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Raising Australian Standards in Mathematics and Science: Insights from TIMSS (Conference Proceedings)

Australian Council for Educational Research (ACER)

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Raising Australian Standards in Mathematics and Science: 
INSIGHTS FROM TIMSS

Conference Proceedings
ACER National Conference 1997
ACER National Conference 1997

Raising Australian Standards in Mathematics and Science: Insights from TIMSS
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WELCOME TO THE CONFERENCE

The following message of welcome was given by ACER’s Executive Director, Professor Barry McGaw.

On behalf of the Australian Council for Educational Research, I am pleased to welcome you to this conference on the implications for Australia of the findings of the Third International Mathematics and Science Study.

An enormous amount of effort was put into this study by the international team responsible for it, including Ray Adams and his psychometrics research group at ACER which did all of the scaling of results, and the many national teams. It would be a tragedy if we did not seek to learn as much as we can from the study and to use that knowledge creatively in the development of curriculum and teaching of mathematics and science in Australian schools.

I am particularly pleased that we will have, in our conference, an international perspective on the study and its findings through the contributions from our speakers, Mrs Chang Swee Tong from Singapore and Professor James Stigler from the USA. I welcome them particularly.
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Thank you for your welcome.

I speak this morning in lieu of two Ministers who could not be here—Dr David Kemp, who has recently been promoted to Minister for Employment, Education, Training and Youth Affairs, and Senator Chris Ellison, who has taken on the responsibility of Minister for Schools, Vocational Education and Training.

This conference comes at a critical time for school education in Australia. At the end of the 20th century our young people are facing a world which is changing faster than ever, one in which a sound education is no longer just an advantage, but a vital necessity. How can we be confident that the education we provide our children is the best we can provide?

One way is to compare what is going on in Australia with what is happening internationally, and when it comes to mathematics and science, TIMSS has provided us with a rich source of data which we are only really beginning to explore.

But before we can be sure that young Australians are getting the education which is their right we must have a clear grasp of what we expect of them, and how we measure and report what they have achieved.

If you are a visitor to Australia unfamiliar with our school system, this might seem to be stating the obvious. Don’t Australian schools have curriculum standards? Don’t they have ways of assessing and reporting on what their students have learnt?

The answer of course is ‘yes’—many ways; as many ways as there are education systems in Australia, and more. That is what made the decision by all nine Australian education ministers in July 1996 to develop national standards and their agreement in March 1997 to a national reporting framework so significant. This question of national standards is something I would like to come back to in a moment.

For Australia, TIMSS has been enlightening for several reasons.

It has shown that our middle primary and lower secondary students are capable of high achievement in mathematics and science. Australia is ranked alongside most western nations, and the achievements in TIMSS of some States and Territories are on a par with the world leaders. TIMSS provides evidence of the fine job our teachers are doing in maths and science classrooms, and they have cause to be proud of their accomplishment.

But TIMSS is also increasing our awareness about how far we still have to go. It has brought home to us the realisation that we must do better if we want to look to the so-called ‘knowledge economy’ of the 21st century with confidence.
The countries that are world leaders in teaching maths and science—Singapore, Korea, Japan, Hong Kong—are near neighbours and significant trading partners of ours. Some, like Singapore, have not only excelled, but they have actually improved their performance over time.

We have a lot to learn from their experience. As the American project director of TIMSS commented, the test scores provide only the context of the study. The real interest is in determining why the test scores turn out the way they do.

The Commonwealth congratulates ACER not only for the professional way in which it has managed Australia’s participation in TIMSS, but also for presenting its results in a comprehensive yet readily understandable way. This is no easy task, and we hope all at ACER—particularly Jan Lokan, director of Australia’s participation, and those who have worked with her on TIMSS—will accept the appreciation of the Commonwealth for a job well done.

But as ACER itself points out, so much of what TIMSS has to tell us has yet to be teased out. For example, what student characteristics are most associated with achievement? What are the teaching practice influences?

DEETYA has commissioned ACER to explore some of the key factors which appear to influence achievement in Australian maths and science classrooms. This project is carrying out multilevel and multivariate analyses of the TIMSS data to identify the system, school, classroom and personal background variables that jointly explain Australian students’ achievement levels in TIMSS, concentrating on identifying those factors which are most amenable to change.

This is important and fascinating work, and we look forward to seeing the outcomes of ACER’s research.

Over the next two days you will have the chance to listen to some distinguished international visitors talk about TIMSS as it relates to school systems overseas. You will hear about an intriguing comparative study into classroom practice in Germany, Japan and the USA, and you will get some perspectives about maths and science education in top performing Singapore.

The importance that is being attached to the results of this study overseas is indicated by the intention to use TIMSS tests as a basis for the new national test in eighth grade in the United States, outlined by President Clinton in his State of the Union address earlier this year.

When President Clinton issued his challenge for every American state to be testing every fourth grader in reading and every eighth grader in maths by 1999 he made the point that raising national education standards is not easy. Some children will not be able to meet them at first—but good tests show who needs help, what changes in teaching to make, and which schools need to improve.

We all have reason to be encouraged by what Australian students have shown through TIMSS, but we can afford to be no more complacent than the Americans. Evidence from so many sources—including surveys managed by ACER such as the Longitudinal Surveys of Australian Youth and the National School English Literacy Survey—shows clearly that too many of our young people face lifelong disadvantage because of poor literacy and numeracy.
It is clear that unless we make a coherent national effort to raise standards in literacy and numeracy we risk consigning our children to a second-rate future in the 21st century.

That is why we need national action, firstly in setting national educational standards and, secondly, in measuring achievement against those standards. Putting in place national standards, together with a mechanism to enable us to compare the outcomes of schooling across the country, is one of the greatest challenges facing Australia’s federal education system in the late 1990s.

When Australia’s education ministers came together in Hobart in 1989 they promulgated this country’s first set of national goals for schooling. One goal was to develop in students a range of skills and understandings including the skills of English literacy and numeracy. These goals have served us well enough as general objectives—summary descriptions of what Australian schools aim to do.

But eight years down the track it has become apparent that something more is needed, and needed urgently, if Australian students are to be properly equipped to face the future. When it comes to the key areas of literacy and numeracy, what is required are specific objectives, linked with agreed strategies and with agreed targets and timelines.

Last March, Commonwealth and State Ministers unanimously agreed to work towards a new national goal for literacy and numeracy attainment. Underlying this goal is the assumption that we should have high expectations for all of our school students.

The new goal states: *that every child leaving primary school should be numerate, and be able to read, write and spell at an appropriate level.*

At the same time, Ministers agreed to a new sub-goal: *that every child commencing school from 1998 will achieve a minimum acceptable literacy and numeracy standard within four years.*

Goals, of course, are not enough on their own. In order to implement them, Ministers adopted a national literacy and numeracy plan which identified the major elements which will be used to work towards attaining the goals.

At the heart of the plan are new national standards or ‘benchmarks’ for school literacy and numeracy proficiency at particular year levels, and the reporting of achievement against those standards, through rigorous State-based assessment procedures.

While the Commonwealth government has provided a good deal of leadership in this process, it is important to recognise that, in signing up to the national plan, all governments in Australia made a major commitment to raising standards in literacy and numeracy in schools.

We should acknowledge, too, that despite some differences of view (hardly a surprising feature amongst the education community) the benchmarking process has been characterised by good will and collaboration, between governments and among the other interested parties involved.

Let me quickly outline for you the way the national benchmarking work for numeracy is proceeding.
The Ministerial Council (MCEEYTA) has set up a benchmarking taskforce, drawn from government and non-government education authorities and the Commonwealth, to develop the benchmarks. The Curriculum Corporation is doing the development work.

The benchmarks themselves are standards describing student achievement at a particular year level for each of years 3, 5, 7 and 9, with development of the primary school benchmarks being undertaken first.

They will consist of indicators, presented for a broad community audience, which identify the essential aspects of numeracy expected for a given year level.

The benchmark will define the minimum acceptable level of numeracy without which a student will have difficulty making sufficient progress at school. There will be two additional higher standards representing ‘proficient’ and ‘exceptional’ achievement at a year level.

Like the literacy benchmarks, the national benchmarks for numeracy will be determined after a process which includes:

- consultation with professional and numeracy education experts;
- trialing of draft national benchmarks;
- comparison with data from surveys such as TIMSS, and from State and Territory assessment programs; and
- reference to the States’ curriculum frameworks.

It will be important that the benchmarks are accepted by the teaching profession and the broader community as credible, valid and professionally based. To this end, independent assessment experts and experts from the States are being consulted on linking the benchmarks with State and Territory assessment protocols.

ACER has been one of the expert bodies consulted in the benchmarking process, and it has been engaged in some valuable work, funded by the Commonwealth, in examining the relationships between the draft numeracy benchmarks and TIMSS.

Education Ministers will consider the year 3 and year 5 numeracy benchmarks towards the end of 1997, with national reporting by States and Territories against the benchmarks to be phased in for year 3 numeracy and literacy achievement from 1998.

One of the misconceptions about developing standards in numeracy and literacy is that this implies criticism of teachers. But teachers have a lot to gain from this process. Benchmark standards permit schools and teachers to demonstrate their successes in areas like numeracy which really matter to the community.

TIMSS tells us that the morale of many maths and science teachers in Australia is low. But the results also show that we have reason to be proud of the quality and dedication of Australia’s teachers, and to have faith in their ability to do a job equalled anywhere in the world.

The Commonwealth believes that national benchmark standards, and the assessment and reporting which goes with them, will show that this confidence is well placed.

There is another misconception about benchmarks, which concerns the most educationally disadvantaged students in our schools.
It is clear that lowering expectations or setting lower standards for particular groups (usually characterised as socio-economically disadvantaged) has not worked effectively. To put it bluntly, there is no evidence to suggest that the strategies of the past have done anything to improve the most important educational outcomes—like literacy and numeracy achievement—for these students.

The national plan, with its emphasis on standards and on accountability for the achievement of all students, addresses the needs of educationally disadvantaged students in a practical way which focuses attention not on program inputs, as in the past, but on getting results.

Literacy and numeracy are the key equity issues in education today, and a national literacy and numeracy plan is fundamental to ensuring that educational disadvantage is overcome. It is interesting to see that the new government in Britain is adopting many of the same strategies as we are here in the key areas of numeracy and literacy.

Benchmarks are also about accountability. The public, employers and parents have a right to be concerned about standards in numeracy and literacy, and to be informed about how children are performing in relation to levels of expected achievement. Parents need to know, too, how well schools are doing and what their plans are in key learning areas.

National benchmark standards provide school systems and governments with the nationally valid evidence they need either to defend their record or to lift their game.

The Community has a right to expect that the massive public investment in schooling is being properly accounted for. Public expenditure on school education in Australia exceeds $14 billion a year.

The Commonwealth alone provides almost $4 billion a year in tied grants for schools, including over $160 million a year specifically for school numeracy and literacy. In fact, overall the government has increased the national funding aimed at literacy, and between now and the year 2000 it will provide over $670 million for literacy and numeracy.

This is a very significant contribution, and the Commonwealth is bound to ensure it is used effectively. Our efforts must make a difference, because the welfare of our children in the next century is at stake. Each child’s needs must be met, and this can only be done if the authorities which run our schools have in place strategies for underachievers in the vital areas of literacy and numeracy.

The Commonwealth wants these strategies to be squarely in the public domain, reported openly in the framework of the national benchmarks. It should be obvious that the States have much to gain by this. But Dr Kemp has made it clear that if the Commonwealth has to look again at how it provides funds to the States for schooling, in order to get open and meaningful reporting on how Australian students are progressing in literacy and numeracy, it will do so.

I said earlier that we all have reason to be encouraged by what Australian students and their teachers have shown they can do through TIMSS. But it is worth repeating that, as the Commonwealth Ministers see it, we can’t afford to be complacent about the results. We lag behind in some areas where we should excel.
If we want to foster excellence in our schools and our students, as we should, we must first know how they are measuring up, both internationally and within Australia. TIMSS has played an important part in making this possible.

I mentioned before our appreciation for the professional way in which ACER have managed Australia’s participation in TIMSS. Before finishing, I would like to add to that the Commonwealth’s appreciation for the other people who have contributed so much to TIMSS, too many to mention here. I am thinking of the advisory committee members, curriculum people and others from the State systems and, most importantly, those in the schools—the teachers, principals and students, who gave their time to take part in this study.

Thank you, and I wish the conference well.
OVERVIEW OF THE THIRD INTERNATIONAL MATHEMATICS AND SCIENCE STUDY (TIMSS) IN AUSTRALIA

Jan Lokan

SCOPE OF TIMSS

TIMSS is the largest, most comprehensive study of educational achievement ever undertaken. More than half a million students from over 15,000 schools in 45 countries participated in the study, as did their mathematics and science teachers and the principals of their schools.

The students were sampled randomly from three target populations in each country. The target populations were defined as:

- **Population 1**: the two adjacent grade levels containing the largest proportion of nine-year-old students at the time of testing
- **Population 2**: the two adjacent grade levels containing the largest proportion of thirteen-year-old students at the time of testing
- **Population 3**: the final year of secondary schooling.

In Australia, these definitions meant that in some states the Population 1 students came from Years 3 and 4 (in NSW, Victoria, Tasmania and the ACT) and in some they came from Years 4 and 5 (in Queensland, SA, WA and the NT). Similarly, the Population 2 students came from Years 7 and 8 or Years 8 and 9. The Population 3 students were in Year 12 in all states and territories. Over 29,000 Australian students, from about 1500 classes in almost 450 schools, participated in TIMSS. The Population 1 and Population 2 testing took place in Australia late in 1994 and the Population 3 testing was done late in 1995. In northern hemisphere countries all three populations were tested from March to May 1995 (almost at the end of their school year, as was also the case in Australia).

WHY DO INTERNATIONAL STUDIES?

The idea behind international studies such as TIMSS is that they make use of naturally existing differences which would not be possible to implement within a single country. Countries differ in the ways their school education is organised, in the curricula they offer, in the preparation required of their teachers, in the styles their teachers use to present the curricula, in their expectations of students, and in many other factors potentially related to effective teaching and learning. In the final secondary years, curriculum differences and differences in the organisation of schooling are even more pronounced than they are at earlier stages (for example, in many European countries the senior secondary students attend schools with very different types of programs).
Well designed international studies can provide information on what is possible for students to achieve and what conditions are most likely to facilitate their learning. Whatever a country’s reasons for taking part in a study like TIMSS, the underlying challenge will always be to determine more about effective school organisation and effective teaching and learning.

**WHAT DATA WERE COLLECTED IN TIMSS?**

Altogether, at Population 1, there were 107 mathematics test questions and 101 science test questions; at Population 2 there were 157 mathematics and 140 science questions; and at Population 3 there were 83 ‘mathematics and science literacy’, 68 advanced mathematics and 67 physics questions. (The Population 3 results had not been released at the time of the ACER conference, and hence the remainder of this paper is concerned with Populations 1 and 2 only.)

The test questions were divided up into several booklets, which were allocated to the students at random, so that equivalent groups of students answered each test booklet and each student answered only one booklet. The majority of the test questions were multiple choice format, but about a third of the testing time was taken up with questions to which the students had to construct their answers.

In addition, there were questionnaires for students, their mathematics and their science teachers, and the principals of their schools. In these ‘context’ questionnaires, more than 1500 questions were asked. Each question related to an aspect of education that was thought to be important in relation to student achievement, often because it had been found to be so in previous research.

The TIMSS tests and questionnaires were translated into 31 languages, for use by the 45 participating countries.

**WHAT DID THE TESTS ASSESS?**

Items in the TIMSS tests assessed the objectives and skills that were thought to be important on the basis of curriculum analyses undertaken in most of the countries which participated in the Population 2 testing.

Content areas in mathematics were:

- Fractions and number sense;
- Algebra (Patterns, relations and functions at Population 1);
- Geometry;
- Data representation, analysis and probability;
- Measurement; and
- Proportionality (Population 2 only).

Content areas in science were:

- Life science;
- Physics;
- Earth science;
- Chemistry; and
- Environment and Nature of science.
Most of the skills assessed were similar in mathematics and science:

- Knowing;
- Using routine procedures;
- Performing complex procedures;
- Understanding simple information;
- Understanding complex information;
- Theorising, analysing and solving problems; and
- Investigating the natural world (science only).

Some of the investigative aspects were assessed more deeply in the ‘performance assessment’ component of TIMSS which was carried out in a much smaller sample of schools and students (a subsample of participants) than the main study.

**WHAT WERE THE MAIN RESEARCH QUESTIONS THAT TIMSS WAS SEEKING TO ANSWER?**

In keeping with TIMSS’s conceptualisation of the curriculum as occurring at three levels, three of the four general research questions that guided the development of the study focused on the curriculum levels:

1. **The intended curriculum**

   *What are mathematics and science students around the world expected to learn? How do countries vary in their intended goals, and what characteristics of education systems, schools and students influence the development of these goals?*

2. **The implemented curriculum**

   *What opportunities are provided for students to learn mathematics and science? How do instructional practices in mathematics and science vary among countries, and what factors influence these variations?*

3. **The attained curriculum**

   *What mathematics and science concepts, processes and attitudes have students learned? What factors are linked to students’ opportunity to learn, and how do these factors influence students’ achievements?*

The fourth general research question incorporated all curriculum levels in relation to the contexts in which schooling occurs:

4. **Relationships of curricula to social and educational contexts**

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

**WHAT WERE AUSTRALIA’S RESULTS?**

It is possible here to describe only a few features of Australia’s results, which are reported in detail in two books of more than 200 pages each.
Relative standings overall

In terms of relative standing, our Australian students performed well, equal to or better than their peers in other English speaking countries and in many European and other countries. Relatively, our standing in science was rather better than our standing in mathematics, and our primary students (Population 1) performed slightly better than our lower secondary students (Population 2). The main area of concern for us is that, in both populations, the students from our neighbouring Asian countries of Singapore, Korea, Japan and Hong Kong outperformed our own students in mathematics, by quite a large margin, and students from the first three of these countries usually outperformed our students in science. Countries performing significantly better than Australia are shown by population in Table 1.

Table 1  Countries Performing Better than Australia

<table>
<thead>
<tr>
<th>Population 2 upper grade</th>
<th>MATHEMATICS</th>
<th>SCIENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>Belgium (Flemish)</td>
<td>Singapore</td>
</tr>
<tr>
<td>Korea</td>
<td>Czech Republic</td>
<td>Japan</td>
</tr>
<tr>
<td>Japan</td>
<td>Slovak Republic</td>
<td>Czech Republic</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>Switzerland</td>
<td>Korea</td>
</tr>
<tr>
<td>Population 2 lower grade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>Belgium (Flemish)</td>
<td>Singapore</td>
</tr>
<tr>
<td>Korea</td>
<td>Czech Republic</td>
<td>Bulgaria</td>
</tr>
<tr>
<td>Japan</td>
<td>Netherland</td>
<td>Slovenia</td>
</tr>
<tr>
<td>Hong Kong</td>
<td></td>
<td>Belgium (Flemish)</td>
</tr>
<tr>
<td>Population 1 upper grade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>Hong Kong</td>
<td>Korea</td>
</tr>
<tr>
<td>Korea</td>
<td>Netherland</td>
<td>Japan</td>
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<tr>
<td>Japan</td>
<td>Czech Republic</td>
<td></td>
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<tr>
<td>Population 1 lower grade</td>
<td></td>
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</tr>
<tr>
<td>Korea</td>
<td>Japan</td>
<td>Korea</td>
</tr>
<tr>
<td>Singapore</td>
<td>Hong Kong</td>
<td></td>
</tr>
</tbody>
</table>

Highest achieving students

An alternative perspective on relative performance is provided in Figures 1 and 2. These show, for a subset of the participating countries, how each country contributed to the highest scoring ten per cent of students from all countries combined. For example, of the highest scoring ten per cent in Population 2 mathematics around the world (about 27 000 students), over 3700 were from Singapore, which was about 45 per cent of the participating students from that country. The highest scoring ten per cent worldwide contained about 13 per cent of the Australian students in Population 2 mathematics, about 18 per cent in Population 2 science, about 14 per cent in Population 1 mathematics and about 16 per cent in Population 1 science. So we can say that we were ‘a little ahead of the game’, so to speak, but definitely not what might be regarded as ‘outstanding’.
Perhaps we are not doing as much for our best students as we could, to challenge them and help them to achieve their potential.

Figure 1  Country Percentages of Students in World’s Top Ten Per Cent, Population

Figure 2  Country Percentages of Students in World’s Top Ten Per Cent, Population
Figures 1 and 2 are also interesting in that they highlight the greater spread of ‘top ten per cent’ students worldwide among countries in mathematics than in science. They also show how much better some countries did in mathematics than in science (particularly the Asian countries) together with the converse of countries doing somewhat better in science than in mathematics (particularly the USA and New Zealand in both populations and England in Population 1).

Content area results

Some interesting comments can also be made about Australia’s performance in the various content areas represented in the TIMSS tests. Our students achieved above average or average results in all areas tested, at both populations. At Population 2, our achievement was furthest above average (relative to ourselves) in the mathematics areas of ‘algebra’ and ‘chance and data’ and in the science areas of ‘environmental issues’, ‘nature of science’ and ‘physics’. At Population 1 we were furthest above average in the mathematics areas of ‘measurement’ and ‘geometry’ and the science areas of ‘environmental issues’ and ‘nature of science’.

Results by gender

Australia shared the distinction with only a handful of other countries of having our boys and girls performing at equivalent levels in both mathematics and science. Of eight main gender comparisons, by upper and lower grade within population on each of the mathematics and science tests, only one gender difference occurred in Australia—at Population 1, our upper grade boys achieved significantly higher science scores than the upper grade girls. There were only four countries where no gender difference was found in any of these eight possible comparisons—Cyprus, Ireland, Singapore and Thailand. Internationally, gender differences were not common in mathematics but were pervasive in science. Australia can take heart that our efforts over the past 10 years or so to make mathematics and science instruction more gender equitable seem, at least from the TIMSS results, to have largely achieved that purpose.

State and territory results

Just as our results were at or above the international average in both mathematics and science overall, the same was true for our results considered separately by state. There was considerable spread between our highest and lowest performing states, but even the lowest achieved results at the international average. Our highest achieving states performed at the level of the highest achieving countries worldwide, with WA sharing top position with Korea in Population 1 science.

We all recognise that it is difficult to make comparisons of results among the Australian states and territories because there are many contextual factors that need to be taken into account. The same is true internationally, of course. Internationally, TIMSS took the view that actual results should be reported, but they should be accompanied by a wide range of contextual data to allow countries to interpret results in as informed a way as possible. The same practice was adopted in reporting results for the Australian states and territories, each of which is best informed about the contextual factors underlying its own education system and policies — differences in school starting age, for example.
I will return later to a discussion of relationships between achievement and some of the contextual factors measured in the TIMSS questionnaires. At this stage, while we are thinking about Australia’s results, it will be useful to focus on some examples of individual TIMSS test questions and on how the Australian students performed on these. I have chosen questions which illustrate the full range of our students’ performance, from some on which we were best in the world, some on which our performance was average internationally, and some on which our performance was lowest in the world. Where it is of particular interest, I have shown results for Singapore (the highest achieving country in all areas but Population 1 science) or for the four Asian countries combined.

There are messages for our policy makers in some of the examples and results shown. The items on this page are all ones on which Australia scored substantially below the four Asian countries, even if close to the international average on some. These items, plus those on the next three pages, are from the Population 1 test.

\[
\begin{array}{lll}
\text{Subtract:} & 6000 \\
& - 2369 \\
A & 4369 & C & 3631 \\
B & 3742 & D & 3531 \\
\hline
\end{array}
\]

Aust: 47 %
Int'l: 71 %
Asian: >90 %

\[
\begin{array}{lll}
\text{Add:} & 6971 \\
& + 5291 \\
A & 11162 & C & 12262 \\
B & 12162 & D & 1211162 \\
\hline
\end{array}
\]

Aust: 76 %
Int'l: 84 %
Asian: 95 %

**Addition Fact**

\[4 + 4 + 4 + 4 + 4 = 20\]

Write this addition fact as a multiplication fact.

\[
\begin{array}{ll}
\_ \times \_ = \_ \\
\_ \times \_ = \_ \\
\end{array}
\]

Aust: 71 %
Int'l: 77 %
Asian: >90 %

25 \times 18 is more than 24 \times 18. How much more?

\[
\begin{array}{lll}
A & 1 & C & 24 \\
B & 18 & D & 25 \\
\hline
\end{array}
\]

Aust: 41 %
Int'l: 45 %
Asian: >70 %
On the next two items, which teachers here would say are more closely related to our curriculum, Australia did score above the international average—at a similar level to the Asian countries on the first of the two but below the Asian countries on the second.

