Introduction

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CHAPTER 1

INTRODUCTION

NATURE AND WORK OF IEA

The International Association for the Evaluation of Educational Achievement (IEA) is an international, non-profit-making cooperative of research institutions. A permanent secretariat is located in Amsterdam, in the Netherlands. The principal purposes of IEA are to:

• undertake comparative educational research on an international scale;
• promote research aimed at examining educational problems in order to provide factual information which can help in the ultimate improvement of education systems;
• provide means whereby research centres in the various member countries of IEA can undertake cooperative projects.

Within each country, a leading research organisation represents their country on IEA. The organisation is responsible for the conduct of any IEA research project in which it and national authorities agree participation is desirable. In New Zealand, the Ministry of Education is the member institution of IEA.

New Zealand participated in its first IEA study — the Six Subject Survey — in the early 1970s, followed by the Second International Mathematics Study (SIMS) in 1981. Other studies in which New Zealand has taken part include the Written Composition Study (1984), the Computers in Education Study (1989), and the Reading Literacy Study (1990). New Zealand did not take part in the Second International Science Study (SISS, 1983).

New Zealand’s participation in the current study — The Third International Mathematics and Science Study (TIMSS) — is the subject of a series of reports, of which this is the third.

BACKGROUND TO THE STUDY

Overview

One of the most important features of TIMSS is that it enabled the collection of information on the nature of teaching and learning at both international and national levels. The result will be a current description of student achievement in mathematics and in science. The study will be able to place these achievements into context as a result of investigation of the curricula and teaching and
classroom practices in participating countries. It will also provide a benchmark for educational systems to evaluate the current status of their mathematics and science education, and determine their needs in terms of assessment practices and resources for the twenty-first century. For New Zealand this is particularly pertinent, as data for the study were collected at a time when new mathematics and science curricula were being developed and introduced.

Coordination of the Study

In New Zealand, TIMSS is being administered by the IEA Unit within the Research and International Section of the Ministry of Education, Wellington. International administration of the study and subsequent analyses of the data and production of the international reports is the ongoing responsibility of the TIMSS Study Centre, Boston College, Boston, Massachusetts, USA. The Study Centre is supported by the International Coordinating Centre (ICC) located at the University of British Columbia, Vancouver, Canada.

Participating Countries

New Zealand is one of more than 40 countries or educational systems taking part in the study. The 26 participating countries at the middle primary level are:

Australia          Iceland          New Zealand
Austria            Iran (Islamic Rep.) Norway
Canada             Ireland          Portugal
Cyprus             Israel           Scotland
Czech Republic     Japan            Singapore
England            Korea            Slovenia
Greece             Kuwait           Thailand
Hong Kong          Latvia           United States
Hungary            Netherlands

New Zealand Report

The main aim of this report is to describe the achievement of New Zealand students in mathematics and science at the standards 2 and 3 levels. While the focus of the report is on the New Zealand results, where possible international data have been included to put the achievement of New Zealand students into an international context. Unless otherwise stated, TIMSS population 1 data for other participating countries is unpublished at the time of writing and, while it is very unlikely to change, should be regarded as preliminary. Where items have been used as examples, for some only a description of the content is given due to an international policy on the release of achievement items.
Other New Zealand reports

Two reports have already been published:
• Mathematics Performance of New Zealand Form 2 and Form 3 Students (Garden, 1996a); and
• Science Performance of New Zealand Form 2 and Form 3 Students (Garden, 1996b).

Topics for later reports will be:
• Mathematics and science literacy of New Zealand’s school leavers;
• The achievement of New Zealand students in mathematics and science in an international setting;
• The New Zealand technical report.

The two earlier reports included only New Zealand data. This report, and subsequent reports, will include international data.

International Reports

A series of major reports dealing with the mathematics and science achievement for each population is being published by the Study Centre in Boston. Two of these reports — published in November 1996 — present the international mathematics and science results for population 2 (forms 2 and 3 in New Zealand). For further details see Beaton et al, 1996a and 1996b. Results of the curriculum analysis component are being published from Michigan State University, where the team responsible for TIMSS curriculum analysis is located; the first volume on mathematics was released in March, 1997, with the companion volume on science to follow. See Schmidt et al, 1997a and 1997b. In addition, a series of monographs is to be published.

