Review of Research

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CHAPTER 2

REVIEW OF RESEARCH

MATHEMATICS ACHIEVEMENT AT THE 9-YEAR-OLD LEVEL

TIMSS is the first large-scale investigation of mathematics achievement in New Zealand in which attempts will be made to identify factors linked with high and low achievement within an international context. In both previous IEA mathematics studies, the First International Mathematics Study (1963–64) and the Second International Mathematics Study (1981), the latter of which New Zealand participated in, the youngest student population investigated internationally was at the 13-year-old level. It has only been quite recently, in 1991, that a major international study has focused at a younger age level. In view of the shortage of comparative information about mathematics and science at the 9-year-old level, some results from studies involving 10- or 11-year-olds have been included.

International Comparisons — IAEP Study

The only major international comparative study prior to TIMSS to focus on the mathematics and science achievement of 9-year-old students was the United States-based International Assessment of Educational Progress (IAEP) study conducted in 1991. Fourteen countries or school systems took part but in four of these — England, Emilia-Romagna (Italy), Portugal, and Scotland — the results had to be considered in light of either low participation rates or restricted populations. New Zealand was not a participant.

The mathematics test for the IAEP study (Lapointe et al, 1992a) consisted of five content areas — Numbers and Operations (32 items); Measurement (9 items); Geometry (6 items); Data Analysis, Statistics and Probability (8 items); and Algebra and Functions (6 items). The mean score across all the countries was 63 percent, and the variation between the highest and lowest scoring countries was 20 percent. Students from Korea were the highest scoring (75%) while those from Hungary, Taiwan, Emilia-Romagna (Italy) and Scotland also scored significantly higher than the IAEP mean. In five countries, students’ achievement was found to be significantly below the IAEP mean. These were Ireland, Canada, United States, Slovenia, and Portugal.

The mathematics achievement of 9-year-olds was also analysed by gender. In three countries — Korea, Israel, and Emilia-Romagna (Italy) — significant differences were reported, with boys doing better than girls in each country. From data collected at the 13-year-old level, it was evident that the early advantage held by boys in Korea and Israel had disappeared some four years later. Only in
Emilia-Romagna (Italy) was there a consistent trend across both age groups indicating that the boys did better in mathematics.

NAEP Study

State-wide surveys of educational achievement have been conducted periodically in the United States by the National Assessment of Educational Progress (NAEP) since 1969. The most recent survey of mathematics achievement for which information is available was carried out in 1992. It focused on three populations, including 9-year-olds (Mullis, 1994). The overall national (USA) proficiency in mathematics at this level had improved in all regions except for the West compared with the results of the most recent prior survey held two years earlier. The average mathematics achievement for boys and girls had both improved but gender differences were neither large nor consistent. Mullis summarised the results of the NAEP mathematics assessment thus:

“... student performance is improving nationally and in some states, but [a] considerable challenge remains. The proportions of students demonstrating success with more complex tasks continued to be low, particularly for those sub-populations of students historically considered to be at risk.” (p3.)

Mathematics Achievement in New Zealand

There has been in-depth analysis of the number skills of New Zealand 5-year-old new entrants by Young-Loveridge (see for example 1988, 1993), and Higgins (1994) has examined teaching practices and resource use in mathematics classes in the first two years of schooling. There has also been research into aspects of mathematics teaching and learning at the middle and upper primary school levels, for example by Irwin (1996) and Graham (1991). Research of this kind is expected to illuminate the more broad-brush findings from TIMSS.

In 1981, as part of SIMS, the New Zealand National Advisory Committee decided that a survey of mathematics achievement at the standard 4 level should be conducted (May & Lamb, 1987). Test materials and school, teacher, and student background questionnaires for the survey were approved by the advisory committee. The sample consisted of 200 schools, and within each school one class was selected at random. Over a third (37% of the students) were 10-year-olds at the time of testing, while the large majority (60%) were 11-year-olds. The total number of students was 4632.

May and Lamb listed 12 content areas covered by the test questions including: Fractions, Geometry, Numbers and Numeration, Number Sentences, Graphs and Statistics, Measurement, Sets, Decimals, Addition of Whole Numbers, Subtraction of Whole Numbers, Multiplication of Whole Numbers, and Division of Whole Numbers. All the questions were in multiple-choice format.

The mean test scores for the content areas ranged from 51 percent (Decimals) to 81 percent (Number Sentences), although the overall mean was 62 percent. Eight of the 12 content areas had mean scores between 60 and 65 percent. The areas that students had most difficulty with included Decimals, Graphs and Statistics, and Measurement.
For Decimals the authors noted that:

“Students had considerable difficulty with the place value of decimal digits and they also showed confusion about the number of decimal places in multiplication and addition. They were more successful on items dealing with money.” (p27.)