Here is a paper clip.

| ← Length → |

About how many lengths of the paper clip is the same as the length of this line?

Answer: 4 paper clips

Aust: 58 %  
Int'l: 48 %  
Asian: 60 %

Craig folded a piece of paper in half and cut out a shape.

| fold |

Draw a picture to show what the cut-out shape will look like when it is opened up and flattened out.

Aust: 72 %  
Int'l: 59 %  
Asian: 85 %
The first item below, a science item, is interesting because of the differences between the Asian countries, with Hong Kong and Japan performing much above the international average, Singapore (with Australia) at the international average and Korea considerably below this level. The second item is a further mathematics item on which Australia performed at the international average, but much below the Asian countries.

Which of these would most likely be measured in millilitres?

A. the amount of liquid in a teaspoon
B. the weight of a pin
C. the amount of petrol in a tank
D. the thickness of 10 sheets of paper

Aust: 45%
Int'l: 38%
HK/Japan: 75%
S'pore: 45%
Korea: 31%

Which number represents the shaded part of the figure?

A. 2.8
B. 0.5
C. 0.2
D. 0.02

Aust: 40%
Int'l: 40%
Asian: >70%
The three items illustrated on this page, all Population 1 science items, are ones on which the Australian students performed well, much above the international average. The items relate to life science or environmental science, areas of strength for us. The Asian countries had varying performances on these items, some above average and some well below. In the main, Japan and Korea performed better on these items than Singapore and Hong Kong.

The human brain is inside the skull. Write down one advantage of the skull being thick and strong.

The skull protects the brain so you won't have many bad injuries like a hand thrown at your head.

Aust: 66 %
Int'l: 51 %

Write down one thing your heart does that helps the other parts of your body.

Your heart pumps blood to the muscles and that helps you move.

Aust: 69 %
Int'l: 40 %

Write as much as you can about why large oil spills in rivers and seas are harmful to the environment.

Because it cause dangers to all sea and river life by killing them off then all the other animals die to from eating posioned food which starts a chain reaction. It also pollutes our waterway.

Aust: 75 %
Int'l: 58 %
Now we have moved to items from the Population 2 tests. On the kinds of items shown on this page, Australia performed either worst of all countries or close to worst. The Asian countries all performed very highly. Division of fractions, items involving more than two fractions and most items involving decimals were areas of weakness in Australia. A teacher commented to me recently that ‘we would not expect students to do the decimal division without a calculator’, but, if you know what you’re doing, the item involves no more than division by 4—a skill which it could be argued that Year 8 and 9 students should have.

\[
\frac{3}{4} + \frac{8}{3} + \frac{11}{8} = \quad \text{Divide: } 0.004 \div 24.56
\]

A  \( \frac{22}{15} \)  
B  \( \frac{43}{24} \)  
C  \( \frac{91}{24} \)  
D  \( \frac{115}{24} \)  
E  \( 6140 \)  

Aust: 35 %  
Int'l: 50 %  
Aust: 23 %  
Int'l: 44 %

\[
\frac{8}{35} + \frac{4}{15} = \quad \text{Divide: } 8 \div 35 + 4 \div 15
\]

\[
\frac{2}{35} \times \frac{15}{1} = \frac{30}{35} = \frac{6}{7}
\]

Aust: 25 %  
Int'l: 43 %
Performance on the three items shown on this page was generally quite low around the world. The Asian countries all scored about 80 per cent correct on the mathematics item shown below and on the science item about the splint bursting into flame. On the item about which gas is found in the greatest amount in air, the Asian countries were still substantially above average, each scoring between about 50 and 60 per cent correct.

Subtract: \(\frac{2x}{9} - \frac{x}{9} = \)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>D</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>E</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Australia: 48% correct  
International: 51% correct

Air is made up of many gases.  
Which gas is found in the greatest amount?

- A nitrogen  
- B oxygen  
- C carbon dioxide  
- D hydrogen  

Australia: 16%  
International: 27%

Which gas could cause a glowing splint to burst into flame?

- A neon  
- B oxygen  
- C nitrogen  
- D carbon dioxide  

Australia: 38%  
International: 50%
The science items on this page were done relatively well by the Australian students, in relation to the international average performance. The Asian countries performed at the same level as Australia, or slightly lower, on the first item shown here. On the item about the unwanted consequences of introducing a new species to an area, Australia performed highest in the world, considerably higher than the Asian countries (especially Hong Kong and Japan, which performed below the international average).

Animals are made up of many atoms.
What happens to the atoms after an animal has died?

A  The atoms stop moving.  (13 %)
B  The atoms recycle back into the environment.  (36 %)
C  The atoms split into simpler parts and then combine to form other atoms.  (8 %)
D  The atoms no longer exist once the animal has decomposed.  (43 %)

International average (upper grade):  26 % correct

What could be the unwanted consequences of introducing a new species to a certain area? Give an example.

An ecological disaster.
Eg. - Rabbits eat food meant for native animals. Native animals starve and rabbits multiply so all natives die and lots of rabbits live.

Aust:  74 %
Int'l:  37 %
The novel science item featured on this page was one on which the Australian students’ performance was at the international average. Singapore and Hong Kong students performed very well on this item; Japanese and Korean students performed at about the same level as Australia. The correct answer for this item is shown on the left hand side of the lower diagram. The most common wrong answer was to draw the line parallel to the bottom of the tilted can. Several of the more unusual wrong answers are illustrated on this page.

A watering can is partly filled with water as shown.

The watering can is tipped so that the water just begins to drip through the spout.

Draw a line to show where the surface of the water in the can is now.

<table>
<thead>
<tr>
<th>Per cent correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pop. 2</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Pop. 1</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
To be fully correct on the item shown on this page, the diagram had to include reference to all three of evaporation, transportation (e.g. of clouds by wind) and precipitation. Both of the responses shown on this page were assessed as fully correct, although one is a less conventional response than the other (and, strictly speaking, not factually correct—the important point is that the response refers to all three of the process aspects required).

**Draw a diagram to show how the water that falls as rain in one place may come from another place that is far away.**

---

*Aust: 59 %
Int’l: 57 %*
The two responses shown on this page are examples of responses that could not be assessed as correct. The upper diagram received a partially correct mark for showing both a water source and precipitation, although the student obviously did not have much idea of the total process. The student who gave the response in the lower diagram had no idea of what is involved!
Some relationships with contextual factors

As mentioned earlier, data on a wealth of contextual variables were collected in TIMSS, by means of questionnaires to principals, teachers and students. Today I will report the relationship with achievement of some of the student-level variables only, for a mixture of variables that are often reported in other research studies and also for a few that are interesting in this particular context. To support the contention that the ‘hands-on’ performance assessment tasks in TIMSS measured rather different skills than were measured in the written tests, I will also provide for you some correlations between the two sets of tasks.

Student background variables

The relationship of a range of student demographic and other variables to mathematics and science achievement overall is shown for both populations in Table 2.

<table>
<thead>
<tr>
<th>Population 1</th>
<th>Population 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maths</strong></td>
<td><strong>Science</strong></td>
</tr>
<tr>
<td>Number of books in home</td>
<td>.18</td>
</tr>
<tr>
<td>Family size</td>
<td>-.14</td>
</tr>
<tr>
<td>Parents’ education status</td>
<td></td>
</tr>
<tr>
<td>Parents’ occupation status</td>
<td>.27</td>
</tr>
<tr>
<td>Home background composite</td>
<td>.36</td>
</tr>
<tr>
<td>Language background composite</td>
<td>.11</td>
</tr>
<tr>
<td>Word Knowledge</td>
<td>.61</td>
</tr>
<tr>
<td>Like mathematics</td>
<td>.16</td>
</tr>
<tr>
<td>Like science</td>
<td>.14</td>
</tr>
<tr>
<td>Attribute success to luck</td>
<td>-.32</td>
</tr>
<tr>
<td>Self-efficacy belief</td>
<td>.16</td>
</tr>
</tbody>
</table>

Table 2  Correlations between Student Background Variables and Achievement on TIMSS Written Tests

Because of the large sample sizes, these correlations are all highly significantly different from zero. With the exception of the associations between scores on the Word Knowledge test and achievement, the relationships indicated by the correlations in the table are not strong, though all are in the direction expected. The relatively high correlation between word knowledge and achievement was expected, particularly at Population 1, because the objective of embedding test items in contexts familiar to students meant that the mathematics and science items could not be divorced from reading, even though the language demands were kept as low as possible.

Number of books in the home, as an indicator of students’ educational environment, has been found to be a useful predictor of achievement in earlier IEA studies. The ‘home background composite’ variable is an index built from the students’ responses to the first four variables in the table, and was correlated only slightly more highly with achievement than three of the four variables on their own. Parents’ countries of birth (whether English speaking or not English speaking, for one or both parents), and the...
extent to which English is spoken at home, were combined to form the ‘language background composite’ variable. A positive correlation indicates a greater degree of ‘Englishness’, which was found to be related to achievement but at a marginal level.

Among the affective variables measured in the Student Questionnaires, believing that success is due to luck or chance rather than to one’s own efforts was the most predictive of achievement in all four tests, with higher levels of achievement associated with lower levels of such belief. ‘Self-efficacy’, or believing that one is doing well in the subject, was more highly related to achievement at Population 2 than at Population 1. Whether the students liked mathematics or science was only marginally related to achievement at Population 1, slightly less marginally related at Population 2.

Correlations between some of the above student variables, with the addition of gender which was not related to achievement on the written tests in Australia, are shown in Table 3 for the ‘hands-on’ performance assessment tasks at Population 2. This part of the assessment was done by a much smaller number of students, although correlations of about .10 were still significantly different from zero at the .01 level of confidence.

**Table 3** Correlations between Student Background Variables and Achievement on TIMSS ‘Hands-on’ Performance Assessment Tasks, Population 2

<table>
<thead>
<tr>
<th>Mathematics tasks</th>
<th>Sex (1=F; 2=M)</th>
<th>Language (1=Eng, 2=not)</th>
<th>Word knowledge</th>
<th>Home bkgd composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dice</td>
<td>.23</td>
<td>.12</td>
<td>.33</td>
<td>.33</td>
</tr>
<tr>
<td>Calculator</td>
<td>.11</td>
<td>-</td>
<td>.42</td>
<td>.27</td>
</tr>
<tr>
<td>Folding &amp; cutting</td>
<td>-</td>
<td>-.13</td>
<td>.23</td>
<td>.12</td>
</tr>
<tr>
<td>Around the bend</td>
<td>-</td>
<td>-</td>
<td>.41</td>
<td>.30</td>
</tr>
<tr>
<td>Packaging</td>
<td>.11</td>
<td>-.17</td>
<td>.40</td>
<td>.25</td>
</tr>
<tr>
<td>Plasticine</td>
<td>-</td>
<td>.21</td>
<td>.17</td>
<td>.19</td>
</tr>
<tr>
<td>Science tasks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse</td>
<td>.18</td>
<td>.16</td>
<td>.44</td>
<td>.29</td>
</tr>
<tr>
<td>Magnets</td>
<td>-</td>
<td>-</td>
<td>.44</td>
<td>.44</td>
</tr>
<tr>
<td>Batteries</td>
<td>-.18</td>
<td>-</td>
<td>.15</td>
<td>.22</td>
</tr>
<tr>
<td>Rubber band</td>
<td>.32</td>
<td>-</td>
<td>.29</td>
<td>.44</td>
</tr>
<tr>
<td>Solutions</td>
<td>.30</td>
<td>-</td>
<td>.36</td>
<td>.39</td>
</tr>
<tr>
<td>Shadows</td>
<td>-</td>
<td>-</td>
<td>.34</td>
<td>.27</td>
</tr>
</tbody>
</table>

* Correlation not significant at p ≤ .01

Home background factors and word knowledge were mostly less important to achievement on the performance assessment tasks than on the written tests, especially tasks like ‘Folding and cutting’, ‘Plasticine’ and ‘Batteries’, which required a minimum of explanation of procedures followed or reasoning about conclusions. An English or non-English speaking background was not or only marginally associated with success on the performance assessment tasks—in favour of English speakers on some tasks and non-English speakers on other tasks. Apart from ‘Rubber bands’ and ‘Solutions’, both of
which required carrying out, recording results and justifying conclusions from an investigation, gender was only weakly associated with performance on any of the tasks. The only task performed better by boys than girls was the task requiring identification of which two of four batteries were worn out.

The final table of correlations, Table 4, shows the degree of association of success on each performance assessment task with achievement on the written tests, also at Population 2. The relationships are positive, as would be expected on measures of achievement, but generally lower than one would find between mathematics and science achievement assessed in written tests. The correlations are low enough to indicate that the performance assessment tasks are likely to be measuring somewhat different skills from those measured in the written tests. The correlations provide no clear justification for the proposed classification of some of the performance assessment tasks as ‘mathematics’ and some as ‘science’, however.

I would also like to share with you some graphs of relationships to achievement of some variables that are often thought to be ‘culprits’ in partly accounting for lower achievement and some that might be expected to be associated with higher achievement. The variables are ‘extent of daily TV watching’ (Figure 1), ‘time spent each day in playing computer games’ (Figure 2), ‘time spent each day on homework’ (Figure 3), and ‘frequency of students’ doing science experiments’ (Figure 4). Relationships were usually similar at both Population levels.

<table>
<thead>
<tr>
<th>Written test total score</th>
<th>Mathematics</th>
<th>Science</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mathematics tasks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dice</td>
<td>.35</td>
<td>.34</td>
</tr>
<tr>
<td>Calculator</td>
<td>.36</td>
<td>.36</td>
</tr>
<tr>
<td>Folding &amp; cutting</td>
<td>.28</td>
<td>.27</td>
</tr>
<tr>
<td>Around the bend</td>
<td>.43</td>
<td>.46</td>
</tr>
<tr>
<td>Packaging</td>
<td>.45</td>
<td>.41</td>
</tr>
<tr>
<td>Plasticine</td>
<td>.25</td>
<td>.25</td>
</tr>
<tr>
<td><strong>Science tasks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse</td>
<td>.44</td>
<td>.47</td>
</tr>
<tr>
<td>Magnets</td>
<td>.44</td>
<td>.42</td>
</tr>
<tr>
<td>Batteries</td>
<td>.26</td>
<td>.27</td>
</tr>
<tr>
<td>Rubber band</td>
<td>.41</td>
<td>.31</td>
</tr>
<tr>
<td>Solutions</td>
<td>.45</td>
<td>.38</td>
</tr>
<tr>
<td>Shadows</td>
<td>.43</td>
<td>.38</td>
</tr>
</tbody>
</table>
Figure 1  Mathematics and Science Achievement and Time Spent Watching TV

Figure 2  Mathematics Achievement and Time Spent Playing Computer Games
Overview of TIMSS in Australia

Homework and maths achievement

Figure 3  Mathematics Achievement and Daily Time Spent on Homework

Impact of science experiments

Figure 4  Science Achievement and How Often Experiments are Done in Science Lessons
As we might expect, there are some detrimental effects, as far as school achievement is concerned, associated with too much watching of TV or playing of computer games. For both, though, there is an initial rise in achievement for students who spend only a moderate amount of time—up to two hours a day (TV) or one hour a day (games). After that, achievement declines, though not seriously until beyond four hours a day of TV and two hours a day of computer games. We cannot attribute cause and effect here—the association with lower achievement is clear, but it may be that the less able students are drawn to more TV watching and game playing, rather than that the large amount of time spent in these activities is the reason for their lower achievement. A similar comment can be made about the relationship between amount of homework and achievement, an example of which is shown in Figure 3. One suspects that the lower achievement of those who say they do the most homework has more to do with the students’ ability level than with the time spent.

Finally, a classroom practice variable that is positively associated with achievement on the TIMSS science test is illustrated in relation to achievement in Figure 4. The relationship is positive, because the more often students do experiments in their science classes (as reported by the students themselves), the better their achievement. The largest differences in achievement occur for the steps from ‘never’ to ‘occasionally’, and from ‘occasionally’ to ‘often’.

**IN CONCLUSION**

The results I have shared with you today are only a tiny portion of the information and insights that we can glean from the large amount of data collected in TIMSS. Others presenting papers at this conference today and tomorrow will contribute further insights from the Australian data, from international data, and from other related initiatives that have taken place in Australia recently in the fields of numeracy and science education.

We have seen that the Australian students’ performance was excellent in some areas, poor in others—especially in some aspects of mathematics. We have also seen that our students performed very creditably on the world stage, though not quite at the very top level. I should like to close with some questions that we need to reflect on, as policy makers, researchers, and mathematics and science educators, as we determine the kind of mathematics and science education Australian students will receive in the years to come. Most of these could arise without reference to TIMSS, but the experience and findings from TIMSS reinforce their importance:

- Is sufficient curriculum time being devoted to mathematics and science instruction in Australia, particularly at primary level? Are there priorities within mathematics and science that should be changed? If so, what are these, and how might we go about making the changes?

- Are our mathematics and science curricula too broad? Or perhaps too narrow? Are we introducing topics later than we need to, in terms of what students are capable of doing? Are we doing enough to cater for the interests and capacities of our best students?

- How can we best make use of technological aids (e.g. calculators and computers) in our mathematics and science teaching? Are there dangers in introducing such aids too early, so that students become unduly reliant on them? Have our teachers had sufficient opportunities to adapt their teaching to incorporate the best uses of computers and calculators? What are the best uses?
• Do we need to rethink the nature and role of homework, practice and self-study? How important is feedback to students on the homework they have done?

• Are we equipping students with appropriate skills to cope with and make critical judgements about the large amounts of information they now have access to? Are they ‘numerate’ enough, for example, to judge advertising material?

• How important are the skills of being able to explain, justify or generalise? TIMSS suggests that students in all countries have trouble with these. Should we be facilitating the development of these skills more than we are doing now?

• Finally, where would we want to be placed in the next major cross-national study? What would we need to do to ensure that we can achieve that goal?

We hope that the discussion sessions we have set up for this conference will be useful in addressing these questions, and others you may wish to raise.

1 J. Lokan, P. Ford & L. Greenwood, Maths and Science On the Line: Australian Junior Secondary Students’ Performance in the Third International Mathematics and Science Study, TIMSS Australia Monograph No. 1, Melbourne, ACER, 1996; and

INSIGHTS FROM TIMSS FOR AUSTRALIAN SCIENCE EDUCATION

Peter Fensham

As I began to think about insights or implications that TIMSS, as it has so far been reported, has for school science education in Australia, that well known Shakespearean title, *Much Ado About Nothing*, kept coming into mind. Anyone who has heard Dr Jan Lokan’s account of the vast amount of effort that TIMSS involved (and which my own limited experience of the project entirely confirms), will readily accept that there was certainly much *ado*. For me to suggest that all that effort implies *nothing* for Australian science education is unfair, but, as I will go on to explain, *next to nothing* may not be too far from the mark.

To make any assessment of what the three international and two Australian reports, for the primary and lower secondary populations in TIMSS, have to say about science education at these levels in Australia, it is important to be clear what aspects of school science TIMSS was able to include, and what it excluded. I will begin with some background about the project as a whole, and hence what it might have been and what it chose to be.

AN OPPORTUNITY TO RETHINK

Initially the time the project took to be established and progress on several of its fronts was slower than had been planned. During 1993 an international team led by Professor Richard Shavelson of Stanford University conducted a review of the progress of TIMSS thus far (AERA Think Tank, 1993). It found three areas of serious concern for which it recommended remedial actions. These were:

1. The *Common Comparison* model chosen for the project would not adequately recognise the numerous new developments in curriculum for school science that had occurred since the Second International Science Study in the early 1980s and the adoption of *Science for All* as the priority for school science in many countries.
2. The sample items of the three types that had, at that stage, been developed were too often simply testing recall of information.
3. The presentation of the items was boring and did not reflect the newer styles of assessment that set out to engage students positively in responding to them.

To deal with the second and third concerns, the Review Team recommended new contracts be let for developing the items. This indeed happened, and the quality of the paper and pencil items improved considerably, although the essentially prose form for items and their limitation to three types of items—*multiple choice, short answer* and *free response*—was maintained.

As an alternative model for the whole achievement study, the Review Team suggested a *Multiple Comparison* one, but this suggestion was rejected by the Project Management, no
doubt for a mixture of statistical, political and economic reasons. It is important to be aware of what was involved in this crucial decision about the choice of comparative model, and what its consequences were for TIMSS.

The *Common Comparison* model involves identifying a core of common science learnings that all the participating countries see, to a greater or lesser extent, as being learning that can be expected of their students as a result of the intended or implemented curriculum for science. The students from all countries then take the same tests, made up of items that reflect these common learnings, and that are designed to form one overall scale (which may be made of several sub-scales) of achievement.

The *Multiple Comparison* model involves identifying, in addition to a core of science learnings, a number of different sorts of learnings that are associated with the new developments in school science curricula. For the international purposes of TIMSS a development might be included as long it was of interest to, say, at least five countries. Test items would then be developed for the learnings of the core and for the range of recognised developments. Each country would choose which set of items, in addition to the core set, its students would undertake.

An advantage of the *Common Comparison* model is that it provides statistically higher reliability for a limited comparison of some kinds of science learning across all the participating countries. Among its disadvantages are that it ignores a number of kinds of science learning that are now recognised as important in sub-groups of the participating countries and, by doing so, the project misses an important opportunity in comparative studies to disseminate these alternative views of school science to other countries that have yet to consider such reforms of their curriculum for school science.

The *Multiple Comparison* model would have enabled these alternative views of what quality learning in school science is, and how it can be assessed, to become known internationally. It would have provided comparative findings, albeit rather less statistically reliable, about the core learnings across all the countries, and also about measures within the sub-groups of countries of how their students were faring, compared with those in the countries that shared the same interest in the learnings associated with the new curriculum developments.

In Table 1, I have listed some of the new emphases in school science content and some of the newer forms of assessment that could have been considered for inclusion, if the recommendation for a Multiple Comparison model had been adopted. (The assessment developments are not intended to ‘match’ with the content development items as listed in the table, although at times they do.)

<table>
<thead>
<tr>
<th>Content developments</th>
<th>Assessment developments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science/Technology/Society</td>
<td>Performance testing</td>
</tr>
<tr>
<td>Science for Communication</td>
<td>Oral testing</td>
</tr>
<tr>
<td>Science for Personal Development</td>
<td>Testing communicating</td>
</tr>
<tr>
<td>Science through Technology</td>
<td>Testing for Understanding</td>
</tr>
<tr>
<td>Science as Applications</td>
<td>Criterion-referenced testing</td>
</tr>
<tr>
<td>Environmental Science</td>
<td>Testing open problem solving</td>
</tr>
<tr>
<td>Science as Open Problem Solving</td>
<td>Testing large scale investigations</td>
</tr>
<tr>
<td>Science for Quality of Life</td>
<td>Testing attitudes</td>
</tr>
<tr>
<td>Science for Decision Making</td>
<td>Testing for conceptual learning</td>
</tr>
<tr>
<td>Nature of Science</td>
<td></td>
</tr>
</tbody>
</table>
A number of these developments have had prominence in Australia for the different levels of school science since the mid 1980s, but very few of them fell within the core of learnings that TIMSS included. Accordingly, TIMSS can tell us very little about these Australian interests.

**PSYCHOMETRIC PRIORITY AND ITS CONSEQUENCES**

It was clear that the project was determined to stay with high reliability, information about a traditional and limited core of school science learnings that would lead to international league tables. The dominance of this psychometric priority for TIMSS was to be experienced on a number of occasions as the project continued through its development, application and reporting phases.

One particularly unfortunate consequence was the exclusion of the findings of the hands-on, practical testing of Science Performance from the main international reports for Populations 2 and 1 in November 1996 and June 1997 respectively. This decision overrode the very strong pleas from the project’s Science Subject Matter Advisory Committee. Although there appeared throughout the project to have been a commitment that these hands-on tests of science abilities were a most important aspect of the learning of school science, they were, in the end, for various reasons, undertaken by only some of the countries and by fewer students in each of the sample classes than took the paper and pencil tests. This lowered their reliability as test scores and this psychometric property prevailed in the decision of the International Project to exclude them. As a result, we find this very expensive exercise in comparative education effectively announcing to the world, and to those who provide the funds for school science, that practical learning and the facilities for it are not important for school science.