The first three have been published:
• Curriculum Frameworks for Mathematics and Science (Robitaille et al, 1993);
• Research Questions and Study Design (Robitaille & Garden, 1996);
• Mathematics Textbooks: a comparative study of grade 8 texts (Howson, 1995).

The fourth monograph deals with mathematics and science literacy.

RATIONALE FOR THE STUDY

Conceptual Framework of the Study

The conceptual framework for TIMSS is based on the concepts of the intended, implemented, and attained curricula and was derived and adapted from the model used in the IEA Second International Mathematics Study (SIMS), as shown in Figure 1.1.
This model has subsequently been modified and updated during the development of a framework for TIMSS. This framework is shown in Figure 1.2.
For the purpose of this study, the *intended* curriculum refers to the aims, content, and methods for teaching and learning mathematics and science as defined by education authorities at the national, regional, or local level. It is described in published documents such as curricula guides, prescriptions, syllabuses, policy statements, and other official statements produced to guide schools and teachers. Textbooks, resources, and examinations also reflect the essence of the *intended* curriculum. The mathematics and science content students are expected to learn may be described in the form of concepts, processes, skills, and attitudes. As well as being set within a specific educational context which includes institutional arrangements for the system, the *intended* curriculum is also set within the context of a society. Societal factors influencing the context may include the goals and expectations the society holds for schooling, participation rates, the role of independent schools, the professional preparation of teachers, the status accorded to teachers, the resources society has, and the proportion of those resources allocated to education.

Teachers in turn interpret, translate, and implement the intentions of the mathematics and science curricula according to their own experiences and beliefs. The educational milieu in which the *implemented* curriculum is placed embodies institutional arrangements made at the school and class level but is largely influenced by system level arrangements. Teacher interpretation of content and teaching practice in terms of teaching strategies used in their lessons, and time allocation, also contribute to the nature of the *implemented* curriculum. The local community, while often reflecting society-at-large, provides the context for the setting of the *implemented* curriculum. Social, cultural, and economic characteristics of the community, parent involvement in the community, expectations held for schooling, and participation rates of students are just some of the contextual features believed to influence achievement.

The *attained* curriculum consists of the concepts, processes, skills, and attitudes towards mathematics and science that students have acquired during their schooling. Student learning will be affected by what was intended and by the quality and types of opportunities made available to them. Institutional arrangements such as allocation of staff and time made available for instruction also provide a context for the *attained* curriculum. The *attained* curriculum can also be placed in the broader context of students’ backgrounds. Student backgrounds are likely to be influenced by their community and by society-at-large. Attitudes to education, students’ perceptions of their own abilities, and the economic well-being of their families are likely to have an influence on students and are therefore important to take into account when examining the *attained* curriculum (Robitaille et al, 1993; Robitaille & Maxwell, 1996).

The framework depicted in Figure 1.2 thus provides the rationale and context for the development of the research questions.

**Research questions**

The research questions were formulated at two levels. The first level is of broad generality. At the second level, a large number of specific questions, amenable to the provision of specific answers using the data collected, were also framed.
The four general questions under which all specific questions were grouped are:

1. How do countries vary in the intended learning goals for mathematics and science; and what characteristics of educational systems, schools, and students influence the development of those goals?

2. What opportunities are provided for students to learn mathematics and science; how do instructional practices in mathematics and science vary among nations; and what factors influence these variations?

3. What mathematics and science concepts, processes, and attitudes have students learned; and what factors are linked to students’ opportunity to learn?

4. How are the intended, the implemented, and the attained curricula related with respect to the contexts of education, the arrangements for teaching and learning, and the outcomes of the educational process?

Source: Robitaille & Maxwell, 1996.

Curriculum Frameworks

To enable systematic analyses of curricula as well as valid inter-country comparisons of mathematics and science education in participating countries, common curriculum frameworks for each of mathematics and science were developed. They provide structures from which the intended curricula of countries can be compared, as well as providing a basis for developing appropriate achievement tests and questionnaires.