For Graphs and Statistics it was evident that questions involving graphs were answered correctly more often than those making use of simple statistics.

For Measurement the authors reported that:

“Understanding and computation caused the most trouble, particularly the calculation of a radius, the area of a triangle, and area calculations to find the length of a rectangle.” (pp 26–27.)

May and Lamb also investigated content differences by gender. Girls scored higher in eight of the 12 content areas; in contrast, boys performed better in three areas. The largest difference in favour of girls was recorded in Subtraction of Whole Numbers (6%), followed by Multiplication of Whole Numbers (4%), Addition of Whole Numbers (4%), Division of Whole Numbers (4%), and Decimals (4%). Boys achieved smaller advantages on questions relating to Measurement (3%), Geometry, and Graphs and Statistics (both 2%).

The Progressive Achievement Test (PAT) of Mathematics, developed by the New Zealand Council for Educational Research (NZCER, 1993), is one of a series of standardised tests of achievement used by teachers to assess students from standard 2 to form 4. This test has recently been revised but there were two earlier checks of the norms which were first established in 1973.

Reid (1979) found, using a national sample of students, that the performance of New Zealand students on the PAT Mathematics Test showed very little change after six years for the standard 2 to form 2 levels. Overall, standards 2 and 3 girls achieved slightly better than their male counterparts on both the 1973 and 1979 test administrations. Gilmore and Reid (1985) undertook a second check of the norms in 1985 and, although there had been a small decline in mathematics performance across all class levels tested, the results for the standards 2 and 3 students were relatively stable over time. Girls again had slightly higher achievement at this level.

ATTITUDES AND BELIEFS OF 9-YEAR-OLDS ABOUT MATHEMATICS

International Surveys

In the IAEP study only one question on attitudes to mathematics was included at the 9-year-old level. Students were asked to indicate whether or not they thought mathematics was equally appropriate for boys and girls. Lapointe et al (1992a) reported that in all but one of the 14 countries, over three-quarters of the students indicated they agreed with the statement. The highest levels of
support were found in Scotland and Spain (both 90%), but in Korea only about half (48%) of the 9-year-old students responded that they agreed with the statement.

Attitudes and Beliefs of New Zealand Students

As part of a longitudinal study of students’ number concepts, Young-Loveridge (1992) interviewed 68 9-year-olds (27 boys and 41 girls) about their attitudes and beliefs towards mathematics. The results were analysed in terms of the students’ gender and their number knowledge (either low or high ability).

First, students were asked to indicate, from a list of seven school subjects, what their favourite subject was, and, also, their second and third choices. A quarter of all students chose mathematics as their favourite subject, compared to 34 percent who chose art and 15 percent who selected reading. Over half (53%) placed mathematics as one of their top three subjects; in contrast, most of the children (84%) selected art in the top three and 43 percent included reading as well. By gender, more than twice as many boys (37%) as girls (17%) chose mathematics as their favourite subject. Included as part of their top three, again many more boys (70%) preferred mathematics than did the girls (41%).

Second, students were asked if they enjoyed mathematics. Some 57 percent responded yes, nine percent no, and the remaining third were not sure. By gender, nearly three-quarters of boys said yes, and only seven percent no. In contrast, the respective figures for girls were 46 percent and 10 percent. By ability grouping, 65 percent of the high ability group indicated they enjoyed mathematics, in comparison to 50 percent of the low ability group.

The third factor investigated related to the students’ self-concept of their mathematics ability, that is, “Do you think you’re good at mathematics?” Overall, 32 percent of students reported yes, 15 percent no, and the remaining 51 percent were not sure. By gender, 44 percent of boys and 24 percent of girls thought they were good at mathematics, while four percent of boys and 22 percent of girls indicated no.

The fourth factor of interest focused on how the students dealt with difficult mathematics problems. Nearly all (87%) of the 9-year-olds indicated that they would initially attempt to do difficult problems themselves. Boys (41%) were more likely than girls (22%) to say they would not attempt difficult questions.

The fifth question asked whether the students thought mathematics was important. The result was clear cut, with 91 percent agreeing with this statement.