To ACER’s and the Australian TIMSS Committee’s credit, there was no such reluctance to include these findings in the Australian reports. The limitation from an Australian perspective lies with the restricted range of performance tasks that were included. In this range (which was less than the APÜ (1983) in England covered more than a decade earlier), Australian Year 4 and Year 8 students performed relatively well internationally, although the actual performance for the younger of these populations overall was not high.

Another limiting consequence relates to the science content of the TIMSS items. The initial TIMSS Curriculum Framework for Science was an attractive one and, in practice, it was to lead to every item in the tests having an identity coding on a *Content* dimension and a *Performance* dimension (Robitaille et al, 1993). Eight areas of content were included. These were:

(a) **Earth Sciences** (16%);
(b) **Life Sciences** (30%);
(c) **Physical Sciences** (Physics (30%), Chemistry (14%));
(d) Science and Technology;
(e) **Environmental and Resources**
(f) **Nature of Science**
(g) History of Science and Technology; and
(h) Science and other Subjects.

This promising range of *Content* for school science was, however, reduced in the actual tests to the five areas listed in bold, together with their percentage share of the test items. This limitation of content assessed arose primarily from two considerations.
Firstly, in the testing time available for the Science component of TIMSS, only so many items could be included, and secondly, a certain number of items from a single content area are needed to produce a valid scale score for it, as distinct from single item scores. The combination of these two constraints led to only the areas indicated in bold being measured, and, alas, the emphasis on a core of content meant that four of the five scales were in traditional content areas, leaving the other three above out of TIMSS’s consideration.

**PERFORMANCE - A PROJECT PLUS**

Regardless of the *Content* dimension, however, it was still possible to explore in the testing a range of categories of *Performance*. This, I believe, is one of the real strengths of TIMSS and it is the feature of the findings that does provide real implications for Australia. There were five categories of *Performance*:

(a) Understanding simple information;
(b) Understanding complex information;
(c) Theorising, analysing and solving problems;
(d) Using tools, routine procedures and science processes; and
(e) Investigating the natural world.

The interesting interpretations that these have in the items of the TIMSS tests were a real plus from the reletting of the contracts for the production of items.

An exemplary item in each of these categories is shown in the Appendix to this chapter, and these should suffice to indicate that TIMSS items, in general, required considerable reading and comprehension by the students. Furthermore, even those multiple choice ones in the category of Understanding simple information were not of the direct recall of an answer type, a point I take up later in this paper.

Australian students’ achievement (as has been reported by Lokan in her paper for this Conference, and in the many tables in the published reports to which she has referred) were pleasingly high overall for Population 2, and surprisingly high for Population 1. There was quite a spread of achievement among the states for each of these levels, but even the lowest state was above the international average. There were also welcome signs that the differences between Australian boys and girls found in the Second International Science Study had disappeared for Population 2 and for one of the two grade levels for Population 1.

If there had been no primary level population in TIMSS, it would be tempting to conclude that in the limited content areas of science included in the tests, Australian students and schools are performing at a good level with room for improvement in a number of particular aspects of science learning (where our average scores were lower), provided we decide that these aspects are as worthy of curriculum attention as those numerous topics in our curricula that were not included in TIMSS.

For example, there is an item about the level of water in a watering can at rest and in a particular rather unusual pouring position (*Physical sciences; Understanding complex information*). Australian students achieved poorly on this item although it was a difficult one overall. What should we conclude? Efforts should be made to ask teachers to spend more time teaching about water levels. If so, at the expense of what other topic? If the item had been about how to relate water level to accurate measuring with a measuring cylinder in the category, *Using tools, routine procedures, and science processes*, and a
similarly poor performance was achieved, we might well conclude that it would be worth more attention in Australian classrooms, because of the many aspects of science such good behaviour influences. From another point of view, research studies in students’ conceptions of scientific phenomena are now known to be quite context dependent, so that their responses to this single item are by no means a clear indication of their conceptual understanding of liquids in other contexts.

The point is that the level of achievement alone for any particular item is not an indicator for rejoicing or for gloom and remedy unless we put relatively high value on that particular learning among all the possible learning we may, in Australia, wish to achieve for our students in school science at their level of schooling. In a lesser but still similar manner, the larger scale scores in TIMSS earn only an initial significance for Australia by their international ranking. Their ultimate significance lies in how we value their sort of science learning compared with the other science learnings that are not part of TIMSS as I have discussed already.

THE PRIMARY DILEMMA

The presence of a primary student population in TIMSS raises for me a more complex perspective on how we should draw implications from TIMSS. This stems from the quite unexpectedly very high performances of the students in some of the Australian states in the Population 1 study. Western Australia ranked first among the participating countries and South Australia, Queensland and ACT were only slightly lower. These results contradict all the considerable evidence we have locally on the state of Australian primary science teaching and learning.

Of course, it may be that the international level of science learning in primary schooling is universally low, but that would be to deny the achievements in countries like Korea, Singapore and Japan, for which there is at least some independent evidence that there is considerable teaching of science topics like those included in TIMSS (for example, Tay, 1994 and Schmidt et al, 1997).

Nevertheless, in the case of Australia there is a dilemma. The local evidence about primary science is consistently poor before and after the TIMSS testing in 1994, and before 1995 this was not differentiated significantly by state. The international evidence from TIMSS is very good in several states, and internationally better than average in the others.

Which evidence should we believe, or is there some way to reconcile this dilemma?

PRIMARY SCIENCE - A CHRONIC CASE

Some of the sources of the local evidence of poor quality primary science in Australia are now briefly described.

The findings of the National Disciplinary Review of Teacher Education in Mathematics and Science (Speedy et al, 1989) were so alarming that its authors reported ‘the situation in schools is so bad and the quantitative presence of science in primary teacher education is generally so far below what it needs to be, that the Panel considered recommending abandoning science as part of primary education’.

Primary science had also been highlighted as being limited and generally of poor quality in reviews by the Australian Science, Technology and Engineering Council (ASTEC, 1987) and by the Prime Minister’s Science Council (1990). Accordingly, the Australian
Science, Technology and Engineering Council decided in 1995 to investigate the condition of science and technology in primary schooling to see whether any real improvement was evident. This took place during 1996, and the findings were reported (ASTEC, 1997) just a few months before the TIMSS reported on its primary study (Population 1). As Associate Professor Tim Hardy reports elsewhere in this Conference, the Council has found some signs of hope for improvement as a result of initiatives since 1990 such as:

- the increase of science in some preservice teacher education programs;
- the Academy of Science’s project for the new Primary Investigations materials;
- the National Professional Development program; and
- the new science curricula for primary science in a number of states derived from the National Profiles.

These major innovations were all too late to contribute to the state of primary science that was being assessed by TIMSS in Australia at the end of 1994. Despite the prospects for improvement in the immediate future that these initiatives may have, the Council found that:

- the status of primary science and technology in school systems is still too low;
- much more still needs to be done to lift primary teachers’ substantive and teaching knowledge in these areas; and
- more adequate time should be allocated to them in the curriculum of primary schooling.

In 1993, a testing in science of students in Years 3, 7 and 10 took place in Western Australia as part of the Monitoring Standards in Education program, using tests that emphasised students’ understanding of concepts (Monitoring Standards in Education Project, 1993). These very novel tests were a development from the pioneering approach to group testing of conceptual understanding in science that were developed by ACER and which became available in 1991. This type of test uses a format that heightens student motivation, and draws on contemporary research findings to provide an assessment of how students’ conceptual understanding in science is developing. They would have been a notable addition to TIMSS if they could have been part of its testings.

The understanding of science of each of these student populations in WA (including the one that would perform so highly on the TIMSS a year later) was found to be at least a level below the anticipated understanding, and the further years of schooling only marginally lifted this understanding.

In 1996 (just 15 months after the TIMSS testing of the 9-year-old population), the Learning Assessment Program (LAP) in Victoria included tests for science of students in Years 3 and 5. Unlike the ‘satisfactory findings’ in this program for the students’ levels of learning in Mathematics and English language, the Science findings were so unsatisfactory that the Minister of Education immediately released substantial funds to assist schools to lift their level of teaching and learning in science (Gude, 1996; Victorian Board of Studies, 1966).

Although there is no comparable set of local findings about the state of lower secondary science teaching and learning, this dilemma for science in the primary years in Australia raises at least some of the same doubts about how to interpret the generally good, but not very high achievement by Australia in the Population 2 study of TIMSS—a matter to which I shall briefly return.
TOWARDS RESOLVING THE DILEMMA

To make some resolution of the primary dilemma I used the analyses of the TIMSS items provided in its reports and extended them in a comparative sense to the items used in 1996 for the national testing of science in England and Wales and for the LAP Science test in Victoria. The comparison of the Victorian LAP test with the one in England and Wales is particularly apt, since Victoria is one of the Australian states that has, with its Curriculum and Standards Framework, adopted a curriculum for science with many features that are modelled on the National Curriculum for Science in England and Wales. The results of the comparisons of item types in these three settings are shown in Table 2.

Table 2 Percentages of Items of Various Types in the Primary Level Tests of TIMSS, the Victorian LAP, and the National Testing in England and Wales

<table>
<thead>
<tr>
<th>Item type</th>
<th>TIMSS (%)</th>
<th>Victoria (%)</th>
<th>England/Wales (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple choice</td>
<td>66</td>
<td>96</td>
<td>28</td>
</tr>
<tr>
<td>Short answer</td>
<td>17</td>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>Free response</td>
<td>17</td>
<td>0</td>
<td>32</td>
</tr>
</tbody>
</table>

TIMSS was a sampling of the target student population in Australia as a part of a massive international testing. The testings in England and Wales and in Victoria were meant to be of the whole of their target student populations. The very different distributions in Table 2 make it clear, therefore, that the use of a type of item can be a matter for an authority’s choice of educational intention, as much as it is an outcome of cost constraints, marking convenience, and so on.

In Table 3, I categorised the items in the tests in England and Wales, and in Victoria, according to the categories of performance response in TIMSS.

Table 3 Percentages of Items in the Categories of Performance Response in TIMSS Compared with those in the Testings in Victoria and in England/Wales

<table>
<thead>
<tr>
<th>Performance response</th>
<th>TIMSS (%)</th>
<th>Victoria (%)</th>
<th>England/Wales (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding simple information</td>
<td>40</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Understanding complex information</td>
<td>29</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Theorising, analysing, problem solving</td>
<td>21</td>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>Using tools, standard procedures and science processes</td>
<td>6</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>Investigating the natural world</td>
<td>4</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>
Again, there are some obvious differences among the distributions of these categories, with the test in England/Wales emphasising the fourth and fifth categories more than TIMSS, and the Victorian test underplaying the third category of *Theorising, analysing, problem solving*. The meaning of these distributions became clearer, when a further analysis of the items was made in terms of the opportunity students would have to answer them by *reasoning* as distinct from *recall* of taught knowledge. This is not easy without a detailed knowledge of the implemented curricular content. Nevertheless, this classification is possible if it is made in terms of *opportunity to answer by reasoning*. Many of the items in this category could be also answered by *recall* if the student had this knowledge from teaching. The items, on the other hand, that are classified as *recall* could not be answered by *reasoning* alone. Table 4 gives this classification.

<table>
<thead>
<tr>
<th>Process</th>
<th>TIMSS (%)</th>
<th>Victoria (%)</th>
<th>England/Wales (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recall</td>
<td>36</td>
<td>60</td>
<td>35</td>
</tr>
<tr>
<td>Reasoning</td>
<td>64</td>
<td>40</td>
<td>65</td>
</tr>
</tbody>
</table>

Almost all the Victorian items in the *Understanding simple information* category and at least half of those in *Understanding complex information* can only be answered by *recall*, so that students without that *recalled* knowledge must score low on the test. Students in both the TIMSS and the England/Wales tests can score quite well by *reasoning*, with *recalled* knowledge boosting their scores further.

**A RESOLUTION**

One plausible inference from these analyses is that the success of Australian primary students in TIMSS is an outcome of their general literacy in the science contexts the rather verbose TIMSS items presented, together with their abilities to reason out answers to questions, even when their knowledge of the detailed science content involved is quite incomplete. The high level indication of these considerable learning achievements in Australian primary students is very heartening, particularly at a time when the issue of literacy in primary schooling is under such debate.

These general learning achievements are also not inconsistent with the Monitoring Standards findings in Western Australia of low conceptual understanding of science and the very poor direct recall of science information found in the Victorian LAP. The TIMSS data, through the free response items, does provide a limited capacity for assessing conceptual understanding, but their analysis, though at least partially carried out, has not yet been reported. No such measures can be derived from the Victorian LAP test because of its almost total use of multiple choice items and its emphasis on direct recall.

In a small independent study of one group of Victorian students immediately after they had completed the TIMSS tests for Population 3 in 1995, the students’ techniques for answering the different types of items were explored. More than 90% used ‘guessing’ as the shorthand description of their technique for multiple choice items (Fensham, 1997). On probing what they meant by ‘guess’, a number of fairly clearly articulated accounts of ‘logical guessing’, ‘reasonable guessing’, ‘filling in of partial knowledge’, etc. emerged. Although these were Year 12 students, it may well be that the development of these
techniques and strategies begins very early in Australian schooling and contributes to quite an extent to how students in the three TIMSS populations have achieved the science scores they have.

If the argument I have tried to develop does in fact have substance, one major implication that the TIMSS findings do have for school science is that we should take great care in how science is presented to students, particularly in the primary years. We need to present it in a way that can make use of the students’ general literacy and willingness to reason things out (which we seem now to foster well), rather than in ways that ignore or even discourage these positive achievements.

A POSTSCRIPT ON DIFFERENCES IN ACHIEVEMENT

Two other aspects of the TIMSS results must at least be commented upon. The first relates to the international relativities. There is evidence from other sources, as I mentioned earlier, that in some of the countries with higher TIMSS achievement scores for Populations 1 and 2 than Australia, more systematic teaching of traditional science knowledge does occur at all levels of schooling, including the primary years. It could be that their students’ scores reflect this more extensive teaching which enables more items to be answered by recall supplemented by reasoning, than Australian students with their reliance on the reasoning approach. The students in many of the countries with lower scores in TIMSS are known to experience very limited amounts of formal science learning of any quality, and perhaps, unlike Australians, their students are not so encouraged to reason things out in topics that they have forgotten or not studied at all.

The second relates to the differences between the achievements of the students in the Australian states. It may be that secondary analyses, using the data TIMSS collected about systems, schools and students’ backgrounds, will reveal some contextual features that correlate with these differences. There are, however, other possible sources of these differences, which the TIMSS data will not so easily reveal. An attempt at an independent study of the schools in the TIMSS sample in Victoria, just after the testings for Populations 1 and 2 in late 1994, encountered very low morale in the schools, because of the massive closures of schools, the redundancies of many teachers, and other state changes. I suspect that these negative attitudes (also noted in the TIMSS data) flowed over to how the tests were administered, and hence to the students’ participation and lower achievements. The refusal and reluctance of a number of selected schools to take part is another indicator that, in some states at least, TIMSS became a victim of a more pressing set of local problems for the schools and their teachers.

REFERENCES


Prime Minister’s Science Council (1990). *Science and Mathematics in the Formative Years*. Canberra : AGPS.


APPENDIX

Whenever scientists carefully measure any quantity many times, they expect that
A. all of the measurements will be exactly the same.
B. only two of the measurements will be exactly the same.
C. all but one of the measurements will be exactly the same.
D. most of the measurements will be close but not exactly the same.

Performance Category: Understanding simple information

One way for animals to protect themselves is by escaping (running, flying, or swimming away). What are two other ways they protect themselves?

1. Some other animals eat the animal.
2. By injecting poison into them.

Performance Category: Understanding complex information

When a glass jar is placed over a lighted candle, the flame goes out.

Why does this happen?

Because, if you put something over it, the flame can’t get any oxygen and it goes out.

Performance Category: Theorising, analysing and solving problems
The diagram shows five different Celsius thermometers. The body temperature of sick people ranges from about 36°C to 42°C. Which thermometer would be most suited for accurately measuring body temperature?

A. thermometer A
B. thermometer B
C. thermometer C
D. thermometer D
E. thermometer E

Performance Category: Using tools, routine procedures and science processes

The diagram shows different trials Ahmed carried out with carts having different-sized wheels. He started them from different heights and the blocks he put in them were of equal mass.

He wants to test this idea: The heavier a cart is, the greater its speed at the bottom of a ramp. Which three trials should he compare?

A. G, T, and X
B. O, T, and Z
C. R, U, and Z
D. S, T, and U
E. S, W, and X

Performance Category: Investigating the natural world
IMPLICATIONS OF TIMSS FOR MATHEMATICS EDUCATION

Kaye Stacey

The implications for mathematics education of a study as large and comprehensive as TIMSS are very wide reaching. The results reported to date concern teachers, teaching practices, attitudes to mathematics and achievement, but in this paper I am concentrating almost exclusively on the last of these. The paper is based principally on the very comprehensive TIMSS reports for Populations 1 and 2 from ACER (Lokan, Ford & Greenwood 1996, 1997), as well as some of the data on individual items that are held at ACER.

I preface my analyses by noting that a study like TIMSS has enormous strengths in the data but it certainly does not measure everything that one might want to measure. Despite the vast amount of data that have been collected, it is still rather frustrating to try to look in depth at something, and then find that the explanation is not really there. There are some puzzling results that have already been discussed this morning. For example, why does more homework not necessarily improve students’ achievement? At the moment, the analyses of the raw data do not help sort out these puzzles and one can only speculate. Some of the speculation will be reduced when more sophisticated statistical analyses explore how the variables are linked together. The analysis presented in this paper has not incorporated anything of this nature, but is based on looking at the ‘raw’ results, generally percentages of particular responses to individual items or relative scaled scores.

Teachers

Firstly, as a teacher educator, I must mention two striking things from the survey of teachers. Only five per cent of the teachers of 13-year-olds in Australia are now under 30. This is a serious problem, not just for the long-term adequacy of staffing of schools, but also for the special contribution that young members of staff make to the school environment. Only 26 per cent of the teachers of Australian 13-year-olds think that society appreciates their work and half of them would change their career if they had another chance. The results for the teachers of nine-year-olds are only a little bit better. These are important findings for governments to address.

Attitudes

Australian students’ attitudes to mathematics seem generally quite positive. Over 80 per cent of students feel they do well at mathematics and at least two thirds say they enjoy learning mathematics. Attitudes in primary school are more positive than in secondary school, which is in line with findings from other studies. A lot of children in the primary schools think that mathematics is easy and over 80 per cent think it is important to do well in it. At least in comparison with other countries, Australia does not have a problem with attitudes to mathematics.
Australia’s international ranking

The international comparisons from the TIMSS results for the written tests for both nine-year-olds and 13-year-olds and the performance data show that Australia has done reasonably well. Our nine-year-olds tied for seventh out of 26 countries. Amongst western English speaking countries we did very well indeed. The situation is much the same for the 13-year-olds. In the rest of this paper, I look behind these generally positive results, trying to assess them in more depth.

Before that, however, it is worthwhile pointing out the positions of some interesting countries. Other papers at the conference will refer to the impressive achievement of the Asian countries and what we might learn from them. However, we can also learn from other countries. For example, the Netherlands has done very well. Mathematics educators know that the Netherlands has had at least 25 years of highly professional, very systematic curriculum development for schools. In developing their ‘realistic mathematics education’, they have built a strong curriculum centre, which works through careful research and classroom trialling. My guess is that there is much we can learn from a country like the Netherlands, as well as learning from the Asian countries.

ASSESSING AUSTRALIA’S RESULTS AGAINST AUSTRALIA’S GOALS

To make an assessment of Australia’s success, we must measure performance against what we have tried to do. Although there are important regional differences, there is a great deal of commonality around Australia of goals and assumptions about school mathematics, as is evidenced, for example, in the National Statement for Mathematics in Australian Schools (AEC, 1991). In mathematics education in primary and lower secondary school, we have aimed for:

• wide participation from all sections of the population including both genders;
• a broad curriculum which includes a wide range of mathematical topics;
• an emphasis on everyday usefulness;
• development of concepts and understanding first and then skills, through activity based teaching methods.

I will attempt to assess the results against these features of our Australian curricula.

Wide participation

In her paper earlier today, Dr Jan Lokan mentioned several results about the success of different groups in mathematics. The TIMSS results show that the effort teachers and schools have put into addressing gender differences in mathematics has been effective. In mathematics actually there has not been a gender difference overall at the junior levels in Australia in any of the international studies, although there have been gender differences on individual items. Such differences have now largely disappeared.

Whilst we have made progress with gender differences, we have made no progress about addressing socio-economic differences. The correlation of achievement with home background at around 0.4 is largest of all social factors and not reducing. A recent visitor to my university department from Japan was interested in how schools were tackling various issues related to gender and about twice a week I could bring an article from the newspaper to show what was being done. But there is nothing in the newspaper about what we are doing about home background, a much more substantial
social factor. Perhaps one implication of the TIMSS results is that we need a major campaign of the scale of the gender campaign, involving individuals, schools and governments to address socio-economic disadvantage. It would be harder than the gender campaign—there is no group of articulate, well-connected ‘victims’ of this discrimination to lead it—but it is even more a source of differing life chances.

Before leaving issues about participation and success, it is interesting to note that the Australian achievement results have quite a high standard deviation. England and New Zealand, countries similar to Australia in their education system, also have a high standard deviation. It may be worthwhile checking whether this is a statistically meaningful observation and, if so, investigating what causes the larger spread of achievement in our schools.

A broad curriculum

A fundamental assumption behind the recommendations of the Australian National Statement is that students should be exposed to a broad mathematics curriculum. In some states of Australia, especially New South Wales, this is now being questioned. Does spending time on areas of lesser importance in mathematics, for example, the Chance and Data strand, detract from number skills in primary school? Since the TIMSS mathematics results were reported overall and in six content areas, one way to gather evidence for this question is to compare how well countries do on particular areas of the curriculum and overall. My initial reading of the international data is that performance is usually even across content areas and broadly similar to the overall performance. The implication for me is that there is no evidence at the moment that we should narrow down our curriculum scope.

Some interesting features of the results by content area help us see trends in our own curriculum more clearly. For example, Australia has done very well for the nine-year-olds in geometry on the international ranking, but for 13-year-olds it is our worst area. Our excellent results for the nine-year-olds presumably reflect the enthusiastic way in which we have embraced spatial work in primary schools, emphasising practically oriented familiarity with three dimensional shapes and how they fit together, locations and directions, etc. We have done this well, but we do not know how or whether that leads on to high school geometry. We have strength in informal spatial thinking, but do not have a good transition into formal treatment of geometric properties and how they are logically connected. For me, the implication of the contrast between our primary and secondary school performance in the geometry/spatial area is that we are successful in the first but ambivalent in the second—secondary school geometry is in need of revitalisation. Geometry is not well done in some parts of Australia.

Everyday usefulness in the modern world—understanding versus skill

I noted above that the Australian curriculum emphasises everyday usefulness of mathematics and the development of concepts and understanding as a first priority and skills as a second priority. To a large extent these two goals have evolved together, as technology has freed people from needing extensive, fast arithmetic skills in the workplace. Hence, our emphasis on everyday usefulness is reflected in the widespread use of calculators, found by TIMSS in Australia. We have changed the curriculum
because most people in real life are going to use a calculator rather than a pencil and paper. In practice, we also now have a very informal mathematics, with little idea of mathematical proof and little rigour. Probably the TIMSS items have favoured such an emphasis: Australia’s core curriculum was reasonably similar to the one that was tested.

As part of the freeing up of the mathematics curriculum by technology, it has been possible to change the orientation of mathematics education from one emphasising skill to one emphasising conceptual development and understanding. Documents such as the National Statement promote strong understanding as a first priority and skills as the second priority. This aim is certainly not evident in all teaching, but it underlies our curriculum—certainly in the rhetoric, but also in the degree of mastery of skills we expect, the timing of topics, their spread across years of schooling, the basis of teachers’ planning in activities, and so on. In place of arithmetic computation, we emphasise understanding of the meaning of numbers and the operations that we carry out on them. What I will do now is look at the extent to which we have done those two things.