In previous IEA studies, particularly those pertaining to mathematics, “content-by-cognitive-behaviour” grids were used for comparing curricula and constructing achievement measures. They were usually represented by a two-dimensional grid with the horizontal dimension representing student cognitive behaviours in hierarchical levels (e.g., simple recall, comprehension, applications, analysis). Content areas were specified in the vertical dimension. Achievement test items or curricular material were assigned to cells within this grid. There were limitations associated with such grids as they failed to take account of the inter-relationship of content areas or of cognitive behaviours. Consequently, for TIMSS there are three dimensions to the frameworks: content, performance expectations, and perspectives.

Content was defined as the mathematics or science subject matter being considered. Performance expectations is a re-conceptualisation of the cognitive behaviour dimension and is intended to be non-hierarchical in nature. The aim is to enable a description of many kinds of performance expected of students who experience the intended curriculum. The intention of the perspectives aspect is to describe curricular goals that promote positive attitudes, interest, and motivation in mathematics and in science. In addition, learning situations which promote the participation of under-represented groups, as well as those which encourage students to pursue careers in mathematics, science, or technology, can be described using these perspectives (Robitaille et al, 1993).
Figure 1.3

The mathematics framework

Content
- Numbers
- Measurement
- Geometry: position, visualisation, and shape
- Geometry: symmetry, congruence, and similarity
- Proportionality
- Functions, relations, and equations
- Data representation, probability and statistics
- Elementary analysis
- Validation and structure
- Other

Performance Expectations
- Knowing
- Using routine procedures
- Investigating and problem solving
- Mathematic reasoning
- Communicating

Perspectives
- Attitudes
- Careers
- Participation
- Increasing interest
- Habits of mind

The science framework

Content
- Earth sciences
- Life sciences
- Physical sciences
- Science, technology, and mathematics
- History of science and technology
- Environmental and resource issues related to science
- Nature of science
- Science and other disciplines

Performance Expectations
- Understanding
- Theorising, analysing, and solving problems
- Using tools, routine procedures, and science processes
- Investigating the natural world
- Communicating

Perspectives
- Attitudes
- Careers
- Participation
- Increasing interest
- Safety
- Habits of mind

A description of the mathematics and science categories identified in Figure 1.3 can be found in Garden (1996a) and Garden (1996b), respectively. A more detailed account is reported in Robitaille et al (1993).

**POPULATION DEFINITIONS**

The target populations for this study were located in primary, lower secondary, and upper secondary schools. The international population definition for the youngest age group is:

*Population 1: all students enrolled in the two adjacent grades that contained the largest proportion of students in the age 9 cohort (at the time of testing).*

In New Zealand, this translated to: all students in standard 2 and standard 3 in October, 1994.\(^1\)

The international definition for the middle age group is:

*Population 2: all students enrolled in the two adjacent grades that contained the largest proportion of students in the age 13 cohort (at the time of testing).*

In New Zealand, this translated to: all students in form 2 and form 3 in October, 1994.\(^2\)

The international definition for the oldest student group is:

*Population 3: all students enrolled in their final year of secondary education.*

In New Zealand, this translated to: Year 12 and Year 13 students in form 6 or form 7 in August, 1995.

Two class levels of students were included in population 3, since there was still a relatively large proportion of students leaving school after their form 6 year. The apparent retention rate from form 3 to form 7 was 48 percent in 1994 (Ministry of Education, 1995a). The flexible nature of form level enrolment in relation to the level at which subjects are being studied in the senior school in New Zealand, combined with the classification of senior students, was the other reason for defining the population as above.

**SAMPLING**

The following discussion provides a brief outline of the procedures used to obtain the New Zealand samples. A detailed explanation of the sampling procedures will be presented in *Technical Report of the TIMSS Study in New Zealand* (May & Udy, in press), available from the IEA Unit, Research and International Section, Ministry of Education.

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\(^1\) Using the new nomenclature, which was formally introduced in 1996, Years 4 and 5 students are mostly located in standards 2 and 3.

\(^2\) Form 2 is the final year of primary school and form 3 is the first year of secondary school (Years 8 and 9 respectively).
There were two stages to the sampling — school level and class level. The teacher sample was made up of teachers of the selected classes. The following discussion describes the procedures used in New Zealand to select the schools, students, and teachers at the standards 2 and 3 levels.