The final area investigated was the causal attribution for success and failure in mathematics. The students were asked to attribute their success and failure according to four possible causes — ability, effort, luck, or difficulty. In relation to success, 19 percent selected natural ability, with over twice as many boys (30%) as girls (12%) making this choice. By far the largest proportion of students (65%) felt success was due to the effort they put in. Only a few 9-year-olds, six percent of boys and nine percent of girls, chose luck or difficulty. In relation to failure in mathematics, only 12 percent of students thought that a lack of natural ability was the cause. Over one-fifth of students agreed that failure was due to a lack of effort: again there were more boys (33%) than girls (15%) agreeing with
this proposition. About half of the students reported that their failure was because mathematics was too difficult, with more girls (59%) than boys (41%) doing so. Only 10 percent of students felt luck was a cause of failure.

Young-Loveridge suggested a possible explanation for the significant gender differences in self-assessment in mathematics:

“. . . the parents of the boys gave them greater encouragement in mathematics than did the parents of the girls.” (p114.)

In May and Lamb’s (1987) study of standard 4 students conducted in 1981, they found that most of them enjoyed mathematics, especially Addition of Whole Numbers (95%), Subtraction of Whole Numbers, and Multiplication of Whole Numbers (both 78%). The content areas they least enjoyed working in included Decimals (42%) and Geometry (53%) — the former was the area where student achievement on the test was lowest. Overall, about a third indicated that they had difficulty with mathematics.

The authors reported that those students with a positive attitude and a belief in their own ability tended also to perform better in mathematics. As well, more than half the standard 4 students displayed a positive attitude to their future involvement or study of mathematics, but significantly more boys than girls wanted a job that involved mathematics. Finally, students perceived their parents to want them to do well in mathematics, although few students reported receiving assistance with their mathematics homework.

ATTITUDES AND BELIEFS OF TEACHERS

There is a commonly held assumption that the attitudes of teachers to mathematics affects the attitudes and achievement of their students (eg Aiken, 1976; Gilbert & Cooper, 1976; Karp, 1991; Phillips, 1973; Schofield, 1981; Schofield & Start, 1978; and Twillie, 1992). It is generally recognised that teachers who enjoy teaching mathematics and are good at it are in a position to stimulate similar attitudes and achievement in their students. However, a number of studies (eg Lazarus, 1974; Luchins, 1976; Smith, 1979; Stroup & Jasnoski, 1979; Tobias & Weissbrod, 1980; and Walden & Walkerdine, 1982) have reported that many primary school teachers, especially women, have poor attitudes to, and low achievement in, mathematics. This situation is said to have led to a cycle of at best inhibition, or at worst anxiety, about the teaching of mathematics among women, who typically out-number male teachers at the primary level. These authors see an urgent need for some sort of programme to assist teachers to overcome the fears and anxieties associated with mathematics. The work of Tobias (1987) may be a useful starting point.

May and Lamb’s (1987) standard 4 survey included questions to find attitudes of the teachers to the teaching of mathematics. Most responded that “their enjoyment of teaching was high and they found teaching challenging and satisfying even if at times frustrating” (p30). About half the teachers had a preference for teaching at the standard 4 level, while 22 percent preferred older students, and another 15 percent younger students. A final 13 percent reported they had no preference. Teachers were asked to indicate which subjects they enjoyed teaching the most — mathematics was the highest
(27%), followed by English (19%), and social studies (17%). However, only six percent of teachers thought mathematics was the most important subject for students at this age level. In comparison, 62 percent selected English.

TEACHING PRACTICES IN MATHEMATICS

Overseas Trends

In the United States there have been strong calls for primary teachers to reform their classroom practices in teaching mathematics (Peterson et al., 1992). These reforms focus on the change from the transmission of knowledge approach to a student-centred approach emphasising stimulation of learning (National Research Council, 1989). The types of changes in practice called for as a consequence of this shift in focus included decreased emphasis on rote learning, one answer-one method approaches, written practice, and teaching by telling; and increased emphasis on use of manipulative materials, discussion of mathematics, justification of thinking, a problem-solving approach to instruction, and writing about mathematics (National Council of Teachers of Mathematics, 1989 and 1991).

Researchers (eg Peterson et al., 1992; Zambo, 1994) have collected data on instructional practices to construct profiles of mathematics teaching in the United States to help gauge the progress of change. While the results indicated that many teachers were engaged in stimulation of learning practices, others were still focusing on tasks reflecting a transmission of knowledge approach.

Japanese mathematics educators have recently been focusing on the importance of developing higher-order problem-solving skills (Hashimoto, 1987; Nohda, 1987; and Sawada, 1980). To assist with this task, teachers have been using open-ended, non-routine problems to teach problem-solving skills to students in Japanese primary and intermediate level schools (Becker et al., 1990). The careful selection of appropriate open-ended problems gives teachers the opportunity to discuss and compare the different methods used by students to solve these problems. This enables students to develop a sound understanding of mathematical enquiry.