Firstly, we have certainly succeeded in NOT emphasising arithmetic computation. The Australian results for most items are a little above the international average—consistent with our overall ranking. However, in computation, the percentages of students correct are near or below the international average, as can be seen from Table 1. Australia had the lowest success rate of any country on the item requiring division of fractions. [25% correct for 13-year-olds in the upper grade on \( \frac{8}{35} \) divided by \( \frac{4}{15} \).]

Table 1 Measures of Computational Skill for Nine-year-olds (Upper Grade)

<table>
<thead>
<tr>
<th>Item</th>
<th>Australian per cent correct</th>
<th>International average per cent correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>6000 - 2369</td>
<td>47</td>
<td>71</td>
</tr>
<tr>
<td>23 x 3</td>
<td>at int'l average</td>
<td>84</td>
</tr>
<tr>
<td>6971 + 5291</td>
<td>76</td>
<td>84</td>
</tr>
</tbody>
</table>

Now let us look at the extent of success on building understanding. It is hard to find TIMSS items that really test understanding (the format mitigates against in-depth probing) but items such as those in Table 2 are reasonably satisfactory for this purpose. The item in Table 2 required students to select the largest of four given fractions. On this item Australia’s result is better than the international average—43 per cent instead of 39 per cent. So in a sense, we have done well, but I find it disappointing. If we really emphasised understanding of the meaning of fractions, we might have been distinctly above the international average. A similar item required students to select the order of three decimals and a fraction. Forty-seven per cent of the upper grade 13-year-old group was correct in Australia against an international average of 44 per cent. On the other hand, Singapore had a success rate of 84 per cent on this item. My own research shows that, even at Year 10, our students are not achieving at such a level (Moloney & Stacey, 1997). My overall assessment is that Australia has gone down in one area (computation) and this does not of itself concern me. However, Australia has not seen a corresponding improvement in basic understanding, which might have been expected even in a topic as central to everyday life as number.
Table 2  Percentages of 13-year-old Students (Upper Grade) Who Selected Each Response as the Largest Number of the Four

<table>
<thead>
<tr>
<th>Which number is the largest?</th>
<th>Australia</th>
<th>International</th>
<th>Singapore</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/5*</td>
<td>42.9</td>
<td>38.9</td>
<td>76.1</td>
</tr>
<tr>
<td>3/4</td>
<td>35.7</td>
<td>30.8</td>
<td>18.4</td>
</tr>
<tr>
<td>5/8</td>
<td>3.2</td>
<td>4.4</td>
<td>2.2</td>
</tr>
<tr>
<td>7/10</td>
<td>17.9</td>
<td>24.1</td>
<td>3.3</td>
</tr>
</tbody>
</table>

* Correct answer

The results for nine-year-old students shown in Table 3 show a similar pattern. Australia is much above average on the item about making the smallest whole number out of the four digits, 4,3,9,1. This is a common classroom activity in Australia, so I feel that we have probably had an advantage. However, on explaining why a quarter of a pie is less than a third of a pie, Australia is just on the international average. If we have paid for this understanding by dropping computation skill with fractions, I would expect that we should have done better.

Table 3  Conceptual Understanding of Number (Nine-year-olds, Upper Grade)

<table>
<thead>
<tr>
<th>Item</th>
<th>Australian per cent correct</th>
<th>International average per cent correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4 as four tenths</td>
<td>48</td>
<td>39</td>
</tr>
<tr>
<td>25 x 18 is how much more than 24 x 18?</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>smallest whole number made from 4,3,9,1</td>
<td>65</td>
<td>43</td>
</tr>
<tr>
<td>1/4 pie less than 1/3 pie</td>
<td>25</td>
<td>26</td>
</tr>
</tbody>
</table>

For the item in Table 4, children have to choose whether the value of 0.4 is four, four tenths, four hundredths or one quarter. The results probably indicate that this is a topic that our children often learn between the lower and upper grades of the nine-year-old sample (e.g. between grade three and grade four in Victoria). Australia’s results are right on the international average, but again, quite different from the Singapore pattern. These should not be hard questions; they are very basic.

Table 4  Percentage of Nine-year-old Students Who Selected Each Response as the Same as 0.4

<table>
<thead>
<tr>
<th>0.4 is the same as</th>
<th>Australia lower grade</th>
<th>Australia upper grade</th>
<th>International upper grade</th>
<th>Singapore upper grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>four</td>
<td>50.5</td>
<td>29.4</td>
<td>37.4</td>
<td>3.0</td>
</tr>
<tr>
<td>four tenths*</td>
<td>21.5</td>
<td>48.1</td>
<td>39.1</td>
<td>90.3</td>
</tr>
<tr>
<td>four hundredths</td>
<td>5.9</td>
<td>6.5</td>
<td>6.4</td>
<td>4.5</td>
</tr>
<tr>
<td>one fourth</td>
<td>21.1</td>
<td>16.5</td>
<td>14.9</td>
<td>2.0</td>
</tr>
</tbody>
</table>
The contention above is that the TIMSS results show lowered computational skill that has not been compensated for by better understanding. Why might this be and what could be done about it? One possibility to consider in Australia is to start earlier on some key ideas and aim to do them more thoroughly. This may not be a good idea, but my early reading of the evidence is that the high performing Asian countries teach basic ideas early and well (see Table 4) and then capitalise on this basic understanding across the mathematics curriculum.

Another possible course of action is to examine the conceptual demand of the common activities for developing conceptual understanding. In my opinion, many of the activities widely used in the name of conceptual understanding are time wasting. For example, too many of the activities supposedly aimed at developing the concept of fractions are really colouring-in exercises. Children spend lots of time on activities such as colouring in three corners of a square divided into four to ‘develop the concept of three-quarters’. Does this develop the concept of three-quarters or do many children simply learn that you look at the number on the top of the fraction (e.g. 3) and shade in three of the parts—whatever they are? The concept of a fraction involves welding the two components, numerator and denominator, into a single thing, whereas the colouring exercise focuses on counting. We need to think more carefully about how to really develop understanding and concepts.

Around the world, research knowledge of the fundamental concepts underlying mathematical topics is growing. Australia has had an ad hoc approach to curriculum development. We have promoted excellent ideas for individual lessons, but have not engaged in serious construction of sequences of lessons to develop strong understanding in the long term such as has been done in the Netherlands, for example. The Japanese lessons that Jim Stigler will be talking about also show activities that really focus on the central ideas of the topic. The problem solving required in the Japanese TIMSS lessons is very challenging and also extremely carefully crafted to use the main substance of the lesson integrally in the solutions to the problems set.

**DIFFERENCES BETWEEN THE STATES**

The variations between the states are potentially an important source of ideas about how to improve mathematics education across Australia. The broad homogeneity of society around Australia and the commonalities of schooling mean that a study of differences between the states is more likely than international comparisons to pinpoint factors that might be changed. There are very significant differences in overall achievement and interesting variations in performance by content area, although these do tend to follow the overall pattern.

Some states are doing really well in international terms yet some are below the international average. For nine-year-olds, Queensland, Western Australia, South Australia, NT and ACT are significantly better than New South Wales, Victoria and Tasmania (except that ACT was not different from Victoria). The pattern is similar, although not the same, for 13-year-olds. Table 5a below, and Table 5b on the next page, indicate the significant differences.
Table 5a Significant Differences between States, Nine-year-olds
(States Ordered by Achievement)

<table>
<thead>
<tr>
<th></th>
<th>QLD</th>
<th>WA</th>
<th>NT</th>
<th>SA</th>
<th>ACT</th>
<th>NSW</th>
<th>VIC</th>
<th>TAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>QLD</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WA</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NT</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SA</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACT</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSW</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIC</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAS</td>
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<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5b Significant Differences between States, 13-year-olds
(States Ordered by Achievement)

<table>
<thead>
<tr>
<th></th>
<th>WA</th>
<th>ACT</th>
<th>SA</th>
<th>QLD</th>
<th>NT</th>
<th>NSW</th>
<th>VIC</th>
<th>TAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>WA</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACT</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SA</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QLD</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSW</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIC</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAS</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What causes the state differences? My first hypothesis is that they may relate to age and years at school. My second is that it relates to differences in the expectations of children in different states. The first hypothesis certainly receives initial support from the TIMSS results. Table 6 shows just four states. These are New South Wales, Victoria, Queensland and Western Australia, chosen because they have similar home background indices, as shown in the rightmost column. New South Wales and Victorian Year 3 students have a lower score than those in Queensland and Western Australia, but they are on average six months younger. Similarly, the Year 4 students, who are ten on average in Victoria and NSW, do not perform as well as the ten and a half-year-olds in Queensland and Western Australia. So an initial analysis of the TIMSS results indicates that, although the number of years of schooling is the same, older children have learned more mathematics. This might be because of their age, or it might be because of what is expected of the first year(s) of school. The data need to be analysed carefully because they may have important policy and resource implications.
Table 6  Achievement, Age and Years at School

<table>
<thead>
<tr>
<th>State</th>
<th>Mathematics score</th>
<th>Average age</th>
<th>Years at school</th>
<th>Home bkgrd</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yr 3   Yr 4 Yr 5</td>
<td>Yr 3 Yr 4 Yr 5</td>
<td>Yr 3 Yr 4 Yr 5</td>
<td></td>
</tr>
<tr>
<td>NSW</td>
<td>469 526</td>
<td>9.0 10.0</td>
<td>3.75 4.75</td>
<td>9.1</td>
</tr>
<tr>
<td>VIC</td>
<td>465 536</td>
<td>9.1 10.1</td>
<td>3.75 4.75</td>
<td>9.1</td>
</tr>
<tr>
<td>QLD</td>
<td>513 574</td>
<td>9.5 10.5</td>
<td>3.75 4.75</td>
<td>8.9</td>
</tr>
<tr>
<td>WA</td>
<td>514 577</td>
<td>9.5 10.5</td>
<td>3.75 4.75</td>
<td>9.3</td>
</tr>
</tbody>
</table>

There are other explanations for the state differences that should also be carefully examined although it is more complicated to do so. I have been able to look at the state results, held at ACER, for just a few items. One where I had expected to find a difference, and did so, is shown in Table 7. The cognitively significant aspect of this equation for Year 8 students is that ‘x’—the unknown number—is on both sides. Australia’s percentage correct (35 per cent) was below the international average (45 per cent) and substantially below the Singapore result of 80 per cent. The states’ results in Table 6 show that some are really doing quite well, at least up to the international average, and others very poorly. In my opinion, Victoria’s result, of 26 per cent correct, reflects poor curriculum practice and low expectations of students.

Table 7  Selected International and National Results* for an Algebra Item

<table>
<thead>
<tr>
<th>Find x:</th>
<th>10x − 15 = 5x + 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>Result</td>
</tr>
<tr>
<td>Australia</td>
<td>35%</td>
</tr>
<tr>
<td>Singapore</td>
<td>80%</td>
</tr>
<tr>
<td>International</td>
<td>45%</td>
</tr>
<tr>
<td></td>
<td>State</td>
</tr>
<tr>
<td></td>
<td>NSW</td>
</tr>
<tr>
<td></td>
<td>VIC</td>
</tr>
<tr>
<td></td>
<td>QLD</td>
</tr>
<tr>
<td></td>
<td>SA</td>
</tr>
<tr>
<td></td>
<td>WA</td>
</tr>
<tr>
<td></td>
<td>TAS</td>
</tr>
<tr>
<td></td>
<td>ACT</td>
</tr>
<tr>
<td></td>
<td>NT</td>
</tr>
</tbody>
</table>

* Percentages are percentages correct

Researchers around the world have shown that linear equations with only one occurrence of an unknown are significantly easier than equations with the unknown occurring twice, especially on both sides of the equation. In Victoria, for reasons relating to the popularity of ‘backtracking’ (MacGregor & Stacey, 1995), the harder equations receive little emphasis. Twenty years ago, it was a topic in Year 7, then in Year 8 and currently there is a popular textbook for mainstream students which does not do this before Year 11. In Table 8 is a list of the widely used Year 10 textbooks and the number of linear equation questions with an unknown on both sides that students encounter in the whole of Year 10. One textbook series does not do this topic at all—and this is not because it has been done in earlier years. Others show significant variability around a low base.
My guess is that because it is known to be a difficult topic, teachers and some textbook writers in the *laissé-faire* curriculum climate of Victoria in the eighties and early nineties decided to leave it out or postpone it. The international research identifies the reason for the difficulty as lying at the heart of algebraic thinking (and therefore worth working on), but it would not have been consulted. The success that students in other places have with this topic would not have been considered. We need a more careful approach to curriculum development.

**Table 8  Number of Linear Equations with Unknown on Both Sides**

<table>
<thead>
<tr>
<th>Victoria</th>
<th>Naked equations</th>
<th>Problem situations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbook 10A</td>
<td>34</td>
<td>1</td>
</tr>
<tr>
<td>Textbook 10B</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Textbook 10C</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>Textbook 10D</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Textbook 10E</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Textbook 10F</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>Textbook 10G</td>
<td>18</td>
<td>0</td>
</tr>
</tbody>
</table>

*Note:* these are the current versions of the textbook series popular in Victoria.

Before we leave Table 8, there are two other observations worth pausing to consider. Firstly, why do so many of the textbooks consider that linear equations is a Year 10 topic when they only repeat the elementary equation types from earlier years? The other thing that’s really quite striking is the contrast between education rhetoric and practice. We say, in Victoria as elsewhere in Australia, that we teach mathematics through a problem solving approach. If this is the case, the numbers of equations in problem situations in Table 8 is indeed shocking. I selected Victoria, my own state, to be the target for this example simply because I have the research data to illuminate its low performance on this item. I expect that careful analysis of curriculum expectations (much more careful than was able to be done for the TIMSS study) will yield further explanations and directions for improvement.

**HAS AUSTRALIA DONE WELL?**

The TIMSS results released so far show that Australia has done well, on many measures of both attitudes and achievement. But there are two more serious questions: ‘Are we doing as well as we need to?’ and ‘Are we doing as well as we can?’ To both these questions I think the answer is ‘no’. All governments have realised that Australia’s economic future depends on healthy mathematics and science. Even if we are pleased to be above the international average, we have to be somewhat dismayed at the actual level of performance everywhere on some of the items. Improving and indeed even maintaining mathematics performance in Australia and around the world is a challenging task.

Australia could improve its performance in mathematics without changing the curriculum time allocated. The TIMSS results indicate that we should give immediate consideration to the pace and the timing of the curriculum; thinking much more carefully about the design of conceptual work; trying to promote teaching practices that really focus on children’s learning; expecting high achievement and including challenging work in the curriculum; and to a careful, professional, long-term approach to state and national curriculum development.
REFERENCES


Perhaps the most important finding of the TIMSS video study is that the Japanese approach to teacher development is very different from the American approach. The biggest long-term problem for the United States is not how we teach now but that we have no way of getting better.

The video component of the Third International Mathematics and Science Study (TIMSS) was the first attempt ever made to use videotape to study national probability samples of teachers at work. In this article, we present a brief overview of this unprecedented study, which involved detailed analysis and comparison of eighth-grade mathematics teaching in three countries: Germany, Japan, and the United States. We also discuss implications of the video study for the improvement of classroom mathematics teaching in the United States.

Collecting national samples of teaching can serve two important purposes. First, it gives us solid information about the processes of teaching and learning inside US classrooms, information that is crucial for developing sound education policies. Efforts to improve student learning succeed or fail inside the classroom, a fact that has too often been ignored by would-be reformers. Setting standards for content and performance is an important first step. But student learning will not be improved merely by setting standards and holding teachers accountable. We must study directly the processes that lead to learning in the classroom, for if we do not understand these processes we will have little chance of improving them. Most other professional and industrial fields have determined that improving the quality of the processes is the surest road to improving products, but we in education have yet to learn this lesson. The videotape study of classroom instruction allows us to refocus on teaching processes, with the aim of improving students’ learning.

National samples of teaching also enable us to compare US teaching methods with those used in other countries. This comparison allows us to see teaching in a new way. Teaching is a cultural activity. It is an everyday event that occurs throughout all parts of American society. Over time, we have developed norms and expectations for teaching that are widely shared and passed along as one generation of students becomes the next generation of teachers. Because our models of how teaching should look are so wide and so familiar, they become nearly invisible. We come to believe that this is the way teaching must be. When we observe teaching in other countries, these accepted and unquestioned practices are brought to light, and we see that we teach the way we do because we choose to teach this way. This realisation is crucial because it opens up new possibilities for how we might improve teaching.
CONDUCTING THE TIMSS VIDEO STUDY

US students performed poorly in the Second International Mathematics Study (SIMS), conducted in the 1980s. Consequently, as planning commenced for the TIMSS, there was great interest in being able to go beyond the cross-national achievement data to focus on the underlying processes that produce achievement. Instructional processes in the classroom were assumed to be an important cause of student learning. But how could something as complex as teaching be studied on a large scale, across cultures?

One approach is to give teachers a questionnaire asking them to describe their instructional practices. Although such a questionnaire had been administered as part of SIMS, there are problems with this approach. Even within the US, we lack shared meanings for the words we use to describe teaching. One teacher will call something ‘problem solving’ while her colleague next door calls the same thing a ‘routine exercise’. The problem of no shared language is compounded in a cross-cultural questionnaire study. The responses are nearly impossible to interpret.

Thus the decision was made to collect direct information on teaching by videotaping classroom instruction. Video had long been used for small-scale, in-depth qualitative research but had never been employed on such a large scale before. For this reason, the scope of the study was limited to one of the three grade levels studied in TIMSS (eighth grade) and to three of the 41 TIMSS countries (Germany, Japan, and the United States). Germany and Japan were chosen because they are both viewed as important economic competitors of the US. Japan is of special interest because it has repeatedly scored near the top in international comparisons of mathematics achievement.

Three straightforward goals guided the study: 1) to learn how eighth-grade mathematics is taught in the United States, 2) to learn how eighth-grade mathematics is taught in the two comparison countries, and 3) to learn how American teachers view reform and to see whether they are implementing teaching reforms in their classrooms. To achieve these goals, a number of methodological hurdles had to be cleared.

Sampling

If we wanted to use video to paint national portraits of eighth-grade mathematics instruction, we needed to be sure that the videotapes we analysed were representative of instruction in each country. A number of issues were considered. First, how should classrooms be selected? Fortunately, the TIMSS sampling plan was highly sophisticated. For this reason, it was possible to construct the video sample as a random subsample of the full TIMSS sample. Not only were specific teachers selected, but specific class periods as well. No substitutions were allowed, either by another teacher within the same school or by another class period with the same teacher. The final video sample included 231 classrooms: 100 in Germany, 50 in Japan, and 81 in the United States.

Having chosen the classrooms, we next needed to decide how many lessons to videotape in each one. In the end, we videotaped one lesson in each classroom. Although this enabled us to study the largest number of teachers within our budget, it precluded our studying some important parts of the teaching process, such as the methods teachers use for linking lessons together into units.
Finally, we wanted to be sure that our sample was representative of the entire school year. This was especially important in Japan, where a national curriculum dictates that different topics be taught at different times of the year across the entire nation. Although we succeeded in videotaping evenly across the school year in the United States and Germany, we were somewhat less successful in Japan, where our sample was skewed toward geometry and away from algebra. For some analyses, therefore, we selected balanced subsamples of algebra and geometry lessons in each country.

**Videotaping procedures**

At first glance, videotaping classroom instruction seems straightforward: bring in a camera and turn it on. Unfortunately, things are not so simple. Seemingly minor decisions on the part of videographers—such as where to point the camera at any given moment—can significantly affect our view of what is happening in the classroom. To get useful, comparable video in all classrooms, numerous such issues had to be anticipated and resolved in advance.

Standardised procedures for camera use were developed, tested, and revised, and videographers were trained.' Only one camera was used in each classroom, and it focused on what an ideal student would be focusing on—usually the teacher. After taping, teachers filled out a questionnaire describing the goal of the lesson, its place within the current sequence of lessons, how typical the lesson was, whether they had used methods recommended by the reforms, and so on.

**Coding the tapes**

When the tapes arrived at our research lab in Los Angeles, they were digitised (to increase durability and random access) and then translated and transcribed. The transcripts were then linked by time codes to the video in a multimedia database. These technical features helped to ease the viewing of the tapes, but they did not help in deciding what to code. Coding classroom instruction is notoriously difficult because there is so much to choose from. We kept two goals in mind: code those aspects that might make a real difference in the mathematics the students were learning, and define codes that would yield valid and informative descriptions of instruction across the three cultures. For the first goal, we drew from the research on teaching and learning in mathematics and from reform documents such as the Professional Standards for Teaching Mathematics."

To meet the second goal, we convened a team of six code developers, two from each country, and spent the summer of 1994 watching and discussing 27 field-test tapes. Out of these intensive discussions emerged the initial coding system, which included categories such as the nature of the tasks, the kind of work expected of students, and the nature of classroom discourse. The system was refined regularly as the primary coding team began applying it to the actual study tapes and as inter-coder reliability checks indicated that categories needed further definition.

As the coding process unfolded, we found it essential to construct a summary table to represent each lesson. These lesson tables were skeletons of each lesson that showed, on a time-indexed chart, how the lesson was organised through alternating segments of classwork and seatwork, what pedagogical activities were used (e.g., explaining tasks, demonstrating procedures), what tasks were presented, and the solution strategies for
the tasks that were offered by the teacher and the students. Some categories could be
coded directly from the tables; some required re-viewing the tapes.

Advantages of video

The benefits of video are well worth the methodological challenges and the labour-
intensive demands that this approach imposes. Video provides the researcher with two
kinds of data: visual images rich in descriptive power and quantifiable indicators that
summarise the contents of large numbers of images. Visual images are vivid and
powerful, but they can mislead.vii They can create such a powerful impression that the
viewer is seduced into thinking that a single case tells the whole story. Coding relevant
indicators enables us to check the representativeness of the images. Each kind of data is
significant, and each strengthens the other.

Video data are also relatively raw, in that they are not yet categorised or quantified.
Unlike narrative observations or on-site coding, videos have not been filtered through
the eyes of individual researchers and are not as constrained by the initial hypotheses of
those who design the study. For this reason they can be analysed by multiple coders
with different interests using different coding schemes. We took advantage of this fact
by asking a team of four postsecondary mathematics teachers (hereafter, the ‘Math
Group’) to analyse the mathematical content of the lessons.

TEACHING IN GERMANY, JAPAN, AND THE UNITED STATES

Descriptions of teaching must be selective. There is more going on in a classroom than
can be reported, even in a lengthy document. In a brief article, the problem is
compounded. What follows is a selection from both the quantitative and qualitative
data to illustrate the kind of information the study provides.

Some questions we have examined

What kind of mathematics do students encounter?

The nature and level of students’ learning are probably influenced by the nature of their
mathematical experiences in the classroom. An opening consideration is the kind of
mathematics that students in these classrooms encountered. One indicator is how
advanced the topics were when compared with their average placement in the
mathematics curricula of the 41 TIMSS countries.viii Matched against this scale, the
average grade level for lesson topics in the videotape sample was mid-seventh grade for
the United States, mid-eighth grade for Germany, and beginning ninth grade for Japan.

For information on the mathematical content students encountered, the Math Group
analysed 15 algebra lessons and 15 geometry lessons randomly selected from each
country.ix The group based its analyses on the detailed descriptions of mathematical
content contained in the lesson tables described in the previous section. To reduce
likelihood of bias, tables were disguised so that it was not possible to tell which country
the lessons came from. After analyses were complete, the results were tabulated by
country.
One feature on which the team members focused was deductive reasoning, a form of mathematical activity that they considered central for students’ engagement in important mathematics. They defined deductive reasoning as the reasoning needed to draw logical conclusions from premises. Mathematical proofs are the most familiar form of such reasoning. Deductive reasoning, as defined by the Math Group, was not common. Only a quarter of the 90 lessons contained instances of it. As it turned out, these instances were found in 62% of the Japanese lessons, 21% of the German lessons, and 0% of the US lessons.

Together, these indicators suggest that the kind of mathematics studied was significantly different for US students than for their Japanese peers. But this is not the whole story. Perhaps US teachers developed the lower-level content in ways that provided students with rich learning opportunities.

