Teaching Mathematics in Australia

Results from the TIMSS 1999 Video Study

TIMSS Australia Monograph No. 5

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FOREWORD

Australia, through the Australian Council for Educational Research (ACER), has taken part in most of the studies carried out under the auspices of the International Association for the Evaluation of Educational Achievement (IEA). These studies, which have occurred over a timespan of almost 40 years, have become progressively better at validly assessing student achievement in a wide variety of school subject areas. With their underlying aim of improving both students' learning opportunities and learning outcomes, they have also succeeded in measuring many characteristics of students, teachers and schools that might account for differences in student achievement from country to country.

Until recently, one very important cluster of variables has either not been measured in these studies or has been measured only superficially by questionnaire – namely, variables pertaining to what actually goes on in classrooms. What content are the students exposed to, and what strategies are used to teach it? Instinctively, it seems that differences in these variables should be important in relation to achievement differences.

In parallel with the Third International Mathematics and Science Study (TIMSS), carried out in more than 40 countries in 1995, the IEA was adventurous enough to include a pioneering companion study in which mathematics lessons were videotaped in three countries. The results and methodology from this video component created a great deal of interest among educators. To some extent, their interest was fuelled by articles, reports, and publicly released illustrative snippets of the videotaped lessons. To a larger extent, all who heard the Director of the TIMSS 1995 Video Study (Professor James Stigler of the University of California at Los Angeles) were inspired to appreciate what the methodology could offer to studies of classroom teaching and learning.

In Australia, educators and researchers were fortunate to hear Professor Stigler speak about the project on two occasions. The first was in mid 1994 when he was a keynote speaker at the 17th Annual Mathematics Education Research Group of Australasia (MERGA) Conference, and visited some university Education faculties. The second was late in 1997 when he was a keynote speaker at the ACER inaugural annual Research Conference held in Melbourne.

Among the audience at the ACER Conference were representatives from most education system offices throughout the country. When the possibility of participating in the expanded TIMSS 1999 Video Study arose in 1998, the Commonwealth, State and Territory Departments were pleased to accept and support the opportunity.

ACKNOWLEDGMENTS

The TIMSS 1999 Video Study was conducted by LessonLab, Inc. (Santa Monica, California) under contract to the National Center for Education Statistics (NCES), U.S. Department of Education. The U.S. National Science Foundation and the participating countries provided additional funding for the study. Half of the funding for Australia's participation was provided by NCES, with the other half provided jointly by the Commonwealth, State and Territory governments. The Australian Council for Educational Research (ACER) was contracted to coordinate Australia's participation.

Eighty-seven Australian teachers and about 2000 Australian Year 8 students, from all regions and school sectors, participated in the mathematics portion of the TIMSS 1999 Video Study. ACER extends its appreciation and thanks to the principals, teachers and students concerned for allowing the video camera into their classrooms. The study would have been impossible without their willing cooperation. Special thanks are extended to the four Australian teachers, and the principals of the schools involved, who agreed to their videotaped lessons being publicly released.

Thanks are also due to Silvia McCormack, who recruited the schools and was responsible for the complex task of arranging the filming of the classes, and to Stephen Skok and Rowan Humphries, of *Pixelworks*, who did the filming of all the Australian classes.

Much of this report is drawn, with permission, from the international report of the study, *Teaching Mathematics in Seven Countries: Results from the TIMSS 1999 Video Study* (NCES 2003-013), by James Hiebert, Ronald Gallimore, Helen Garnier, Karen Bogard Givvin, Hilary Hollingsworth, Jennifer Jacobs, Angel Miu-Ying Chui, Diana Wearne, Margaret Smith, Nicole Kersting, Alfred Manaster, Ellen Tseng, Wallace Etterbeek, Carl Manaster, Patrick Gonzales, and James Stigler.[1] ACER and the authors of this Australian report acknowledge, with thanks, the contribution of the international report authors to the Australian report.

[1] This can be accessed or ordered from the NCES website: http://nces.ed.gov/timss

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EXECUTIVE SUMMARY

The broad purpose of the Third International Mathematics and Science Study (TIMSS) Video Study was to investigate and describe Year 8 mathematics and science teaching practices in a variety of countries. The seven countries involved in the TIMSS 1999 Video Study were Australia, the Czech Republic, Hong Kong SAR,[1] Japan,[2] the Netherlands, Switzerland, and the United States. The initial TIMSS survey of students' mathematics and science achievement took place in 1995. On average, students from the United States were significantly outperformed on the TIMSS 1995 mathematics assessment by students from the other six countries that participated in the 1999 video study.

The TIMSS 1999 Video Study was conducted by LessonLab, Inc. (Santa Monica, California) under contract to the National Center for Education Statistics (NCES), U.S. Department of Education. The U.S. National Science Foundation and the participating countries provided additional funding for the study. Half of the funding for Australia's participation was provided by NCES, with the other half provided jointly by the Commonwealth, State and Territory governments. The Australian Council for Educational Research (ACER) was contracted to coordinate Australia's participation.

The international report of the mathematics component of the TIMSS 1999 Video Study was released in March 2003.[3] This Australian report, *Teaching Mathematics in Australia*, includes a brief summary of the international results, but focuses on making comparisons and commentary from an Australian perspective. It also includes additional analyses of the Australian data. The report is accompanied by a CD-ROM containing videos of eight lessons (four from Australia, and one each from the Czech Republic, Hong Kong SAR, Japan and the Netherlands) released publicly to illustrate the report findings and act as a resource for teacher professional development programs.

What was the Aim of the TIMSS 1999 Video Study?

The 'video survey' methodology used in the TIMSS 1999 Video Study enabled very detailed snapshots of mathematics teaching to be collected. Internationally, a general aim was to use these snapshots to describe patterns of teaching practices in the participating countries. More specific aims included:

- development of objective, observational measures of classroom instruction to serve as quantitative indicators of teaching practices;
- comparison of teaching practices to identify similar or different lesson features across countries; and
- development of methods for reporting results of the study, including preparation of video cases for both research and professional development purposes.

Australia's goals for participating in the study emphasised:

- obtaining authentic and rich information on mathematics teaching in Australian lower secondary schools;

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[1] For convenience, Hong Kong SAR is referred to as a country. Hong Kong is a Special Administrative Region (SAR) of the People's Republic of China.

[2] Japan did not collect new mathematics data for the 1999 video study. Lessons taped in 1995 for the more limited TIMSS 1995 Video Study were reanalysed using the revised and expanded coding scheme developed for the 1999 study.

[3] The international report, entitled *Teaching Mathematics in Seven Countries: Results from the TIMSS 1999 Video Study* (NCES 2003-013), can be accessed or ordered from the NCES website: http://nces.ed.gov/timss. The report of the science portion of the study will not be released until 2004.

- ascertaining the extent to which Australian mathematics teaching in 1999 reflected emphases in curriculum documents developed during the 1990s;
- viewing Australian teaching practices in relation to those Asian countries that were among the highest achieving countries on the TIMSS 1995 mathematics assessment;
- assembling an information base of classroom practice for professional development purposes; and
- taking advantage of the opportunity to learn from the study's innovative methodology.

A secondary objective in Australia was to examine differences in content and pedagogy between high and low achieving classrooms.

Why Study Teaching Across Countries?

The TIMSS 1999 Video Study was based on the premise that the more educators can learn about teaching as it is actually practised, the more effectively they can identify factors that might enhance student learning opportunities and, by extension, student performance.

Comparing teaching across cultures allows teachers to look at their own teaching practices from a fresh perspective, providing food for thought about what they are doing well and possible improvements they might try. It can also reveal alternatives in and stimulate discussion about choices that are being made for teaching within a country. By highlighting where these differ from another country's choices, the merits of different approaches can be debated in relation to the countries' learning goals. Although a variety of teaching practices is usually found within a country, it sometimes requires looking outside one's own culture to see something new and different that might be worth incorporating into one's repertoire of practices.

Scope of the Study

The mathematics component of the TIMSS 1999 Video Study comprised 638 Year 8 lessons collected from all seven participating countries. The 50 lessons collected in Japan for the 1995 video study are included in this tally. The required sample size in 1999 was 100 lessons per country. One lesson per school was randomly selected within each of approximately 100 randomly selected schools per country.[4]

The Australian sample was randomly selected in such a way that it was proportionally representative of all states, territories, school sectors, and metropolitan and country areas. Altogether 87 of the selected Australian schools and their randomly selected Year 8 mathematics teachers agreed to take part in the study.

In each school the selected teacher was filmed for one complete Year 8 mathematics lesson, and, in each country (except Japan), videotapes were collected throughout the year to try and capture the range of topics and activities that can occur across a whole school year. To obtain reliable comparisons among countries, the data were appropriately weighted to account for the sampling design.

Processing of the data was a long, complex and labour-intensive undertaking. Several specialist teams were needed to decide what should be coded, what kinds of codes to use, and how reliably the codes could be applied. Many revisions were made to codes before a satisfactorily reliable set was put in place. All coding was done at LessonLab. An Australian mathematics educator/researcher, Dr Hilary Hollingsworth, was based at LessonLab for the duration of this work, together with colleagues in a similar role from the other countries.

[4] The weighted response rate reached the desired 85 per cent or more in all countries except the United States, where it was 76 per cent.

Major International Findings

Internationally, the TIMSS 1999 Video Study of Year 8 mathematics teaching showed in general terms that there is no one way to undertake successful teaching of mathematics. The results showed that teachers in the high achieving countries included in the study used a variety of teaching methods and combined them in different ways, thereby providing several perspectives on effective teaching. All countries shared some common features however, and most countries were found to have some distinctive features.

Common features across the countries included:

- At least 95 per cent of lesson time, on average, was spent on mathematical work (excluding the time taken to organise the students in relation to their mathematical tasks).
- At least 80 per cent of lesson time, on average, was spent in solving mathematical problems, regardless of whether the main purpose of the lesson was review of previously learned content or presentation or practice of new content.
- Lessons generally included some review of previous content as well as some attention to new content.
- Most of the time, lessons included some public, whole-class work and some private, individual or small group work – during their private work time, students mostly worked individually rather than in pairs or groups.
- At least 90 per cent of lessons made use of a textbook or worksheet of some kind.
- Teachers talked much more than students, both in terms of numbers of words and in terms of length of utterances. The ratio of teacher to student words was at least 8:1. Most teacher utterances were at least 5 words long while most student utterances consisted of fewer than 5 words.

Distinctive features found related to the introduction of new content, the emphasis on review of previous content, the use of various strategies to make lessons more coherent, the topics covered, the procedural complexity of the problems discussed and set, and classroom practices regarding use of individual work time and use of class time for homework. Findings on these and other variables are presented below from an Australian perspective.

What Were the Major Australian Results?

The Australian results are summarised here in two sections, according to whether they were provided as contextual information in the Teacher Questionnaire or whether they were derived from the observational data in the videotapes.

Contextual information

On teacher qualifications and experience:

- Sixty-four per cent of the Australian teachers had a major study in either mathematics or mathematics education compared with at least 90 per cent in the Czech Republic and the Netherlands and only 41 per cent in Hong Kong SAR. However, 93 per cent of the Australian teachers had at least a minor study in one of these areas. Almost all teachers in all the countries were qualified to teach, including all in Australia, though four of the Australian teachers had primary training only.
- The number of years that the Australian teachers had been teaching mathematics ranged from 1 year to 38 years, with a mean of 16 years and a median of 15 years. This placed them in the middle range between medians of 7 years in Hong Kong SAR and 21 years in the Czech Republic.

On work responsibilities:

- Australian teachers reported spending, on average, 36 hours per week either teaching or engaging in other school-related activities, including 12 hours actually teaching mathematics. This placed them at the lower end of the international findings. Teachers in the Netherlands taught mathematics for 20 hours a week, on average, while teachers in Switzerland were similar to Australia in this respect. However, no account was taken of whether teachers were employed full- or part-time, which seems likely, from the overall hours reported, to have had a greater effect in Australia than in other countries.

On the typicality of the videotaped lessons:

- Eighty per cent of Australian teachers thought that the difficulty of the mathematics content of the videotaped lesson was about the same as usual. Internationally, 75 per cent or more of the lessons were said to be typical in this respect. With regard to the influence of the video camera on their teaching, 80 per cent of the Australian teachers said there was little or no effect. More than 90 per cent of the teachers in the Netherlands and the United States thought that their lesson was about the same as usual, but only 38 per cent of the teachers in the Czech Republic shared this belief.
- Along with teachers in the Netherlands, Switzerland and the United States, three-quarters of the Australian teachers said that their students' behaviour during the videotaped lesson was about the same as usual. The Czech Republic had the lowest percentage (44%) in this respect, with Czech teachers describing their students as 'less active' and 'more shy and afraid to give wrong answers' than usual.
- The Australian teachers reported spending more time (39 minutes, on average) than usual (24 minutes) in planning their lessons. The difference in average times spent in preparation was highest (about 20 minutes) in the Czech Republic and Hong Kong SAR, and lowest (four minutes) in the Netherlands. Average preparation time for normal lessons ranged from 12 minutes per lesson in the Netherlands, to more than 30 minutes per lesson in the Czech Republic, Switzerland and the United States.

On the intended goals for the lessons:

- Between 75 and 95 per cent of the teachers per country identified a 'content' goal as the 'main thing' they wanted their students to learn from the videotaped lesson (Australia was lowest in this respect). 'Process' goals (most often concerned with using routine operations or calculations) were identified for 90 per cent of Australian lessons and more than 90 per cent of lessons in all other countries. 'Perspective' goals, such as developing students' interest or confidence in doing mathematics, were much less common, ranging from almost none in Hong Kong SAR to 23 per cent of the lessons in Switzerland. This kind of goal was identified for 14 per cent of the lessons in Australia.

Observations from the videotapes

In relation to the general features common to all countries:

- On average, 95 per cent of lesson time was spent on mathematical work in Australia.
- On average, 81 per cent of lesson time was devoted to solving mathematical problems in Australia – the highest average percentage (91%) was observed in the Netherlands, significantly higher than in any other country except the United States (85%).
- On average, 36 per cent of lesson time in Australia was devoted to reviewing previous content. Highest in this respect was the Czech Republic (58 per cent of lesson time), which was significantly higher than any other country except the United States (53%). Numerically lowest were Hong Kong SAR and Japan (24%), but this percentage was not significantly different from that in the remaining countries, including Australia.

- Australia and the United States had the numerically highest percentage of lessons (28%) that were entirely review. However, only Hong Kong SAR and Japan (8 and 5 per cent of lessons, respectively) differed significantly from Australia in this respect.
- On average, new material was introduced in the Australian lessons for 30 per cent of the lesson time. Japan, at 60 per cent of lesson time, was significantly higher than all the other countries. As well as in Australia, between 30 and 40 per cent of lesson time was spent on presenting new material in Hong Kong SAR, the Netherlands and Switzerland. Lowest were the Czech Republic and the United States (22 and 23 per cent, respectively), though this was not significantly different from the percentages in Australia and the Netherlands.
- Australia had one of the most equal partitions of lesson time into whole class versus 'private' work activities (52 and 48 per cent of the time, respectively). The time proportions were similar to Australia's in the Netherlands and Switzerland, and most different in Hong Kong SAR, where an average of 75 per cent of lesson time was spent on whole class work.
- Australia had the numerically highest percentage of private work time spent working in pairs or small groups (27%), most commonly in pairs, though this was not significantly different from the time in Japan, the Netherlands, Switzerland or the United States. Lowest was Hong Kong SAR, where almost all students worked individually during their private work time.
- Ninety-one per cent of the Australian lessons made use of a textbook or worksheet.
- The ratio of teacher to student words in the Australian lessons was 9:1 – Hong Kong SAR had the highest ratio, at 16:1.

In relation to other aspects of lesson organisation:

- Australia had the numerically lowest percentage of lesson time devoted to problems worked on 'publicly' (26 per cent, on average), when the whole class worked on the same problem simultaneously, either by themselves or together with the teacher. The Netherlands and Switzerland were similar to Australia in this respect. The percentage of time spent on publicly worked problems was significantly higher in the other four countries and numerically highest in Japan (64 per cent, on average). Correspondingly, a greater proportion of time was spent in Australia, the Netherlands and Switzerland on 'concurrent' problems assigned as seatwork than in the other countries.
- The Australian lessons fared relatively well on aspects of coherence such as use of goal statements. The Czech Republic, where 91 per cent of the lessons contained at least one goal statement, was higher than all of the other countries in this respect. Australia, at 71 per cent, was similar to Japan, numerically higher than the United States (59%) and Hong Kong SAR (53%), and significantly higher than Switzerland (43%) and the Netherlands (21%). Summary statements were used in no more than about a quarter of the lessons within a country, which occurred in Japan, the Czech Republic and Hong Kong SAR. In Australia, only 10 per cent of the lessons included a summary statement, while in Switzerland and the Netherlands summary statements were rarely used.
- Homework was assigned in about 60 to 80 per cent of the sampled lessons per country (62 per cent in Australia), except in Japan (36 per cent of lessons). This does not mean that Japanese students do less mathematics outside of class than their counterparts in other countries, as many Japanese students take part in supplementary private lessons. In Australia, on average, only about one minute of lesson time was spent in discussing previous homework problems, and about four minutes were spent beginning new homework. The Netherlands spent more time, on average, going over previously assigned homework (16 minutes per lesson) than most of the other countries, and more time, on average, beginning work on new homework (10 minutes per lesson) than all the other countries.

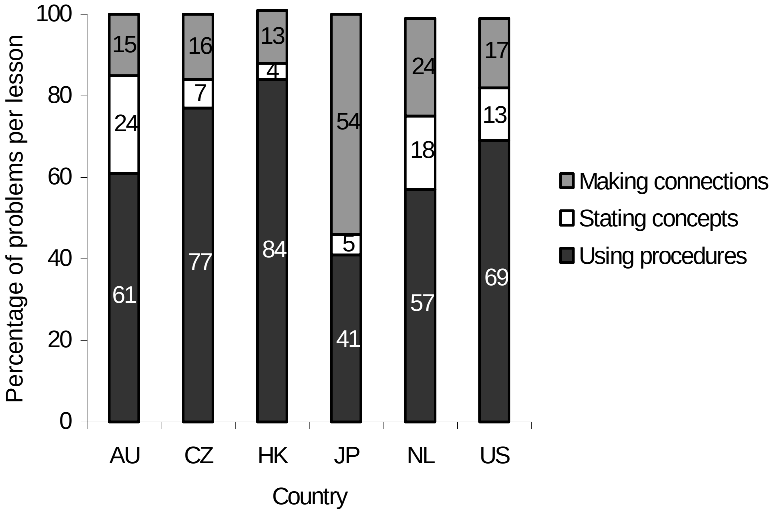
On mathematics topics covered during the lessons:

- There were indications that the curricular level of the Australian Year 8 mathematics lessons, particularly the algebra content, was lower than in most of the other six countries (Switzerland was similar to Australia in some aspects of content).