In the IAEP (1991) survey of mathematics achievement, there was considerable variation amongst the participating countries in the use of classroom organisational practices. Nearly 80 percent of schools in Scotland reported using ability grouping for students during mathematics lessons. Between 40 and 60 percent of schools in Korea, Hungary, the Soviet Union, Ireland, Canada, Slovenia, England, and Portugal made use of ability grouping as well. In the remaining countries, the majority of schools employed mixed-ability grouping to organise mathematics classes (Lapointe et al., 1992a).

Lapointe and his colleagues also reported that approximately 40 to 70 percent of 9-year-old students across most of the countries were frequently required to work independently on mathematics exercises. In half of the 14 countries significant, positive relationships were found between frequency of working independently on exercises and student achievement (only one negative relationship was observed). However, students who spent a lot of time working with mathematics
equipment (e.g., counting blocks, geometric shapes, or geometric solids) produced significant, negative correlations with mathematics performance in 11 countries.

**Practices of New Zealand Teachers**

To gain an insight into the practices of New Zealand primary teachers teaching mathematics, it is of interest to look at May and Lamb’s (1987) study again. It should be remembered that this data was collected over a decade ago in 1981.

Most of the standard 4 teachers indicated that they taught mathematics mainly as a separate subject, with little integration occurring with other subject areas. In more than half the classes surveyed, the same content was taught to all students, although they could work at their own pace. Another 30 percent of teachers reported they offered groups of students work adapted to their ability levels.

May and Lamb also found that 90 percent of teachers gave much importance to the teaching and learning of basic facts. A lot of time was also spent on the development and practice of computational skills, and, to a lesser extent, to neat setting out (61%), applying mathematics to everyday situations (53%), and to checking answers by reworking problems (42%). On the other hand, only 28 percent and 22 percent of teachers respectively thought that estimating answers to problems and locating patterns in shapes and numbers should receive much emphasis.

On average, teachers spent up to four hours per week teaching mathematics and another 90 minutes in lesson preparation. In comparison, the standard 3 teachers in the IEA Reading Literacy Study reported a mean of about five hours per week for reading instruction (Chamberlain, 1993).

Teachers tended to rely mainly on materials provided by the Department of Education when selecting topics and goals, teaching strategies, practice exercises, and test items. Not much classroom material was generated from journals, workshops, and courses, although the majority of teachers reported that they valued attendance at refresher courses and in-service training.

The teachers’ attitudes and beliefs regarding discipline and classroom management were sought through their responses to a series of scales. May and Lamb (1987) concluded that, overall, these characteristics represented “a classical or conservative style of teaching” (p32). The exceptions to this style included the orientation of lessons towards the individual learner and discouraging students from comparing their achievement with others in the class.

**SCIENCE ACHIEVEMENT AT THE 9-YEAR-OLD LEVEL**

There have been three major international comparative studies on science achievement in primary schools. The most recent, the IAEP study conducted in 1991 (in conjunction with mathematics), focused on the 9-year-old level. The other two were IEA studies, the First International Science Study (FISS) (1970–71) and the Second International Science Study (SISS) (1983–84), both of which surveyed the achievement of 10-year-olds. Although New Zealand participated in FISS it was only at the two higher population levels — 14-year-olds and students in the final year of schooling.
As with mathematics, prior to TIMSS there has been no large-scale research on the science achievement of New Zealand primary students within an international context.

Research into primary school science by the Learning in Science Project (LISP) undertaken at the University of Waikato, which focused on the teaching and learning of science in forms 1 to 4 has been widely recognised. LISP has been conducting research in New Zealand schools since the late 1970s.

The National Education Monitoring Project (NEMP) began in 1993 under the direction of the Educational Assessment Research Unit based at the University of Otago. Science was one of the first set of three subjects assessed in the first year of implementation, 1995. Science achievement of standard 2 and form 2 students was measured by a range of assessment methods (Crooks & Flockton, 1996b).

**International Comparisons — IAEP Study**

The same 14 countries took part in the science component of IAEP as participated in the mathematics component. Again, in four of these — England, Emilia-Romagna (Italy), Portugal, and Scotland — the results had to be considered in light of either low participation rates or restricted populations. The four science topics covered in the achievement tests included: Life Sciences (23 items); Physical Sciences (17 items); Earth and Space Sciences (10 items); and Nature of Science (8 items).

Lapointe et al (1992b) reported that the range of means across the 14 countries was just 13 percent, with some students in all countries achieving very highly and others achieving poorly. The mean percent correct across all countries was 62 percent.