**Are mathematical concepts and procedures developed?**

Mathematical concepts and procedures can either be simply stated by the teacher or be developed through examples, demonstrations, and discussions. Suppose the topic is the area of right triangles. Teachers can state that the area is found by measuring the base, measuring the height, multiplying them together, and dividing the product by 2; demonstrate this procedure for a triangle or two; and then assign problems that enable students to practise the procedure. Alternatively, teachers can develop this procedure, showing, for example, how the formula 1/2 base \( \times \) height can be derived by combining two triangles to form a rectangle. Of course, the teacher might ask students to develop some of this themselves. We coded a particular mathematical topic ‘developed’ if teachers made any attempt to motivate a procedure or explain why it worked. As shown in Figure 1, concepts and procedures were usually developed in German and Japanese lessons but merely stated in US lessons.

![Figure 1 - Average Percentage of Topics Containing Concepts That Were Developed or Only Stated](image-url)
What are students expected to do?

In the findings presented thus far, Germany and Japan have appeared more similar to each other than either is to the US. When we examine what students actually do during the lessons, however, Germany and Japan diverge. In all three countries, in almost all lessons, students were asked to solve problems. Lessons differed, however, in how much creative mathematical work was expected of the students. In some lessons, a procedure was demonstrated or developed by the teacher, and students were then asked to apply this procedure to solve the assigned problems. In other lessons, students were asked to develop procedures themselves, based on what they had learned in previous lessons.

We coded the nature of the work expected of students during seatwork into three categories: 1) practising routine procedures, 2) applying procedures in new situations, or 3) inventing new procedures and analysing new situations. The first category is familiar: the teacher demonstrates or develops a procedure, such as solving a linear equation for \( x \), and then assigns a number of similar problems on which students are to practise the same procedure. The second category includes cases in which a procedure is demonstrated or developed for solving one kind of problem—say, finding the area of a right triangle by adjoining an identical triangle to form a rectangle and calculating half its area. Students are asked to apply the same procedure to another kind of problem, say, finding the areas of non-right triangles. The third category requires even more of students: they are asked to invent solution methods, analyse mathematical situations, or generate mathematical proofs. For example, students might be asked to predict the sum of the interior angles of a 10-sided polygon after measuring the sums for three-, four-, and five-sided polygons.

Coding seatwork into these three categories resulted in the differences shown in Figure 2. Japanese students spent less time practising routine procedures and more time inventing, analysing, and proving than their peers in the other countries. German and US students spent almost all their time practising routine procedures.
What is the teacher’s role?

Based on the information presented thus far, the reader may have developed the impression that teachers play a far more active role in Germany and the US than in Japan. For example, whereas German and US students usually practise methods developed or presented by the teacher, Japanese students are often asked to develop methods themselves. But to assume that Japanese teachers are less active or directive than German or US teachers would be a mistake.

Although it is true that Japanese teachers give students time to struggle with challenging problems, they often follow this up with direct explanations and summaries of what the students have learned. This is why Japanese teachers were coded as engaging in more direct lecturing than either German or US teachers. Although the time devoted to lecturing was minimal in all three countries, 71% of Japanese lessons contained at least some lecturing, compared with only about 15% of German and US lessons. Japanese teachers also control the direction of the lesson in subtle ways, such as creating conditions in the classroom that will govern the kinds of solution methods students are likely to invent. For example, to begin a lesson, they often select problems that can be solved by modifying methods that were developed during the previous lesson.
How are lessons organised?

Even with the small set of indicators presented to this point, it is clear that eighth-grade mathematics teaching differs across countries, especially between Japan and the United States. Students in these classrooms have different mathematical experiences. The differences are not just a matter of degree: US students apparently experience a different kind of mathematics than their Japanese peers. But the indicators don’t tell us everything. For example, how do teachers in each country design and implement lessons to produce such clear differences on the indicators?

The benefits of video are well worth the methodological challenges and labour-intensive demands that video imposes.

In order to understand how lessons are developed, it is useful to know what goals teachers set. Teachers were asked in the questionnaire what ‘main thing’ they wanted students to learn from the lesson. Most teachers focused either on mathematical skills (solving specific kinds of problems or using specific formulas) or on mathematical thinking (exploring, developing, and understanding mathematical ideas or inventing new ways to solve problems). As shown in Figure 3, there were large differences between countries. Japanese teachers emphasised thinking; German and US teachers emphasised skills. To understand how these goals are translated into classroom lessons, it is helpful to consider the larger context within which they are constructed.

Figure 3  Main Thing Students Are to Learn from Lesson
We noted earlier that teaching is a cultural activity. Cultural activities often have a ‘routineness’ about them that ensures a degree of consistency and predictability. Lessons are the daily routine of teaching and are usually organised according to a ‘cultural script’, a commonly accepted and predictable way of structuring a classroom session and sequencing the instructional activities. Although we may have a feel for American lessons from our shared experiences, most of us do not know what Japanese lessons look like. For this we need the videos, the visual images. Our sense of the scripts that underlie Japanese and American lessons gradually emerged as we watched the videotapes and discussed what we saw with coders and observers from the other countries. The differences in the scripts undoubtedly follow from different instructional goals and are probably based on different assumptions about the nature of mathematics, the ways in which students learn, and the appropriate role for the teacher. Our presentations of these scripts are obviously based on subjective impressions, but their veracity can be checked by other observers and by examining whether they are consistent with the indicator results.

The typical eighth-grade mathematics lesson in the US is organised around two phases: an acquisition phase and an application phase. In the acquisition phase, the teacher demonstrates or leads a discussion on how to solve a sample problem. The aim is to clarify the steps in the procedure so that students will be able to execute the same procedure on their own. In the application phase, students practise using the procedure by solving problems similar to the sample problem. During this seatwork time, the teacher circulates around the room, helping students who are having difficulty. The problems that are not completed by the end of the lesson are often assigned as homework.

The typical eighth-grade mathematics lesson in Japan follows a different script. The lesson focuses on one or sometimes two key problems. After reviewing the major point of the previous lesson and introducing the topic for today’s lesson, the teacher presents the first problem. The problem is usually one that students do not know how to solve immediately but for which they have learned some crucial concepts or procedures in their previous lessons. Students are asked to work on the problem for a specified number of minutes and then to share their solutions. The teacher reviews and highlights one or two aspects of the students’ solution methods or presents another solution method. Sometimes this cycle is repeated with another problem; other times, students practise the highlighted method or the teacher elaborates it further. Before the lesson ends, the teacher summarises the major point for the day. Homework is rarely assigned.

Of course, not all teachers in each country teach in these ways, and not all lessons follow these scripts. But what is striking, when viewing the videotapes across the two countries, is how many of the lessons appear consistent with these scripts.
How do teachers view reform?

It is interesting to note that in some respects Japanese lessons appear consistent with reform recommendations proposed by such documents as the *Professional Standards for Teaching Mathematics* of the National Council of Teachers of Mathematics (NCTM). Japanese lessons include high-level mathematics, a clear focus on thinking and problem solving, and an emphasis on students’ deriving alternative solution methods and explaining their thinking. In other respects, though, Japanese lessons do not follow such reform guidelines. They include more lecturing and demonstration than even the more traditional US lessons, and we never observed calculators being used in a Japanese classroom.

Regardless of whether Japanese classrooms share features of ‘reform’ classrooms or not, it is quite clear that the typical US classrooms do not. This is especially interesting given the fact that the US teachers, when asked if they were aware of current ideas about the best ways to teach mathematics, responded overwhelmingly in the affirmative. The vast majority reported having read the NCTM standards. Seventy per cent of the teachers even claimed to be implementing such ideas in the very lesson that we videotaped. It may be that teachers have changed some features of their instruction and have adopted such reforms as using real-world problems, manipulatives, or cooperative learning. But our data suggest that these changes have not affected the deeper cultural scripts from which teachers work. US teachers are still emphasising the acquisition and application of skills.

BEWARE OF SIMPLE SOLUTIONS

Given the high mathematics achievement of Japanese students, it is tempting to conclude that US teachers should teach more like their Japanese counterparts. Although there are probably many useful ideas for US classrooms in the Japanese videos, we are pessimistic that such ideas can simply be imported. Indeed, if teaching could be changed by just disseminating ideas, the record of reform in the US would be more successful than it is. The data on how teachers view reform, presented above, are quite sobering in this regard.

Besides the ineffectiveness of just disseminating prescriptions, systems of teaching are not easily transported from one culture into another. Teaching, as a cultural activity, fits within a variety of social, economic, and political forces in our society. The effects of teaching are determined, in part, by all of these forces. Thus if one imports a system of teaching into a different culture, one cannot expect that system to produce the same results. The Japanese system of teaching is enmeshed within Japanese culture—the social and behavioural norms; the expectations and involvement of parents; the national curriculum; outside educational activities such as juku (so-called ‘cram schools’), i.e. coaching colleges; values of education held by students, parents, and the public; and so on. All these factors no doubt play important roles in supporting the kind of teaching we see on the Japanese videotapes.

An additional problem with simple solutions for improving teaching is that they often focus on individual features of teaching, such as using concrete materials, asking higher-order questions, or forming cooperative groups. But teaching is not just a collection of individual features. It is a system composed of tightly connected elements. And the system is rooted in deep-seated beliefs about the nature of the subject, the way students learn, and the role of the teacher. Attempts to change individual features are likely to have little effect on the overall system. The changes often get swallowed up or reshaped.
If we cannot improve teaching by importing another system or by manipulating individual features, what can we do? A recent popular approach is to create content and performance standards and then hold teachers accountable for achieving them. Although we firmly believe that such standards are necessary, a focus on standards and accountability that ignores the processes of teaching and learning in classrooms will not provide the direction that teachers need in their quest to improve.

Another common American approach is to ask experts to meet and discuss the problem and issue written documents to guide a reform. Reforms are needed, presumably, because past policies have failed. The experts decide that we need to break with current practice and try something new. Current documents contain recommendations for such things as how schools should be structured, how market forces should drive improvements, and how technology should change the classroom. This approach, too, is problematic because it assumes that these changes will automatically improve the quality of teaching.

IMPROVING CLASSROOM TEACHING

What we need to improve teaching over time is an approach that recognises that teaching can be studied and improved but at the same time acknowledges the cultural complexity and embeddedness of teaching. How can we break out of our conventional approaches and imagine more productive alternatives? Comparative studies are especially helpful here, and this is where we can learn something from the Japanese.

The approach to improving teaching used in Japan is not based on distributing written reports, or on reforming features of instruction, or on assuming that teaching will change when surrounding elements change. It is based on the direct study of teaching, with the goal of steady improvement in the mathematics learning of students.\textsuperscript{xiii}

The process of professional teacher development in Japan begins with clearly stated goals for student learning. Japanese mathematics teachers are very familiar with the widely shared goals for student learning at each grade level. The documents that present these goals are similar to the content standards that have received so much attention in the US in recent years. To the extent that American teachers share these goals and understand their meaning and intent, these standards can set the stage for improving teaching. Unfortunately, the reading of the standards documents is often the end of the process in the US; in Japan, becoming familiar with the learning goals is only the beginning.

During their careers, Japanese teachers engage in a relentless, continuous process of improving their lessons to improve students’ opportunities to achieve the learning goals. A key part of this process is their participation in ‘lesson study groups’. Small groups of teachers meet regularly, once a week for about an hour, to plan, implement, evaluate, and revise lessons collaboratively. Many groups focus on only a few lessons over the course of the year with the aim of perfecting these.\textsuperscript{xiv}

A group of fourth-grade teachers, for example, might be dissatisfied with its current lessons on adding fractions with unlike denominators. So this study group sets the goal of replacing these lessons. The group designs several lessons, one group member tries them out while the others observe and evaluate what is effective and what is not, and they revise the lessons. Maybe they change the wording of the opening problem, or maybe they change the kinds of follow-up questions they ask, or maybe they learn more about what methods students are likely to invent and then build these methods into the whole-class discussion. Then they try out the lessons again, perhaps with other teachers
observing. This process may go on for several years. When the replacement lessons are ready, they are shared with other teachers, in other schools. Through the lesson study groups, teachers improve their own pedagogy and they improve the curriculum. More than that, they improve the collective practice of teaching as they share their work with others.

The belief that drives these lesson study groups is that students’ opportunities to learn will improve with better lessons and that better lessons come through collaborative planning and testing. Japanese teachers assume that this task is so big that every teacher must be involved; the wisdom and experience of all teachers are needed to make progress. Further, they assume that improvement will come through a steady, gradual, cumulative process. As they learn from their experiences and pool their information, they will become more highly skilled teachers who have access to increasingly more effective lessons. By focusing on lessons, the Japanese teacher development system formulates and assesses new ideas in the same context in which these ideas will be applied. In this way, the Japanese lesson study group respects the cultural complexity of teaching, focusing on contexts in which all relevant parts of the system of instruction are naturally incorporated.

THE TRUE PROFESSION OF ‘TEACHING’

The Japanese approach to teacher development stands in stark contrast to the American approach. Our biggest long-term problem is not how we teach now but that we have no way of getting better. We have no mechanism built into the teaching profession that allows us to improve gradually over time. We have reports of individual teachers who, through heroic efforts of their own, become unusually effective. But these are individuals, not large numbers of teachers, and, sadder still, we have no way of learning from their experiences. Indeed, we have no way of harvesting the best ideas of the thousands of teachers who work, by themselves, to improve their own teaching.

There are many reasons for the absence of a systemic approach to teacher development in the US. For example, Americans hold the notion that good teaching comes through artful and spontaneous interactions with students during lessons. This kind of on-the-fly decision making is made possible by the innate intuitions of ‘natural’ teachers. Such views minimise the importance of planning increasingly effective lessons and lend credence to the folk belief that good teachers are born, not made. If we really believe this, it is no wonder that teacher development is not a high priority. Unfortunately, it is not just one belief, but an entire cluster of beliefs, some of them contradictory, that dampen our commitment to improving teaching. Beliefs about teacher autonomy; about the intractable complexity of teaching, on the one hand, and its common simplicity, on the other; about the likelihood that it will ever change, on the one hand, and the persistent optimism of reformers, on the other—all these tenets work against efforts to institute mechanisms for continuous, long-term improvement.

We are not arguing for simply importing the Japanese method of teacher development. Just as the Japanese method of teaching mathematics is embedded in a particular culture, so is the Japanese system of teacher development. However, in both cases, we can study these alternative systems to gain new insights into our own systems, and we can use these insights to challenge the status quo.

We believe that our failure to take teacher development seriously is closely tied to the issue of professionalism. For years, educators have called attention to the relatively low status of teaching and have bemoaned the lack of respect bestowed on teaching by the media and the public. Much rhetoric has been devoted to this issue, as if demanding
higher status or labeling teaching a profession would solve the problem. A true profession of teaching will emerge as teachers find ways and are given the opportunities to improve teaching. By improving teaching, we mean a relentless process in which teachers do not just improve their own skills but also contribute to the improvement of Teaching with a capital T. Only when teachers are allowed to see themselves as members of a group, collectively and directly improving their professional practice by improving pedagogy and curricula and by improving students’ opportunities to learn, will we be on the road to developing a true profession of teaching. The TIMSS videotape study points us beyond the data, not to a critique of how we currently teach but to a recognition of the need to implement a mechanism whereby we can, over time, improve our teaching.

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The scenes shown are taken from the CD-ROM of the video study released by the National Center for Education Statistics, Washington, DC, USA, with permission.

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NOTES

i The research reported in this article was funded by the National Center for Education Statistics, US Department of Education. The study was conducted in collaboration with Jurgen Baumert and Rainer Lehmann in Germany and Toshio Sawada in Japan. The authors gratefully acknowledge the assistance of Patrick Gonzales, Takako Kawanaka, Steffen Knoll, and Ana Serrano, all of whom functioned as primary researchers on the study, and of Eric Derghazarian, Gundula Huber, Fumiko Ichioika, and Nicole Kersting, among many, many others. The writing of this article was supported, in part, by a grant from the American Federation of Teachers.


iii A number of researchers have pointed out that teachers teach much in the way they were taught. See, for example, Daniel C. Lortie, Schoolteacher: A Sociological Study (Chicago: University of Chicago Press, 1975); and Sharon F. Nemser, ‘Learning to Teach’, in Lee Shulman & Gary Sykes, eds., Handbook of Teaching and Policy (New York: Longman, 1983), pp. 150-70.

iv A complete description of sampling procedures can be found in James W. Stigler et al., The TIMSS Videotape Classroom Study: Methods and Findings from an Exploratory Research Project on Eighth-Grade Mathematics Instruction in Germany, Japan, and the United States, (Washington, D.C.: National Center for Education Statistics, 1997).

v For a full description of videotaping considerations and procedures, see Stigler et al., 1997.


The ‘Math Group’ was led by Alfred Manaster of the University of California, San Diego. Other members of the group were Phillip Emig, Wallace Etterbeek, and Barbara Wells.

A videotape with examples from German, Japanese, and US lessons, together with an accompanying study guide, can be obtained by phoning the National Center for Education Statistics at +1/202/219-1333 or by sending e-mail to timss@ed.gov.

Other studies have also shown that reform recommendations are often implemented in superficial ways. See, for example, the case studies of California teachers conducted by researchers from Michigan State University and reported in a special issue of Educational Evaluation and Policy Analysis (Fall 1990).


Our description of the Japanese process of improving teaching comes from our conversations with Japanese educators and a number of written sources, including Nobuo K. Shimahara & Akira Sakai, Learning to Teach in Two Cultures: Japan and the United States (New York: Garland, 1995); and two special issues of the Peabody Journal of Education devoted to Japanese teacher education (Spring and Summer 1993).

For more information on lesson study in Japan, see Catherine Lewis and Ineko Tsuchida, ‘Planned Educational Change in Japan: The Shift to Student-Centered Elementary Science’, Journal of Educational Policy, in press.
INTRODUCTION

Education in Singapore is a national priority as people are the country’s only resource, it focuses on the development of human resources to meet Singapore’s need for an educated and skilled workforce, and the inculcation of sound Asian values as a cultural ballast in the face of rapid progress and change.

The main thrust of Singapore’s education is to develop a highly skilled, productive, and innovative workforce to keep Singapore competitive in the global economy. Our education also prepares the workforce to meet challenges emerging out of developments in technology and changes in the business environment. The emphasis of the education system is, therefore, on the proficiency in English and mathematics.

This paper outlines the mathematics and science education programs in Singapore’s schools.

THE MATHEMATICS CURRICULUM

Mathematics is a compulsory core subject at the primary and secondary levels (age 6+ to 16+). This is to ensure that students are equipped with fundamental mathematical knowledge to prepare them for further education and training.

The teaching and learning of mathematics in Singapore schools are guided by the mathematics syllabuses developed by the Ministry of Education. The syllabuses state the aims and objectives, the mathematics content, and the performance standards in the form of learning outcomes. They also provide guidelines on instructional pedagogy and assessment methods to achieve these standards. Provision is made to stretch students to the maximum of their abilities. Differentiated syllabuses are provided to cater to the different ability groups of students at the primary and secondary levels. The mathematics syllabus designed for the weakest pupils, for instance, highlights a smaller range of mathematics content to be taught at a more gradual pace. This is to allow weaker students to attain a firm foundation in basic mathematical concepts to prepare them for higher education.
Aim

The mathematics curriculum aims to provide a minimal-level acquisition of basic numeracy knowledge and skills for all students and a foundation for continuous life-long learning. It enables students to acquire the necessary mathematical knowledge and skills, develop thinking processes, and apply them in mathematical situations of everyday life.

Emphasis

The mathematics syllabuses were revised in 1990. The focus of the revised syllabuses is on the development of mathematical concepts and the ability to apply them to solve mathematical problems. Greater emphasis is placed on the meaningful understanding of concepts through activities, mathematical thinking and the processes of doing mathematical tasks.

The spirit and emphases of the revised syllabuses are best illustrated in the following framework:

Figure 1  Mathematics Education Framework in Singapore

Singapore’s mathematics education framework is centred on mathematical problem solving. The students’ learning involves not only the acquisition of concepts and skills but also underlying mathematical thinking, general strategies of problem solving and attitude towards and appreciation of mathematics.

This framework represents the intent for the teaching and learning of mathematics in schools. It is included in all the syllabus documents. The framework was conceptualised to guide curriculum planners, materials developers, teacher trainers and, most importantly, the teachers, in interpreting and implementing the syllabuses as intended.
Curriculum time

Mathematics instruction takes up 3.5 to 6.5 hours of the weekly curriculum time at the primary level (grades 1 to 6) and 3.5 to 5 hours of the weekly curriculum time at the secondary level (grades 7 to 10).

Mathematics content

The syllabuses developed by the Ministry of Education provide specific mathematics content to be covered at each grade level up to grade 8 (lower secondary). This is to ensure that students develop a good foundation in the fundamental concepts and skills needed for further studies.

At the primary level (grades 1 to 6), students are taught the basic concepts of whole numbers, fractions, decimals, mensuration, geometry, statistics (handling data) and algebra. The emphasis is on building a strong foundation in number work. A large proportion of time is spent on the development of concepts involving whole numbers and solving simple arithmetic problems.

The curriculum for the lower secondary level (grades 7 and 8) aims to prepare students for further mathematical studies at the higher levels. It builds on the foundation developed at the primary level. Students learn the various topics covered at the primary level in greater depth. The more able students study additional topics such as trigonometry.

The curriculum for upper secondary and pre-university levels (grades 7 to 12) is based on the University of Cambridge General Certificate in Education mathematics syllabuses for Normal, Ordinary and Advanced levels.

The mathematics content covered at the upper secondary level includes topics such as arithmetic, mensuration, algebra, geometry, trigonometry, statistics, simple transformation and vectors. The more able students can also opt to do a second mathematics subject, Additional Mathematics. This subject exposes students to higher level mathematics so they are better prepared for engineering courses at the Institute of Technical Education and the polytechnics.

Mathematics is an optional subject at the pre-university level. Students who are mathematically inclined can choose to do two mathematics subjects at the advanced level.

Pedagogy

The framework of the mathematics curriculum provides a basis for mathematics teaching and learning. Teachers are free to adopt teaching strategies to implement the syllabus in ways that best suit the abilities, needs, and interests of their students. Desirable teaching approaches are included in the syllabus as suggestions. These include practical and investigative work, mathematical communication, problem solving and mental calculation.

Mental calculation is a key feature of the mathematics program in most primary schools. Manipulative materials are commonly used in the primary grades to enable students to develop conceptual understanding. Scientific calculators are used from grade 7 onwards. All schools are equipped with computer laboratories. Teachers are beginning to use computers and the Internet in their teaching although generally the expository
approach is used. Practice and consolidation is an important part of instruction. The provision of homework and assignments for students to consolidate their learning is a common practice. The remedial help for weak students varies from individualised attention to small group instruction.

THE SCIENCE CURRICULUM

Aim
Science education aims to prepare students for further studies and training in science, engineering and technology courses at the universities, polytechnics and Institute of Technical Education. It enables students to understand and make informed decisions relating to science and technology. The ever-expanding content knowledge makes it impossible for students to absorb all facts. Hence, science education provides for the acquisition of information retrieval and processing skills and encourages curiosity, open-mindedness, perseverance, and positive attitudes which are necessary for the lifelong learner.

Emphasis
The science syllabuses for primary and secondary levels were revised in 1990. The revised syllabuses give greater emphasis to the acquisition and development of process skills, problem-solving and inquiry skills. This shift in emphasis is to prepare our students to meet the challenges and demands of a high-tech society better. In addition to imparting scientific knowledge and skills, economic, social and environmental considerations of science and technology are also taught. In the process, students are equipped with the understanding necessary for decision-making.

Curriculum time
Science is taught as a subject from Primary 3 (grade 3). The weekly curriculum time ranges from 1.5 hours for Primary 3 to 2.5 hours for Primary 6. Science instruction at the secondary level takes up 2.5 to 3.5 hours per week for lower secondary level (grades 7 and 8) and 3 to 9 hours per week for upper secondary level (grades 9 and 10).

Science content
At the primary level, the science subject in Singapore enables students to learn about themselves and their environment. The main idea that permeates the science syllabus is Man and his interaction with the environment. Students are taught general and foundational science concepts and skills which are selectively taken from the various disciplines of science.

At the lower secondary level, science is a core subject in the curriculum. The focus of the syllabus is on the development of science concepts, acquisition of process skills and positive attitudes. The syllabus contains fundamental principles drawn from the various disciplines of science. Some social issues which are of national concern such as water conservation, air and water pollution, drug and inhalant abuse, alcohol, smoking and the prevention of AIDS and other sexually transmitted diseases are also dealt with.
The curriculum at the upper secondary and pre-university levels, guided by the Cambridge General Certificate in Education (Normal, Ordinary and Advanced Levels) syllabuses, builds on the general science foundation developed at the lower levels. The various science subjects and combinations provide relevant foundations in science required for different post-secondary pursuits, be these science or engineering studies at the tertiary level or technical-vocational training at the Institute of Technical Education.