On the problems set and the way(s) they were solved:

- Forty-five per cent of problems per Australian lesson, on average, were classified as 'applications', compared with 74 per cent in Japan. Numerically lowest were the Czech Republic and the United States (about 35%). The percentage in Japan was significantly higher than that in any other country except Switzerland (55%).
- Despite the proportions of problems classified as applications, in most countries the problems set tended to be rated as low in procedural complexity (requiring four or fewer steps to solve). In the Czech Republic, Hong Kong SAR, the Netherlands, Switzerland and the United States, about two-thirds of the problems, on average, were classified as being low in procedural complexity. More than three-quarters of the problems were placed in this category in Australia, numerically the highest of any country though significantly different only from Japan (17%). Apart from in Japan (39%), only 6 to 12 per cent of problems per country were considered to be high in procedural complexity.
- In all countries except Japan, at least 65 per cent of problems set for students to do in class were repetitions of one or more problems they had done earlier in the lesson. In Australia, 76 per cent of problems were in this category, 13 per cent were mathematically related, 8 per cent were thematically related, and 4 per cent were unrelated to previous problems. Hong Kong SAR (24%) and Japan (42%) were significantly higher than Australia in the proportion of the mathematics problems set that were mathematically related to earlier problems.
- Along with the emphasis on repetition, the majority of problems in all countries except Japan involved emphasis on correct use of procedures to solve them (see Figure 1).[5] Problems intended to involve higher-level processes, such as making mathematical connections or reasoning mathematically, were much less common, ranging from about one-sixth of problems in Australia, the Czech Republic, Hong Kong SAR and the United States, to one-quarter in the Netherlands and more than one-half in Japan.

Figure 1 Average percentage of problems per Year 8 mathematics lesson of each problem type

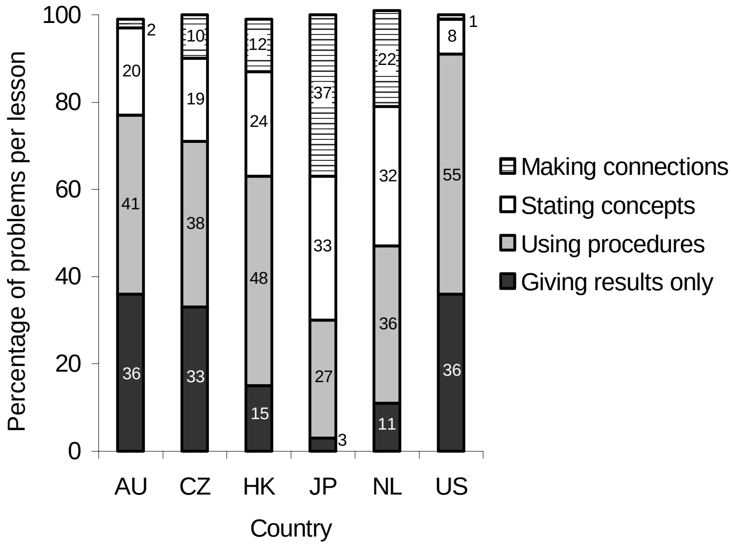


Note: AU=Australia; CZ=Czech Republic; HK=Hong Kong SAR; JP=Japan; NL=Netherlands; US=United States

[5] Switzerland was not included in this analysis.

- In Australia, the Czech Republic and the United States, around one-third of problems per lesson, on average, were solved publicly by giving the answer only (see Figure 2).[5] Lessons in Australia and the United States contained the smallest percentages of problems (2 and 1 per cent, respectively) solved publicly by making mathematical connections. In Australia, only 8 per cent of the 15 per cent of problems intended to be solved by making mathematical connections were actually solved that way publicly.

Figure 2 Average percentage of problems per Year 8 mathematics lesson solved publicly using processes of each type



Note: AU=Australia; CZ=Czech Republic; HK=Hong Kong SAR; JP=Japan; NL=Netherlands; US=United States

- On average, just over a quarter of problems in Australia were set up with use of real-life connections, significantly more than in Japan where almost 90 per cent of problems were formulated in mathematical language and symbols only. The Netherlands (42%) was higher than all countries except Australia and Switzerland in its use of real-life scenarios.
- Problems involving proofs were almost non-existent in all countries except Japan, where at least one problem involving a proof occurred in 39 per cent of the lessons.
- More than 90 per cent of problems in all countries except Japan (83%) were presented to students as having only one solution. Very little encouragement was given to students anywhere to think of and discuss other possible solutions or solution methods.

Lesson signature

The concept of 'lesson signatures' is used to show the way that lesson activities change during the course of a lesson. Lesson signatures consist of several horizontal histograms, one for each major lesson activity (e.g., teacher lecture, review, whole class working with the teacher in solving one or more problems, seatwork, and so on). More emphasis on an activity shows in thicker parts of the histogram for that activity.

The lesson signature for Australia, included in Chapter 6, shows that 87 per cent of the videotaped lessons began with review of previously learned content. Most lessons focused on review for about the first 20 per cent of the lesson time. From about a third of the way into the lesson, a majority of the Australian teachers began introducing new content, representing an average of 56 per cent of the lesson time when practising the new content is also taken into account. Very few problems were worked on publicly (by the teacher working together with the whole class) after the first quarter of the lessons. For the remainder of the lesson time, students usually worked individually on problems that asked them to repeat procedures that had been demonstrated earlier in the lesson.

The average picture of Australian lessons illustrated by the lesson signature closely supports the hypothesised model of an Australian Year 8 mathematics lesson proposed by mathematics educators at the beginning of the study (shown in Appendix D). However, while the aggregate picture supports expectations, some large departures from the overall pattern were observed for individual lessons. The timelines of activities displayed in Chapter 6 for the four Australian lessons publicly released provide a good example of the range of variability observed.

Adjusting Teaching According to Students' Needs

As explained above, the international results show that there is no one way that mathematics is taught to Year 8 students in the various high-achieving TIMSS countries. In both Australia and Switzerland, an additional research question was posed: 'Do teachers tend to use different strategies when teaching classes of different skill levels?' To help investigate this question, all or part of the TIMSS 1995 mathematics test was given to the videotaped classes in these two countries as a measure of achievement.

Looking at groups of classes categorised as higher achieving or lower achieving on the TIMSS test items in Australia, the answer to whether teachers adjust their teaching to help cater for differences in students' skill levels is 'Yes and no'. Insofar as the question can be answered by the variables measured in the study, there is evidence of:

- some differences in subject matter (more emphasis on algebra in the higher achieving group, more on measurement in the lower achieving group);
- more teacher awareness of students' interests, thinking and difficulties in the lower achieving group than in the higher achieving group;
- differences in the ways that problems were worked on (more time spent on 'independent' problems – problems set one at a time for the whole class to work on either by themselves or with the teacher or both – in the higher achieving group, more on problems set as a batch to be done as seatwork in the lower achieving group);
- more use, in the lower achieving group than in the higher achieving group, of having students work in collaborative pairs or small groups;
- more lessons involving introduction and practising of new content in the higher achieving group than in the lower achieving group, though no difference in the relative time spent on new and previously learned content; and
- more interaction between teacher and students in the lower achieving group than in the higher achieving group.

Most of the above findings were expected and generally illustrate appropriate adjustment of teaching strategies for students of different skill levels. There were other variables, however, where differences were expected but were not found. The most crucial of these were that there was no difference in the level of procedural complexity of the problems undertaken in the two groups of classes or in the relative sophistication of the skills needed to solve them. Even in the higher achieving classes the students tended to be set large numbers of low procedural complexity, routine problems. Higher-level processes such as mathematical reasoning or making reference to mathematical relationships were hardly ever used for problems solved publicly in the Australian lessons, regardless of the skill level of the class.

Implications of the Study for Mathematics Teaching in Australia

The final chapter of the report includes reactions and comments from four Australian mathematics educators on what, in their view, the findings mean for mathematics education in Australia. While they have different roles in the Australian mathematics education community (two are academics, one is a secondary teacher whose class was one of the videotaped classes, and one represents the Australian Association of Mathematics Teachers), their reactions to the findings are more similar to than different from each other.

In their comments, we are reminded of Australian students' track record in international studies of mathematics achievement. Australia performs relatively well in these studies and has done so over four decades. There is no compelling reason for Australian Year 8 mathematics teaching practices to be abandoned in favour of adopting methods used somewhere else. For a start, the highest achieving countries use methods that differ from each other in many respects. As one of the commentators notes, 'Learning and teaching mathematics occurs in, and responds to, widely differing social, cultural and educational contexts. There isn't a "silver bullet"!'.

However, there are some strong threads running through the study's findings that indicate that some overhaul of Year 8 mathematics teaching in Australia is warranted. Australian students would benefit from more exposure to less repetitive, higher-level problems, more discussion of alternative solutions, and more opportunity to explain their thinking. Using the lessons filmed for this study as a guide, there is an over-emphasis in Australian Year 8 mathematics, as in some of the other countries, on 'correct' use of the 'correct' procedure to obtain 'the' correct answer. Opportunities for students to appreciate connections between mathematical ideas and to understand the mathematics behind the problems they are working on are rare.

Another of the commentators notes that the Australian results expose 'a syndrome of shallow teaching, where students are asked to follow procedures without reasons', and that more than 'shallow teaching' is needed for students' conceptual understanding and problem solving abilities to improve. Australian students already perform relatively well in international mathematics studies. With more exposure to more challenging material, at all levels but particularly in more able classes of students, it seems likely that Australia would perform even better.

Changing teaching practices takes time and resources. The total set of 28 publicly released lessons from the TIMSS 1999 Video Study provides a wealth of examples from Australia and other countries that could be used as the stimulus for discussions in professional development programs. In some of the lessons, students can be seen working on longer, more challenging problems, sometimes discussing their solutions with the teacher in front of the class. A message for Australia from the study's findings is that it would be beneficial to reduce the time students are expected to spend in solving large numbers of short, repetitive problems, and to use the freed time to work on fewer, more varied, more challenging (but accessible) problems, each for a longer time. Such a change could be made without major disruption to timetables, or 'changing the whole world', as one of our commentators notes.

Chapter 1

INTRODUCTION

This chapter describes the background to the TIMSS 1999 Video Study, and Australia's involvement in the study. It outlines the contents of the remaining chapters and concludes with a summary of the international results of the study.

The TIMSS 1999 Video Study

The broad purpose of the 1998–2000 Third International Mathematics and Science Study Video Study (hereafter, TIMSS 1999 Video Study) was to investigate and describe teaching practices in Year 8 mathematics and science in a variety of countries. It is a supplement to the TIMSS 1999 student assessment, a successor to TIMSS 1995.[1] The TIMSS 1999 Video Study expanded on the earlier 1994–1995 (hereafter 1995) TIMSS Video Study (Stigler et al., 1999) by investigating teaching in science as well as mathematics, and sampling classroom lessons from more countries than the TIMSS 1995 Video Study.

The TIMSS 1995 Video Study included only one country, Japan, with a relatively high score in Year 8 mathematics as measured by TIMSS. It was tempting for some audiences to prematurely conclude that high mathematics achievement is possible only by adopting teaching practices like those observed in Japan. The TIMSS 1999 Video Study addressed this issue by sampling Year 8 mathematics lessons in more countries – both Asian and non-Asian countries – where students performed well on the TIMSS 1995 mathematics assessment. Countries participating in the TIMSS 1999 Video Study were Australia, the Czech Republic, Hong Kong SAR,[2] Japan, the Netherlands, Switzerland, and the United States.

Table 1.1 below lists the countries that participated in the TIMSS 1999 Video Study along with their scores on the TIMSS 1995 and TIMSS 1999 mathematics assessments. The TIMSS 1999 mathematics assessment was administered after the TIMSS 1999 Video Study was underway and played no role in the selection of countries for the video study.[3]

The TIMSS 1999 Video Study was conducted by LessonLab, Inc. (Santa Monica, California) under contract to the National Center for Education Statistics (NCES), U.S. Department of Education. The U.S. National Science Foundation and the participating countries provided additional funding for the study.

Goals of the study

In addition to the broad purpose of describing teaching in seven countries, including a number with records of high achievement in Year 8 mathematics, the TIMSS 1999 Video Study had the following research objectives:

- To develop objective, observational measures of classroom instruction to serve as appropriate quantitative indicators of teaching practices in each country;

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[1] TIMSS was conducted in 1994–95 and again in 1998–99. For convenience, reference will be made to TIMSS 1995 and TIMSS 1999 throughout the remainder of this report. In other documents, TIMSS 1995 is also referred to as TIMSS 1994, and TIMSS 1999 is also referred to as TIMSS 1998 and TIMSS-R (TIMSS-Repeat).

[2] For convenience, in this report Hong Kong SAR is referred to as a country. Hong Kong is a Special Administrative Region (SAR) of the People's Republic of China.

[3] Of the countries that participated in the TIMSS 1999 Video Study, only one experienced a significant change in mathematics achievement at Year 8 between 1995 and 1999. The average mathematics achievement of Year 8 students in the Czech Republic was lower in 1999 than in 1995, as measured through TIMSS (Mullis et al., 2000).

- To compare teaching practices among countries and identify similar or different lesson features across countries; and
- To describe patterns of teaching practices within each country.

Building on the interest generated by the TIMSS 1995 Video Study, the TIMSS 1999 Video Study had a final objective regarding effective use of the information:

- To develop methods for communicating the results of the study, through written reports and video cases, for both research and professional development purposes.

Table 1.1 Average scores on TIMSS 1995 and TIMSS 1999 mathematics assessments of TIMSS 1999 Video Study participating countries

	1995[1]	1999
Country	Average score	Average score
Australia[2] (AU)	519	525
Czech Republic (CZ)	546	520
Hong Kong SAR (HK)	569	582
Japan (JP)	581	579
Netherlands[2] (NL)	529	540
Switzerland[3] (SW)	534	–
United States (US)	492	502

[1] Rescaled TIMSS 1995 mathematics scores are reported here.
[2] Nation did not meet international sampling guidelines in 1995; the Australian sample was 4% below the internationally specified response rate and the Netherlands' sample was 15% below (Beaton et al., 1996).
[3] Switzerland did not participate in TIMSS 1999.
TIMSS 1995: AU, NL>US; HK, JP>AU, NL, SW, US; JP>CZ; CZ, SW>AU, US
TIMSS 1999: AU, NL>US; HK, JP> AU, CZ, NL, US
SOURCE: Gonzales, P., Calsyn, C., Jocelyn, L., Mak, K., Kastberg, D., Arafeh, S., Williams, T., and Tsen, W. (2000). *Pursuing Excellence: Comparisons of International Eighth-Grade Mathematics and Science Achievement from a U.S. Perspective, 1995 and 1999* (NCES 2001- 028). U.S. Department of Education. Washington, DC: National Center for Education Statistics.

Why study teaching across countries?

The reason for conducting a study of teaching is quite straightforward: to better understand, and ultimately improve, students' learning, one must examine what happens in the classroom. The classroom is the place intentionally designed to facilitate students' learning. Although relationships between classroom teaching and learning are complicated, it is well documented that teaching makes a difference in students' learning (Brophy & Good, 1986; Hiebert, 1999; National Research Council, 1999).

The TIMSS 1999 Video Study is based on the premise that the more educators and researchers can learn about teaching as it is actually practised, the more effectively they can identify factors that might enhance student learning opportunities and, by extension, student achievement. By providing rich descriptions of what actually takes place in mathematics classrooms, the video study can contribute to further research into features of teaching that most influence students' learning.

Comparing teaching across cultures has additional advantages.

- It allows educators to examine their own teaching practices from a fresh perspective by widening the known possibilities. In addition to examining how teachers in their own country approach mathematics, opening up the lens to include an examination of how teachers in another country approach the same topic can make one's own teaching practices more visible by contrast and therefore more open for reflection and improvement (Stigler & Hiebert, 1999; Stigler, Gallimore & Hiebert, 2000; Carver & Scheier, 1981; Tharp & Gallimore, 1989).

- It can reveal alternatives and stimulate discussion about the choices being made within a country. Although a variety of teaching practices can be found within a single country, it sometimes requires looking outside one's own culture to see something new and different. These observations, combined with carefully crafted follow-up research, can stimulate debate about the approaches that may make the most sense for achieving the learning goals defined within a country.

Observing that teaching influences students' learning is not the same as claiming that teaching is the sole cause of students' learning. Many factors, both inside and outside of school, can affect students' levels of achievement (e.g., National Research Council, 1999; Floden, 2001; Wittrock, 1986). In particular, Year 8 students' achievement in mathematics is the culmination of many past and current factors. For these reasons, no direct inferences can or should be made to link descriptions of teaching in the TIMSS 1999 Video Study with students' levels of achievement as documented in TIMSS 1999 (Mullis et al., 2000). Moreover, in most of the participating countries the videotaped classrooms were not the same ones in which students took the achievement tests.

Why study teaching using video?

Traditionally, attempts to measure classroom teaching on a large scale have used teacher questionnaires. Questionnaires are economical and simple to administer to large numbers of respondents and responses usually can be transformed easily into data files that are ready for statistical analysis. However, using questionnaires to study classroom practices is problematic because it can be difficult for teachers to remember classroom events and interactions that happen quickly, perhaps even outside of their conscious awareness. Moreover, different questions can mean different things to different teachers (Stigler et al., 1999).

Direct observation of classrooms overcomes some of the limitations of questionnaires but important limitations remain. Significant training problems arise when used across large samples, especially across cultures. A great deal of effort is required to ensure that different observers are recording behaviour in comparable ways. In addition, and like questionnaires, the features of teaching being investigated must be decided ahead of time. Although new categories might occur to observers during the study, the earlier lessons cannot be re-observed.

Video offers a promising alternative for studying teaching (Stigler, Gallimore & Hiebert, 2000). Using national video surveys to study teaching has special advantages.

- Video enables detailed examination of complex activities from different points of view. Video preserves classroom activity so it can be slowed down and viewed multiple times, by many people with different kinds of expertise, making possible detailed descriptions of many classroom lessons.
- Collecting a random national sample provides information about students' experiences across a range of conditions, rather than the exceptional experiences. The ability to generalise nationally can elevate policy discussions beyond the anecdotal. Therefore it is important to know what actual teaching looks like, on average, so that national discussions can focus on what most students experience.

Collection of data by video also presents many challenges (see Jacobs et al., in press), such as ensuring that standardised filming procedures are used in all countries; determining what information to extract from the classroom events recorded on the tape and how to quantify the information so that it can be analysed in a meaningful way; and investing sufficient time and expertise to develop codes to describe the data and to train coders so that the data are reliable. Some information on how these aspects were dealt with in the TIMSS 1999 Video Study is given in Appendix A.

Sampling and methodology

The TIMSS 1999 Video Study final sample comprised a total of 638 Year 8 mathematics lessons collected from the seven participating countries.[4] This includes the Japanese lessons that were collected as part of the TIMSS 1995 Video Study.[5]

For each country, the lessons were randomly selected to be representative of Year 8 mathematics lessons overall. In each case, a teacher was videotaped for one complete lesson, and in each country, videotapes were collected across the school year so as to try to capture the range of topics and activities that can take place throughout an entire school year.[6] In each sampled school, no substitution of a teacher or a class period was allowed. The designated class was videotaped once, in its entirety, without regard to the particular mathematical topic being taught or type of activity taking place. The only exception was that teachers were not videotaped on days when a test was scheduled for the entire class period. Teachers were asked to do nothing special for the videotape session, and to conduct the class as they had planned. To obtain reliable comparisons among the participating nations, the data were appropriately weighted to account for sampling design. Sampling and participation rate information can be found in Appendix A.