Nine-year-olds from four countries scored significantly above the IAEP mean — Korea (68%), Taiwan, Emilia-Romagna (Italy) (both 67%), and United States (65%). Students from Canada, Hungary, England, Spain, Soviet Union, Scotland, and Israel all achieved at a level close to the IAEP mean. Finally, three countries scored below the IAEP mean; these were Slovenia (58%), Ireland (57%), and Portugal (55%).

An analysis of the results by gender revealed significant differences for eight countries in science — Korea, Taiwan, Canada, Hungary, Spain, Israel, Ireland, and Portugal — all favouring the boys. The largest gender gap was found in Korea, where the boys scored, on average, about five percent higher than the girls.

**IEA Studies**

The First International Science Study (FISS) was one component of a research project called the Six Subject Survey, conducted from 1966 to 1973. The chief purpose of FISS was “to assess students’
scientific knowledge and to measure their ability to understand the nature and methods of science” (Medrich & Griffith, 1992, p13). Sixteen countries or educational systems took part at the 10-year-old level. There were four science content areas — Biology, Physics, Chemistry and Earth Science — included in the achievement tests (two forms of 20 items each) at this level. As well, students were required to complete an attitude questionnaire of about 20 items.

The science achievement results showed that students from Japan significantly outperformed those from all other countries. After Japan, there was a group of countries whose students were performing at a similar level: these were Sweden, Belgium (Flemish), United States, Finland, Hungary, and Italy.

Comber and Keeves (1973) reported gender-related differences for the total science score, with boys performing better than girls by about 0.25 of a standard deviation across all but two of the 16 countries.

For the Second International Science Study (SISS), conducted in 1983–84, the context of the research was expanded. Apart from the comparative achievement aspect, other goals included a description of the science education of each country taking part; seeking explanations for the differences between students within countries; and investigating any changes in student performance between the first and second studies. Fifteen countries participated in the SISS at the 10-year-old level. The tests consisted of 24 core items given to each student and eight randomly assigned items from a pool of 32. In addition to the achievement tests, students also had to complete a Student Questionnaire and Attitude Questionnaire.

The countries with the highest scoring students were Japan, Finland, and Korea. The next group of countries who performed at a similar level comprised Sweden, Canada, and Hungary. In contrast, the 10-year-olds achieving in the lower ability range came from United States, England, Poland, Israel, Singapore, Hong Kong, the Philippines, and Nigeria. Gender differences were analysed again — and revealed a similar pattern in favour of boys, as reported in FISS.

The collection of data from two separate studies over a period of years provided an opportunity to measure the change in achievement over time. Keeves (1992) analysed the results from seven countries who participated in both studies at the 10-year-old level. In all cases there was a positive change in science achievement. Keeves estimated that the mean gain across all seven countries was between three-quarters and a full year of schooling in science.

Science Achievement in New Zealand

Major research on science education in New Zealand has been undertaken as part of the Learning in Science Project (LISP), under the auspices of the Science Education Research Unit (now the Centre for Science, Mathematics, and Technology Education Research), based at the University of Waikato. The LISP was designed to have three broad phases of enquiry focused at the 10- to 14-year-old level: observation of the teaching and learning of science in classrooms and the identification of problems and difficulties; an in-depth look at the teaching and learning of specific science topics; and an action-research phase based on the outcomes of the first two phases (Osborne et al, 1980).
The LISP research (e.g., Bell, 1993; Osborne & Gilbert, 1979, 1980a, and 1980b; Pearson & Bell, 1993; and Tasker, Osborne & Freyberg, no date) is largely of a descriptive nature, based on qualitative methods such as participant observations and interviews, typically involving small numbers of students. Although the initial phases of the work were primarily concerned with learning processes, the findings provide valuable insights into student understanding of science ideas.

Osborne (1980), and subsequent studies, investigated students’ cognitive structures by focusing on students’ views of the world, and the meanings they develop for words and concepts used in science lessons. A number of student characteristics were evident from the analysis of interview data:

- personalised and egocentric views of science concepts;
- quantities that cannot be observed were thought not to exist;
- surface knowledge only of scientific concepts and events;
- a more scientific understanding of the world was often associated with confusion about physical quantities.

Later studies by Tasker (1981) and Osborne (1982) focused on the different expectations of students and teachers during typical science lessons. They found that students bring a wide range of background knowledge to classes and, despite the best efforts of teachers, leave still holding ideas and concepts that are some distance from the understanding of scientists, and that what some students learn during a science lesson is often not intended by the teacher or curriculum.