**Pedagogy**

The principal role of science teachers is to provide opportunities for using the tools required to understand and internalise knowledge and skills. These tools include both laboratory equipment and scientific inquiry skills.

Teachers use a variety of methods in science teaching to accommodate different learning styles. These methods include lectures, demonstrations, discussions, role-play, instructional films, field trips, case studies, projects and practical work, debates, and field work. As in mathematics, science teachers are also beginning to use computers and the Internet in their teaching. Within a given curriculum time, a variety of teaching methods is often used to capture and sustain student interest. A period of teacher-centred activity, for example, is often followed by a period of pupil-centred activity. The choice of teaching method depends largely on the topic or skill to be learned, since certain topics lend themselves to didactic teaching and others to more pupil-centred strategies.

With the increase in emphasis on the development of process skills and an inquiring mind, opportunities are provided to enable students to be more active in the learning of science. Project work has been introduced into the lower secondary science curriculum since 1987 to further foster the development of such skills. Alternative modes of assessment such as practical tests and checklists for process skills and attitudes are used at the primary and lower secondary levels.

**RESOURCES FOR TEACHING AND LEARNING**

The Ministry of Education produces integrated multi-media curriculum packages which include textbooks, workbooks, teachers’ guides and audio visual aids such as transparency masters, slides, study cards and Educational TV programs for most of the levels. The mathematics and science textbooks at the upper secondary and pre-university levels are mainly produced by commercial publishers.

All primary schools are provided with a science room and a science garden. The former enables students to carry out science experiments while the latter facilitates the learning of science outside the classroom. All secondary schools and junior colleges are provided with laboratories. School libraries also lend good support to the science program in schools with their stock of science books, periodicals, journals and enrichment materials.

Out-of-school resources such as the Singapore Science Centre, Singapore Zoological Gardens, Sungei Buloh Nature Reserve and Bukit Timah Nature Reserve are used by schools to conduct research and enrichment activities. Some private sector companies also facilitate on-site visits and attachment programs for students.
TRAINING AND PROFESSIONAL DEVELOPMENT

Pre-service training is provided for by the National Institute of Education of the Nanyang Technological University. Professional upgrading for teachers is an on-going process. In-service courses, training workshops and seminars are organised for teachers by the Ministry, at times with help from the tertiary institutions. Professional development for teachers, scheduled out of school hours because the teachers do not want it to interfere with teaching time, is provided as an essential part of curriculum reform. Teachers are sent for overseas courses, conferences and training courses. Professional organisations such as the Science Teachers’ Association of Singapore also organise workshops and seminars for teachers. Schools also hold their own professional development activities and sharing sessions.

FOSTERING INTEREST IN MATHEMATICS AND SCIENCE

One of the aims of the mathematics and science curriculum in schools is to enable students to develop interest and positive attitudes in these subjects. At the class-room level, in the case of science, the inculcation of skills and attitudes is achieved through laboratory work, especially in investigative experiments, field studies and project work. The skills range from simple observation and comparing to formulating research questions, planning and investigation. Attitudes necessary for a good researcher such as interest, curiosity, perseverance, objectivity and cooperation are also developed through investigative activities.

The curricular activities which promote interest and attitudes in mathematics and science are complemented by extra-curricular enrichment activities. These enrichment activities provide opportunities for students to sharpen their research capability and display their creativity in science research and mathematical problem solving. They also help to identify, encourage and reward creative talents in mathematics, science and engineering.

The mathematics and science enrichment activities range from those promoting scientific interest and research among students to those specifically targeted at nurturing potential researchers. Examples of such activities and programs include:

- Young Scientist Badge Awards (primary level)
- Questa Club (secondary level)
- Singapore Youth Science Fortnight Fairs (all levels)
- Tan Kah Kee Young Inventors’ Award (all levels)
- National Science Talent Search Award (upper secondary and pre-university levels)
- Applied Science Program (secondary level)
- Biotechnology Program (secondary level)
- Innovation Program (secondary level)
- Science Research Program (pre-university level)
- Technology and Engineering Research Program (pre-university level)
- International Olympiads (Mathematical, Informatics, Physics and Chemistry)
- Overseas research programs (e.g. Research Science Institute Summer Program in USA).

Post-secondary institutions and professional organisations also play an instrumental role in fostering interest in mathematics and science. They organise various other enrichment programs and competitions to provide opportunities for students to display their creative talents in mathematics, science and technology.
CONCLUSION

Singapore’s education system strives to enable all school leavers to have a firm foundation in the basics of English and mathematics. Even the academically weaker school leavers are sufficiently numerate and literate to cope well in the changing working environment through continual self-learning. The effort is further supported by the society and parents who place great emphasis on education. The dedication of teachers and the hard work put in by students are also contributing factors towards the education system’s effectiveness.

Factors which seem most likely to have led to Singapore’s high performance in TIMSS include the centralised education system with its structured and focused approach and streaming policies; the emphasis on problem solving and scientific enquiry in the mathematics and science curricula; the systematic reviews of curricula carried out every ten years; a national emphasis on science and technology; support from parents; and the hard work of teachers and students.

REFERENCES


INTRODUCTION

The National Literacy and Numeracy Plan places numeracy education in centre stage for the next few years. The Numeracy Education Strategy Development Conference will inform policy and program developments at the state and national levels by synthesising the considered input of a wide spectrum of stakeholders in education. The nature and scope of numeracy has been mapped out, and key strategies identified. In this paper, the Project’s broad findings are outlined and considered in relation to some implications from the TIMSS study. Examples from the TIMSS bank of assessment items are used both as illustrations and to help pose some questions for the future of mathematics and science education in this country.

BACKGROUND

The context for the Numeracy Education Strategy Development Conference is the adoption by the Ministerial Council on Education, Employment and Youth Affairs (MCEETYA) in March 1997 of new national literacy and numeracy goals:

• that every child leaving primary school should be numerate, and be able to read, write and spell at an appropriate level

and the endorsement by Commonwealth, State and Territory Governments of a National Plan for Literacy and Numeracy. Many of those associated with mathematics and numeracy education take the view that numeracy education has been significantly neglected in Australia in comparison with literacy education. The national emphasis on numeracy is therefore welcome. It is also timely in the light of the demands which technology is making on citizens’ numeracy.

The question of what should be happening as a result of numeracy becoming a priority is a very real one in the light of the ‘neglect’ mentioned earlier, however. The Numeracy Education Strategy Development Conference was conceived to provide the kind of guidance needed to ensure that students’ numeracy achievements are maximised. It was a project established by the Australian Association of Mathematics Teachers and the Education Department of Western Australia and supported by the Commonwealth Department of Employment, Education, Training and Youth Affairs.

The Conference brought together a wide cross-section of the education community in Perth in May 1997 and its report, Numeracy = everyone’s business, contains a number of key recommendations and a wealth of supporting advice and information. Before
discussing the future directions identified in the Report and how the TIMSS work interacts with these, it is necessary to identify and clarify the position taken by the project in relation to numeracy itself.

WHAT ARE WE REALLY TALKING ABOUT?

The Report takes the view that to be numerate is to use mathematics effectively to meet the general demands of life at home, in paid work, and for participation in community and civic life. In school education, it is a fundamental component of learning, performance, discourse and critique across all areas of the curriculum. It involves the disposition to use, in context, a combination of:

- underpinning mathematical concepts and skills from across the discipline (numerical, spatial, graphical, statistical and algebraic);
- mathematical thinking and strategies;
- general thinking skills; and
- grounded appreciation of context.

To illustrate this, let us consider a few of the items from TIMSS. These are all taken from the Australian reports (Lokan, Ford & Greenwood, 1996, 1997).

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Population 1 — Earth science (Monograph 2, p. 91)

The Sun is bigger than the Moon, but they appear to be about the same size when you look at them from the Earth. Why is this?

Because the moon is closer to Earth than the sun.

Because it is further away it looks about the same size.
Population 2 — Science (physics)  (Monograph 1, p. 80)

A student put 100 mL of water in each of these open containers, and let them stand in the sun for one day. Which container probably lost the most water due to evaporation?

A.  
B.  
C.  
D.  

Population 2 — Science (chemistry)  (Monograph 1, p. 92)

<table>
<thead>
<tr>
<th>AMOUNT OF OXYGEN PRODUCED IN A POND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
</tr>
<tr>
<td>Top Metre</td>
</tr>
<tr>
<td>Second Metre</td>
</tr>
<tr>
<td>Third Metre</td>
</tr>
<tr>
<td>Bottom Metre</td>
</tr>
</tbody>
</table>

Which statement is consistent with the data in the table?

A. More oxygen production occurs near the surface because there is more light there.
B. More oxygen production occurs near the bottom because there are more plants there.
C. The greater the water pressure, the more oxygen production occurs.
D. The rate of oxygen production is not related to depth.
Population 2 — Science (physics) (Monograph 1, p. 93)

The diagram shows five different Celsius thermometers. The body temperature of sick people ranges from about $36^\circ$ C to $42^\circ$ C. Which thermometer would be most suited for accurately measuring body temperature?

A. thermometer A
B. thermometer B
C. thermometer C
D. thermometer D
E. thermometer E

The performance assessment tasks in science are also particularly instructive. For example, from the Population 1 science tasks:

S1: Pulse

Required students to measure their pulse rate and find out how this changes while exercising. Students were instructed to measure their pulse for 10 seconds after each of five minutes spent climbing up and down on a step, record their measurements in a table, and to describe and explain what they found.

S4: Rubber band

Required students to investigate the elastic properties of a rubber band by suspending more and more objects (metal rings) from a hook attached to it. Students had to make, tabulate and describe their measurements and interpret the results.

All of these items relate to and assess important scientific concepts. My intention of highlighting them is to identify the central role that students’ numeracy plays in their learning of the concepts being assessed, and in their actual performance on the items. To learn and perform well in science is to be numerate in science.

The education community would have no difficulty with this last statement changed to read:

*To learn and perform well in science is to be literate in science*

and would, on the basis of substantial developmental effort in the last 20 years, articulate well developed means for attending to the ‘literacy of science’. The same is not true for the numeracy of science (or of any other curriculum area for that matter). Numeracy has largely been assumed to be merely the acquisition of a set of number skills and has been generally ignored as a key set of learnings, capabilities and orientations which contribute to success at school and beyond.
IMPORTANT FUTURE DIRECTIONS

The Report, *Numeracy = everyone’s business*, maps out a future for numeracy education through ten recommendations. A number of these, while important, are not directly relevant in this context. They relate to coordination of efforts in numeracy education, involving the community in its development and issues around identification of students ‘at risk’ and intervention to support their learning, especially in the early years. Research, professional development and assessment are the three areas of recommendation which have direct impact on planning to capitalise on the TIMSS findings.

Research

Clearly, we need to find out more about the area, and, more particularly, what promotes students’ numeracy development. Priorities for research should include:

- aspects of numeracy and their implications across the curriculum and schooling in general;
- teaching for numeracy development; and
- assessment of numeracy.

Each of these will necessarily need to consider the context of science (as well as other curriculum areas). Teachers, curriculum designers and materials developers in all curriculum areas will all do better when this research enables their work to anticipate and meet numeracy learning needs.

Professional development

The literacy education ‘movement’ has only been able to have the impact it has through extensive and sustained professional development. The same will be true of numeracy education and only an effort of substantial magnitude will be sufficient. Target groups for professional development cannot be restricted to teachers, but must include, probably in the first instance, educational leaders and decision makers inside and outside schools and universities. Foci should be based on ensuring that research efforts outlined above are able to be put into practice and should include:

- the nature of numeracy;
- developing shared understandings of the numeracy demands across all learning areas and a commitment from all teachers to contribute, where possible and appropriate, to their students’ numeracy development;
- increasing teachers’ understanding and use of identification and intervention strategies in relation to numeracy; and
- enabling teachers to address the numeracy learning needs of all students.

Assessment

Given the broad description of numeracy being advocated, assessment of all its facets creates some acute challenges. Significant to the changes in expectations that this implies is the pervasiveness of the ‘maths test’ in the community’s psyche as perhaps the quintessential school experience. The numeracy assessment needed in future in the classroom and at school, school system and State and Territory levels goes well beyond the ‘maths test’. Much will need to be based on well-grounded teacher judgements, and efforts will be needed to inform these, and to develop consistency and validity.
TIMSS RESULTS, NUMERACY AND THE FUTURE

There are clearly lessons to be learnt from the TIMSS results in mathematics. Acting on these is part of the essential work on building the best possible mathematics curriculum. We need to recognise, however, that the TIMSS items represent only this one part of the numeracy that is essential to us at work, in education and in our personal and civic lives. We must not be seduced into thinking that this gives any robust measure of our students’ numeracy per se. The numeracy that is important in economic and social terms is underpinned by the kinds of mathematics represented in TIMSS mathematics items, but it is only relevant to economic and social goals through action—students and young people being able to solve problems, doing things, working with and developing technologies, analysing arguments based on ‘mathematical’ concepts and taking their places in the workforce of the future.

The issue of numeracy is arguably more important to science education than it is to mathematics. Those involved in the Numeracy Education Strategy Development Project spent a great deal of time considering ‘context’. The science curriculum—what students do and learn—provides numeracy-rich contexts. Science educators need to know the demands that particular aspects of science place on students’ numeracy, and be aware of the opportunities they have for helping develop numeracy skills. They need to see with numeracy-aware eyes to make achievement in science clearer and more possible for students. With this knowledge base they will be able to develop, adapt, adopt and invent ways which enable young people to become numerate in science, assisted by, or indeed as part of, the kinds of directions suggested by the Numeracy Education Strategy Development Conference. The results of this work may well show up in future studies similar to TIMSS, but the far more important outcome will be the contribution it makes to their capacity to take their places as productive and capable citizens in the next millennium.

REFERENCES


NOTE

The views contained in this paper are those of the author and not necessarily those of the AAMT, the Education Department of Western Australia or the Department of Employment, Education, Training and Youth Affairs as partners in this project.
Towards Improving the Quality of Science and Technology Education in Australian Primary Schools: Issues Arising from the ASTEC Report

Tim Hardy

In May 1997, the Australian Science, Technology and Engineering Council (ASTEC) presented a report to the Federal Government based on a year long investigation of the state of science and technology education in Australia’s primary schools. The report suggests that, while there has been some recent progress in the development of these areas, much remains to be done—especially in the new area of technology education. In the report’s recommendations, ASTEC underlines the need for substantial professional development of teachers. ASTEC believes that primary education has a major role to play in developing foundations for Australia’s future in the 21st century by contributing to literacy in science and technology. However, this will not occur unless science and technology are clearly recognised as key elements in the learning of young children. In this paper, I will describe the research that was done, what was found, the recommendations that were made and the basis for these.

BACKGROUND

During 1996 and the early part of 1997, the Australian Science, Technology and Engineering Council (ASTEC) carried out an investigation into science and technology education in Australian primary schools. The study had its origins in the earlier ASTEC study, Matching Science and Technology to Future Needs: 2010 (ASTEC, 1996), in which it was argued that primary education had a crucial role in increasing the level of the population’s scientific and technological literacy. ASTEC spoke of the need to embed science and technology in Australian culture, and advocated the use of the term ‘technacy’ in school systems as the technological equivalent of literacy and numeracy (1996, 61-63).

ASTEC is a statutory authority which gives independent advice to the Commonwealth Government. The Council presented a progress report (in September 1996) and a final report to the Prime Minister’s Science and Engineering Council (PMSEC) in May 1997, at which time the main respondent was the Minister for Schools, Vocational Education and Training, Dr David Kemp. The report, Foundations for Australia’s Future: Science and Technology in Primary Schools (ASTEC, 1997), is the basis for this paper which provides an overview of the report’s central findings and recommendations. I was a member of the study’s Working Party and presented the report to PMSEC on behalf of ASTEC. In this paper I make personal observations that go beyond the report itself. Some links and comparisons are made to TIMSS, and I raise a number of issues that emerge from the ASTEC report considered in the current political and educational climate.
TIMSS has focused on science and mathematics, but given the nature of the ASTEC study this paper focuses on science and the new area of technology education. While the latter has not been examined to any extent in the TIMSS reports, I consider that it is useful to include discussion of some implications from technology education’s development for both science and mathematics.

PURPOSE AND FOCUS OF THE STUDY

The ASTEC Working Party was asked to review the teaching and learning of science and technology; assess the degree to which primary schools are contributing to developing students’ confidence in dealing with science and technology; identify opportunities for enhancing these two curriculum areas; and to recommend appropriate action.

ASTEC made use of the conceptual framework of TIMSS in distinguishing between the intended curriculum, implemented curriculum, and attained curriculum (ASTEC, 1997, p. 6). The terms of reference for the study fell largely within the level of the implemented curriculum. The Working Party was aware that a considerable amount of data on student learning outcomes in science would be available from TIMSS, and therefore made no attempt to measure these directly. ASTEC focused on exploring the perceptions by teachers, principals, parents and students of the appropriateness and adequacy of the opportunities provided for learning and teaching in science and technology.

METHODOLOGY OF THE STUDY

The Working Party experienced some difficulties in reaching agreement about appropriate conceptions and definitions of science and technology education. It was agreed that a solution to that problem was to adopt the definitions as developed in the national Statement on Science (Australian Education Council, 1994a) and Statement on Technology (Australian Education Council, 1994b). As a consequence, the report uses the following definitions:

Science education: the systematic acquisition of investigative skills and a body of knowledge and understanding of the physical, biological and technological worlds;

Technology education: the purposeful application of knowledge and acquisition of skills to create products and processes that meet human needs.

It was recognised that technology is a new key learning area, and its development is now occurring in all states and territories. Distinctive aspects of technology education identified are its focus on the area of design, the generation of solutions to everyday problems, responsible decision making, and its encouragement of students to be innovative.

The data in this study were obtained through:

• written submissions from scientific, technological and engineering organisations and individuals;
• a national survey of a randomly selected group of government and non-government primary school principals (representing 4% of all principals);
• visits to primary schools in all states and territories (except NSW) and discussions there with principals and teachers;
• focus group discussions with final year primary students and first year high school students;
• surveys of the parents of primary children.

A distinctive aspect of this study was therefore a focus on the views of those teaching and learning in schools.

The results across the country were pooled and there was no individual state analysis or comparison between the states. However, the study did seek to uncover approaches being taken by the different states and territories in addressing the problems identified.

Following the presentation at PMSEC of an interim report, responses to the findings were sought through the national distribution of a discussion paper. The picture of science and technology which ASTEC presented was not challenged in the responses received. Furthermore, early this year some of the findings were also corroborated by reports from Tasmania (on technology education) and NSW (evaluation of the K-6 science and technology curriculum). The Working Party therefore had some reason to feel confident that its review, while limited in a number of ways, had validity.

THE CENTRAL FINDINGS OF THE STUDY:

The study chose 1989 as the year from which to survey developments in science education as it was then that the Discipline Review of Science and Mathematics Teacher Education had made strong statements about the condition of science in primary schools. The Department of Employment Education and Training report of 1989 proclaimed that science in primary schools was ‘in a state of crisis’, and that this was not a recent situation but a continuing one (DEET, 1989, p. 81). The situation in primary schools was seen as being ‘so bad’ that the Panel had even considered recommending abandoning science as part of primary education (1989, p. 82).

In surveying the period 1990-1996, the ASTEC study concluded that there have been important initiatives in curriculum and professional development taken by education systems, professional organisations and scientific and technological institutions. Initiatives such as Primary Investigations (Australian Academy of Science, 1994) and the National Professional Development Program are two notable examples. As a consequence, there has been some progress in science and technology education, but this has generally been patchy and slow.

The surveys showed that there was good agreement among principals and parents as to the most important goals for science and technology. In order of importance they ranked the goals concerned with developing an inquiring mind, problem solving skills, understanding of scientific and technological concepts, and application of science and technology to everyday life. For technology, the goal of becoming innovative in creating products and processes to meet human needs was also seen as being important.

While the survey sample of parents was relatively small and restricted to parents of year 6 children, it is of interest to note that when asked to rank all eight key learning areas (of the Curriculum statements for Australian schools) in importance, they rated science and technology as third and fourth respectively in importance, after literacy and numeracy.
The study concluded that there was strong support from principals, teachers and parents surveyed for the value of science and technology and the learning outcomes of these areas. However, the study uncovered a marked disparity between their valuing and their reported position in schools. There was:

- **low priority given to science and technology**

  Teaching time allocations for the two areas were difficult to determine accurately but appeared to be 45-60 minutes per week. This finding is fairly consistent with the TIMSS finding on instructional time with a mode of 60 minutes per week for science reported, and the Australian median time allocation was among the lowest internationally (Lokan et al, 1997, p. 214). It should be noted that the time allocation reported by ASTEC was for both science and technology, and this suggests that there has generally been no increase in the total time given to the areas of science and technology since the latter’s arrival on the scene over the past two or three years. This might mean there has been a net decrease for science. The ASTEC study found that 70 per cent of the surveyed principals considered these two areas are under-represented in the timetable.

- **lack of teacher understanding of the area of technology**

  Of the responding principals, 68 per cent stated that technology is difficult to teach because it is difficult to describe, and 73 per cent stated that teachers equate it with Information Technology. These responses are hardly surprising given that there is no real history of this curriculum area in primary schools. The statistics point to a major challenge in supporting teachers as they attempt to make sense of the requirements to teach technology.

- **lack of teacher confidence and competence in both areas**

  Those members of the Working Party who visited schools were struck by the comments of many teachers that, even though they were teaching some science, they typically lack a real sense of competence for doing so. In teaching technology there was an even greater lack of confidence and sense of efficacy. The Working Party was of the view that this was the most important factor identified among the impediments to quality primary education in science and technology.

- **limited access to teaching resources**

  Of principals surveyed, 41 per cent considered access to resources to be adequate for the teaching of science but only 29 per cent thought likewise for technology.

These findings suggest that there are major problems across Australia confronting school systems and many primary schools as they implement science and technology curricula.
A WINDOW OF OPPORTUNITY

ASTEC is aware that reform of primary science education is not an easy task. It also recognises that a very major effort will be needed to meet the challenges of implementing technology education in primary schools. However the report has suggested that a window of opportunity currently exists to improve the situation (ASTEC, 1997, p. 9). The present context is conducive as evidenced by:

- agreement across the nation that science and technology are two key learning areas for primary schools as well as for secondary education;
- positive support from teachers, principals, and parents for the potential of these areas for children’s education;
- increasing interest and support coming from scientific and technological bodies; and
- mounting evidence that we have underestimated the capabilities of children in developing understanding in science, and developing creative solutions to technological problems.

In proposing solutions to the identified problems, ASTEC has argued that it is possible to build on the experience gained over the past few years in various initiatives to improve the situation in schools. Clear directions for action can be developed which have a high likelihood of producing the desired outcomes.

RECOMMENDATIONS OF THE REPORT

The ASTEC report has made a series of recommendations based on the study’s findings, and they are discussed briefly in the following paragraphs. These recommendations are largely directed at the Federal Government, and have particular relevance for its school education responsibilities. Some of the recommendations also have implications for state and territory education departments and university faculties of education.

- **Strategies to improve the status of science and technology education need to be developed.**

  ASTEC contends that only when science and technology are well understood and valued at the primary level by teachers, principals, parents and the wider community will lasting and comprehensive change be possible. In discussions within the Working Party, it was suggested that a ‘cultural change’ within schools is needed so that both science and technology become widely accepted as central parts of the learning of students and the teaching of teachers. The report recommends that strategies be developed to support persons working as change agents within schools and systems.

- **Professional development of teachers should be a high priority.**

  ASTEC has taken the view that every teacher must be able to teach science and technology and integrate them into daily programs, rather than opting for a model in which specialist teachers would be responsible for these curriculum areas. To achieve this, carefully planned programs of professional development must be offered to teachers. Programs in WA and SA have been cited as proven models of inservice education (ASTEC, 1997, pp. 22-25), and it is interesting that the TIMSS report has also pointed to these states as having good results for student
achievement in science. ASTEC has recommended a teacher-leader model of professional development with emphasis on inservice education of teachers within their schools.

In view of the need for a rapid and nation-wide response, ASTEC has recommended that the Commonwealth should provide matched funding to support the states and territories to establish new programs and extend existing programs of professional development.