A similar videotaping protocol was followed for both the 1995 and 1999 video studies. However, in the TIMSS 1999 Video Study two cameras were used to film each lesson, whereas in the TIMSS 1995 Video Study only one camera was used. In the 1999 study, one camera followed what an attentive student would be looking at during times of public discussion, usually the teacher, and followed the teacher and sampled students' activities during private work time. A second camera was stationary and maintained a wide-angled shot of the students.

A series of codes was developed for and applied to the TIMSS 1999 video data by a team of individuals that included bilingual representatives from each country, as well as specialists in mathematics and mathematics education.[7] Each code used had an inter-coder reliability of at least 85 per cent. An international team that included representatives from each country and a mathematics education specialist oversaw the mathematics code development process. This team worked closely with two advisory groups: a group of National Research Coordinators representing each of the countries in the study, and a steering committee consisting of five North American mathematics education researchers.

More information about the methodology used in the study can be found in Appendix A and in Volume 1 of the TIMSS 1999 Video Study Technical Report (Jacobs et al., in press).

Australia's Participation in the TIMSS 1999 Video Study

As stated in the Foreword to this report, educators in Australia were interested in being part of the TIMSS 1999 Video Study because of its potential to provide superior information on classroom teaching practices than is possible through more conventional means such as questionnaires. Typically, high quality measures of student achievement are developed for international studies, but there has been an ongoing need for good measures of teacher behaviour. The potential of the video methodology to provide illuminating materials to assist teachers in their professional development was also recognised by Australian educators when they were considering the possibility of involvement in the study.

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[4] See Appendix A for further details.

[5] Japan only agreed to collect new data for the science component of the 1999 video study. The Japanese mathematics lessons collected for the TIMSS 1995 Video Study were re-analysed using the revised and expanded coding scheme developed for the 1999 study.

[6] The sample of Japanese lessons collected for the 1995 study and re-analysed for the 1999 study did not include lessons drawn from across the full school year; most were collected over a four-month period (Stigler et al., 1999). However, while the sampling of the lessons was less than ideal, there is no evidence that the Japanese Year 8 mathematics data are not representative of teaching at that time.

[7] Native English speakers coded the Australian lessons.

Australia's goals for participation in the TIMSS 1999 Video Study placed particular emphasis on:

- Obtaining authentic and rich information on mathematics and science teaching in Australian lower secondary schools, which, because of the study's design, could be aggregated to provide national 'profiles' of teaching in these areas;
- Ascertaining the extent to which mathematics teaching in 1999 reflected emphases formalised in *A National Statement on Mathematics for Australian Schools*[8] (Australian Education Council, 1991);
- Examining Australian teaching practices in relation to those in the highest-achieving Asian countries;[9]
- Assembling an information base of classroom practice, primarily for professional development purposes; and
- Taking advantage of the opportunity to learn from, as well as help shape some aspects of, the study's innovative methodology.

A secondary objective was to examine differences in content and pedagogy between high and low achieving classrooms. This was made possible by administering the *International Benchmark Test (IBT)* in mathematics (level 2), an abbreviated version of the TIMSS 1995 mathematics test for 13 year olds, to students in the videotaped classes.[10]

Half of the funding for Australia's participation in the study was provided by NCES, with the other half provided jointly by the Commonwealth, State and Territory governments. The Australian Council for Educational Research (ACER) was contracted to coordinate Australia's participation.[11]

The sample

Detailed information on the designed and achieved Australian samples is provided in Appendix A. Briefly, 87 mathematics classes were filmed. They were located in all states and territories, though the non-respondents were concentrated in New South Wales, which was experiencing protracted industrial problems.[12] Schools were selected with a probability proportional to their Year 8 enrolment. They came from all sectors and from both metropolitan and country areas.

The methodology required that videographers, trained in the standard procedures for the study, be sent to the sampled schools. A huge number of kilometres was covered to visit schools in all corners of the country – including rural Western Australia, outback and mid-north Queensland, outback New South Wales, and the west coast of Tasmania, as well as to all capital cities and many surrounding towns.

The intention was that filming of lessons should be done throughout the 1999 school year. However, funding for the study was not assured in time for school visits to be made in the first term of 1999. Filming began in second term, but, due to lag time in arranging schedules, most filming was done in terms 3 and 4. A few lessons were filmed in the first term or very early in the

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[8] This document was the forerunner of similar, state-based documents developed during the 1990s.

[9] Although Australia's performance in the TIMSS 1995 achievement study was high relative to that of a large number of countries, and our students achieved at an equivalent or better level than their counterparts in all English-speaking countries, the federal Minister of Education at the time was concerned because Australia's performance was below that of our 'Asian trading partners'.

[10] The International Benchmark Tests in mathematics and science, constructed with permission from the International Association for the Evaluation of Educational Achievement (IEA), are published by ACER.

[11] Dr Jan Lokan was the Australian project director from 1998–2001. Barry McCrae took over as project director at the beginning of 2002. Dr Hilary Hollingsworth was the Australian research associate (based at LesssonLab) throughout the mathematics portion of the study.

[12] Nevertheless, New South Wales was represented by 19 schools. Disparities in representativeness of the achieved sample were compensated for in the analyses by statistical weighting.

second term of 2000. Inevitably, because of the cost of travel to other states from Melbourne, substantial clustering of lessons by out-of-state locality and time of filming occurred (Victoria was the only state in which lessons were filmed in all four terms). Overall (based on unweighted data), 3 per cent of the filmed lessons took place in first term, 16 per cent in second term, 51 per cent across term 3, and 30 per cent across all but the last two or three weeks of term 4. This distribution was not ideal, but was the best that could be achieved.

About This Report

This report focuses on Australia's participation in the TIMSS 1999 Video Study and the findings of particular relevance to Australia. The full results of the study can be found in the international report, *Teaching Mathematics in Seven Countries: Results from the TIMSS 1999 Video Study* (Hiebert et al., 2003)[13], hereinafter referred to as *Teaching Mathematics in Seven Countries*, from which much of the present report is drawn. This chapter concludes with an overview of the international findings of the study.

Chapter 2 discusses the context of the videotaped lessons. It presents information gathered about the teachers and students involved in the study, and examines the typicality of the filmed lessons. Chapter 3 provides information on the structure of the lessons and their main pedagogical components. The mathematical content of the lessons is examined in Chapter 4, focusing on the mathematical problems presented during the lessons and how they were solved. In Chapter 5, the Australian students' results on the *IBT* mathematics test are used to investigate whether there were evident differences in pedagogy and content between groups of classes contrasted on mathematics achievement.

Chapter 6 draws on the analyses of the previous four chapters to identify the features that characterised Year 8 mathematics teaching in Australia. In the final chapter, Chapter 7, four Australian mathematics educators, Associate Professor Alistair McIntosh (University of Tasmania), Sue Martin (one of the participating teachers), Will Morony (Executive Officer, Australian Association of Mathematics Teachers), and Professor Kaye Stacey (University of Melbourne), discuss the implications of the findings of the TIMSS 1999 Video Study for mathematics teaching in Australia.

Statistical analyses

Unless otherwise indicated, the source of all international data and statistics presented in this report is: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999. All Japanese mathematics data were collected in 1995. The following abbreviations are used throughout the report for the seven participating countries: AU (Australia), CZ (Czech Republic), HK (Hong Kong SAR), JP (Japan), NL (Netherlands), SW (Switzerland), US (United States).

For all analyses presented in this report, comparative terms such as 'higher' and 'lower' are applied only to differences that are statistically significant – at the .05 level unless otherwise indicated. All tests for significance were two-tailed and Bonferroni adjustments were made when more than two groups were compared simultaneously (e.g., a comparison among all seven countries)[14]. Weighted data were used in the tests. More detail can be found in Appendix A.

Test results are listed below each table and figure in which comparative data are presented. For example, AU>CZ, NL indicates that Australia's average is greater than those of the Czech Republic and the Netherlands. Only comparisons that were determined to be significant are listed.[15] Because tests take into account the standard error for the reported differences, a large

[13] This can be accessed or ordered from the NCES website: http://nces.ed.gov/timss

[14] See Appendix B.

[15] Note that, if fewer than three lessons within a country had an observed code, no pairwise comparisons involving that country are reported – see Appendix A.

apparent difference in data may not be significant. Similarly, a difference between averages of two countries may be significant while the same difference between two other countries may not be significant.

Public release videos

Accompanying this report is a CD-ROM containing eight full-length lesson videos and associated materials: four from Australia, and one each from the Czech Republic, Hong Kong SAR, Japan, and the Netherlands. Throughout Chapters 3 and 4, reference is made to various time segments of these public release lessons to illustrate lesson features that are being discussed. For example, *AU PRL 1 (00:42:26)* refers to the 42 minute 26 second point of the *TIMSS 1999 Video Study Australia Public Release Lesson 1*.

Altogether there are twenty-eight TIMSS 1999 Video Study public release videos, four from each of the seven participating countries. They are available as a set of four CD-ROMs[16] and include, in addition to lesson videos, accompanying materials such as a transcript in English and the native language, lesson plans, textbook and worksheet pages, and commentaries by teachers, researchers, and National Research Coordinators. These public release videos are intended to augment the research findings, support teacher professional development programs, and encourage wide public discussion of teaching and how it can be improved.

Overview of the TIMSS 1999 Video Study Results

Most of the findings identified here are discussed further, at least from Australia's perspective, in the remaining chapters. More detail can be found in *Teaching Mathematics in Seven Countries*, including (in Chapter 6) discussion of the features that characterise Year 8 mathematics teaching in each of the other six countries involved in the study.

What was the main conclusion of the TIMSS 1999 Video Study?

- ➢ *A broad conclusion that can be drawn from the findings is that no single method of teaching Year 8 mathematics was observed in the seven countries that participated in the study.*

All the participating countries shared some general features of Year 8 mathematics teaching. However, each country combined and emphasised instructional features in various ways, sometimes differently from all the other countries, and sometimes no differently from some countries.

Similarities across the countries

As just mentioned, Year 8 mathematics lessons in all seven countries shared some general features. In particular, the following points can be made:

- On average, at least 95 per cent of lesson time was spent on mathematical work.[17] This excludes time spent on mathematical organisation work.
- At least 80 per cent of lesson time, on average, was devoted to solving mathematical problems (either as a whole class, individually, or in small groups). Solving mathematical problems was the main activity in Year 8 mathematics classes irrespective of the purpose of the lesson segment (reviewing previously learned content, introducing new content, or practising new content).
- Generally, lessons included some review of previous content as well as some attention to new content.
- Most of the time, lessons were organised to include some public, whole-class work and some private, individual or small-group work. During the time that students worked privately, the

[16] The CD-ROM package can be ordered online from the LessonLab web site: http://www.lessonlab.com

[17] The definitions of terms, such as 'mathematical work', that have a specific meaning in the study are given as they arise in Chapters 3 and 4.

most common pattern across the countries was for students to work individually, rather than in pairs or groups.

- At least 90 per cent of lessons made use of a textbook or worksheet of some kind.
- Teachers talked much more than students, at a ratio of at least 8:1 words, respectively. On average, for the six countries analysed, at least 71 per cent of teacher utterances consisted of at least 5 words whereas at least 66 per cent of student utterances consisted of fewer than 5 words.[18]

Differences among the countries

Australia, like Switzerland, did not differ significantly from all other countries on any one feature of Year 8 mathematics teaching. By contrast, Japan differed from all other countries on 15 per cent of the analyses conducted for the report, and the Netherlands differed on 9 per cent of the analyses.[19] The Czech Republic, Hong Kong SAR, and the United States differed on between 1 and 3 per cent of analyses.

Japanese lessons often featured relatively few problems, with students spending a relatively long time on each one. For example, in *JP PRL 1*, only two problems are worked on – the first for about 45 minutes and the second for about eight minutes. Dutch lessons featured a relatively greater emphasis, than classes in the other countries, on the independent, private work of students compared with public, whole-class work. This is a corollary of Dutch students being expected to take responsibility for their own learning – as is emphasised by the teacher in *NL PRL 4 (00:13:40).*

Considering the differences among the countries reveals different choices, such as these, which can be made in teaching Year 8 mathematics classes. These choices may not previously have been considered, or even imagined, by teachers of some countries.

<u>Pedagogical differences</u>

Despite the similarities in the ways in which lessons in the seven countries were organised, a closer look reveals that there were significant differences in the relative emphasis placed on different aspects of the lessons.

- Students in Australia, the Netherlands, and Switzerland spent more time (53 to 61 per cent of lesson time) on average than students in the other four countries working on sets of problems (termed concurrent problems), and less time (26 to 31 per cent of lesson time) working on single problems (independent problems).
- In Japan, on average, more time (15 minutes) was spent working on each independent problem than in the other countries (2–5 minutes). Further, the average percentage (98%) of problems per lesson that were worked on for longer than 45 seconds was greater than in the other countries (55 to 78 per cent). Japanese students spent most of their time during mathematics lessons working on a few, independent problems.
- Lessons in Japan placed greater emphasis on introducing new content (60% of lesson time) than lessons in the other six countries (22 to 39 per cent of lesson time). Lessons in the Czech Republic placed greater emphasis on reviewing previously learned content (58% of lesson time) than all the other countries except the United States (53%). Hong Kong SAR spent a higher percentage of lesson time (37%) on practising new content than the Czech Republic, Japan and Switzerland (16 to 24 per cent), but not significantly higher than the other three countries (25 to 26 per cent).

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[18] Switzerland was excluded from this analysis because English transcripts were not available for all lessons.

[19] This does not take into account differences between participating countries based on responses to the Teacher Questionnaire.

- Although in all seven countries the vast majority of class time was spent in public or private interaction, countries divided their time between these two interaction types somewhat differently. In Hong Kong SAR, a greater percentage of lesson time (75%) was spent in public interaction than in the other countries (44 to 67 per cent). In the Netherlands, a greater percentage (55%) of lesson time was spent in private interaction than in all the other countries except Australia (48%).
- A higher percentage of lessons (91%) in the Czech Republic contained goal statements provided by the teacher than in all the other countries except Japan (75%). Goal statements were provided in a lower percentage (21%) of lessons in the Netherlands than in all the other countries. For all the countries, lesson summaries were considerably less common (contained in 0 to 28 per cent of lessons) than goal statements.
- Different meanings can be associated with the same lesson component. For example, both *AU PRL 3* and *CZ PRL 1* begin with a review of previously learned work (at *00:00:33* and *00:00:19*, respectively). In the Australian lesson, this involves having all students work privately on a set of short 'warm-up' problems. By contrast, in the Czech lesson it involves having two students work a review problem on the board at the front of the room and be publicly 'graded'.

<u>Differences involving the mathematical problems presented</u>

Particular differences were found among countries with regard to the mathematical problems presented and the ways in which they were worked on during the lesson. In general, these differences were consistent with the differences already noted in how lesson time was spent in the seven countries.

- In all seven countries, at least 82 per cent of the problems per lesson, on average, addressed three major curriculum areas: number, geometry (measurement and space), and algebra. In the Czech Republic, Hong Kong SAR, the Netherlands, and the United States, about 40 per cent of problems involved algebra. The percentages for algebra in Australia (22%), Japan (12%)[20], and Switzerland (22%) were much lower.
- In each country, except Japan, at least 63 per cent of the mathematical problems per lesson, on average, were of low procedural complexity and up to 12 per cent of the problems were of high procedural complexity. Japanese lessons, by contrast, contained fewer problems of low complexity (17%) than all the other countries, and more problems of high complexity (39%).
- Problems involving mathematical proofs were evident to a substantial degree only in Japan, and significantly more so than in the other countries. On average, 26 per cent of the mathematical problems per lesson in Japan included proofs and 39 per cent of Japanese lessons contained at least one proof.
- In all the countries, on average, at least 93 per cent of the mathematical problems presented within the lessons were related to previous problems in some way. However, only in Japan were the majority of problems per lesson related mathematically in ways other than repetition. Across all the other countries, at least 65 per cent of problems were repetitions, significantly more than for Japanese lessons (40%).
- In the Netherlands, a smaller percentage (40%) of problems per lesson, on average, were set up using mathematical language or symbols, rather than using a real-life connection, than in the other six countries (69 to 89 per cent).
- Japanese lessons contained a higher percentage (74%) of problems per lesson, on average, that required students to do more than just practise procedures than all the other countries except Switzerland (55%).

[20] As noted previously, Japanese data were collected only over a portion of the school year (in 1995).

- For problems for which a solution was reached publicly:[21]
  - On average, in all the six countries, except Japan, the majority of the problems per lesson (at least 57%) focused on using procedures. By contrast, in Japan, the majority (54%) of problem statements implied that connections had to be made between mathematical ideas, facts, or procedures. This was more than in the other five countries except for the Netherlands (24%).
  - In Australia (36%), the Czech Republic (33%), and the United States (36%), larger percentages of problems per lesson, on average, were solved by giving the answer only than in the other three countries. Australian (2%) and United States (1%) lessons contained the smallest percentages of problems solved by making reference to the mathematical relationships involved. Japan (37%) had a higher percentage than all the other countries except the Netherlands (22%).

In summary

The results of the TIMSS 1999 Video Study suggest that there are many similarities across countries in the teaching of Year 8 mathematics, especially in the basic ingredients used to construct lessons. However, countries do not necessarily combine and emphasise these ingredients in the same way. A comparison of the instructional practices of Japan and Hong Kong SAR (summarised in Table 1.2), the two highest achieving countries on the TIMSS 1995 and TIMSS 1999 mathematics assessments (see Table 1.1), clearly illustrates these two major findings of the study.

Table 1.2 Similarities and differences between Year 8 mathematics lessons in Japan and Hong Kong SAR on selected variables

Lesson variable	Japan[1]	Hong Kong SAR
Reviewing	24% of lesson time	24% of lesson time
New content	76% of lesson time	76% of lesson time
– Introducing new content	– 60% of lesson time	– 39% of lesson time
– Practising new content	– 16% of lesson time	– 37% of lesson time
Problems (as stated)	Making connections (54% of problems)	Using procedures (84% of problems)
Private work activity	Something other than practising procedures or a mix involving practising (65% of work time)	Practising procedures (81% of work time)

[1] Japanese mathematics data were collected in 1995.
Reviewing: No difference detected
Introducing new content: JP>HK
Practising new content: HK>JP
Making connections problems: JP>HK
Using procedures problems: HK>JP
Percentage of private time devoted to something other than practising procedures or a mix: JP>HK
Percentage of private time devoted to practising procedures: HK>JP

In both Hong Kong SAR and Japan, 24 per cent of lesson time, on average, was spent on reviewing previous content, and 76 per cent was spent on new content. However, the new content introduced in mathematics lessons in these countries was worked with in different ways. In Japanese lessons, more time (than in all the other countries) was devoted to introducing the new content and in Hong Kong SAR more time (than in the Czech Republic, Japan, and Switzerland) was devoted to practising the new content. Consistent with this emphasis, a larger

[21] Switzerland was excluded from this analysis.

percentage of mathematical problems in Japanese Year 8 mathematics lessons (than in all the other countries except the Netherlands) were presented with the apparent intent of asking students to make mathematical connections, and a larger percentage of mathematical problems in Hong Kong SAR lessons (than in all the other countries except the Czech Republic) were presented with the apparent intent of asking students to use procedures. These different emphases are reinforced by noting that a larger percentage of private work time in Hong Kong SAR lessons (along with those in the Czech Republic) was devoted to repeating procedures already learned than in Japanese (and Swiss) lessons.