Crooks and Flockton (1996b) reported that results for three science tasks in NEMP had statistically significant differences by gender at the standard 2 level, with boys performing better than girls in each one. Form 2 boys outperformed form 2 girls on the 10 (of 33) tasks on which there were significant gender differences and Crooks and Flockton point to a worrying trend in these statistics.

A comparison between NEMP results for Maori and non-Maori revealed that in the 19 of 31 individual tasks at standard 2 level, and the 19 of 33 individual tasks at form 2 level for which there were significant differences, non-Maori scored higher than Maori.

ATTITUDES AND BELIEFS OF 9-YEAR-OLDS

International Surveys

In the IAEP study, only one question on attitudes to science was included at the 9-year-old level. Students were asked to indicate whether or not they thought science was equally appropriate for boys and girls. In all but one of the 14 countries, almost 80 percent of the students indicated they agreed with the statement. The highest levels of support were found in Spain (91%) and Emilia-Romagna (Italy) (88%). The exception, as reported also in the mathematics study, was Korea, where just 43 percent of the 9-year-old students agreed with the statement. It was interesting to note that Korean students also had the largest gender difference in science achievement — favouring boys (Lapointe et al, 1992b).
As part of the SISS, three constructs of attitudes and beliefs to science were investigated at the 10-year-old level. These included: importance of science, interest in learning science, and ease of learning science (Keeves, 1992). In general, the students’ responses indicated a strong, positive attitude to the learning of science. However, there was a definite decrease in the strength of the attitudes between the 10- and 14-year-old populations. Students from Hungary, Italy, and Thailand were mainly found to possess the strongest positive attitudes to science; in contrast, students from Japan and the Netherlands held less desirable attitudes. Keeves also examined the effects of attitudes on science achievement. He found that for nearly all countries, attitudes to science have a direct link in accounting for differences between students within classrooms, as well as differences between groups of students. An analysis of the attitude results by gender was also completed. Significant differences were observed at the 10-year-old level, with boys indicating more positive attitudes than girls to science.

**Attitudes and Beliefs of New Zealand Students**

Not much research exploring the attitudes of New Zealand primary students to science has been reported. Young-Loveridge (1992) provided some insight through her mathematics research, when she asked 9-year-old students \((n = 68)\) to rate from a list the three school subjects they liked best. As their first choice, science was selected by only one student (2%) and was last of the seven subjects listed. The most liked subjects were art (34%), mathematics (25%), reading, and music (both 15%). When combining the top three subject choices as an overall rating, 25 percent of students indicated they liked science, although it improved by only one position ahead of spelling (19%). The other subjects were much more popular — art (84%), mathematics (53%), reading (43%), music, and writing (both 38%). There were virtually no gender differences in the students’ rating of science.

The NEMP study included questions about students’ science attitudes and aspirations. Crooks and Flockton (1996b) noted that standard 2 girls were less positive than their male classmates about their ability in science, and their suitability to be a scientist when they grew up. Form 2 girls’ attitudes had become considerably more negative and Crooks and Flockton commented that “The survey presents a bleak picture of girls’ enjoyment of science in school, confidence in their performance and ability, involvement in science activities in their own time, and interest in further study in science”.

**ATTITUDES AND BELIEFS OF TEACHERS TO SCIENCE**

**International Surveys**

There is a general acceptance that teachers have a vital contribution to make in the learning of science, not just in their ability to develop understanding and skills, but also through the attitudes towards science they communicate and the way they promote the subject to students.
Keeves (1992) used data from SISS to examine the effects of teacher characteristics on science achievement. He found a cluster of characteristics of teachers at the 10-year-old level that had a positive effect on learning. These characteristics included teacher age, years of experience, years of post-secondary education, frequency of reading science journals, and days of in-service education.

As a result of the curriculum reforms in the late 1980s, science is now taught in British primary schools. Consensus about the standard of scientific knowledge attracted a number of researchers (eg Bennett et al, 1992; Summers & Kruger, 1992; Wragg et al, 1989; Whittaker, 1980) who identified not only a lack of confidence amongst teachers to teach science but also poor understanding of related concepts and processes.

In a recent study, Harlen and Holroyd (1997) interviewed 36 primary school teachers in Scotland about their understanding of science concepts (eg water, electric circuit). Teachers also provided details of their teaching background and confidence in their ability to teach science. Many mistakes about science concepts were evident from the interviews. Most of these were able to be grouped in the following way:

- giving an inappropriate analogy;
- attributing properties that do not correspond with reality;
- proposing a mechanism for which there is no evidence;
- equating everyday language with scientific language; and
- believing that ‘some’ means ‘all’.