**School and Student Level Sampling**

The number of schools required at the standards 2 and 3 levels was determined by the precision required in the results\(^3\) and the need to have enough cases to deal with the large number of independent variables that were under scrutiny.

All schools with at least five students in standard 2 and standard 3 combined, excluding special schools and the Correspondence School, were included in the sampling frame. A sample of schools containing students in New Zealand’s desired target population was drawn from this frame. Schools were implicitly stratified (or sorted) by:

- The size of school; and
- The size of the community in which the schools were located.

Schools were randomly selected with probability proportional to their total number of standard 2 and standard 3 students.

The mathematics groupings within each school were used as the basis for selecting the student sample at the school level. One mathematics group or class was randomly selected from each of the class levels in a selected school. All students in that class were selected to take part in TIMSS except in specified circumstances (eg insufficient familiarity with the English language or a physical disability which would prevent them participating in the actual testing).

**Teacher Selection**

The teacher who taught mathematics to the group or class was selected to take part. The teacher(s) who taught science to a minimum of five students in the mathematics group or class was/were also selected to take part. In many cases, teacher sampling at this population level was very complex due mainly to the structures of some middle school syndicates. For example, if a standard 2 and 3 composite class was selected, and the same teacher taught mathematics and science to both standard 2 and standard 3 students, then the teacher was selected to participate in both subject areas at the standard 3 level only. In other cases, particularly in bigger schools, grouping students by ability for mathematics at these two class levels was common practice; so students moved out of their homeroom for mathematics. In these cases, the mathematics teacher of the selected ‘grouping’ was selected while the homeroom teachers were selected for science.

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\(^3\) The maximum acceptable sampling error for an estimate of proportion correct for an achievement item was set at ±0.05.
Sampling Summary

Table 1.1

<table>
<thead>
<tr>
<th>Explicit strata</th>
<th>Designed sample</th>
<th>Achieved sample*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Schools (N)</td>
<td>Students (N)</td>
</tr>
<tr>
<td>Total</td>
<td>150</td>
<td>5157</td>
</tr>
</tbody>
</table>

Notes: 1^ Participation in at least one session (ie completion of the background questionnaire or at least one of the achievement tests).

2^ One school withdrew from the study too late to be replaced.

Sample Quality

As can be seen in Table 1.2, response rates based on participation in at least one of the achievement testing sessions are very high, exceeding the minimum specified by the international study management by 10 percent.

Table 1.2

<table>
<thead>
<tr>
<th>Explicit strata</th>
<th>Designed sample</th>
<th>In at least one achievement test session</th>
<th>Response rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Schools (N)</td>
<td>Students (N)</td>
<td>Schools (N)</td>
</tr>
<tr>
<td>Total</td>
<td>150</td>
<td>5157</td>
<td>149</td>
</tr>
</tbody>
</table>

A selection of variables were identified as being important to ensure that the achieved sample was representative of the population from which it was drawn. Information gathered from students who completed a Student Background Questionnaire indicated that in the achieved sample Maori students were over-represented, and Pakeha/European students slightly under-represented, compared with the total standards 2 and 3 population at the time of testing in October 1994. These deviations would have given rise to negligible differences in study statistics from those which would have been obtained if the ethnic proportions had been exactly correct.

Thanks to the excellent cooperation of principals, teachers, and students the quality of the achieved New Zealand sample is very high, one of the best in the study. Readers can have a high degree of confidence in the data.
INSTRUMENTATION

Intended Curriculum

There were two main aspects to the study which enabled countries’ intended curricula to be examined. Firstly, information on the context of education at the national level was gathered using survey questionnaires, while the second component to this part of the study involved a detailed analysis of the intended curriculum — referred to below as the Curriculum Analysis.

There were three facets to the Curriculum Analysis. The first involved an analysis of current trends in mathematics and science education within each country. The second, Document Analysis, involved a detailed analysis of curriculum guides and selected textbooks used in each country, while the third, General Topic Trace Map, involved a sequence analysis of each country’s mathematics and science curricula.