The results of the TIMSS 1999 Video Study make it clear that an international comparison of teaching, even among mostly high achieving countries, cannot, by itself, yield a clear answer to the question of which method of mathematics teaching may be best to implement in a given country. Furthermore, a particular country might have specific learning goals that are highly valued and for which particular methods of teaching may be better aligned than others.

Chapter 2

CONTEXT OF THE AUSTRALIAN LESSONS

This chapter describes the context of the sampled lessons, in particular the Australian lessons. Many factors define the context of a school mathematics lesson. These include, among other things, school conditions and resources, characteristics of the teachers, their expectations for mathematics teaching and learning, the lesson topic(s), the ability levels of the students and where the lesson fits in the curricular sequence. Data on most of these factors, and other aspects, were collected by means of questionnaires answered by the teachers and students of the videotaped classes.[1]

Each of the 87 Australian teachers returned a completed Teacher Questionnaire. Student Questionnaires were returned from 86 of the 87 schools, though in some schools not all students completed a questionnaire. According to enrolment data provided by the teachers, there were close to 2300 students enrolled in the videotaped classes. In total, 1942 Student Questionnaires were returned – a response rate of approximately 85 per cent. Depending on the time of year, other studies suggest that between 5 and 10 per cent of students would have been absent from school on the day of filming. The remaining 5–10 per cent of enrolments, about 130–230 students, comprised those students who participated in the study but did not complete the questionnaire, and those students who did not participate, either because they did not return a signed permission slip or because their parents refused permission.

The Schools

The sample

The distribution of sampled schools by state, sector and metropolitan/country area is given in Appendix A. Sixteen schools in the achieved sample of 87 schools were single-sex schools, eight for boys and eight for girls. Most of the single-sex schools were from the Catholic sector, though three of them were government secondary schools. No fully selective school was included in the sample, but three teachers said their schools had programs for gifted students. Eight teachers said their schools were recognised disadvantaged schools or had special needs programs (Special Education, English as a Second Language (ESL), or remedial programs). One further school catered especially for students with behavioural problems, and another was a vocational school attached to a Technical and Further Education (TAFE) college.

Overwhelmingly, teachers said that their schools accepted ‘all who want to come’, though some in private schools also mentioned the need for people to be able to pay the fees and some mentioned a religious preference. Four of the government schools accepted overseas students on a fee-paying basis. Only five private schools used entry tests, typically for placement rather than selection, and two government schools used tests for out-of-residential-zone applicants. On the whole, the Australian school sample, as would be expected, was strongly comprehensive.

Resources

Some information on school resources relevant to mathematics teaching was provided by the teachers in their questionnaire responses. Twenty-four per cent of the Australian teachers indicated that lack of materials or inadequate facilities affected how they taught their videotaped lesson either ‘quite a lot’ or ‘a great deal’. More generally, lack of access to computers, computer software and internet connections were felt most strongly, with only 30 to 35 per cent of teachers indicating that they had sufficient access to these items in their classrooms.[2] By contrast, two-

[1] The questionnaires are available online at http://www.lessonlab.com

[2] The questionnaire data were collected in 1999 and 2000. It is likely that schools would have increased their computing facilities since that time, particularly internet access.

thirds of the teachers said they had sufficient access to audio-visual equipment, calculators, and reference materials (books, journals, magazines).

The Teachers

Teachers were asked their gender and some basic information about the class that was filmed, such as the number of boys and girls enrolled in the class, how often the class met each week and for how long. They were also asked about their formal education, their preparation for teaching, their years of teaching experience, their current teaching responsibilities and their attitudes towards teaching. Teachers' responses about themselves and some of the variables pertaining to qualifications, experience and attitudes, based on weighted data, are tabulated in this section. Information about the classes is reported in the next section.

Gender

Sixty-three per cent of the Australian mathematics lessons were taught by males, a slightly higher percentage than the 58 per cent reported for the TIMSS 1999 student assessment (Mullis et al., 2000). A breakdown of teacher gender is not included by country in the TIMSS 1999 Video Study international report *Teaching Mathematics in Seven Countries* (Hiebert et al., 2003). However, in the TIMSS 1999 student assessment, a majority of classes was taught by a male teacher in each of the six countries that also participated in the video study, except for the Czech Republic (27%) and the United States (40%). Switzerland did not take part in TIMSS 1999, but in TIMSS 1995, 87 per cent of students were taught by males (Beaton et al., 1996).

Educational preparation

Teachers identified the major and minor area(s) of study for their undergraduate degrees, and post-graduate studies where applicable. Only 3 per cent of the Australian teachers did not have at least a bachelor's degree, and 12 per cent had a post-graduate qualification, usually a Graduate Diploma in Education or equivalent. All were qualified teachers, although 4 per cent had training for primary level only. Two of the three who did not have a degree had done only primary training and the other, with a Diploma of Engineering, was teaching in a school, now comprehensive, that had formerly been a technical school. Across the participating countries, between 97 and 100 per cent of the lessons were taught by qualified teachers.

Table 2.1 shows the percentage of lessons in each participating country, except Japan, taught by teachers who identified one or more major fields of study.[3] As the table indicates, 96 per cent and 90 per cent of the Year 8 mathematics lessons in the Czech Republic and the Netherlands, respectively, were taught by teachers who reported having a major in mathematics or mathematics education, either at the undergraduate or postgraduate level, or both. These represent a greater percentage of lessons than in the other four countries, ranging from 41 per cent in Hong Kong SAR to 64 per cent in Australia.[4]

When minor fields of study are taken into account, between 83 and 99 per cent of lessons in all the countries except Switzerland (58%) were taught by teachers who identified mathematics or mathematics education as their major or minor area of study. In Australia, 93 per cent of lessons were in this category. A further 3 per cent of Australian lessons were taught by teachers who had undertaken major or minor studies in science, leaving 4 per cent taught by teachers whose qualifications were lacking in at least a minor in tertiary-level mathematics or science.

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[3] The TIMSS 1995 Video Study used a different Teacher Questionnaire. Results from the Japanese data are not included in most of the analyses of this chapter; they can be found in Stigler et al. (1999).

[4] The percentage of lessons taught by teachers who reported various major fields of study might be affected by the limited samples collected for this study and may differ from national statistics available from other studies. For example, data from the TIMSS 1999 assessment in Australia, also with a limited sample but twice the size (one class from each of 184 schools), indicated that 72 per cent of the mathematics teachers had studied mathematics as a major subject (Zammit, Routitsky & Greenwood, 2002).

Table 2.1 Percentage of Year 8 mathematics lessons taught by teachers identifying one or more major fields of tertiary study

	Country					
	AU	CZ	HK	NL	SW	US
Major field	Percentage					
Mathematics[1]	64	96	41	90	61	57
Science[2]	28	41	33	44	35	17
Education	25	18	9	13	11	50
Other	30	32	35	23	19	27

[1] Mathematics includes teachers' responses indicating a major field of study in either mathematics or mathematics education.
[2] Science includes teachers' responses indicating a major field of study in science, science education, or any of the various fields of science (e.g., physics, chemistry, biology).
Mathematics: CZ, NL>AU, HK, SW, US
Science: NL>US
Education: US>CZ, HK, NL, SW
Other: No difference detected
Note: Percentages for each country may not sum to 100 because teachers could identify more than one major field of study. Percentages are based on responses from teachers who identified at least one major field of study.

Teaching experience

In addition to formal education and teaching qualifications, teachers bring a variety of professional experiences to their classrooms, including the number of years they have been teaching. Teachers were asked to identify how many years they had been teaching, in general, and also how many years they had been teaching mathematics. On average, Year 8 mathematics lessons in Australia, the Czech Republic and Switzerland were taught by teachers who reported teaching at least 17 years (see Table 2.2), with a similar average number of years specifically teaching mathematics (16, 21, and 18 years, respectively). Comparatively, Year 8 mathematics lessons in Hong Kong SAR and in the Netherlands were taught by teachers who reported fewer years' teaching on average (10 and 13 years, respectively), and specifically teaching mathematics (10 and 11 years, respectively), than their counterparts in Australia, the Czech Republic and Switzerland.

Except for the Netherlands, the data on teaching experience is consistent with that reported from TIMSS 1995[5] (Beaton et al., 1996). On that occasion, between 55 and 80 per cent of the students in all countries except Hong Kong were taught by teachers with at least 10 years' experience. In Hong Kong, 53 per cent of students had teachers with no more than 5 years' experience. The range of teaching years in Australia was from 1 to 42, the mean number of years' teaching was 15, and the modal number of years was 20 (Lokan, Ford & Greenwood, 1996).

[5] Corresponding information was not reported from the TIMSS 1999 student assessment.

Table 2.2 Mean, median, and range of number of years that teachers reported teaching in general and teaching mathematics

	Country					
Teaching experience	AU	CZ	HK	NL	SW	US
Years teaching						
Mean	17	21	10	13	19	14
Median	16	21	8	12	20	14
Range	1–38	2–41	1–34	1–33	0–40	1–40
Years teaching mathematics						
Mean	16	21	10	11	18	12
Median	15	21	7	11	20	10
Range	1–38	2–41	1–34	1–32	0–39	1–40

Years teaching (mean): AU, CZ, SW>HK, NL; CZ>US
Years teaching mathematics (mean): AU, CZ, SW> HK, NL; CZ>AU, US; SW>US
Note: Mean years are calculated as the sum of the number of years reported for each lesson divided by the number of lessons within a country. For each country, median is calculated as the number of years below which 50 per cent of the lessons fall. Range gives the lowest number of years and the highest number of years reported within a country.

Work responsibilities

Teachers have many responsibilities, both related and unrelated to their mathematics teaching. To help understand some of these demands, teachers were asked to estimate the amount of time they devoted to teaching mathematics, teaching other classes, and engaging in other school-related activities during a typical week.

Table 2.3 shows that Year 8 mathematics lessons differed in the amount of time teachers reported allocating to teaching mathematics. Lessons in the Netherlands and the United States were taught by teachers who reported spending the largest amount of time, 18 to 20 hours a week on average, in teaching mathematics. Swiss lessons were taught by teachers who reported spending more time teaching classes other than mathematics, an average of 13 hours per week, than teachers in the other countries. Dutch lessons were taught by teachers who reported spending more time on average doing mathematics-related work at home and less time teaching other classes compared with teachers in the Czech Republic, Hong Kong SAR, and Switzerland. Dutch lessons were taught by teachers who also reported spending less time on average doing other school-related activities compared with teachers in Hong Kong SAR and Switzerland.

Some of the results for Australia seem low and warrant additional comment. First, the teachers were not asked about full-time or part-time teaching status. Inspection of the Australian data suggests that up to a quarter of the teachers may not have been full-time. Taking hours spent both at school and at home on school-related activities, 25 per cent of the Australian teachers reported spending less than 29 hours in total, which would probably not have constituted a full-time workload, and 16 per cent reported spending less than 25 hours in total, certainly not a full-time workload. The average number of hours teaching mathematics together with other subjects shown in the table is particularly low compared with that reported by teachers from the other countries. Other countries may also have had teachers working part-time, but the effect of not distinguishing them from full-time teachers in the analysis seems likely to have been greatest in Australia.

Table 2.3 Average hours per week that teachers reported spending on teaching and other school-related activities

	Country					
	AU	CZ	HK	NL	SW	US
Activity	Hours per week					
Teaching mathematics	12	14	13	20	11	18
Teaching other classes	4	8	6	3	13	4
Meeting with other teachers to work on curriculum and planning issues	2	1	1	1	2	2
Mathematics-related work at school	6	6	9	3	3	7
Mathematics-related work at home	6	6	5	8	5	6
Other school-related activities	6	8	7	4	9	5
Total	36	42	41	39	42	42

All teaching and other school-related activities: CZ, SW, US>AU
Teaching mathematics: CZ, HK>SW; NL, US>AU, CZ, HK, SW
Teaching other classes: CZ>AU, NL, US; HK>NL; SW>AU, CZ, HK, NL, US
Meeting with other teachers to work on curriculum and planning issues: AU, SW>HK
Mathematics-related work at school: AU, CZ, HK, US>NL, SW
Mathematics-related work at home: NL>CZ, HK, SW
Other school-related activities: HK>NL; SW>NL, US
Note: Average hours per week were calculated by the sum of hours for each lesson divided by all lessons within a country. Hours may not sum to totals because of rounding.

Confidence

Teachers were asked several questions about their attitudes to teaching in general and to teaching mathematics. Comparative data on these questions were not included in *Teaching Mathematics in Seven Countries*, but it is interesting to note that the Australian teachers taking part in the video study generally expressed positive to very positive attitudes to their work. Sixty-four per cent strongly agreed, and a further 26 per cent agreed, that they had 'a strong mathematics background' in the subject areas they were teaching. Only 5 per cent were not proud of the quality of their teaching and only 6 per cent disagreed that they were effective teachers.

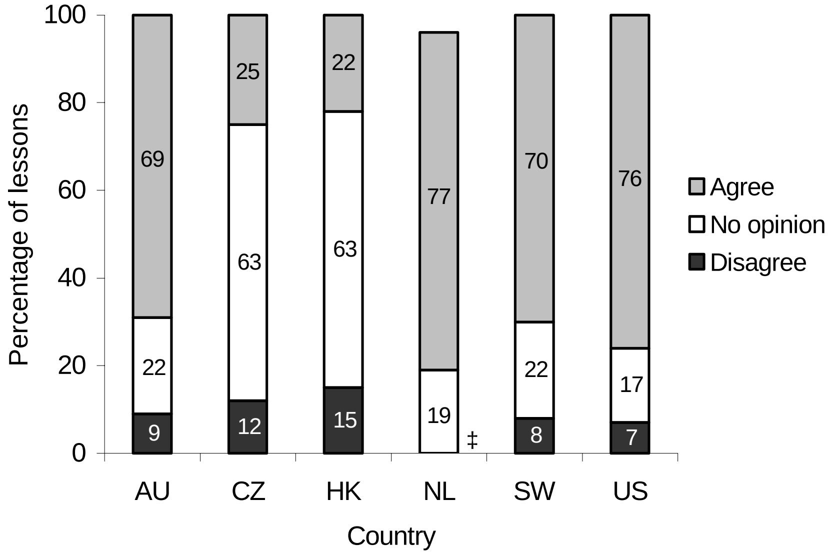
Comparative data from TIMSS 1999 (Mullis et al., 2000) show that, in Australia, the Czech Republic and the United States, the percentages of teachers who judged themselves to be 'very well prepared' to teach Year 8 mathematics topics were all significantly above the international average (73%). The percentage of teachers in this category in the Netherlands was higher in absolute terms but not significantly different from the international average, while the percentage in Hong Kong SAR was very close to the international average. Teachers in Japan were the exception, in that only 23 per cent of them believed themselves to be very well prepared. In the main, TIMSS 1999 found that higher student achievement in mathematics was related to higher levels of teachers' confidence in their preparation, but the result for Japan, a country with high student achievement, highlights that other factors are involved.

Familiarity with current ideas

Several questionnaire items were designed to identify how teachers might have been influenced by current ideas about teaching and learning mathematics. Because 'current ideas' might vary according to the policies, values, and goals of each nation's education system, these items were intentionally phrased in a broad way so that teachers could interpret each question within the context of their country. First, teachers were asked if they agreed or disagreed that they were familiar with current ideas in mathematics teaching and learning, or if they had no opinion. Figure 2.1 shows some contrasting results. On average, more Australian, Dutch, Swiss, and

United States lessons, with at least 69 per cent agreement, were taught by teachers who believed they were familiar with current ideas in mathematics teaching and learning, compared with Czech and Hong Kong SAR lessons. By contrast, 63 per cent of Czech and Hong Kong SAR lessons were taught by teachers who had no opinion about their familiarity with current ideas.

Figure 2.1 Percentage distributions of lessons according to teachers' ratings of their familiarity with current ideas in mathematics teaching and learning



‡ Fewer than three cases reported
Agree: AU, NL, SW, US>CZ, HK
No opinion: CZ, HK>AU, NL, SW, US
Disagree: No difference detected (NL excluded from the analysis)
Note: Percentages may not sum to 100 because of rounding and missing data.

One objective for Australia of participating in the video study was ascertaining the extent to which mathematics teaching in 1999 reflected emphases formalised in *A National Statement on Mathematics for Australian Schools* (Australian Education Council, 1991). In this context, it is interesting to note that only about a quarter of the Australian teachers, when asked to identify documents they were aware of, mentioned their state's curriculum documents as sources of current ideas for mathematics teaching and learning, and only one teacher specifically mentioned the *National Statement*.[6] More commonly, professional development days, other teachers, journals, and mathematics associations were mentioned in relation to sources of current ideas.

The Students

Some brief descriptive data, from unweighted responses to the Student Questionnaire, are provided here as an indication of the composition of the selected classes. Overall, there were approximately equal numbers of boys (51%) and girls (49%) in the Australian classes. Almost 4 per cent identified themselves as Indigenous Australians, which is a little higher than expected from school data, but not out of line with Australian Census data from 2001. Eighty-nine per cent of the students, 69 per cent of their mothers, and 67 per cent of their fathers were born in Australia, while 97 per cent of the students said they spoke English at home at least half the time. These data differ by no more than three per cent from the data reported for TIMSS 1995 and TIMSS 1999 (Lokan, Ford & Greenwood., 1996; Zammit, Routitsky & Greenwood, 2002).

[6] It is likely that more teachers would mention their state's curriculum documents nowadays.

'Number of books in the home' has been used in many IEA studies as a surrogate measure of education and culture in the home. The percentages obtained in Australia in the present study are again within a point or two of those reported in both TIMSS 1995 and TIMSS 1999, with about 40 per cent of students coming from homes with more than 200 books and only about 10 per cent coming from homes with fewer than 50 books.

Age range and curriculum level

It is important to note, as part of the context of the Australian lessons in the video study, that Year 8 students in the various Australian states and territories differ, on average, by as much as seven months in age, because of state-based policy differences in school starting age. It is virtually impossible to disentangle age–grade curriculum issues, but, having had a year less of formal schooling in some of the states, it is possible that Year 8 students in those states may experience some lower level curriculum content, on average, in relation to their counterparts in the other states.

In order to meet the sampling guidelines on student age for the TIMSS 1995 student assessment, students (as in England) had to be sampled from Year 9 in four of the eight Australian states and territories, covering close to 40 per cent of the student age cohort. The TIMSS 1999 Video Study is characterised as a study of mathematics teaching in Year 8 classrooms, not as a study of teaching a specified age group. It is expected that the Australian students in the study would have been several months younger, on average, than the students in the other participating countries and that this may have had some curriculum effect.

The Lessons

Features of the sampled lessons are described in this section, as distinct from characteristics of the schools, teachers and students addressed so far in this chapter, and mathematical content and pedagogy which are each the focus of a separate chapter.