Harlen and Holroyd reported that 10 of the teachers possessed both a high understanding of science and high confidence in their ability to teach the subject. In contrast, there were 12 teachers who were low in both understanding and confidence. Significant differences were evident in confidence to teach science — male teachers tended to be more confident than female teachers, teachers with more recent qualifications than teachers with more than 12 years of experience, and teachers with a science background compared to those without. The researchers believe that the effects of low confidence and low understanding are likely to result in teachers using strategies to avoid or minimise their teaching of science.

Attitudes and Beliefs of New Zealand Teachers

Little recent research is available on the background characteristics and attitudes of teachers of science in New Zealand primary schools.

In their study of standard 4 mathematics, May and Lamb (1987) noted that teachers ranked science as the subject they disliked teaching the most. Further, they also considered science to be one of the least important subjects for the development of students at the primary level.

Data gathered on the general reading habits of standard 3 teachers from the Reading Literacy Study in 1990 included a question on the frequency of reading books on science. Almost half the teachers ‘never or almost never’ read science books, another 40 percent read science books ‘once a term or month’, while only about 10 percent read science books ‘once a week’. In comparison, the standard 3 teachers spent much time engaged in reading material on teaching, reading, novels or short stories, and books for children (Chamberlain, 1993).
TEACHING PRACTICES IN SCIENCE

Overseas Surveys

The teaching and learning of science involves more than the mastery of concepts and principles. It also includes the acquisition of the skills of inquiry through practical and laboratory work. Keeves (1992) set out to investigate the emphasis given to different aspects of science using data from the SISS. At the 10-year-level, Observation was found to have the highest level of emphasis by teachers, followed by: Knowledge and Understanding; Measurement; Attitudes, Interest and Values; Manual Skills; Interpretation of Data; Problem Solving; and Processes.

Practices of New Zealand Teachers

As is the case for mathematics, primary school science is generally taught by ‘generalist’ teachers rather than subject specialists. Approximately 75 percent of standard 3 classes are ‘composite’ (or multi-grade) classes with total class sizes of about 30 students (Chamberlain, 1993).

BACKGROUND CHARACTERISTICS OF 9-YEAR-OLDS

One of the main aims of the IEA studies was to identify factors that may assist in explaining outcomes in mathematics and science achievement. These included such factors as student gender, socio-economic status, home language, household size, home literacy resources, out-of-school activities, student self-ratings, and student attitudes to mathematics and science.

In the 1990 IEA Reading Literacy Study, student background data of 9-year-olds was collected in 27 countries during 1990–91. Caygill (1993) analysed and reported on this data as part of the New Zealand national report.

Socio-Economic Status

Socio-economic status is an important variable in explaining the academic success of school students. It has repeatedly been found that this variable can account for a large part of the variance in student achievement (see for example Nash & Harker, 1994; Willms, 1986, Rutter, 1983; as well as IEA studies).

Direct measurement of variables, such as parental income and occupation, contributing to socio-economic status was not possible for some countries in TIMSS because of privacy laws. This problem became an issue in the Reading Literacy Study, and in that study home and student possession scales were combined to act as a surrogate measure for socio-economic status. Caygill (1993) reported a significant positive correlation between home and student possessions and reading literacy achievement. Similar scales were developed for use in TIMSS.
Ethnicity

In relation to issues of equity and to enable comparisons between ethnic groups, students in the Reading Literacy study were asked to indicate which ethnic group(s) they belonged to. Caygill (1993) reported that a quarter of the 9-year-olds identified as Maori, a further 72 percent as Pakeha/European, about nine percent as Pacific Islands, and about three percent as Asian. As in previous studies, ethnicity was strongly linked to achievement.

Home Language

Success at school can be affected by the language of the home. Caygill (1993) found that more than 90 percent of 9-year-olds ‘always’ or ‘almost always’ spoke English at home. However, six percent and two percent of students respectively spoke English only ‘sometimes’ or ‘hardly ever’. Most of the students who spoke English ‘hardly ever’ were of the Pacific Islands and Other-Non-Pakeha ethnic groups. There was a significant positive relationship between speaking English at home ‘always’ or ‘almost always’ and high scores on the reading achievement tests.

Homework

Educational researchers (see Walberg et al, 1985 and Walberg, 1993) have long emphasised the important role that homework can play in improving student achievement. In the recent IAEP study of mathematics and science (Lapointe et al, 1992a and 1992b) Lapointe and his colleagues again identified significant positive relationships between time spent on homework and student achievement in three countries for science and four countries for mathematics.

Data from the IEA study of Reading Literacy in 1990, indicated that approximately three-quarters of New Zealand 9-year-olds were given reading homework at least ‘once or twice’ per week (Caygill, 1993).