Implemented Curriculum

To examine the implemented curriculum, context questionnaires were given to school administrators and teachers. The School Questionnaire was designed to gather data on a number of aspects related to science and mathematics instruction in schools. The Teacher Questionnaire was used to obtain information about how the curriculum was implemented in the classroom by the mathematics and science teachers of the students involved in the study. It also gathered data on the academic and professional backgrounds of teachers, as well as their opinions about, and attitudes toward, science and mathematics.

Attained Curriculum

To answer questions related to the attained curriculum, information on students was gathered in three ways. Achievement data was collected from students using pencil and paper tests. All students answered both mathematics and science questions. Student achievement was also measured by students’ performance in a number of hands-on tasks. A sub-sample of students located in standard 3 and form 3 took part in this aspect of the study, known as Performance Assessment. In addition, a Student Background Questionnaire was used to gather background and demographic data, as well as gauging student opinion and attitudes toward science and mathematics.

A more detailed discussion of the instrumentation used in TIMSS, as well as the development work involved, is located in Chapter 3.

DATA COLLECTION

Data collection for all facets of the study began in 1992, although there had been some initial trialling for the Curriculum Analysis in late 1991, with student, teacher, and school data collected in October, 1994. Achievement testing for the majority of schools was conducted in the last two weeks.
of that month. The last phase took place in August 1995, with the data collection at the population 3 level. The Curriculum Analysis data was submitted in the first quarter of 1993. This period of time was also characterised by the fact that major curriculum changes — in both mathematics and science — were under way. However, these changes were documented at the time data was submitted. Appendix 1 presents a list of the documents used for this phase of the data collection.

Table 1.3
A summary of data collection schedule
for TIMSS in New Zealand

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Data collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>July</td>
<td>Participation Questionnaire Part I</td>
</tr>
<tr>
<td></td>
<td>September</td>
<td>Participation Questionnaire Part II</td>
</tr>
<tr>
<td></td>
<td>November</td>
<td>Curriculum Analysis trial</td>
</tr>
<tr>
<td>1992</td>
<td>June</td>
<td>Context Questionnaire pre-pilot</td>
</tr>
<tr>
<td>1992-1993</td>
<td>August–April</td>
<td>Curriculum Analysis data collection</td>
</tr>
<tr>
<td>1993</td>
<td>April</td>
<td>Achievement Test pilot</td>
</tr>
<tr>
<td></td>
<td>October</td>
<td>Context Questionnaire pilot</td>
</tr>
<tr>
<td>1994</td>
<td>February</td>
<td>Population 1 &amp; 2 field trial*</td>
</tr>
<tr>
<td></td>
<td>April</td>
<td>Population 3 field trial</td>
</tr>
<tr>
<td></td>
<td>April</td>
<td>Performance Assessment field trial</td>
</tr>
<tr>
<td></td>
<td>October</td>
<td>Population 1 &amp; 2 main data collection</td>
</tr>
<tr>
<td></td>
<td>October</td>
<td>Performance Assessment data collection</td>
</tr>
<tr>
<td>1995</td>
<td>August</td>
<td>Population 3 main data collection</td>
</tr>
</tbody>
</table>

Note: * Because of the timing of the data collection (i.e., at the beginning of the school year in New Zealand) New Zealand did not fully participate in this phase of TIMSS.

QUALITY CONTROL

To ensure that data collected in each country participating in TIMSS are comparable, detailed administration procedures and documentation were developed by the Study Centre in Boston. In each country, the national centre overseeing the study was responsible for adherence to these standard procedures. A detailed discussion on the international and national quality control procedures used in TIMSS is included in Chapter 3.
SUMMARY

New Zealand’s commitment to one of the biggest ever international studies on mathematics and science educational achievement began in 1991. In New Zealand, this culminated in the data collection at the standards 2 and 3 and forms 2 and 3 levels in 1994, and forms 6 and 7 levels in 1995. This chapter has provided an outline of the framework used by IEA in the design of this very complex study, as well as an outline of the methodology used in New Zealand. The purpose of this report is to examine achievement in mathematics and science of standards 2 and 3 students and the factors that influence achievement, making comparisons with other countries where appropriate.