Overall instructional time for mathematics

Before the data on lesson duration for the sampled lessons are presented, it is informative to consider the amount of mathematics instruction time across a full school year in the various countries. Countries differ in the number of lessons conducted per week and the number of school weeks per year. By using the estimated median work time per lesson within a country, however, it is possible to estimate the amount of time Year 8 students might spend studying mathematics in school during a week and during the entire school year.

Based on estimates of the number of Year 8 mathematics lessons per week and per year in each country,[7] estimates were calculated for the median total time spent in mathematical work per week and per year for each country except Switzerland. The three language regions in Switzerland have different school calendars and it was deemed inappropriate to develop one estimate to represent all three regions. Table 2.4 displays the results.

The estimates in Table 2.4 should be considered indicative rather than definitive, particularly as they are limited to in-school instruction and may not accurately reflect the total amount of instruction that students receive in other settings.[8] For this reason, it was deemed inappropriate to compare them statistically. Nonetheless, the data in the table serve as a reminder that it is inappropriate to presume that the individual lesson duration reported in the next section describes the relative time spent by students in each country studying mathematics in school. For example, whereas Year 8 mathematics lessons in Hong Kong SAR had the shortest mean duration of all the

[7] These estimates were provided during the study by the National Research Coordinators and may differ from estimates from education authorities, other mathematics educators, or teachers in these countries.

[8] Across the countries participating in the study, there are various options available to students to obtain additional instruction or study time related to school subject matter. For example, students may have access to after-school programs, tutoring services, parental assistance, or study groups.

countries (see Table 2.5), when taking into account the number of lessons per week and per year, Hong Kong SAR lies in the middle range of estimated time over the school year.

Table 2.4 Estimated median time spent in Year 8 mathematical work per week and per year

Country	Estimated median time in mathematical work per week (minutes)	Estimated median time in mathematical work per year (hours)
Australia (AU)	174	113
Czech Republic (CZ)	179	90
Hong Kong SAR (HK)	175	105
Japan[1] (JP)	200	116
Netherlands (NL)	127	84
United States (US)	179	107

[1] The estimate for Japan is based on data collected in 1995.

Class size

Regular class sizes in the Australian sample ranged from 10 to 35. One school, which was using a team teaching approach, reported an enrolment of 73 students from three classes combined. Leaving out this large 'class' and using weighted data, the average class size was 25.8 students, with a median of 26 and mode of 25. Fifteen per cent of classes had 20 or fewer students, a further 28 per cent had between 21 and 25 students, 38 per cent had between 26 and 30 students, and 19 per cent had between 31 and 35 students (all but four of this group had 31 or 32 students).

Teachers were asked whether the number of students in their class limited them from reaching their ideal for the videotaped lesson. Some teachers answered that their class was too large – some directly (4%), and some by implication (10%), by mentioning, for example, insufficient classroom space, or too much noise, or little opportunity to give students individual attention. The actual sizes of the classes thought to be too large varied from 22 to 35 students, though mostly they were above the Australian average of 26. The teacher of one of the largest classes, with 35 students, commented that the size was 'a challenge, not a limitation'.

Duration

The length of a mathematics lesson provides the most basic element of lesson organisation. Although amount of time does not, by itself, account for students' learning opportunities, it is a necessary ingredient for learning (National Research Council, 1999) and is therefore a good starting point for describing lessons. How the teachers and students filled in the lesson time with mathematical work will become apparent in later chapters of this report.

To ensure that the mathematics lessons filmed for this study were captured in their entirety, the data collection protocol called for cameras to be turned on well before the lesson started and for filming to continue for some minutes after the lesson ended. To determine the length of a mathematics lesson, decisions had to be made about when a lesson began and ended. The beginning of the lesson was defined as the point when the teacher first engaged in talk intended for the entire class. The end of a lesson was marked by the teacher's final talk intended for the entire class, which sometimes included concluding or summary remarks by the teacher. When students worked independently and the teacher did not close the lesson with a public statement, the end of lesson was marked when the bell rang, or when most students packed up their materials and left the classroom.

The lesson duration mean, median, range, and standard deviation of the videotaped lessons in each country are displayed in Table 2.5. One feature of lesson length that is immediately apparent is that that there was a large range in length in some countries. With regard to mean length, the Hong Kong SAR lessons were shorter than those of all the other countries, and Japanese lessons were longer than those of three countries. Because of the large variations, however, the median length is probably the best measure for gauging the length of a typical lesson. The large range of lengths in some countries was due, in part, to what some countries call 'double lessons', in which two traditional instructional periods are joined.

Table 2.5 Mean, median, range, and standard deviation (in minutes) of the duration of videotaped lessons

	Mean	Median	Range	Standard deviation
Country	Minutes			
Australia (AU)	47	45	28–90	13
Czech Republic (CZ)	45	45	41–50	1
Hong Kong SAR (HK)	41	36	26–91	14
Japan[1] (JP)	50	50	45–55	2
Netherlands (NL)	45	45	35–100	7
Switzerland (SW)	46	45	39–65	3
United States (US)	51	46	33–119	17

[1] Japanese mathematics data were collected in 1995.
Mean: AU, CZ, JP, NL, SW, US>HK; JP>CZ, NL, SW; US>CZ
Standard deviation: AU, HK>CZ, JP; US>CZ, JP, NL, SW
Note: For each country, the mean is calculated as the sum of the number of minutes of each lesson divided by the number of lessons filmed for that country and the median is the number of minutes below which 50 per cent of the country's lessons fell. The range shows the lowest number of minutes and the highest number of minutes observed within the country.

Figure 2.2 displays the distribution of lesson durations for each country and shows graphically the clustering of lesson lengths at around 45 minutes for all the countries except Japan and Hong Kong SAR. The figure provides a more detailed look at the variation in lesson length across countries. Whereas Table 2.5 shows that the ranges in lesson duration differed widely, the box and whisker plots in Figure 2.2 reveal that the majority of lessons in all countries except Australia fall within a narrower range.

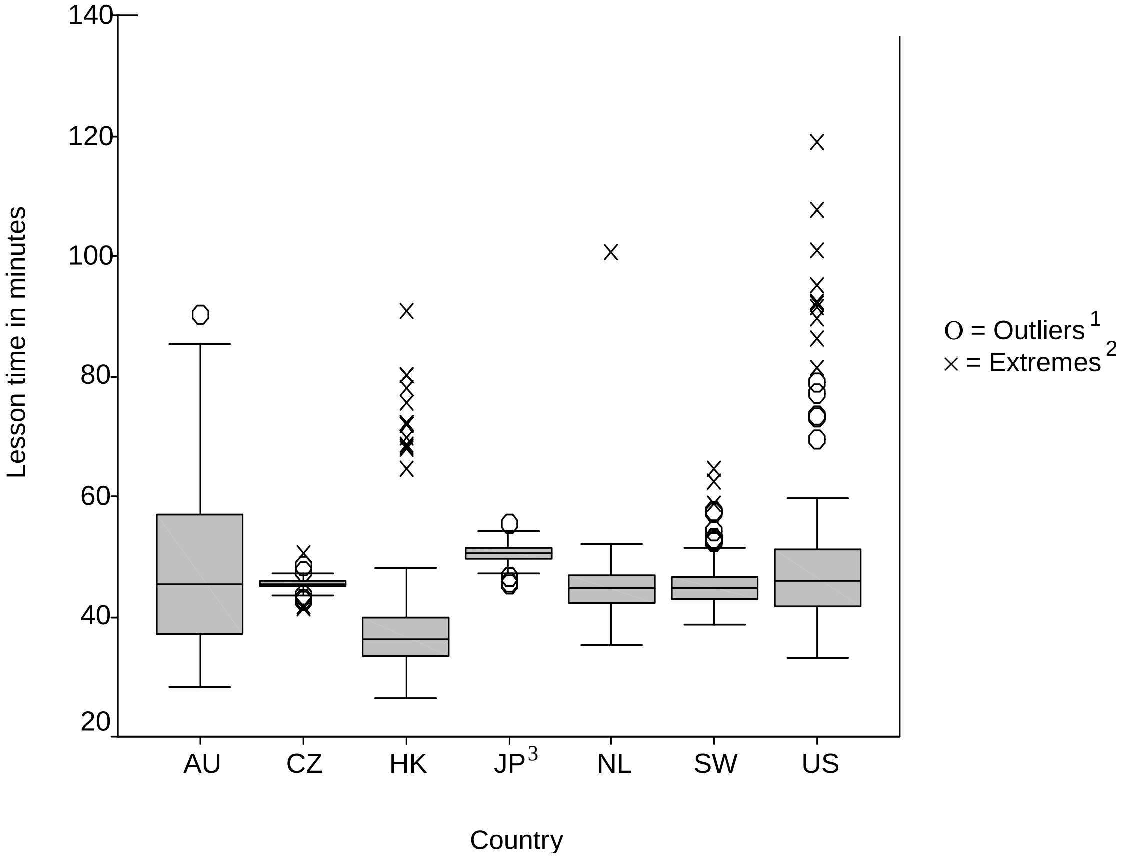
In Australia's case, it can be seen that a quarter of the videotaped lessons were shorter than about 38 minutes while another quarter were longer than about 57 minutes. In fifteen cases, the videotaped lesson was a 'double lesson'. All four of the Australian public release lessons were single lessons, but *AU PRL 4* was a much longer lesson (69 minutes) than the other three lessons (43–46 minutes). The teacher commented as follows:

> All classes in our school are 75 minutes long. We moved to this lesson length after a whole school discussion on optimum learning time. Increased time was seen to benefit group work and allow for conclusions and reflections on activities. In Mathematics this often means two concepts need to be developed in the class to complete the curriculum. In most classes the plan would include approximately three changes in activity. *(AU PRL 4, Teacher's Commentary, 00:00:29)*

If only the single periods are considered in the full Australian sample, the mean and median lesson times were 43 and 44 minutes, respectively, but the standard deviation (8 minutes) was still large compared with that in the Czech Republic, Japan and Switzerland. The double periods had a mean length of 69 minutes and median of 70 minutes, again with a standard deviation of

8 minutes. Variations in lesson duration within Australia are noticeable between states, possibly carried forward from years ago when most schools were centrally administered and had much less autonomy in determining their day-to-day procedures.

Figure 2.2 Box and whisker plots showing the distribution of videotaped lesson durations



[1] Outliers are values from 1.5 to 3.0 box lengths from the upper or lower edge of the box.
[2] Extremes are values greater than 3.0 box lengths from the upper or lower edge of the box.
[3] Japanese mathematics data were collected in 1995.
Note: The shaded box represents the interquartile range, containing 50 per cent of the lessons. The lines extending from the box indicate the highest and lowest values, excluding outliers and extremes (see notes 1 & 2). The horizontal line within the box indicates the median lesson time (half of the numbers fall above or below this value).

As stated previously, the definitions of the beginning and end of a lesson reflect a deliberate intention to capture the length of the whole class period, and not just the mathematics portion of the lesson. In many cases, lessons began or ended with non-mathematical activities. These activities were included in the lesson and later marked as ‘non-mathematical segments’. Nevertheless, the recorded time for a given lesson was nearly always less than the officially designated length of that class period.

When students need to move from one classroom to another, as is common in Australian secondary schools, it can be expected that a few minutes of supposed ‘lesson’ time will be used in this way. Comparison of the Australian teachers’ responses about lesson duration with the duration observed for the videotaped lessons showed about 30 per cent differing by less than three minutes. A further quarter differed by between three and five minutes. All the others, almost half of the videotaped lessons, differed in duration by at least six minutes from the designated lesson time, some by as much as ten minutes. While some of these differences may have been due to the unusual circumstance of having cameras and visitors in the classroom, they may indicate inefficient practices that could be improved. The significant loss of time, if a regular occurrence, would be expected to be particularly crucial for shorter designated class periods.

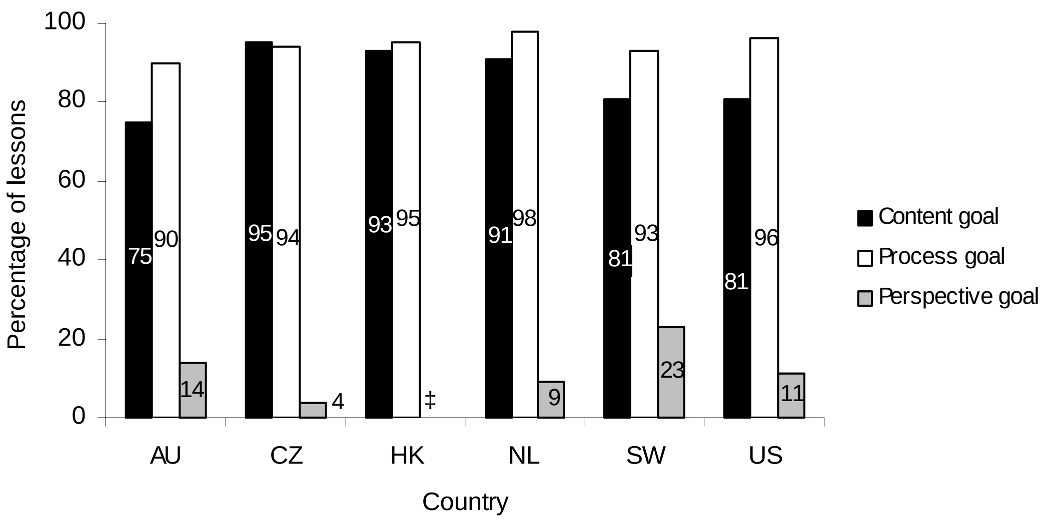
Lesson goals

A key contextual variable that shapes the nature of teaching is the set of learning goals toward which the teacher is working (Hiebert et al., 1997). Teachers were asked to describe, in open-ended questions, the 'main thing' they wanted students to learn from the videotaped lesson. Some teachers listed general topic goals, such as 'learning about linear systems', whereas other teachers described their goals in more detail, such as 'understanding the graphical solution to linear systems: parallel lines have no common value'.

Teachers' responses were coded along each of three dimensions: content, process, and perspective (more than one dimension could apply). These dimensions were based on the coding scheme developed for the TIMSS mathematics curriculum framework (Robitaille, 1995; Schmidt, McKnight, Valverde, Houang, & Wiley, 1997). *Content goals* were identified by statements describing specific mathematical concepts or topics. *Process goals* were defined as descriptions about how teachers wanted their students to use mathematics, such as 'solve equations', 'solve problems', and 'apply mathematics to everyday situations'. *Perspective goals* included those aimed at promoting students' ideas and interest in mathematics and learning, such as 'to see that mathematics is fun', and 'to learn to be neat and orderly in their work'.

The results of applying this coding scheme to teachers' reported goals for the videotaped lessons are summarised in Figure 2.3, which presents the percentage of Year 8 mathematics lessons taught by teachers who identified specific content, process, or perspective goals by country. Between 75 and 95 per cent of the lessons in all countries were taught by a teacher who listed a content goal for the lesson, and between 90 and 98 per cent of lessons were taught by a teacher who listed a process goal for the lesson. Much smaller percentages, between 4 and 23 per cent of lessons, were taught by a teacher who identified a perspective goal.

Figure 2.3 Percentage of lessons taught by teachers who identified content, process, or perspective goals for the lesson



‡ Fewer than three cases reported
Content goal: CZ>SW
Process goal: No difference detected (HK excluded from the analysis)
Perspective goal: SW>CZ

Within-country comparisons indicated no difference in both the Czech Republic and Hong Kong SAR between the percentages of videotaped mathematics lessons taught by teachers who identified content and process goals for the lesson. In Australia, the Netherlands, Switzerland and the United States, a larger percentage of lessons were taught by teachers who identified process goals than content goals. A smaller percentage of lessons in all countries were taught by teachers who identified perspective goals than either content goals or process goals.

Process goals for the videotaped lessons are of special interest because these goals could range from practising routine operations (e.g., computations and symbol manipulation) to reasoning mathematically (e.g., logical reasoning and explaining relationships). The TIMSS 1995 Video Study found significant differences among the three participating countries (Germany, Japan and the United States) in the emphasis teachers placed on developing skills versus thinking and reasoning mathematically (Stigler et al., 1999).

As Figure 2.3 shows, at least 90 per cent of the videotaped lessons were taught by teachers who identified a process goal for the lesson. Table 2.6 presents a breakdown of the nature of the process goals identified. In all countries, using routine operations or calculations was the goal most commonly mentioned (by between 40 and 51 per cent of the teachers). Between 5 and 19 per cent of lessons were taught by teachers who mentioned reasoning mathematically, between 11 and 16 per cent were taught by teachers who mentioned applying mathematics to real world problems, and between 11 and 19 per cent were taught by teachers who mentioned knowing mathematical content. Between 6 and 15 per cent of lessons in all of the countries, except Hong Kong SAR, were taught by teachers who mentioned other process goals, including such processes as acquiring problem solving abilities, meeting external requirements, or reviewing mathematical concepts or problems.

Table 2.6 Percentage of lessons taught by teachers who identified specific process goals for the lesson

	Country					
	AU	CZ	HK	NL	SW	US
Process goal	Percentage					
Using routine operations	40	51	51	42	44	41
Reasoning mathematically	7	9	17	19	5	8
Applying mathematics to real-world problems	12	16	11	16	14	14
Knowing mathematical content	16	11	13	12	18	19
Other process goal	14	6	‡	10	12	15
No process goal identified	10	6	5	‡	7	4

‡ Fewer than three cases reported (country excluded from the relevant analysis)
No between-country differences were detected on any of the specific process goals.
Note: Teachers' responses were coded into one category only. Percentages may not sum to 100 because of rounding and missing data.

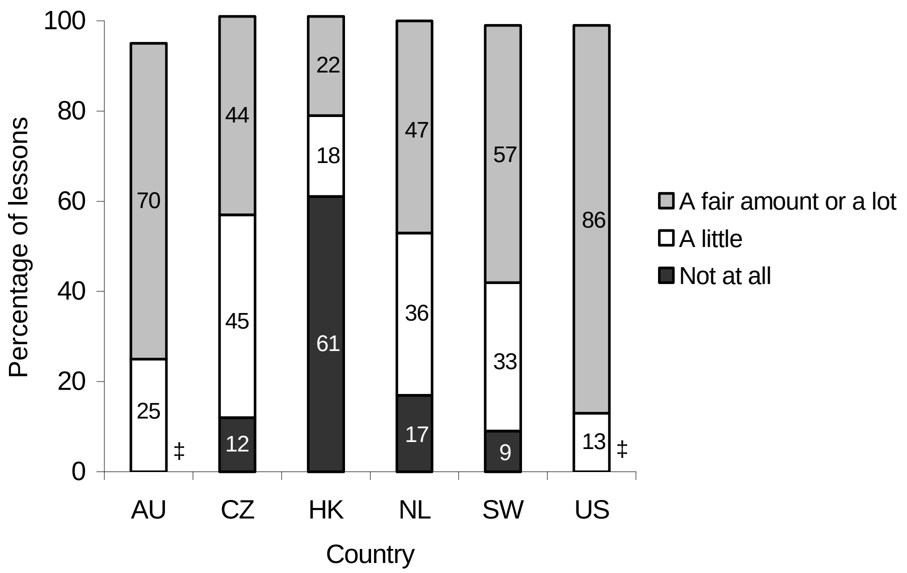
A lesson does not always play out as intended. Interruptions, the need to revisit topics, technical difficulties and other factors may serve as obstacles to conducting the lesson as planned. To give the filmed teachers the opportunity to describe how closely their goals for the lesson matched the outcomes of the lesson, they were asked if they were satisfied that they achieved their stated goals. In all countries, the teachers were similarly satisfied that their lessons played out as they had intended, with at least 83 per cent responding that they were satisfied in this respect.