Television Viewing

In the 1987 IEA report, Writing Performance in New Zealand Schools, Lamb found that low achievers spent much more time than high achievers watching television. Caygill (1993) reported that just over half (55%) of the 9-year-olds spent more than two hours daily watching television or video. There was no difference in the amount of viewing between boys and girls. However, Maori (24%) and Pacific Islands (22%) students were more likely to be ‘heavy’ television viewers (more than five hours per day) compared to Pakeha/European (10%) and Other Non-Pakeha (13%) students. Correlation analyses revealed a significant negative relationship between amount of time watching television and achievement on the reading tests.

Looking at international comparisons, Elley (1992) noted that New Zealand 9-year-olds watched considerably more television than their overseas peers. The mean number of hours for New Zealand was 2.6 (the second highest of all countries), across all countries it was 2.1 hours, and the range was from 1.4 (Indonesia) to 3.0 (United States) hours.
CLASSROOM VARIABLES

The Implemented Curriculum

The implemented curriculum is the programme of lessons and other learning experiences and opportunities that teachers provide for their students. For a given mathematics or science lesson it depends on how the class teacher interprets the intended curriculum, the teacher’s knowledge and beliefs about education in general and mathematics or science in particular, and the teacher’s perception of the abilities and needs of the students in the class. The implemented curriculum is also affected by school level practices and policies which the principal expects to be carried out.

Previous IEA studies (Garden & Irving, 1987; and Keeves, 1992) have shown that the implemented curriculum differs markedly from the intended curriculum in many classrooms.

Class Size

Substantial research has been undertaken in the USA into the effects of class size on student achievement at the 9-year-old level (see for example Odden, 1990; Robinson, 1990). In general, the findings show that a class size of approximately 15-20 or fewer is required to attach significant gains in mathematics and science achievement. In addition to the gain in student achievement, the effects on educational outcomes of improved classroom management, reduction of teacher stress, and a more thorough completion of learning tasks through smaller classes represent important claimed benefits.

On the other hand, classes in countries such as Korea, Hong Kong, and Japan are very large by Western standards, yet student achievement is high, demonstrating that no one variable explains achievement on its own. Improving student achievement significantly involves making changes in several contributing variables.

In the second IEA science study at the youngest population level (10-year-olds), those countries who reported having the smaller classes were more likely to contain the highest-achieving students (Medrich & Griffith, 1992).

Time for Instruction

A key determinant of the extent of the opportunity students have to learn science and mathematics is the time made available for teaching the subjects. This variable also provides an indicator of the importance teachers attach to the respective subjects in relation to the overall curriculum. In the Reading Literacy Study it was found that, on average, standard 3 teachers allocated 22 percent of their total time available for teaching to reading instruction, and a positive correlation existed between time spent on reading instruction and achievement in reading comprehension. TIMSS data will allow comparison between the Reading Literacy instructional time statistic and comparable figures for mathematics and science.

In SIMS (Garden & Irving, 1987), a ratio of three hours of mathematics teaching for every five hours teaching reading was reported by New Zealand standard 4 teachers. At the 10-year-old level
in the Second International Science Study conducted in 1983–84, the mean percent of total instruction time for science across 15 countries (not including New Zealand) was nine percent. England was the country with the lowest mean proportion (3%) (Postlethwaite & Wiley, 1992). Further analysis by Keeves (1992) demonstrated a significant positive relationship between time for instruction and science achievement.

Quality of Teaching

Obviously, a key determinant of student achievement is the quality of teaching that students receive. Many variables are involved in establishing quality teaching, and in a survey measures are necessarily limited. However, it is apparent that a pre-requisite for quality instruction in a field is knowledge of the field, and teaching is likely to be more efficient if teachers have been teaching long enough to have learned how to maximise appropriate opportunity-to-learn for their students. Keeves (1992), and Medrich and Griffith (1992) demonstrate the positive relationships between teaching qualifications and teaching experience and mathematics and science performance.

More than 80 percent of New Zealand standard 3 teachers who participated in the Reading Literacy Study in 1990 had completed their teacher training over a two- or three-year period. A significant positive relationship was observed between number of years of training and student achievement in reading (Chamberlain, 1993).

Summary

The aim in this chapter has been to present an overview of the New Zealand and overseas research focusing on the mathematics and science achievement of students at, or about, the same level as standards 2 and 3 students participating in TIMSS. In addition to past IEA and IAEP surveys of mathematics and science achievement, areas of research relating to the effects of student and teacher attitudes, background characteristics of students, and classroom variables on achievement have been discussed.