- **Preservice teacher education should be examined.**

  The ASTEC report recommends that the adequacy of preservice education needs addressing, and echoes the recommendations of the 1989 Discipline Review in arguing that the balance between learning substantive science and science pedagogy needs reviewing (DEET, 1989, pp. 86-87). The report also is concerned that the time allocated to science and technology within the structure of the degree course should reflect the fact that these constitute two key learning areas. While urging attention to preservice education, ASTEC clearly recognises that professional development of teachers in schools should have a higher priority than changes at the preservice level, given the relatively slow replacement of the existing teaching force.

- **The emphasis on science and technology in teaching needs to be increased.**

  While ASTEC considers that the time devoted to science and technology is too low, it recognises that mandating increased time for these areas would be a simplistic response and could be counter-productive. Increased attention to science and technology can only follow on from increased teacher confidence and competence.

  ASTEC is very aware of the enormous pressure on the curriculum at primary level (a frequently stated concern of Minister David Kemp). It was not a helpful strategy to urge systems and schools to increase time for science and technology if that meant decreased time for other subjects. The report notes that to give greater emphasis to science and technology does not mean that other curriculum areas have to be displaced if science and technology are well integrated into the overall program. For example, teachers can—and some do now—plan to develop numeracy and literacy through learning activities in science and technology.

  It is interesting to note the different tack taken in the TIMSS report following its analysis of the instructional time devoted to science and mathematics. It is suggested that:

  - schools or systems may wish to review their priorities with respect to maths and science in relation to other learning areas. This will depend on judgements about how important competence in science and mathematics is in relation to competence in other areas (Lokan et al, 1997, p. 230).

  As has been noted, the ASTEC report avoided suggesting the need for such a direct comparison of priorities among the learning areas.

- **The special problems of technology education should be addressed.**

  Survey results suggest that there is a deficiency of appropriate technology education materials for primary schools. Given the newness of the area and the low level of teacher understanding of technology and its pedagogy, the availability
of high quality support material is likely to be an important means of improving its implementation in the classroom. ASTEC has recommended that the Commonwealth support a survey of existing resources and the identification of best practice in technology. As an adjunct, ASTEC has recommended that a national inventory of resources should be developed and made available on-line. If these resources are found to be inadequate, ASTEC has argued that there should be prompt development of materials in technology education.

IMPORTANT ISSUES ARISING FROM THE ASTEC STUDY

Within the limits of its terms of reference, methodology and time-frame, I believe that the ASTEC study is a useful contribution to the debates about the development of science and technology in our primary schools. The presentation of the report to the Prime Minister’s Science and Engineering Council provided a rare opportunity in a high level arena to draw attention to problems and possibilities in these two curriculum areas. However, there are a number of issues and questions that now need further exploration, particularly by educators attempting to convince policy makers of the educational and social significance of learning science and technology.

The relationship of the ASTEC findings to the middle primary TIMSS results

While the TIMSS data were collected two years before that of the ASTEC study, it is still useful to link the studies. While both focused on science, TIMSS included mathematics and ASTEC included technology in their respective research. Neither report, then, is able to discuss all three areas in a substantive way, but I make some brief comments on this below.

The generally low status and time allocation for primary science is demonstrated in both studies. The ASTEC study also suggests that as yet there is little time allocation for technology education in many schools. The addition of technology to the range of primary teachers’ responsibilities may well be resulting in increased pressure on teachers, and this type of curriculum demand could be one factor explaining the alarming responses from many teachers about teaching as a preferred career (Lokan et al, 1997, pp. 210-212).

As noted earlier, the ASTEC investigation did not make any attempt to gather data on student learning outcomes in the knowledge that TIMSS had already done so. Given that TIMSS reported its findings after the ASTEC report was published, it was not possible for ASTEC to make reference to them. As we are now aware, in terms of the international comparisons, the Australian middle primary students’ performance is a very good one. And yet the allocation of time to this area is one of the lowest reported internationally!

If the general picture of opportunities for science learning and teaching presented in the ASTEC report are fairly accurate, then some intriguing questions emerge from an apparent paradox. Are Australian students performing well in spite of a generally very low allocation of time to science? Are they learning science skills in other key learning areas? How much are they learning outside the classroom? Maybe some answers will be forthcoming from further analyses of the TIMSS data.
From the perspective of ASTEC, the TIMSS learning outcomes results are somewhat unexpected and do not really assist the Council in arguing the case for action to improve the science area.

**The role of primary education in developing scientific and technological literacy**

As noted in the introduction to this paper it is ASTEC’s position that it is during the primary phase of education that the foundations are laid for developing in future citizens a positive view of the role of science and technology in their lives, thereby helping to ensure a dynamic and sustainable future for Australia.

ASTEC has adopted the position that it is during their seven years of primary schooling that children can develop knowledge, understandings, skills and values in science and technology that will lead to science and technology becoming more effectively embedded in Australian culture.

There is a widespread acceptance in the community that primary schools play a critical role in ensuring that there are acceptable levels of literacy and numeracy in society. But I do not know of solid evidence that the community has similar expectations for primary schools with respect to science and technology.

The ASTEC report has attempted to broaden the currently accepted and narrowly defined meaning for literacy as that which is restricted to language. The report speaks of scientific and technological literacy and that these will be crucial elements of functional literacy for life in the 21st century (ASTEC, 1997, pp. 3-4). I consider this is an important move, but broadening the definition of literacy is not an easy task in the context of the current and very political debate about (language) literacy in schools.

**Developing a sound rationale and purpose for primary science and technology**

There is still a need to convince the general community, parents, educators, policy makers, and politicians that science and technology should have a prominent place in the education of young children. Until the general community demands quality education in these areas progress will continue to be slow. Many adults do not have memories of substantial science and technology in their own schooling and therefore would find it difficult to envisage what a dynamic science and technology education for young children might be like and what outcomes could be achieved. This means that leaders among teachers, schools and school systems will need to engage in the process of educating the community about the significance and value of these curriculum areas.

The national statements on science and technology include statements of aims and rationales justifying their place in the curriculum. But there is no differentiation in these for primary and secondary phases of education. This suggests that there is no difference in purpose for science education and technology education for a child of five and a youth of fifteen. But a case has been made by Fensham (1994) that such distinctions are important and should be made: Fensham argues that there are some purposes that should be emphasised at lower primary, upper primary and secondary levels. If Fensham’s ideas were taken up it would help to develop a rationale for primary science, something that has generally not been the subject of critical discussion (Hardy, 1994, p. 19). But it is possible to develop a strong rationale for the primary level, and this has been outlined for science by Fleer and Hardy (1996, p. 20-21).
Clarifying a range of possible relationships of science education to technology education

It has been noted that the ASTEC study adopted the definitions of science education and technology education to be found in the national Statements. These definitions point to substantial differences between the two areas but indicate nothing of their inter-relationship. The ASTEC study itself throws little light on how schools are treating this issue. We know of course that NSW, alone among all the states and territories, decided before the statements and profiles were developed to bring science and technology together in a K-6 curriculum (NSW Board of Studies, 1991).

It has been interesting to observe the way that advocates of technology education have advanced their cause over the past few years. They have been challenged to argue that their area, as a new key learning area, is distinctive and offers unique opportunities for learning. In doing that, technology educators appear to have defined technology in such a way that its links with science are portrayed as no stronger than with any other curriculum area. Some curriculum documents for technology education studiously avoid ascribing any significance to science! While this may help technology educators in gaining acceptance for the place of technology in the curriculum, it is not the way many others view the relationship between science and technology. (One is reminded of Toynbee’s powerful metaphor of science and technology as a pair of dancers where it is difficult much of the time to discern who is leading whom (Price, 1972, p. 173)). There are a number of ways we can view the relationship, and this has been portrayed graphically in the NSW Curriculum of 1991. Helpful discussion of how science education can be distinguished but also linked to technology education is provided by Gardner (1990, 1992) and in the Discipline Review report (1989, pp. 157-165).

But I hear little of this sort of discussion among gatherings of educators. Two national conferences I have attended this year have brought technology and science educators together physically, but the silence on the issues of the relationship between the two areas has been deafening. I wondered what was the point of having such joint conferences. It appears that while technology educators are understandably preoccupied with staking out territory and promoting a clear definition and understanding of their area, many science educators remain attached to their own views of science and technology as applied science, and are somewhat bemused or even threatened by the arrival of this young upstart. Yet there seems to be a real need for engagement of educators in these issues: while acknowledging important differences in the content and pedagogy of science and technology, there are important linkages and overlaps. These linkages should be taught, for in the world outside school walls technology and science are frequently strongly related.

Articulating the potential for enhanced science and mathematics learning in the contexts of technology education

The acceptance of technology education as a key learning area provides an opportunity for both science and mathematics to have access to a range of new powerful learning contexts. Technology education defines itself in terms of its major strands: systems; information; materials and the process of designing; making and appraising. In learning about these aspects of technology, children need to utilise their mathematical knowledge and understandings in diverse learning contexts. One of the current strong trends in mathematics education is to provide life contexts for learning, and technological activities could provide these. Similarly science could be taught within such technology learning activities or be linked to technology topics. There is a range of potentially powerful possibilities, as Gardner (1990) has argued.
As noted above, the ASTEC report encouraged the integration of the teaching of science and technology into other key learning areas. But it also noted the risks of doing so, if it meant that there was ‘a reduction in the level of substantive science and technology being taught’ (1997, p. 29). It is of interest in that respect that the TIMSS report has suggested that science taught as a separate subject may be relevant to achievement (Lokan et al, 1997, p. 231) and that a future analysis of the data may shed light on this. I believe that it should not be a matter of choosing whether learning areas should be either taught separately or in an integrated manner. For each subject there will be times when it will be appropriate that it should be taught separately, and at other times, in an integrated fashion. Such decisions will depend on the learning outcomes which are planned for a particular content area.

**Identifying effective strategies to achieve action by government and education authorities**

Given the statutory role and membership of ASTEC it is not surprising that its argument to the Commonwealth Government for improving science and technology education was focused on the goal of more effectively creating the foundations for a dynamic and sustainable Australia in the 21st century. It was argued that the economic and social well-being of adults will be more dependent than ever on having become scientifically and technologically literate. And as we have noted, ASTEC has asserted that such outcomes will be largely based on quality teaching of science and technology during children’s seven years in primary schooling. In presenting the ASTEC report’s findings and recommendations to the government I concluded by stating that the ‘Commonwealth Government is in a position to take a positive, national lead in addressing these challenges’ and urged the Government to do so.

A major challenge is to convince government that the problems identified are important enough and that there would be sufficiently positive outcomes from investments to warrant their taking action. But presenting evidence of problems and rational argument often has a limited impact. As we know, governments often act only when there is political pressure. While the ASTEC study presented some limited evidence that parents want to see science and technology given a high priority in the scheme of things in primary schools, there is little pressure exerted by parents and other community members on schools and school systems to improve science and technology education.

Improvement in the provision of quality learning opportunities for science and technology will continue to come about as a consequence of reports to authorities, such as those of ASTEC and TIMSS, the work of professional associations, the support of scientific and technological organisations, and, most importantly, by the continuing efforts of leaders within education systems and schools. Gradually we can expect there will be change in community understandings and expectations for the contributions that science and technology can make to the learning of young children. In that changed context science and technology will be assured of a strong place in the curriculum.
**CONCLUSION**

The ASTEC study has pointed to progress during the 1990s in the implementation of science and technology at the primary level. The TIMSS report on primary level science suggests that students are performing well, particularly when viewed in an international context. While these positive aspects of the primary situation are to be welcomed, there are continuing problems of status, resources and teacher competence. There are also new challenges. Notable among these is the establishment of technology in the primary school curriculum: this requires that educators and the community gain a clear understanding of what it encompasses and its position in the whole curriculum. Technology’s arrival presents new opportunities for improving the teaching and learning of science and mathematics.

**REFERENCES**


The group divided its time between becoming familiar with the actual performance tasks that were used in TIMSS and making some assessment of their worth as performance tasks. We found some of the tasks were very much more worthwhile than others—some were made to look like performance tasks, we thought, but were actually extended paper and pencil tasks. We then looked at the tasks from certain aspects of their usefulness and were, I think generally, bothered about the fact that they required the students to do so much reading. Some students’ failure to comprehend the actual task from written instructions may have led to their embarking on a task which was different from the one that they were meant to do. And so in the ideal world I think we would much prefer the tasks to be administered orally, and to check the students’ understanding of them to ensure a fairer assessment and fuller participation by students in the tasks.

We spent considerable time thinking about what the goals of performance tasks might be. Is getting the correct answer the most important goal? Good performance tasks allow us to assess the students’ understanding and development of concepts and processes; their exploration of scientific proof; communication of scientific knowledge; and use of problem solving strategies. We then looked at ways in which some of those actual tasks that were used in TIMSS could be extended. At least some of them lend themselves to interesting extensions, which would check further aspects that we thought were worth assessing as part of performance.

We then turned to performance in science and mathematics more generally, and had a long and not very conclusive discussion about more extended performance tasks and how these should be seen as part of teaching and learning. As such they should possibly have been part of the TIMSS assessment. This led us to debate what should be assessed in relation to extended performance testing. And that ran into all sorts of problems about ‘what is the role of the teacher’ as both assistant and assessor, all sorts of things which have been debated at length in Victoria and other places. Nevertheless we did see quite a lot of value in more extended performance tasks promoting performance learning that is different from the sort of small tasks that TIMSS was able to include.

Just at the end of our discussion of the TIMSS tasks we came up with the question as to whether or not those tasks were meant to be replications of the sorts of tasks that students would have already practised in many curriculum situations. Alternatively, they might have been intended to be novel tasks involving practical ‘hands on’ activities which were examples in the practical sense of conceptual knowledge learnt earlier, and so they weren’t simply replications of existing practice. I think that’s an interesting question, as to whether or not we should have practical assessment of conceptual learning as well as paper and pencil applications of that conceptual learning.
Another thing that we had quite a lot of discussion about, again without reaching conclusions, was that we consider it important for educators to begin to think about the question of what aspects of performance in science and mathematics we want to encourage, especially as computers become increasingly available in schools. We could structure tasks so that performance involving the computer as a tool is part of what we want to measure. For example, we might be interested in whether or not the students are doing modelling exercises and seeing how they carry these out in science and mathematics. Another large range of tasks we discussed arises from the information of a scientific or mathematical nature that is available to teachers and students from the Internet. We were interested to think about the sorts of performance tasks we could develop that would involve accessing the Internet, critiquing the information obtained and then making use of the information. This may be more relevant for other areas, but there should be important tasks that could be done in maths and science in this way as well.

**Group 2  Classroom Practices**

**Leaders**  Jim Stigler and Joy Cumming  
**Recorder**  Molly de Lemos

The group had wide ranging discussions, which are summarised under three main headings, moving from the ‘macro’ to the ‘micro’ level. Most time was spent on discussing classroom practices at the micro level.

**Cultural issues for classroom practice**

The first factor we thought was important in relation to cultural issues was the status of teachers and the valuing of education, particularly mathematics and science education, in our culture that has a significant impact on classroom practice. Other aspects that kept arising in our discussions throughout the day were issues of homogeneity, as these relate to a national curriculum. If you have a national curriculum should it be specific or vague? Are we moving towards a global curriculum? There is already considerable overlap between curricula in the main English speaking countries. However, there are countries in which a similar kind of curriculum would be quite inappropriate—for example, countries in which most children have no more than primary education. In Japan, the curriculum is carefully planned, so that the program in the early years lays the foundation for subsequent learning. There is much focus on what is being taught in each lesson, and the place of this particular learning in the overall program. This kind of planning is often not present in the United States.

We also discussed the question of how to maintain the respect for the individuality of teaching practices that we believe Australian teachers prefer. How do we feel about practices such as streaming, as used, for example, in Singapore (but not in Japan), and how do we continue to cater for diversity, which we see as a goal for education? There are dangers in thinking that what works in one country will necessarily work in another. For example, the Japanese model implies acceptance of a common set of goals and agreement on procedures. Teachers in Australia value their individuality and would be unlikely to accept a single model, preferring to implement a variety of approaches.
System and resource issues

The second level of issues is identified as ‘system’ or ‘resource’ issues. Usually these boil down to ‘dollars’, because as soon as anyone starts talking about resources teachers always start talking about money. Changes in educational practices cannot be implemented without money. It is important that professional development needs are met and that there are opportunities for sharing among teachers. We think that teachers have to value changes and be motivated to change, and there has to be an atmosphere of support and shared understanding between teachers and systems. Teachers are often resistant to change, particularly if it is imposed ‘from above’.

Our group decided that changed practice has to involve teachers, it has to involve the system and it has to be gradual. We felt that the evolutionary process of Japan seem to be exemplary in that way. In Japan’s case, new ideas are taken seriously, are debated and discussed, adapted and tested, and are implemented gradually as they are found to work and to become accepted by teachers. In the United States, by contrast, there is a tendency to reject new ideas. In-depth consideration of the implications of new practices is rare. Initial reactions are usually based on a fairly superficial analysis of the new approach, and new approaches tend to be equated with other approaches that have been tried in the past and have not worked.

Throughout the discussion of systems and resources, a recurring theme was assessment programs and the effects of assessment on curriculum and teaching practice in Australia. It doesn’t seem to matter what Australian State you’re in at this time, assessment is a major factor. Contrasted uses of assessment in Japan and Australia were noted. In Japan, assessment is regarded as part of teaching practice. Monthly tests are used to monitor student performance and also to inform teachers of the effectiveness of particular approaches to teaching a topic. Teachers take a cooperative approach in discussing results of tests and using the results to improve their teaching practice. In Australia, some teachers might ideally like to do this, but usually would not have the time.

As an aside, but an important one, the group also spent some time discussing the perceived poor links between educational research and classroom practice, and some discussion that had occurred earlier in the day in relation to specific problems and differences between teachers’ actual actions, teachers’ perceptions of their actions, and others’ perceptions of their actions, particularly researchers’.

Classroom level issues

Many aspects of classroom teaching and organisational practices were discussed. One of the topics that arose was the amount of time that is spent in Australian classrooms with the whole class working together versus working on group activities, and the nature of the learning expectations that we have from each kind of work. This was a fairly significant discussion. We talked about what sort of group or class knowledge development we are expecting to occur—for example, the issues of listening engagement and communication development. We noted the very desirable effect of the consolidation we had seen in the Japanese lesson from Jim Stigler’s videotape study.

The role of teachers in directing learning, not necessarily in lecturing but in actually taking a role in directing even within activity-based instruction, received some attention from the group. We discussed ways of catering for diversity and also talked about structuring the curriculum and making sure teachers are provided with sufficient resources for their classroom activities. We felt that teachers in fact have a desire for
more structure and assistance, particularly in the earlier years of schooling. We talked about the need to develop rich activities that focus on learning purposes rather than on the activities themselves. This is particularly relevant for technological aids, which should be used in classrooms to enhance learning, not just for their own sake.

To summarise, the classroom practices we discussed seem to come down to four main points. These were: activity-based learning for mathematics and science (how is this best done?); the teacher’s role in directing learning, which seems to be fairly strong in terms of how teachers in Japan and Singapore assist their students and how the teachers are assisted; the issue of student motivation and engagement in their learning; and the structure and resources that might be provided to assist teachers in doing their work.

Group 3 Primary Level Curriculum Issues

Leaders Tim Hardy and Brian Doig
Recorder Brian Doig

We had a diverse group and our discussion covered many topics. Some of it focused on TIMSS data and the reports but also a lot was stimulated by the various speakers that we heard, and of course the Japanese classroom lesson that we saw. For example, clarifying the basis on which we would make content decisions was an issue that was raised. Would we just want to follow what’s done in Singapore versus what’s done in Western Australia, Queensland and so forth? Should we be concerned about the fact that we include things in our curricula that others don’t, and vice versa? We felt that it is important for countries to set their own priorities, but it is also interesting to see what others are doing.

A second topic we addressed was how good ideas can be communicated. This was a strong point that came from the video and the discussion about the Japanese teachers’ study groups. We realised that sometimes in Australia good ideas exist in one classroom and don’t necessarily transfer anywhere else because others don’t ever get to see or hear about them. So there is probably something we can gain from the Japanese practice of getting teachers together more to discuss how they do the good things.

The issue of the preparation of teachers was raised because we tend to talk in terms of secondary teachers being well skilled in their disciplines, but we tend not to expect that of primary teachers. The issue was raised mainly in relation to science. There was concern about the level of science knowledge that primary teachers have, which is not high, though we also debated whether or not one needs a lot of science background to teach science well. Some of the group regarded this as still an open question.

We spent some time discussing differences between primary and secondary teacher cultures. One of our group members is part of a K to 12 school. Others are familiar with transition problems and the differences in the culture of primary and secondary level teachers. We’ve heard a lot about culture between countries, we thought about cultural changes between states, and then finally realised that there also is a culture difference between primary teachers and secondary teachers, and this may be a very important issue for those involved with either junior secondary classes or those who are in K to 12 schools. The teachers don’t necessarily want the same culture—someone in our group quoted their primary teachers as saying, ‘We don’t want the secondaries coming down and telling us what to do’. Many studies have found that it is difficult for teachers to change their ways, and so transition between primary and secondary levels will probably remain an issue for students.
With regard to the specification of curriculum content, the issue relevant to TIMSS was that there may be more in our States’ curricula than was included in the TIMSS tests, or there may be things in TIMSS that we do not cover. Is this a concern? Does it really matter? We thought the curriculum and text book analyses that have been published in association with TIMSS might give us some insight into what other countries cover and would give us food for thought, though not necessarily something just to follow. How to achieve balance between specific subject matter knowledge and broader investigations involving more process aspects of mathematics and science is the issue. What sort of balance do we require? How much detail do we need to specify in State curriculum documents and how much can be left to teachers’ own experience and skills in tackling and leading children into investigative work? Some of these ideas and issues arose out of what has currently been published from the TIMSS data, but the other issue that was raised is that there must be more data which others could analyse to throw light on some of these questions. Graduate students and other researchers interested in specific issues should think about making use of the internationally released TIMSS data base.

**Group 4  School Level Responses, Mathematics**

*Leader*  Will Morony  
*Recorder*  John Lindsey

Our group was a group of teachers, and one of the things someone had done in the group was count the number of teachers present. It is not a high representation and there are many reasons for that. But I don’t think that the small numbers can in any way moderate the importance of what people at the coal face say, and so I was privileged to be part of the conversation and I hope I can reflect it in this summary.

We talked a fair bit about the general issue of the valuing of education. If we think about the TIMSS data, the relatively low perceived status of teachers is a measure of what we see as a very substantial social issue for this country, which might hinder us in moving in the directions we want to go. So that issue was our overarching comment, which then flowed down into a whole range of more specific topics that we talked about but I am not presenting these in any particular order.

The first topic was that we are close to crisis point in the supply of teachers. People in schools know that this is a ‘real and true’ fact, as people say, and we do need to translate a commitment to education into creative mechanisms for making sure that we recruit teachers and make teachers’ lives in school feel rewarding to them. We’re living in a time of enormous curriculum change. The key thing we kept coming back to was the implementation of technology for learning in schools, which raises what we saw as a really key question. What should be the core of what we really need students to learn, given that, for example, ‘Mathematica’, as a software tool that is available to students now, can do lots more than you or I can do by hand. But we can’t just give it to students unthinkingly. We need to know what has to sit underneath it to turn use of it into meaningful and worthwhile learning.

Because of the times of change, professional development really does have to be a very high priority. Teachers desperately need to be able to come to grips with what the availability of technology means for their classroom practice and their students’ learning. Maybe it’s a personal note, but I was really impressed by the Japanese experience, where it seemed that there was a fundamental trusting among teachers in their professional development sessions. That was one of the key messages that I’m taking away from Jim Stigler’s presentation.
We were mostly secondary teachers in the group, which was unfortunate, but there was a clear recognition that the ‘early years’ focus that the government is taking is absolutely essential. It is good building blocks that build good secondary learning of mathematics and we therefore strongly support that emphasis. We need to know more about what is productive mathematical learning arising from classroom activity, though. Again, the Japanese experience showed a vision of some of that seeming to work well.

It was interesting that the people in our group were not nervous about accountability and accountability measures, but talked about them in terms of having constructive accountability measures. They were not seriously questioning the value of census testing, but in addition would like more insightful assessment programs that could highlight issues like some of those that Kaye Stacey raised. Things that are highlighted in a good survey will give results for teachers to get to work on, and which should lead to improvement. That was the group’s line of thinking—rather than just identifying from the census testing the children who may have problems, and then not knowing how to redress that.