Embodiment of current ideas

As seen earlier in the chapter (see Figure 2.1), around 70 per cent or more of the teachers in Australia, the Netherlands, Switzerland and the United States believed that they were familiar with current ideas in mathematics teaching and learning, while only a quarter of the teachers believed this to be so in the Czech Republic and Hong Kong SAR (data were not available for Japan). To understand how teachers might have implemented their knowledge of current ideas, they were asked to rate the degree to which the videotaped lesson reflected current ideas about teaching and learning mathematics.

Figure 2.4 shows that at least 44 per cent of the lessons in all countries except Hong Kong SAR were taught by teachers who believed that their lessons contained a fair amount or a lot of aspects that reflected current ideas. In particular, United States lessons were taught by teachers who described their lessons as more consistent with current ideas relative to teachers in all other countries except Australia. On the other hand, more Hong Kong SAR lessons (61%) were taught by teachers who reported that the lesson did not reflect current ideas at all compared with lessons in other countries.

Figure 2.4 Percentage distributions of lessons by extent to which their teachers rated the lesson to be in accord with current ideas about teaching and learning mathematics



‡ Fewer than three cases reported
A fair amount or a lot: AU, CZ, NL, SW, US>HK; AU, US>CZ; US>NL, SW
A little: CZ, NL, SW>US; CZ>HK
Not at all: HK>CZ, NL, SW (AU and US excluded from the analysis)
Note: Percentages may not sum to 100 because of rounding and missing data.

Typicality

Being videotaped could have affected the typicality and quality of the lesson. How typical were the videotaped Australian lessons?

- *The Australian teachers believed that their lessons were about the same as usual with regard to their teaching, the difficulty of the content, and their students' behaviour. However, they spent more time than usual in planning their lessons.*

Several questionnaire items asked teachers to describe how typical the videotaped lesson and their planning for it were, and to describe the influence of the camera on the lesson. To provide a context for these responses, teachers also were asked about the course of which the videotaped lesson was a part.

<u>The course of which the videotaped lesson was part</u>

Teachers were asked if all Year 8 students in the school took the same mathematics course as the one in the videotaped lesson. A large majority of lessons in the Czech Republic and the Netherlands (100%), Hong Kong SAR (99%), the French-language area of Switzerland (86%),[9] and Australia (82 %) were taught by teachers who reported that Year 8 students in their school were required to take the same mathematics course. By contrast, 75 per cent of lessons in the United States were taught by teachers who reported that not all students in their school took the same mathematics course.

Questions such as this one often lead to difficulties in interpretation in Australia. Within each state, curriculum guides indicate course content appropriate either to a year level or, more commonly, to a band of two years that constitutes a 'level' within the curriculum. Thus, it is not a simple matter to define a 'Year 8 curriculum' even at the state level. Nevertheless, until the upper secondary years, all students in a state are in theory expected to cover the same curriculum in the core subjects, of which mathematics is one. In some schools, however, students are grouped into classes of different ability levels for mathematics instruction. Indeed, six of the Australian teachers in the study reported that their class comprised higher ability students and three that their class contained only low ability students. In such classes, the teachers may have been teaching additional material or more basic material, depending on the students' capabilities (some of the teachers annotated their questionnaires to this effect), and it is a matter of interpretation as to whether the students were taught the same 'course' as was taught to other Year 8 classes in the school.

<u>Students' behaviour</u>

A teacher's ability to conduct a successful lesson is related, in part, to students' behaviour. A second question examining the typicality of the videotaped lesson asked teachers to rate their students' behaviour during the lesson. As shown in Figure 2.5, at least half of the lessons in each country were taught by teachers who reported that the students behaved about the same as usual, except in the Czech Republic (44%). Forty-one per cent of Czech lessons were taught by teachers who replied that their students did not behave as well as they usually did. On a follow-up question, these Czech teachers described their students as less active (64%), more shy and afraid to give wrong answers (44%), or less focused (9%) than usual. The percentage of lessons in Australia for which the students' behaviour was reported to have been 'worse than usual' was low, at only 5 per cent.

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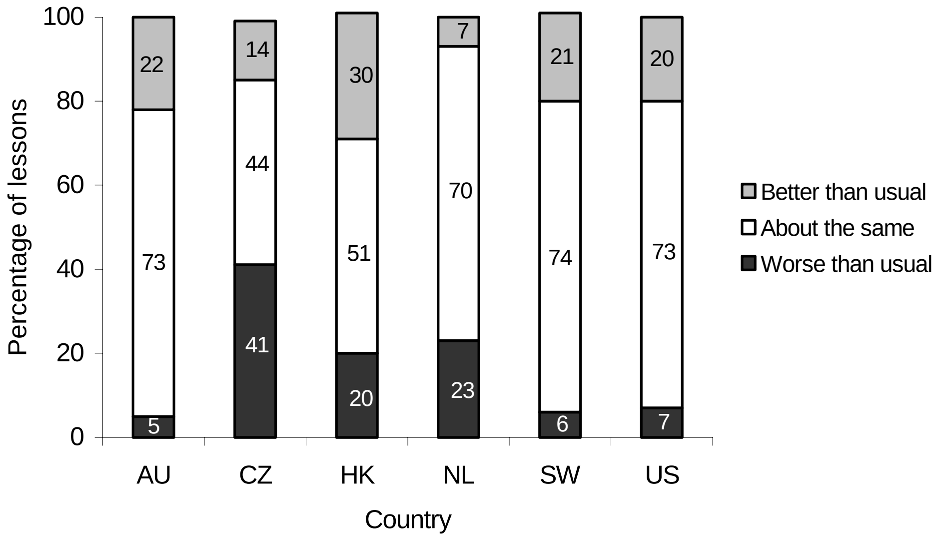
[9] The teachers in the German- and Italian-language areas of Switzerland were not asked this question because, according to country experts, all students in those schools were required to take the same mathematics course.

Figure 2.5 Percentage distributions of videotaped lessons by teachers' ratings of their students' behaviour during the lesson



Better than usual: HK>NL
About the same: AU, NL, SW, US>CZ; SW>HK
Worse than usual: CZ>AU, SW, US
Note: Percentages may not sum to 100 because of rounding.

<u>Teaching methods</u>

With respect to pedagogy, the teachers were asked, 'How often do you use the teaching methods that are in the videotaped lesson?'. The two response options of 'often' and 'almost always' accounted for between 74 and 97 per cent of the responses in each of the six countries.[10] Across the countries, no more than 26 per cent of lessons (recorded in both Australia and Hong Kong SAR) were taught by teachers who reported that they 'sometimes' or 'seldom' used the teaching methods captured on the videotape.

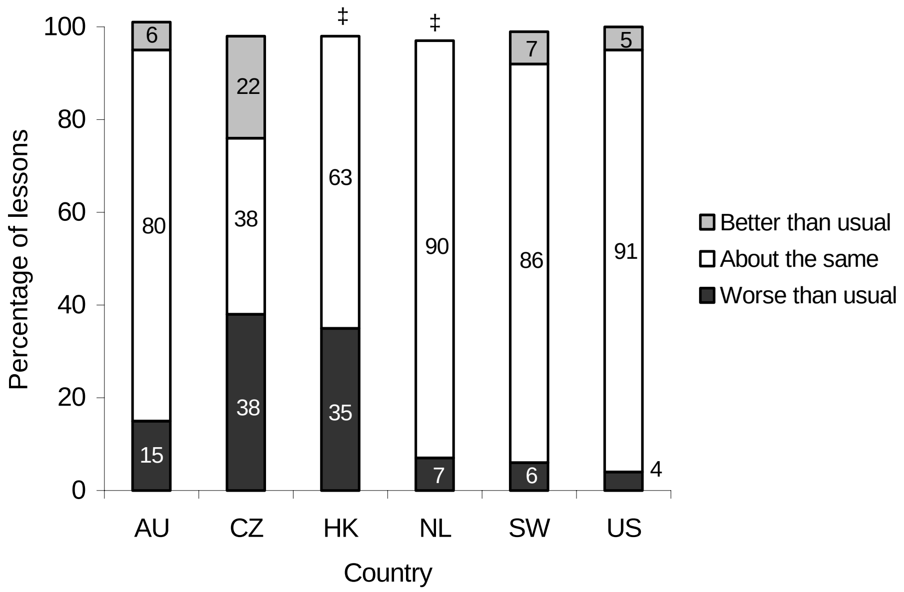
<u>Influence of videotaping</u>

A comment that is often made about studies of this kind is that lessons cannot be 'typical' because of the presence of the camera and the videographer. To check the teachers' perspectives on this, they were asked specifically about the influence of the videotaping on their teaching of the class. Teachers were asked whether the camera caused them to teach a lesson that was worse than usual, about the same, or better than usual. As shown in Figure 2.6, between 80 and 91 per cent of the videotaped lessons in Australia, the Netherlands, Switzerland, and the United States were taught by teachers who reported that their lesson was 'about the same'.[11] Fewer Czech teachers than in the other five countries thought their lesson was 'about the same', whereas more teachers in the Czech Republic and Hong Kong SAR thought their lesson was 'worse than usual'.

[10] Data not shown: see Hiebert et al. (2003), Figure 2.4

[11] The same question was asked of the Japanese teachers in the TIMSS 1995 Video Study. They reported that the videotaped lesson was better than usual in 12 per cent of the lessons, the same as usual in 61 per cent of the lessons, and worse than usual in 27 per cent of the lessons (Stigler et al., 1999).

Figure 2.6 Percentage distributions of teachers' ratings of the influence of the camera on their teaching of the videotaped lesson



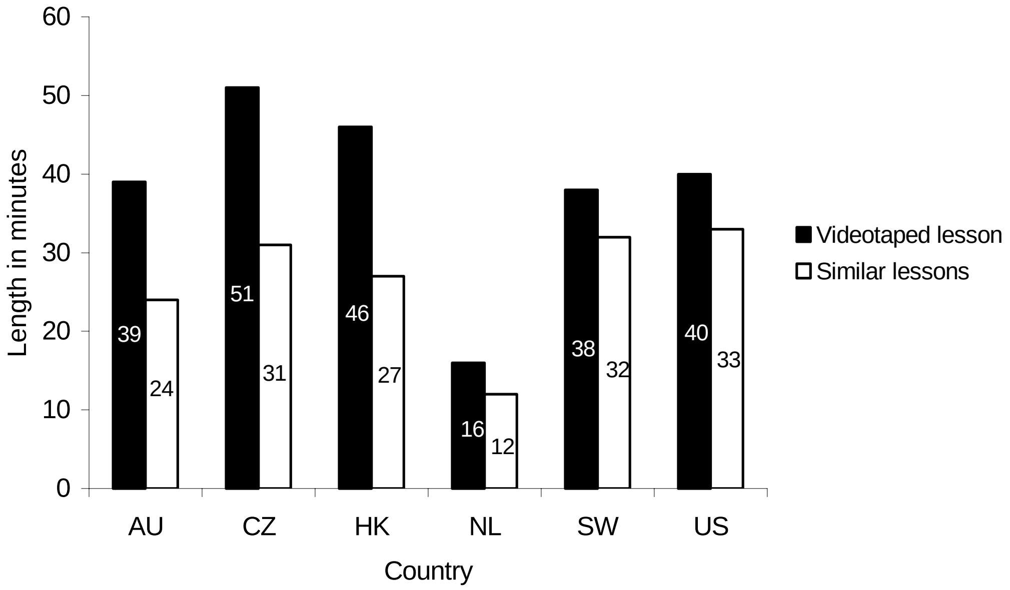
‡ Fewer than three cases reported
Better than usual: CZ>AU, SW, US (HK and NL excluded from the analysis.)
About the same: AU, HK, NL, SW, US>CZ; NL, SW, US>HK
Worse than usual: CZ, HK>AU, NL, SW, US
Note: Percentages may not sum to 100 because of rounding and missing data.

Amount of planning

In anticipation of being filmed, the teachers could have invested more effort in planning a lesson, potentially altering how they would normally teach. Teacher reports of how many minutes they spent planning for the videotaped lesson and how many minutes they typically spent planning for a similar mathematics lesson are shown in Figure 2.7. Teachers in the Netherlands reported spending less time planning for the videotaped lesson, and less time planning for similar lessons, than teachers in the other five countries.

Within-country comparisons indicated that, on average, lessons in Australia, the Czech Republic, Hong Kong SAR, and Switzerland were taught by teachers who spent significantly more time planning for the videotaped lesson than usual. On the other hand, no difference was detected in the Netherlands or the United States in the average amount of time teachers spent planning for the videotaped lesson compared with the amount of time they usually spent planning for a lesson.

Figure 2.7 Average length of time that teachers reported planning for the videotaped lesson and for similar Year 8 mathematics lessons



Videotaped lesson: AU, CZ, HK, SW, US>NL
Similar lessons: AU, CZ, HK, SW, US>NL
Note: Average length of time was calculated as the sum of minutes reported for each lesson divided by the number of lessons within a country.

Difficulty of content

Another item assessing lesson typicality explored the difficulty of the mathematics content of the lesson. Teachers were asked if the content for their Year 8 students was more difficult, less difficult, or about the same level of difficulty as most lessons.[12] Between 75 and 92 per cent of the videotaped lessons in each country were taught by teachers who identified the content level as ‘about the same’ as for most lessons. In Australia, 80 per cent of teachers responded ‘about the same’, while 6 per cent responded ‘more difficult’ and 13 per cent responded ‘less difficult’.

Fit of lesson in curricular sequence

An individual mathematics lesson is normally embedded in a sequence designed to teach a particular topic in the curriculum. Lessons that are not part of a sequence might be suspected to be atypical lessons conducted especially for the benefit of this study. Therefore, teachers were asked to provide information on whether the videotaped lesson was part of a larger unit or sequence of related lessons, or whether it was a ‘stand-alone’ lesson. Between 92 and 100 per cent of the videotaped lessons in all countries were taught by teachers who reported that the lesson was part of a sequence, with no between-country difference found.[13] Fewer than three stand-alone lessons were reported in the Czech Republic. Otherwise, the percentage of stand-alone lessons ranged from 2 per cent in Australia and the Netherlands to 8 per cent in Hong Kong SAR and the United States. The Australian lessons in this category were specifically identified by the teachers as ‘review’ lessons prior to a yearly or half-yearly exam, and therefore not typical examples of their teaching.

[12] Data not shown: see Hiebert et al. (2003), Figure 2.6

[13] The same question was asked of the Japanese teachers in the TIMSS 1995 Video Study. Ninety-six per cent of lessons were taught by teachers who reported that the videotaped lesson was part of a sequence (Stigler et al., 1999).

If the lesson was part of a unit, the teacher was asked to identify how many lessons were in the entire unit and where the videotaped lesson fell in the sequence (e.g., lesson number 3 out of 5 in the unit). Table 2.7 shows that, on average, the total number of lessons in the larger unit of which the videotaped lesson was a part ranged from 9 to 15. The average length of units in the Czech Republic (15 lessons per unit) was significantly longer than the average length in all the other countries except Switzerland. On average, the lessons captured on videotape were located within the middle third of the lessons within a unit.

Table 2.7 Average number of lessons in unit and placement of the videotaped lesson in unit

Country	Average number of lessons in unit	Average placement of the videotaped lesson in unit
Australia (AU)	10	5
Czech Republic (CZ)	15	8
Hong Kong SAR (HK)	9	4
Netherlands (NL)	9	5
Switzerland (SW)	12	6
United States (US)	9	5

Average number of lessons in unit: CZ>AU, HK, NL, US

Summary

The Australian sample for the TIMSS 1999 Video Study consisted of 87 Year 8 classes from all states and territories, from all sectors, and from both metropolitan and country areas. Internationally, a total of 638 Year 8 classes from seven countries were filmed. This chapter presented information about the teachers of those classes, including their academic qualifications and teacher training, their teaching experience, their familiarity with current ideas, and their goals for the videotaped lessons. In addition, information was presented on a range of characteristics of the lessons themselves, in particular, the duration of the lessons. Most of the information in the chapter was derived from the questionnaire answered by the teachers, but some arose from analysis of the lesson tapes. Data were not available for Japanese teachers on most of the questionnaire variables.

A finding common to all six countries was that all, or almost all, of the videotaped classes were taught by teachers who were certified to teach. Further, teachers in most of the countries (including Australia) were well qualified to teach mathematics at Year 8 level. Teachers nearly always identified process goals for their lessons, and generally identified content goals, but identified perspective goals relatively rarely (Figure 2.3).

The median observed duration of lessons was around 45 minutes in all countries, except for Hong Kong SAR (36 minutes) and Japan (50 minutes) (Table 2.5). In all countries, except Australia, there was relatively little variation in the durations of most lessons (Figure 2.2).

Importantly for the credibility of the results of the study, the teachers involved perceived their videotaped lessons to be typical of their Year 8 mathematics teaching, especially with regard to teaching methods, difficulty of content, and its fit within a curriculum unit (Table 2.7). In all countries except the Czech Republic, the majority of teachers thought that their lesson, and their students' behaviour, was about the same as usual (Figures 2.5 & 2.6). However, teachers in Australia, the Czech Republic, Hong Kong SAR, and Switzerland, spent more time than usual planning for the videotaped lesson (Figure 2.7).

Key results concerning Australia reported in this chapter include the following:

- In Australia, 64 per cent of the teachers had a major study in either mathematics or mathematics education (Table 2.1), 93 per cent had at least a minor study in one of these areas, and all were qualified to teach. However, four teachers had primary training only.
- The number of years that the Australian teachers had been teaching mathematics ranged from 1 year to 38 years, with a mean of 16 years and a median of 15 years (Table 2.2). Sixty-three per cent of the teachers were males.
- Australian teachers reported spending, on average, 36 hours per week either teaching or engaging in other school-related activities, including 12 hours actually teaching mathematics. However, no account was taken of whether they were employed full- or part-time (Table 2.3).
- Close to 70 per cent of the Australian teachers agreed that they were familiar with ‘current ideas’ in mathematics teaching and learning, and a similar percentage said that the videotaped lesson was ‘a fair amount or a lot’ in accord with such ideas (Figures 2.1 & 2.4). However, several Australian teachers said they were not familiar with current ideas and that they were not aware of sources of information about them.
- Seventeen per cent (15) of the 87 videotaped Australian lessons were ‘double periods’. The mean and median observed durations of single-period lessons were 43 minutes and 44 minutes, respectively, with a standard deviation of 8 minutes.
- Process goals (most often concerned with using routine operations or calculations) were identified for 90 per cent of Australian lessons, content goals for 75 per cent of lessons, and perspective goals for 14 per cent of lessons (Figure 2.3 and Table 2.6).
- Eighty per cent of Australian teachers thought that their teaching of the videotaped lesson (Figure 2.6), and the difficulty of the content, were about the same as usual. Seventy-four per cent of the teachers reported that they often used the teaching methods they employed in the videotaped lesson, and 73 per cent thought their students’ behaviour was about the same as usual (Figure 2.5). However, Australian teachers spent more time (39 minutes, on average) than usual (24 minutes) in planning their lessons.

