
TIMSS 1995	62%

Figure 10. Item 9

There were a further two number questions for which the performance of the longitudinal students was as low as the New Zealand TIMSS 1995 cohort. One of the items involved proportional reasoning (Figure 11), and one was a word problem involving calculations of rate (Figure 12). Given that proportions and rates are not addressed until the higher stages of the Number Framework, many year 8 students would not be sufficiently advanced on the Number Framework to have experienced problems of these types.

12. Jan had a bag of marbles. She gave half of them to James and then a third of the marbles still in the bag to Pat. She then had 6 marbles left. How many marbles were in the bag to start with?	
a. 18	
b. 24	
c. 30	
d. 36	

	Percentage
Longitudinal	55%
NZ 1995	353%
TIMSS 1995	62%

Figure 11. Item 12

13. A car has a fuel tank that holds 35 L of fuel. The car consumes 7.5 L of fuel for each 100 km driven. A trip of 250 km was started with a full tank of fuel. How much fuel remained in the tank at the end of the trip?	
e. 16.25 L	
f. 17.65 L	
g. 18.75 L	
h. 23.75 L	

	Percentage
Longitudinal	38%
NZ 1995	36%
TIMSS 1995	35%

Figure 12. Item 13

The question with the poorest performance by longitudinal students was item 23, in which students were asked to order a set of numbers including decimals and fractions (Figure 13). Twenty-seven percent of longitudinal students answered correctly, similar to the performance of New Zealand students in 1995 but 11% lower than the international sample.

23. Which list shows the numbers from smallest to largest?

- a. 0.345, 0.19, 0.8,  $\frac{1}{5}$
- b. 0.19,  $\frac{1}{5}$ , 0.345, 0.8
- c. 0.8, 0.19,  $\frac{1}{5}$ , 0.345
- d.  $\frac{1}{5}$ , 0.8, 0.345, 0.19

	Percentage
Longitudinal	27%
NZ 1995	26%
TIMSS 1995	38%

Figure 13. Item 23

### Concluding Comment

The performance of students in the longitudinal schools on the TIMSS items is encouraging. The year 5 longitudinal students performed on average 9% better than the 1995 New Zealand TIMSS cohort. Similarly, the year 4 longitudinal students performed 6% higher than the 1995 New Zealand TIMSS cohort. The year 8 longitudinal students' average overall test score was not significantly higher than that of the New Zealand students in TIMSS 1995, although they outperformed them on six questions and were lower on three. The comparatively low performance of year 8 students may be partly explained by fewer years of involvement in the NDP by both the students and their teachers. It may also be the result of requiring students to unlearn procedures and skills learnt prior to the NDP. Both of these possibilities require further investigation.

### References

- Christensen, I. (2003). *An evaluation of Te Poutama Tau 2002: Exploring issues in mathematics education*. Wellington: Ministry of Education.
- Christensen, I. (2004). *An evaluation of Te Poutama Tau 2003: Exploring issues in mathematics education*. Wellington: Ministry of Education.
- Garden, R., Ed. (1997). *Mathematics and science performance in the middle primary school: Results from New Zealand's participation in the Third International Mathematics and Science Study*. Wellington: Research and International Section, Ministry of Education.
- Higgins, J. (2003). *An evaluation of the Advanced Numeracy Project 2002: Exploring issues in mathematics education*. Wellington: Ministry of Education.
- Higgins, J. (2004). *An evaluation of the Advanced Numeracy Project 2003: Exploring issues in mathematics education*. Wellington: Ministry of Education.
- Irwin, K. C. (2003). *An evaluation of the Numeracy Project for Years 7–10, 2002: Exploring issues in mathematics education*. Wellington: Ministry of Education.
- Irwin, K. C. (2004). *An evaluation of the Numeracy Project for Years 7–9, 2003: Exploring issues in mathematics education*. Wellington: Ministry of Education.
- Ministry of Education (2004). *The Number Framework: Teachers' material*. Wellington: Ministry of Education.
- Ministry of Education (1997a). *Quality teachers for quality learning: A review of teacher education*. Wellington: Ministry of Education.
- Ministry of Education (1997b). *Report of the Mathematics and Science Taskforce*. Wellington: Ministry of Education.
- Thomas, G., Tagg, A., & Ward, J. (2003). *An evaluation of the Early Numeracy Project 2002: Exploring issues in mathematics education*. Wellington: Ministry of Education.
- Thomas, G. & Tagg, A. (2004). *An evaluation of the Early Numeracy Project 2003: Exploring issues in mathematics education*. Wellington: Ministry of Education.

Thomas, N. & Wright, V. (2002, July). *Development of a number framework*. Paper presented at the 25<sup>th</sup> annual conference of the Mathematics Education Research Group of Australasia, University of Auckland.

Young-Loveridge J. (2004). *Patterns of performance on the Numeracy Projects 2001–2003*: Exploring issues in mathematics education. Wellington: Ministry of Education.

<http://timss.bc.edu/timss1995.html>