Our last topic was the need for general commitment to the notion of equity and a fair go in education. This is particularly relevant at classroom level—having to attend to the different cultures in the classroom. We saw technology and access to technology as a significant equity issue. We have to work to avoid ‘have’ and ‘have not’ classrooms, and take steps to solve this if it has already occurred.

**Group 5  School Level Responses, Science**

*Leader*  John Ainley

*Recorder*  Tracey Frigo

It is always a risk that, in collapsing together into themes what was a fairly wide ranging discussion over a number of disparate topics, a mischief to the actual spirit of the discussion that took place will be done. But it did seem to us when we came towards the end of the discussion time that there were four main things that we had talked about. In this summary, I have attempted to group the various points together under those four main themes. They are not in the order in which we proceeded, and so I’ve probably done a mischief in that sense also.

First of all we did talk a bit about what was meant by the theme of this conference, *Raising Standards*. What do we mean by ‘Raising Standards’? We thought that, for us, we meant that we would have raised standards if we’d increased students’ understanding and applications of principles and ideas from science and mathematics. But we also thought there were other ways in which one could interpret it. We didn’t take it that we would necessarily have raised standards if in a normative sense we’d moved a few places up the league table in TIMSS. But we did think there might be something about raising standards that we ought to be looking at in relation to some of the more enduring outcomes of schooling. For example, what happens beyond school? We need to think about standards in that sense. We also talked a bit about issues of assessment validity. What would we take as evidence that standards in mathematics and science have been raised? We talked about different forms of assessment, the balance of the types of assessment and the balance of items.
The second of our themes was concerned with the idea of the world being an international laboratory. To what extent, and with what value, can we gain from looking comparatively at what happens in other countries? We thought there was a lot to be learned from international studies, but it is important to take some note of the cultural contexts. What you see in the TIMSS data, and even what you see when looking at the videotape, is only a glimpse of what happens; it’s not the whole of what happens, and there are also issues of context within the cultures in which those things took place. Contextual aspects like the expectations that parents hold of education systems; the expectations that the community holds for its schools; what roles they expect their schools to fill; and the sorts of government imperatives that might be driving processes in schools and other educational institutions, are all important. But, having exercised that caution, we recognise that there is a great deal of value in being able to look at what happened and link it to some notion of outcomes, which is the virtue of what TIMSS offers us at least in principle, and to a large extent in practice.

We thought there were ways in which we could use TIMSS to give wider perspectives, because our own views of what happens are constrained by our own schools, States and Territories. Structures and policies vary across states, schools and countries in ways that we don’t necessarily imagine. So, among the specifics that arose from TIMSS were some questions about the effects of ability grouping, or streaming or tracking—or what name you give it—that differ in practice across countries or states but are often fairly uniform within a given education system.

The third of our themes came from a fairly wide ranging discussion of the videotape from Japan that Jim Stigler showed us. We gave this theme the heading of ‘the centrality of teaching’. There was a good deal of fascination and interest in the notion of looking at the structure of lessons in that way—looking at the shared development of ways in which one proceeded through the details of a teaching sequence. In a way, that has separated the structuring of the lesson from the performance of the teaching. This was an idea that we began to explore—the extent to which one could have standardised sequences in the way that was implied by the videotape from Japan.

We wondered whether what we observed in mathematics would also be a feature of the teaching of science. We had a member of our group who had actually taught in Japan for some time and who felt that perhaps it didn’t always happen in science lessons in the way it appeared to happen in mathematics lessons. But, having said that, the interesting thing in our view that came out of the Japan videotape was the centrality of the teaching action, the centrality of the teacher in the lesson, even when the students were very much involved. The focus here was very strongly on the structure of the lesson. In Australia, we would be more likely to think, if we wanted to do something about performance in mathematics at Year 9, about a structural reorganisation of the school or the curriculum and not about the detail of what occurred in class lessons.

The final issue that we raised was concerned with implementing new ideas. Basically, how do you change the tyre while the car’s still moving, and how do you get things to happen back in your school when you come away with some new ideas that you want to have happen in practice? That led us to think about the constraints when schools have a strong existing focus. Schools and teachers are not comfortable with having expectations thrust on them, and, if what is expected for them to deliver is very broad and diverse, it is sometimes difficult for them to see what the gain would be from trying to change.
Group 6  System Level Responses, Mathematics

Leader  Pam Hammond
Recorder  Eve Recht

Our discussion had a strong focus on what should happen as far as the curriculum is concerned, which for us would very much be concept development. We came up with a range of ways that we’re recommending for that to occur. The other issue we discussed was the status of education, particularly as this impinges on teaching and teachers.

Like the other groups, we had a very wide ranging discussion, and this summary certainly does not reflect the richness of the discussion that occurred. We aimed to produce some recommendations coming from the group. Broadly speaking, they fall into the two areas I just mentioned. The recommendations themselves had two components—some on further research and some for systems support to actually see what can be gained from further examination of the TIMSS data. There must be a lot in those data that could inform what happens in the future.

With regard to research—and we’ve had several groups mention this also—we recommended that ACER conduct further analysis of the TIMSS data, firstly in relation to the state differences both in results and in the curriculum that was current at the time of TIMSS, looking to see if that can inform the current debate on how we and raise standards. But there is also a need to look at the curriculum as it is now, because there’s been a lot of change in curricula around Australia since TIMSS was conducted.

Another component for research that we identified was classroom organisation and teaching practices. There were a lot of data collected through the TIMSS surveys that we think could be analysed in more depth, to ‘pull it apart’ to see if there are any trends there. It should be useful to look at the teaching systems world-wide. For example, can we be informed by what other systems are using to encourage people into teaching? Are there incentives being offered? What are the teacher education institutions doing within their programs? How are they selecting students? What can we do to attract good people into teaching? The other aspect of this is the conditions of teaching in other countries, and how other countries manage to keep good teachers within their systems. There is an opportunity there for some research both through TIMSS but also in broader terms. There was even a suggestion that there be funding for our system people to visit various countries. From the TIMSS results, we could suggest a few that might be high priorities for them to go and visit just to see what is going on. The group made the point that the research should lead to recommendations, to inform both Federal and State systems as to how they might move forward.

The other area is from a systems support perspective, when we talked about reviewing the current curriculum and the emphasis on concept development. The group decided what we need most is a national emphasis on professional development for teachers. Teachers are out there generally doing what they consider the best job they can possibly do. What we need is to look at the professional development of teachers from a professional perspective. The National Professional Development Program (NPDP), and the way that funding was distributed around the country with consortia being put together to bid for funds, was a good model.

We discussed the teaching support group idea in Japan where they actually sit down and look at things at the school level and work together to decide how they can improve their lessons. There are models around the country where we already have networks that look at school-based issues, but maybe some more funding towards those types of initiatives could help.
In relation to this conference, funds could be targeted in the area of concept development in mathematics. We need to encourage teachers to see the richness of the concepts within mathematics and how they can create environments in the classroom to encourage students to be developing those concepts in a rich and genuine way, engaging students in exploring them. We would like to see children being mathematicians and not just ‘doing maths’. Along with these proposals about concept development, we also discussed skills like critical thinking, reasoning and justifying, which are all, of course, tied in with rich concept development. Those issues came through from several of the papers at this conference, particularly some of the things that Mrs Chang told us are happening in Singapore.

Finally, our discussion moved to whether and how we can raise the national priority of education. We already have a national priority towards education, of course, but we would like to say that it should be raised even further. This could be done in a range of ways, linking with national associations in raising awareness of mathematics and science within families and communities, and so encouraging them to see the value of these learning areas. Commerce and industry people should be brought on board in this as well. There was discussion about the ‘mathematical sciences linking with industry’ program that we had heard a little bit about at the AAMT (Australian Association of Mathematics Teachers) conference, and how industry is in fact valuing mathematics skills. What we need to do nationally is to have an awareness raising campaign that actually values mathematics and science within families and the community, so that the culture of valuing them within our education systems can be raised. The best ways of achieving all the aspects we talked about are, of course, big issues that will need a lot more discussion. Even so, our group thought that the richness of the discussion we had was very fruitful.

**Group 7  System Level Responses, Science**

**Leader** Richard Jenkin  
**Recorder** Ray Adams

Our group also had extensive discussion about many issues, some of which are very difficult issues. We raised a number of the same matters as were raised in the mathematics group. For a start, we were concerned about whether TIMSS tested those things that we value in our curriculum in Australia. Further analysis of the TIMSS items would help us determine what the results imply about the curriculum aspects that were valued by TIMSS and those that were not. We need to be informed about that before we make any decisions at a system level, or at a national level, about the kinds of changes that we would wish to make to our science curriculum, or to our teaching and assessment practices.

We discussed the need to explore the possibility of developing a ‘fidelity’ score that measures the extent to which an education system reaches or achieves its intended curriculum. We would then have a better grasp of the relationship between the intended curriculum, the implemented curriculum and the achieved curriculum. Obviously we need information about the intended curriculum, and our education systems do put effort into specifying that. We’re getting better at the assessment of curriculum goals, too. Our group recognised that the missing link is information about the implemented curriculum, about what teachers actually do in their classroom teaching. The videos that we watched as part of Jim Stigler’s presentation were very illuminating. Perhaps this is where we should be focusing our research now, on what is actually happening in classrooms and achieving a better understanding of that.
We had an interesting discussion about teachers’ morale. The TIMSS results could be useful input to the current or proposed or ‘soon to be’ senate inquiry on the status of teaching. How accurately do the teachers’ views reflect actual community views? A point in relation to TIMSS, and the primary science survey done by ASTEC that we heard about at this conference, is how well our teachers are prepared to teach mathematics and science. Does the community value science education? Perhaps the teachers’ views are a reflection of the lack of support for science education by many governments.

We were interested in the apparent relative decrease in the performance of Australian students in science from Population 1 to Population 2 (this seemed to happen in some other countries too). If this decrease is real, it is the symptom of something that we need to address further. Generally speaking our discussions were about the need for further analysis to look at factors that might be associated with the relative decrease, to ensure that any decisions we make are based on information. We also talked about the need to improve our communication when studies like TIMSS, and the proposed OECD study for 15-year-olds, are being planned. It would be good if systems could have more involvement at the beginning, have more consultation and hopefully more ownership of the data. This should increase the possibility of value adding. Studies like TIMSS and the OECD survey allow for national options, which we should take up to include things like studies of teachers’ work that we would like to address ourselves in systems. This seems to be a more efficient way of going about these investigations.

**Group 8  Teacher Educator Responses**

*Leader* Kaye Stacey  
*Recorder* Wendy Bodey

Ours was the group on teacher education, and we had a very large, wide ranging discussion that has been rather hard to summarise. We started with a complaint. We felt that a lot of other people have been thanked for the good results in TIMSS, but we didn’t hear any thanks for teacher educators. Those of us who believe that a good teaching profession is at least partly due to good teacher education feel a little bit neglected in that respect. A related point is that increasingly we see that teacher education is somehow getting isolated from the main game of school systems and schools. It makes us feel like a range of small competing providers for some sort of fairly marginal service. There is a lot of professionalism in teacher education, and education faculties in general, that we think is being undervalued. These points mainly came up in discussion of inservice education and professional development.

I won’t dwell here on the concern for teacher morale found in TIMSS. We had a lot of discussion about that and the status of the profession. We noticed that student teachers in Singapore are paid. When we looked at the video we thought the way that teachers in Japan are improving lessons was quite interesting. It might be quite good to focus on improving lessons rather than on trying to change teachers. It seems like a really productive new way of thinking—how we can move the skills of teaching forward for the profession. Instead of saying, ‘You’re a teacher who needs to change’, we will say, ‘This is a lesson that could be made better’.
As a group, we are worried about fairly simplistic interpretations of the TIMSS data. You can see fairly clearly from the data, for example, that older teachers in New Zealand produce students at least one year behind in achievement than younger teachers in New Zealand produce. We presume this is clearly ridiculous and that some other factor is influencing this ‘relationship’. It is very easy to seize on simple interpretations of empirical data without thinking about what is behind the data, and we felt there were some temptations here to do that. Another example is the result that larger classes and higher achievement are linked. These are difficult data to handle in the public arena. Obviously there are other things going on that we may or may not see more of later as further, more complex analyses are done with the TIMSS data. At the moment there is a level of simplistic interpretation that needs very special handling.

Overall, when we looked at some of the data on teaching practices, we felt that most of the results were ambiguous and therefore not very helpful. The data that can be gathered about teaching practices in questionnaires does not get to the heart of the matter. All we have is reports from teachers about how many times people did such and such, whether their students used calculators, or whether they explained things beforehand, and so on, which is really rather superficial data. Teaching practice variables deserve more extended study. The TIMSS results could be used as a stepping off point. It might be a good idea for us to do some more work in this area, and a video study is probably the only way to do it.

Finally, we wanted to reiterate that the main debate for TIMSS should not be ‘how Australia can do better in the fourth international study’, but should be ‘how Australia can help students in schools achieve what we really value from our education system’. We think that would be the most useful.
THE WAY FORWARD:
SUGGESTED RESPONSES FOR
AUSTRALIAN EDUCATION SYSTEMS

Alan Rice

I wish to convey appreciation to ACER, to Dr Jan Lokan and her team, to the Advisory Committee and to participating systems and schools across Australia for their contributions to this study.

The document *Maths and Science On the Line* is an important statement on achievement in mathematics and science education in its own right. However, this conference has provided additional information on the results of the performance assessment tasks and has been preparing us for answers to some tantalising questions arising from further analysis of the data and based on key factors identified as having an impact on student performance.

The overview of this international study has reminded us of the sheer size of the undertaking, both in the breadth of its curriculum coverage and in the level of participation—45 countries and three sampled populations involving 50 000 students in 15 000 schools.

There are undoubted difficulties in the conduct of this type of study and ACER has had to resolve some major issues in sampling and quality control. The point has been made that even within Australia, comparisons become difficult because of the need to balance differences in school starting ages and in the role of the first year of school.

International comparisons seem to me to be very worthwhile in focusing the mind on issues. What is clear is that valuable data is available on the state of mathematics and science education.

Because of the comprehensive planning required for the study, we should be able to learn a great deal about factors linked to top performance achievement and be able to identify some teaching and learning factors considered to be amenable to change. The study is relevant to curriculum experts in maths and science through its strong focus on the improvement of curriculum and teaching practice.

We have also been reminded of other important outcomes that arise from a study based on international benchmarks. For the community—parents, business, industry, the media, the profession—there is information that gives confidence for the future and points to the development of an educated, skilled and productive workforce, capable of meeting the challenges and changes of the 21st century. Teachers should have faith in their ability to achieve high standards and know that confidence in the profession is well placed. Teacher educators should also be recognised for their contribution to sound teaching practice and student learning through their research and pre-service and in-service responsibilities.
Governments also are concerned about the effective use of funds. On the basis of international benchmarks, there is accepted and agreed information available to government as well as to other audiences to inform policy decisions and priority determination.

First, an overall judgement. It is evident from discussion of the results that Australian students are capable of world best performance and our teachers of world class teaching and learning. Much has been accomplished in terms of access to, and participation in, a strong curriculum by all students.

The evidence is here that Australian students have performed well; in some aspects the results are outstanding; in others there is room for improvement as we lag behind where we should be in front. There is no basis for complacency as areas for improvement revealed in this study will require a carefully planned and detailed response.

Where would we want to be placed in the next major cross-national study? The message from this conference is clear, that we want to do even better and believe that we can improve on our student’s achievements.

This conference has provided international perspectives to help amplify the cross-country comparisons.

The clarity of the analysis of Singapore’s achievements by Mrs Chang Swee Tong highlighted the importance of agreed priorities and explicit and systematic instruction. I noted the extent of the commitment by government, parents, students and teachers to education generally and to fostering interest and achievement in mathematics and science, in particular. The specific advantages of consistency and cohesiveness in curriculum and teaching in Singapore as indicated in the presentation, enable us to reflect on approaches in Australia, particularly in relation to those political, socio-cultural and professional values that underpin our educational context.

The introduction to the TIMSS video study where we observed classroom instruction in mathematics in three cultures proved helpful in generating discussion about the content of curriculum and about teaching methodology. The rich images of the classrooms provided opportunity to analyse teaching and learning issues with particular attention to the subject knowledge of each teacher, the explicit teaching strategies adopted by the teachers and the ways in which they ensure learning outcomes for each student. Research producing similar exemplars of teaching practice based on Australian classrooms could provide a valuable resource for the professional development of teachers.

**CURRICULUM IMPLICATIONS**

We have been reminded of recent developments in both the mathematics and science curricula. Emeritus Professor Peter Fensham reminded us that ‘what’s not in the study is more important than what is’. We do need to evaluate critically those values and related teaching strategies that underpin the mathematics and science curriculum before determining that change and new directions are needed.

Peter Fensham revisited the past fifteen years of curriculum activity by science educators and emphasised the values that now underpin science curricula across Australia. He made the point that curriculum and teaching and learning practice as it affects systems, schools and classrooms is slow to change. We need to consolidate and evaluate the current practice before pursuing other goals.
Professor Kaye Stacey made a similar point about the current emphasis in mathematics where strategies to develop understanding in students have taken precedence over earlier approaches. She extended her argument to suggest that curriculum planners should consider the extent to which both mathematics and science education equip students to make judgements when confronted by large amounts of information and to develop the skills of explaining, justifying and generalising. These are essential high order skills in which all countries evidenced a need for improved achievement.

What are some suggestions for improvement of teaching and learning that have arisen from discussions around *Maths and Science On the Line*?

1. Fine tuning of mathematics and science curricula will provide an opportunity for educators to bring the latest research into national and state curriculum documents. The results challenge our expectations of our students and the placement of content at particular levels. There appears to be an argument for teaching harder material earlier and to ensure that talented students are accelerated in their development.

   We need to continue discussions on the place of early learning in mathematics and science education. How can the informal approaches of classrooms in the preparatory years better address the literacy and numeracy learning of students? Where does science fit into the early childhood curriculum—as in Singapore, where it commences in year three?

   The study also demonstrates the continuing growth of students in the middle years between year five and year eight. How can we ensure that growth is maximised as a student moves between the upper primary classroom and into secondary education?

2. Curriculum issues clearly are receiving attention in relation to the teaching and learning of mathematical and science concepts and in their contribution to the development of higher level thinking skills. The place of technology in the curriculum as a field of study also appears to be a subject for resolution.

3. Despite our achievements across the nation in relation to reducing gender differences there are issues to be addressed in ensuring equitable outcomes in mathematics and science for all groups of students in our schools. There is need for a fair go for all. Questions and policy issues have arisen about provisions for the highest level achievers and for the students in schools in low socio-economic communities. In addition, there is a need to share information about the nature and effectiveness of intervention strategies devised to support students at risk.

4. Enhancement of classroom practice and the profession generally has been a broad focus of this conference. There is so much to consider in the report that relates to the centrality of teaching and the status of the profession. Issues are clearly before us in supporting teachers through advice on programming, teaching strategies and assessment.

   With the profile of the profession indicating that a large portion are in the final quarter of a relatively satisfying but technology free career, there is need for training to ensure appropriate applications of technology and other teaching strategies to mathematics and science education.
Other professional issues relate to the teachers’ expectations of their students and to the apparent contradiction between the teaching processes proposed in the intended curriculum and the views expressed by students and teachers about actual classroom teaching methods. Teachers need support, encouragement and confidence to implement mathematics and science programs effectively. The profession, which is complex in its structures and relationships, can use the TIMSS information as well as later TIMSS products as a means of refocusing attention on the centrality of teaching.

CONCLUSION

In conclusion, I note that governments are taking a strategic approach to management and resource allocation. Literacy and numeracy are the current focus of their attention.

In NSW, literacy in the form of the State Literacy Strategy was endorsed in 1996 for at least three years. The national plan has endorsed literacy and numeracy. Across the nation, every endeavour is being made to improve early literacy and early numeracy through mainstream curriculum and early intervention strategies.

However, this is also a time of agenda building. Within the complex education structures, there are ongoing broad discussions about future needs and direction. From this consensus building will emerge priorities, based upon an assessment of overall curriculum needs and in line with the aspirations of the community.

There is therefore a significant role for teacher professional associations and for experts in mathematics and science education to build upon TIMSS and upon other research, to identify teaching standards and to have input into the determination of priorities.

This is the first national conference conducted by ACER. It is to be congratulated on the success of this venture. The focus on the future of mathematics and science education is a significant issue. Whilst the report Maths and Science On the Line has provided data for debate and reflection, we look forward to the additional reports to be released in 1998 and to their contribution to our thinking and action.
ABSTRACTS OF PAPERS

Jan Lokan:
Overview of TIMSS in Australia

A brief overview of the aims and scope of TIMSS worldwide was given, followed by a summary of Australia’s participation. The presentation concentrated on describing results achieved by Australian middle primary and lower secondary students, with areas of strength and weakness illustrated by examples from the tests. Comparisons of achievement were made in relation to the various assessment modes used in the tests. The discussion of results was placed in context as far as possible, with a range of home background and instructional practice factors considered.

Peter Fensham:
Insights for Australian Science Education

Some international possibilities and realities of TIMSS were discussed from the perspective of a member of the international Subject Matter Advisory Committee. The limitations of the project’s model and tests were used to discuss the significance of the international findings. For Populations 1 and 2 (middle primary and lower secondary levels), other relevant Australian data were used to provide reference for the intra-Australian results. A follow-up study of Australian students’ reactions to the Population 3 (Year 12) testing were also briefly reported, as a ‘meta-preface’ for how the results for these senior students may be gauged.

Kaye Stacey:
Insights for Australian Mathematics Education

A mathematics curriculum evolves as a product of history and choice and in response to changes in the subject and in society. In recent years, Australian mathematics curricula have chosen to give high priority to mathematics for everyday usefulness, to the use of technology and to encouraging wide participation. The results of the TIMSS study give some clues about the way our choices affect learning. The talk presented some examples of the ways in which Australian mathematics curriculum and teaching is distinctive from that in other countries and drew together some of the TIMSS data to see the outcomes that these arrangements might have produced for students. Future decision making about curriculum should be informed by results such as those from TIMSS as well as vigorous debate about the values that underlie education in mathematics.
James Stigler and James Hiebert:

Classroom Mathematics Instruction in Three Cultures:
An Introduction to the TIMSS Video Study

This talk introduced the methods and findings of a unique and unprecedented video survey of eighth-grade mathematics instruction in Germany, Japan and the United States. Part of TIMSS, this study marked the first time that videotaped records of classroom instruction, in any subject, were collected from nationally representative samples of teachers. Methods for overcoming the considerable logistical challenges posed by the study were discussed. Teaching practices in each culture were described, using both quantitative indicators and video examples. Implications of the study for improving classroom practice were discussed.

Mrs Chang Swee Tong:

Mathematics and Science Education in Singapore

The presentation outlined the mathematics and science curricula for primary and secondary levels in Singapore’s schools, with emphasis on the teaching and learning of mathematics and science in the Singapore environment. It included an overview of the subject content, instructional practices and teacher training. The influence of parental guidance and expectations and the various supports from higher institutions and other organisations were also covered.

Will Morony:

Report form the Numeracy Education Strategy Development Group

The Australian National Literacy and Numeracy Plan places numeracy education, alongside literacy education, in centre stage for the next few years. The Numeracy Education Strategy Development Group, through its conference held in May 1997 and the resulting report, aimed to inform policy and program developments at the state and national levels by synthesising the input of a wide spectrum of stakeholders in education. The nature and scope of numeracy was mapped out and key strategies identified. The project’s broad findings were outlined in the presentation. Examples from the released TIMSS items were used as illustrations and to help pose some questions for the future of mathematics and science education in Australia.

Tim Hardy:

Report from the ASTEC Primary Science Investigation

In May 1997, the Australian Science, Technology and Engineering Council (ASTEC) presented a report to the Federal Government on a year-long investigation of the state of science and technology education in Australia’s primary schools. The report, entitled Foundations for Australia’s Future: Science and Technology in Primary Schools, suggests that, while there has been some progress in these areas, much remains to be done—especially in the new area of technology education. In the report’s recommendations, ASTEC underlines the need for substantial professional development of teachers. ASTEC believes that primary education has a major role to play in developing foundations for Australia’s future in the 21st century by contributing to literacy in science and technology.