Chapter 3

PEDAGOGICAL ELEMENTS

Chapter 2 presented contextual information related to the video lessons. This chapter presents information on the way in which the lessons were organised. The following pedagogical elements are examined:

- The amount of time spent studying mathematics during classroom lessons;
- The main type of activity used to study mathematics in classrooms – solving mathematical problems;
- The ways in which lessons were partitioned among reviewing old material, introducing new material and practising new material;
- The grouping structures used to study mathematics – whole-class public discussions and private independent work, and combinations;
- The ways in which key ideas were clarified and lesson flow was enhanced or interrupted;
- The discourse evident during classroom lessons;
- The role of homework; and
- The resources used during classroom lessons.

These are some of the elements that together shape the learning environment for students. The research literature does not definitively suggest a preferred combination of these elements, or a right or wrong way of arranging them. Exploring the choices made by teachers in different countries provides an opportunity to gauge whether the choices made by Australian teachers are the best choices to achieve their learning goals.

Time Spent Studying Mathematics

As reported in Chapter 2, the median lesson length for the Australian videotaped lessons was 45 minutes. Although lesson length provides the boundaries of possible instruction time, the measure of most interest is the time actually spent working on mathematics. How much time did Australian Year 8 students spend studying mathematics?

➢ *In all the countries, including Australia, most lessons focused almost entirely on mathematical work (at least 95 per cent of lesson time).*

Because lesson time can be spent on other things, such as chatting about a musical concert the students attended the night before, it is important to mark the segments of the lesson devoted to mathematical work. The codes captured the following ways in which time was spent during the lessons:

- <u>Mathematical work</u>: Time spent on mathematical content presented either through a mathematical problem or outside the context of a problem, e.g., talking or reading about mathematical ideas, solving mathematical problems, practising mathematical procedures, or memorising mathematical definitions and rules.
- <u>Mathematical organisation</u>: Time spent preparing materials or discussing information related to mathematics, but not qualifying as mathematical work, e.g., distributing materials used to solve problems, discussing the marking scheme to be used on a test, or distributing a homework assignment.
- <u>Non-mathematical work</u>: Time spent on non-mathematical content, e.g., talking about a social function, disciplining a student while other students wait, or listening to school announcements on a public-address system.

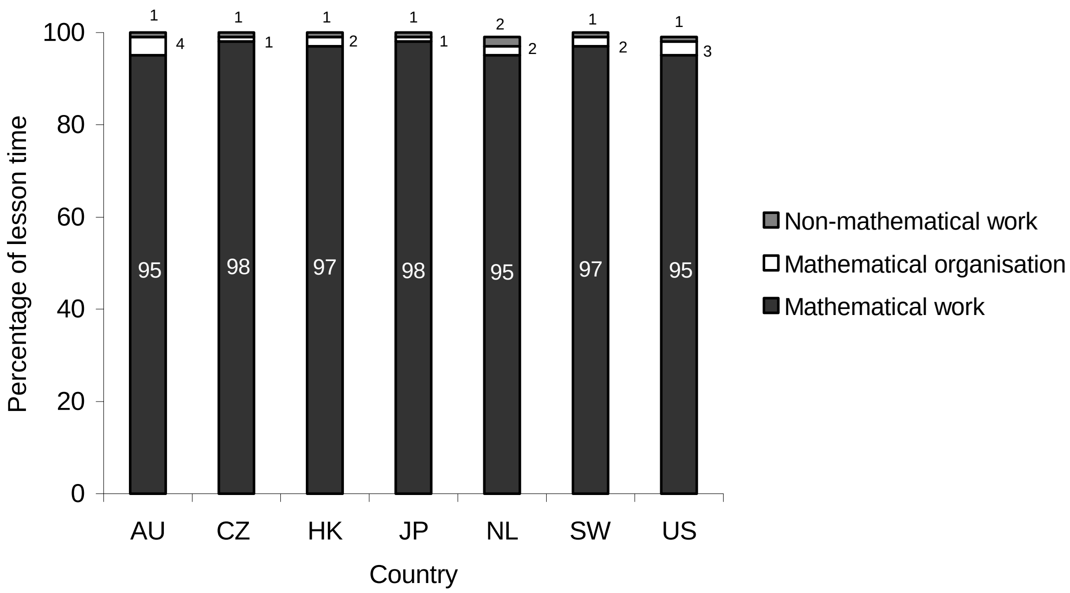
- Break: Time during the lesson, or between double lessons, that teachers designated as an official break for students.
- Technical problem: Time during the lesson when there was a technical problem with the video (such as lack of audio) that prevented members of the international coding team from making confident coding decisions about the segment.

The five types of lesson segments were mutually exclusive and exhaustive. Every second of every Year 8 mathematics lesson was coded into just one of these five types.

Figure 3.1 shows that, in all seven countries, an average of between 95 and 98 per cent of Year 8 students' lesson time focused on mathematical work. In Australia, 95 per cent of lesson time focused on mathematical work, or, putting this another way, only 5 per cent of time was *not* devoted to mathematical work. Multiplying by the median lesson time yields an estimated median time of only 2.25 minutes per lesson that Australian students were not engaged in mathematical work.

Nevertheless, Australian Year 8 students spent more lesson time (4%), on average, involved in mathematics organisation tasks than students in the Czech Republic, Hong Kong SAR, Japan and Switzerland. An example of a mathematics organisation segment in an Australian lesson can be viewed in *AU PRL 3*. In the segment, *41:00–43:10*, the teacher and students pack up a set of calculators they had used during the lesson.

Figure 3.1 Percentage of lesson time devoted to mathematical work, mathematical organisation, and non-mathematical work



Non-mathematical work: NL> CZ, HK, JP, SW
Mathematics organisation: AU>CZ, HK, JP, SW; NL>CZ; US>CZ, JP, SW
Mathematical work: CZ, JP>AU, NL, US; SW>AU, US, NL; HK>AU
Note: Percentages may not sum to 100 because of rounding. For each country, the average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons.

The Role of Problems

Given that most of the lesson time focused almost entirely on mathematical work, what did Australian Year 8 students do during mathematical work time?

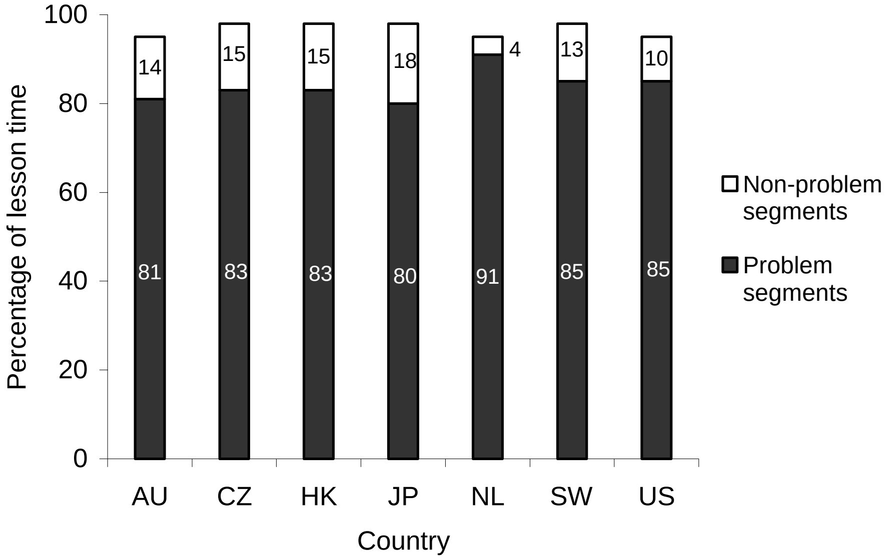
➢ *In all the countries, including Australia, at least 80 per cent of Year 8 students' lesson time, on average, was spent solving problems.*

While reviewing the videotapes, it became apparent that a considerable portion of lesson time was spent solving mathematical problems. During the remaining mathematical work time, the teacher might, for example, give a brief lecture. Therefore, mathematical work time was divided into mathematical problem segments and mathematical non-problem segments.

- Problem segments: Problems were defined as events that contained a statement asking for some unknown information that could be determined by applying a mathematical operation. Problems varied greatly in length and complexity, ranging from routine exercises to challenging problems. Although problems could be relatively undemanding, they needed to require some degree of thought by Year 8 students. Simple questions asking for immediately accessible information did not count as problems. Mathematical exercises of the following kinds were common:
  - Adding, subtracting, multiplying, and dividing whole numbers, decimals, fractions, percentages, and algebraic expressions;
  - Solving equations;
  - Measuring lines, areas, volumes, angles;
  - Plotting or reading graphs; and
  - Applying formulas to solve real-life problems.
- Non-problem segments: A non-problem segment was defined as mathematics work outside the context of a problem. Without presenting a problem statement, teachers (or students) sometimes engaged in:
  - Presenting mathematical definitions or concepts and describing their mathematical origins;
  - Giving an historical account of a mathematical idea or object;
  - Relating mathematics to situations in the real world;
  - Pointing out relationships among ideas in the videotaped lesson and previous lessons;
  - Providing an overview or a summary of the major points of the lesson; and
  - Playing mathematical games that did not involve solving mathematical problems (e.g., a word search for mathematical terms).

Figure 3.2 shows the average percentage of Year 8 mathematics lesson time devoted to problem and non-problem segments. Working on mathematical problems constituted a majority of Australian lesson time (81% on average). A greater percentage of lesson time was spent on mathematical problems in the Netherlands (91%) than in Australia and all the other countries except the United States.

Figure 3.2 Average percentage of lesson time devoted to problem and non-problem segments



Non-problem: AU, CZ, HK, JP, SW, US>NL
Problem: NL>AU, CZ, HK, JP, SW
Note: Percentages sum to average percentage of lesson time devoted to mathematical work per country (see Figure 3.1). For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons.

Independent, concurrent, and answered-only problems

Solving problems made up a large part of Year 8 students' mathematical work. What types of problems did Australian students work on?

➢ *Australian Year 8 students spent more time per lesson, on average, working on 'concurrent' problems than on 'independent' or 'answered-only' problems.*

Mathematical problems were treated in three different ways or, said another way, played three different roles during the lessons:

- Independent problems: Presented as single problems and worked on for a clearly definable period of time. These problems might have been solved publicly – as a whole class – or they might have contained a private work phase when students worked on them individually or in small groups.
- Concurrent problems: Presented as a set of problems, usually as an assignment from a worksheet or the textbook, to be worked on privately. Some of these problems might have eventually been discussed publicly as a whole class. Because they were assigned as a group and worked on privately, it was not possible to determine how long students spent working on any individual problem of this kind.
- Answered-only problems: Most often from homework or an earlier test, these problems had already been completed prior to the lesson, and only their answers were shared. They included no public discussion of a solution procedure and no time in which students worked on them privately.

It was important to distinguish among the problem types because they can provide different experiences for students. For example, working on a single problem with the whole class can be a different experience from working on a set of problems individually or in small groups, which can be different still from hearing only answers to problems completed as homework. Distinguishing among the problem types was also important because a teacher's selection of problems determines, in part, the structure and organisation of lessons. More than that, however, separating out the independent problems, for which it was possible to mark beginning and ending times, allowed further analyses of the nature of these problems.

Table 3.1 displays the average number of independent and answered-only problems per Year 8 mathematics lesson. The number of concurrent problems assigned per lesson is not reported because it provided little reliable information about what happened during the lesson. Concurrent problems were assigned as a group to be worked on privately. Sometimes the problems were worked on during class and sometimes outside of class. Sometimes the problems were to be completed for the next lesson and sometimes the assignment was for an entire week.

In Australia, an average of seven independent problems were worked on per lesson. In Japan, an average of three independent problems were worked on per lesson, significantly fewer than in all the other countries except Australia. Answered-only problems were rare, on average, in all countries. In Australia, on average, only one answered-only problem occurred per lesson.

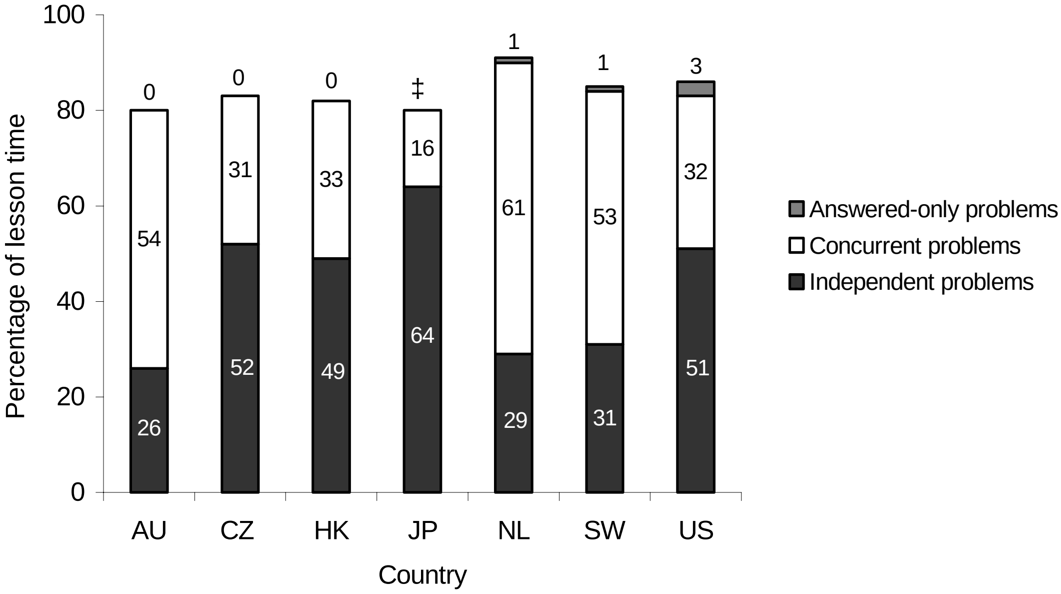
Table 3.1 Average number of independent and answered-only problems per lesson

Country	Independent problems	Answered-only problems
Australia (AU)	7	1
Czech Republic (CZ)	13	0
Hong Kong SAR (HK)	7	0
Japan (JP)	3	‡
Netherlands (NL)	8	2
Switzerland (SW)	5	3
United States (US)	10	5

‡ Fewer than three cases reported
Independent problems: CZ>HK, JP, NL, SW; HK, US>JP, SW; SW, NL>JP
Answered-only problems: US>CZ, HK (JP excluded from the analysis)

Figure 3.3 shows the percentage of Year 8 mathematics lesson time devoted to the different problem types. As noted above, although it was often unclear how many concurrent problems were actually worked on during the lesson, it was possible to accurately determine the proportion of lesson time devoted to solving concurrent problems. When considered together, Table 3.1 and Figure 3.3 provide a snapshot of the roles that mathematical problems played in the lessons within and across countries.

Figure 3.3 Average percentage of lesson time devoted to independent problems, concurrent problems, and answered-only problems



‡ Fewer than three cases reported
Independent problems: CZ, HK, JP, US>AU, NL, SW
Concurrent problems: AU, NL, SW>CZ, HK, JP, US
Answered-only problems: US>AU, CZ, HK (JP excluded from the analysis)
Note: For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons. Percentages sum to average percentage of lesson time devoted to problem segments per country, although in some cases they do not because of rounding or missing data.

Figure 3.3 indicates that part of the time in the videotaped lessons was spent solving independent problems and part of the time was spent working on concurrent problems, although in somewhat different proportions across the participating countries. Students in Australia, the Netherlands, and Switzerland spent more time on average than students in the other four countries working on concurrent problems. Conversely, the Czech Republic, Hong Kong SAR, Japan, and the United States devoted a greater percentage of lesson time on average to independent problems than the other three countries. Further, Australia, the Netherlands, and Switzerland spent proportionally more time on concurrent problems than on independent problems, while the reverse was true in the remaining four countries.

Examples of concurrent problem segments in Australian lessons can be viewed in *AU PRL 2 (00:38:02–00:44:31), AU PRL 3 (00:16:45–00:20:32* and *00:20:37–00:24:16)*, and *AU PRL 4 (00:46:53–00:55:32* and *00:55:54–01:07:38).*

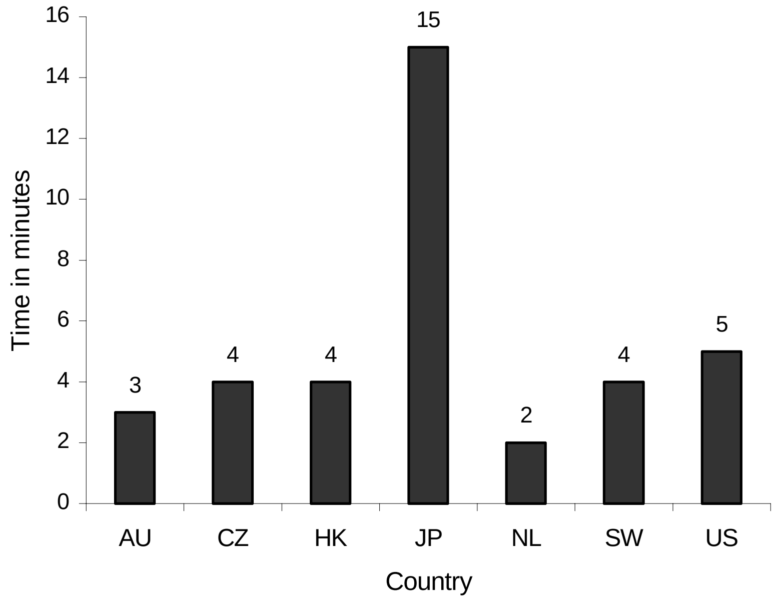
Time spent per problem

As noted earlier, it was possible to examine independent problems more carefully than concurrent problems because the exact time spent working on each problem could be calculated. How much time did Australian students spend per independent problem?

- *In Australian Year 8 mathematics lessons, significantly less time was spent working on an independent problem than in Japanese Year 8 lessons (Australia 3 minutes per independent problem, on average, and Japan 15 minutes per independent problem, on average).*

Figure 3.4 shows the number of minutes, on average, devoted to each independent problem in a lesson in each country. On average, more time (15 minutes) was spent working on each independent problem in Japan than in all the other countries (2–5 minutes). More time per problem could mean that the problems were more challenging, that the class spent more time discussing the problem, or simply that the teacher allowed more time for students to solve the problem.

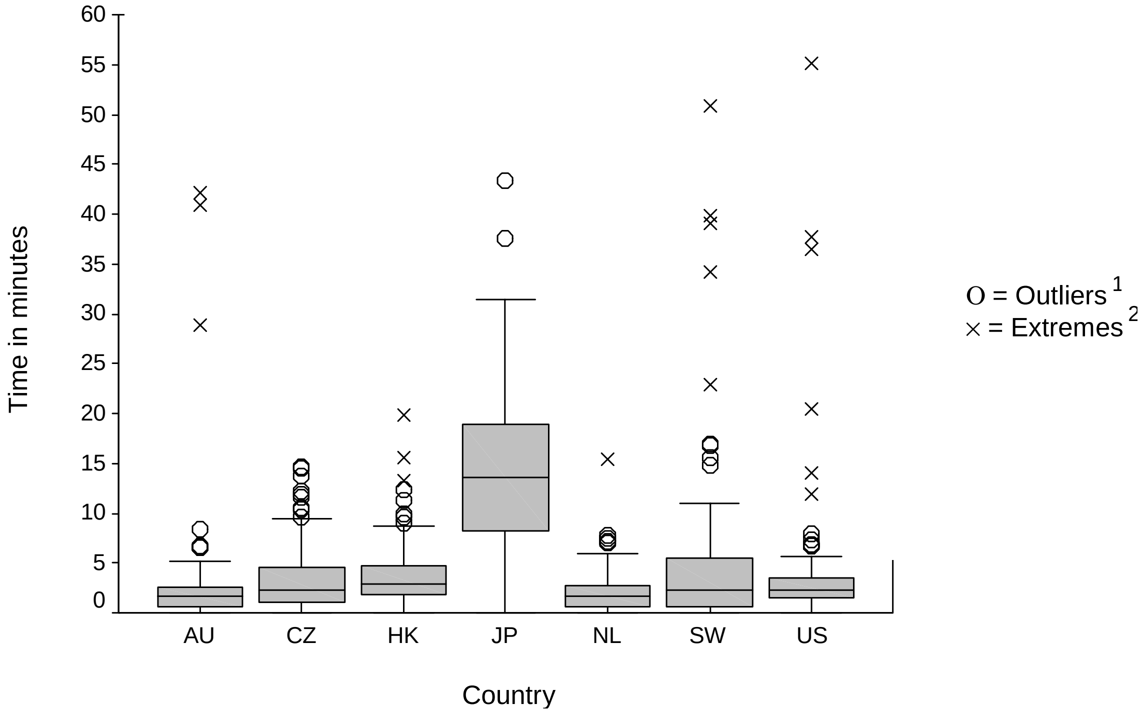
Figure 3.4 Average time per independent problem per lesson



CZ, HK, SW>NL; JP>AU, CZ, HK, NL, SW, US

The number of independent problems and time per independent problem were calculated by averaging across lessons. Naturally, there were variations among lessons with regard to the average time spent per independent problem. To get a sense of the variation within Australia and the other countries, it is useful to look at a box and whisker plot showing the distribution of lessons with regard to average time spent on each independent problem. Figure 3.5 shows this variation within each country.

Figure 3.5 Distribution of lessons based on average length of independent problems



[1] Outliers are values from 1.5 to 3.0 box lengths from the upper or lower edge of the box.
[2] Extremes are values greater than 3.0 box lengths from the upper or lower edge of the box.
Note: The shaded box represents the interquartile range, containing 50 per cent of the lessons. The lines extending from the box indicate the highest and lowest values, excluding outliers and extremes. The horizontal line within the box indicates the median.

As is evident in Figure 3.4, the average length of time per independent problem was higher in Japan than in the other countries. Figure 3.5 further shows that the majority of lessons in Australia and all of the other countries except Japan fell within a narrow range based on average time spent per independent problem. In Japan, the average time per independent problem in most lessons was approximately 10–20 minutes, but lessons with average problem times as long as 30 minutes were not uncommon. In Australia, most lessons had average independent problem times from 1–3 minutes and lessons with average problem times longer than approximately 5 minutes were uncommon. An example of a particularly long independent problem in an Australian lesson can be viewed in *AU PRL 1*. In the segment *00:13:10–00:42:12*, the teacher and students work on one independent problem for a period of 29 minutes. The problem focuses on the investigation of exterior angles in polygons.

By itself, time spent on problems says relatively little about the learning experiences of students. But, like other indicators in this chapter, it provides a kind of parameter that can enable and constrain students' experiences. It might be difficult, for example, for students to solve a challenging problem, to examine the details of mathematical relationships that are revealed in the problem, or to discuss with the teacher and peers the reasons that solution methods work as they do if the problem is completed quickly (National Research Council, 2001).

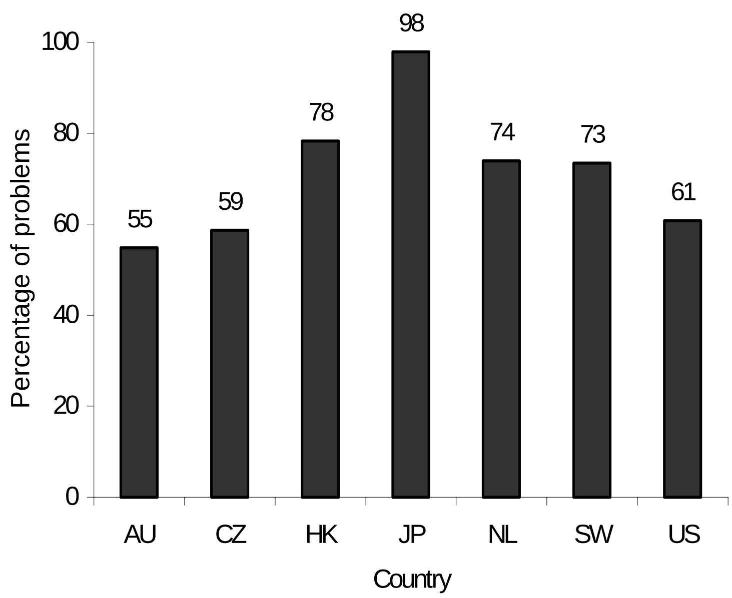
Another way to examine the time spent on problems is to ask what percentage of problems was worked through relatively quickly. Because a mathematical problem was defined to include simple, even routine, exercises, it could be the case that some problems, even a substantial percentage of problems, were worked through relatively quickly (less than 45 seconds). One would not necessarily expect these kinds of problems to provide the same learning opportunities as those that, for whatever reason, required more time to complete (National Research Council, 2001).

What percentage of Australian problems was worked through relatively quickly?

➢ *The percentage of problems per lesson, for which time could be reliably determined, that lasted at least 45 seconds, was significantly lower in Australia than in Hong Kong SAR, Japan, the Netherlands, and Switzerland.*

Problems that were worked out relatively quickly (less than 45 seconds) were distinguished from those that engaged students for longer periods of time (more than 45 seconds). The length of 45 seconds represented the consensus judgment of the Mathematics Code Development Team (see Appendix A) regarding a criterion that might separate many of the more routine exercises in the sample of Year 8 lessons from those that involved more extensive work. Included in this analysis were all problems except for answered-only problems and concurrent problems for which no solution was presented publicly. Figure 3.6 presents the percentage of independent and concurrent problems that exceeded 45 seconds, per Year 8 mathematics lesson, in each country.

Figure 3.6 Average percentage of independent and concurrent problems worked on for longer than 45 seconds



HK>AU, CZ, US; JP>AU, CZ, HK, NL, SW, US; NL>AU; SW>AU, CZ

Note: Concurrent problems with no publicly presented solution were excluded. For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons.

In all of the countries, the majority of problems per lesson, for which time could be reliably determined, were worked on for at least 45 seconds. Notably, almost all of the problems in Japan (98%) met this threshold criterion, a higher percentage than in any other country. This is consistent with findings reported earlier that Japan had the least number of independent problems worked on in each lesson (3, on average) and the longest time spent on each independent problem (15 minutes, on average).

By contrast, on average, Australia had 7 independent problems per lesson, only 3 minutes was spent on each independent problem, and 45 per cent of problems were worked on for less than 45 seconds. These findings seem at odds with *A National Statement on Mathematics for Australian Schools* which advocates that students should be encouraged to persist with tasks for increasing periods of time, and to work by themselves on problems from beginning to end (Australian Education Council, 1991, pp. 40 & 67). It brings the nature of the tasks that Australian students are set into question.

The Purpose of Different Lesson Segments

Mathematical problems, together with non-problem segments, can be used by teachers to accomplish different purposes. Further, different countries might define these purposes in somewhat different ways. In consultation with the National Research Coordinators in each participating country, the following three purposes were defined:

- Reviewing: This category focused on the review or reinforcement of content presented previously. These segments typically involved the practice or application of a topic learned in a prior lesson, or the review of an idea or procedure learned previously. Examples included:
  - Warm-up problems and games, often presented at the beginning of a lesson;
  - Review problems intended to prepare students for the new content;
  - Teacher lectures to remind students of previously learned content;
  - Checking the answers for previously completed homework problems; and
  - Quizzes and grading exercises.
- Introducing new content: This category focused on introducing content that students had not worked on in an earlier lesson. Examples of segments of this type included:
  - Teacher expositions, demonstrations, and illustrations;
  - Teacher and student explorations through solving problems that were different, at least in part, from problems the students had worked on previously;
  - Class discussions of new content; and
  - Reading textbooks and working through new problems privately.
- Practising new content: This category focused on practising or applying content introduced in the current lesson. These segments only occurred in lessons where new content was introduced. They typically took one of two forms: the practice or application of a topic already introduced in the lesson, or the follow-up discussion of an idea or formula after the class engaged in some practice or application. Examples of segments included:
  - Working on problems to practise or apply ideas or procedures introduced earlier in the lesson;
  - Class discussions of problem methods and solutions previously presented; and
  - Teacher lectures summarising or drawing conclusions about the new content presented earlier.

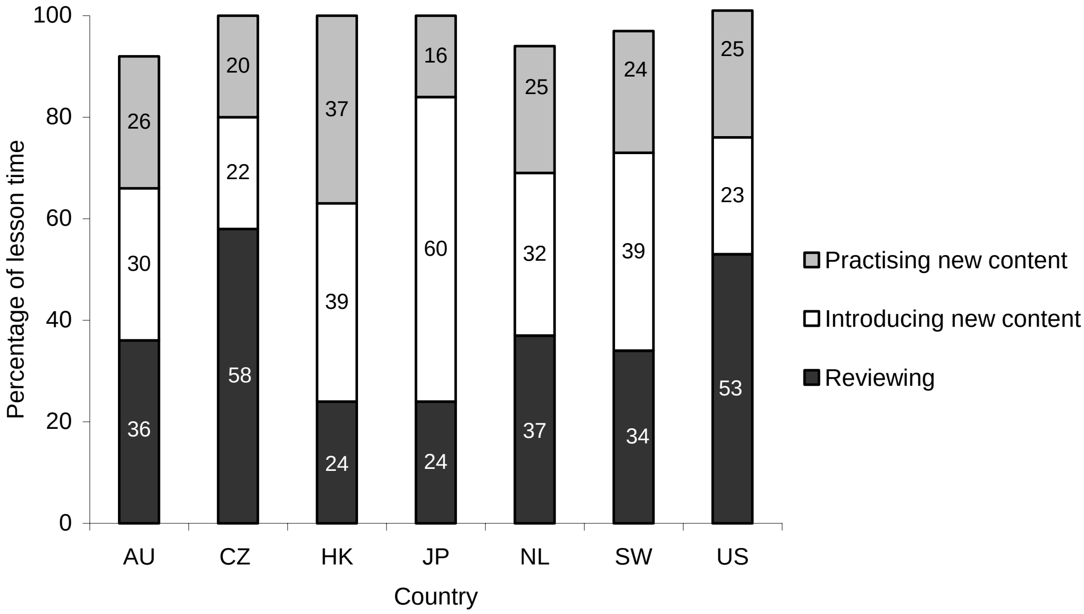
Segments coded as non-mathematical activity or mathematical organisation were incorporated into the immediately following purpose segment, except when they appeared at the end of a lesson in which case they were included in the immediately preceding purpose segment. In this manner, all events in a lesson were classified as one (and only one) of the three purpose types. Only if the purpose of a segment was not clear was it coded ‘unable to make a judgment’.

An entire Year 8 mathematics lesson might have had the same purpose throughout, or it might have been segmented into different purposes. How much time was spent on these various purposes in Australian lessons?

➢ *In Australia, on average, there was no significant difference in the amount of lesson time devoted to each purpose. However, a greater percentage of Year 8 mathematics lesson time, on average, was spent studying new content (i.e., either introducing or practising new content) than reviewing previously introduced content.*

Figure 3.7 displays the average percentage of lesson time devoted to each of the three purpose types.

Figure 3.7 Average percentage of lesson time devoted to various purposes



Reviewing: CZ>AU, HK, JP, NL, SW; US>HK, JP
Introducing new content: HK, SW>CZ, US; JP>AU, CZ, HK, NL, SW, US
Practising new content: HK>CZ, JP, SW
Note: For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons. Percentages may not sum to 100 because of rounding and the possibility of coding portions of lessons as ‘not able to make a judgment about the purpose’.

A typical Australian Year 8 mathematics lesson began with a review of previously learned content (an average of 36 per cent of lesson time), followed by the introduction of new content (30 per cent of lesson time), and the practising of this new content (26 per cent of lesson time). Typically, the review of previously learned content was conducted as a whole class activity led by the teacher, whereas the practising of new content was done by setting students to work individually (or, occasionally, in pairs or small groups) on sets of problems. Comments from the teachers of the Australian public release lessons illustrate this pattern.

> I start every lesson with 10 quick questions which are revision questions from the previous lesson… *(AU PRL 2, Teacher Commentary, 00:00:05)*
>
> Generally, I will ask the students 10 quick questions or give them a lateral thinking problem to bring them to focus so that workbooks are opened etc. and no time is wasted once the lesson proper begins. This I find useful to revise any formulas which might be used during the forthcoming lesson. *(AU PRL 3, Teacher Commentary, 00:00:33)*

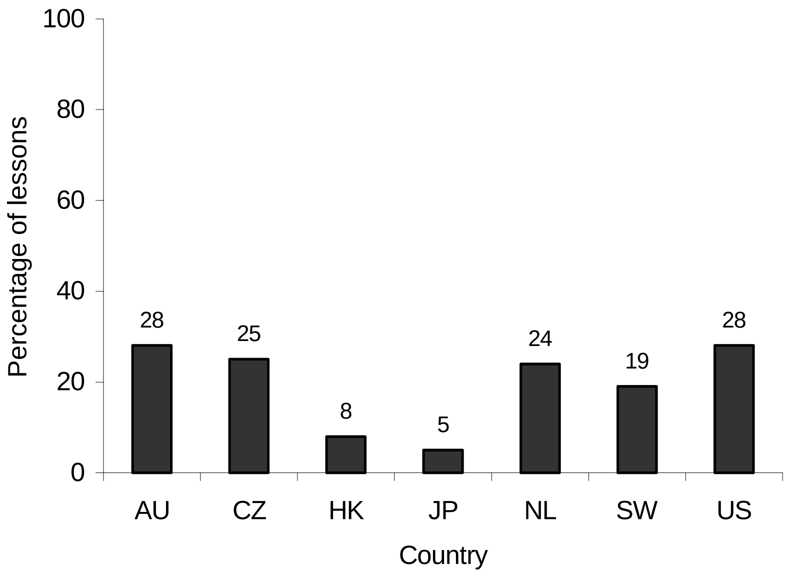
Teachers in all of the participating countries engaged students in the various purpose segments; but they differed in the emphases that they placed on reviewing previously introduced content and studying new content. More of the lesson time in Japan was spent introducing new content (on average, 60 per cent of lesson time) than in lessons in Australia and the other five countries. In Australia, Hong Kong SAR, Japan, the Netherlands, and Switzerland, a greater percentage of Year 8 mathematics lesson time was spent on new material relative to previously learned material (compare the lower section of each column of Figure 3.7 with the sum of the two upper sections). In the Czech Republic, the reverse occurred. In the United States there was no difference found between the average amount of time spent reviewing older material and working on new material.

An additional lens through which to view the distribution of lesson segments devoted to review of old content, versus those devoted to the introduction and practice of new content, is the percentage of lessons that focused on only one purpose. A question of special interest is whether any Year 8 mathematics lessons were limited only to review. Such lessons would seem more likely to provide students with opportunities to become more familiar and efficient with content they have already encountered, but less likely to have opportunities to learn new material. How many Australian lessons were limited only to review?

- *Australia, along with the United States, had the highest percentage of lessons that were entirely review (28%); Japan had the lowest percentage of lessons that were entirely review (5%).*

Figure 3.8 displays the percentage of lessons that were entirely review for each country. With more than one-quarter of lessons devoted to review, Australian students may have had more opportunities to consolidate content that was previously introduced to them than students in most other countries. However, it also indicates that there may have been less emphasis on students' accepting responsibility for their own learning than in some of the other countries.

Figure 3.8 Percentage of lessons that were entirely review



CZ, US>HK, JP

Classroom Interaction

Another element of the classroom environment that can enable and constrain different kinds of learning experiences for students is the way in which the teacher and students interact (Brophy, 1999). Many classrooms include both whole-class discussions or public work, in which the teacher and students interact publicly, with the intent that all students participate (at least by listening), and private work, in which students complete assignments individually or in small groups, and during which the teacher often circulates around the room and assists students who need help.

After viewing a number of the Year 8 mathematics lessons in the TIMSS 1999 Video Study sample, the Mathematics Code Development Team observed that some teachers in the seven participating countries occasionally used interaction types different from these two. To capture all the interaction structures, five types of classroom interaction were defined:

- Public interaction: Public presentation by the teacher or one or more students intended for all students.
- Private interaction: All students work at their seats, either individually, in pairs, or in small groups, often while the teacher circulates around the room and interacts privately with individual students.
- Optional, student presents information: A student presents information publicly in written form, sometimes accompanied by verbal interaction between the student and the teacher or other students about the written work; other students may attend to this information or work on an assignment privately.
- Optional, teacher presents information: The teacher presents information publicly, in either verbal or written form, and students may attend to this information or work on an assignment privately.
- Mixed private and public work: The teacher divides the class into groups – some students are assigned to work privately on problems, while others work publicly with the teacher.

These interaction types were mutually exclusive and exhaustive; each segment of lesson time was classified as a single type. What was the nature of classroom interaction in the Australian lessons?

➢ *Year 8 mathematics lessons in Australia devoted relatively equal amounts of time, on average, to public and private interaction categories.*

Table 3.2 displays the average percentage of lesson time devoted to public, private, and 'optional, student presents information.' 'Optional, teacher presents information' and 'mixed private and public work' together accounted for no more than 2 per cent of the lesson time in each country, on average, and are not shown in the table.

Table 3.2 Average percentage of lesson time devoted to 'public interaction', 'private interaction' and 'optional, student presents information'

	Public interaction	Private interaction	Optional, student presents information
Country		Per cent	
Australia (AU)	52	48	0
Czech Republic (CZ)	61	21	18
Hong Kong SAR (HK)	75	20	5
Japan (JP)	63	34	3
Netherlands (NL)	44	55	‡
Switzerland (SW)	54	44	1
United States (US)	67	32	1

‡ Fewer than 3 cases reported (NL excluded from the relevant analysis)
Public interaction: CZ>NL; HK>AU, CZ, JP, NL, SW; JP>AU, NL; US>AU, NL, SW
Private interaction: AU, SW>CZ, HK, JP, US; JP, US>CZ, HK; NL>CZ, HK, JP, SW, US
Optional, student presents information: CZ>AU, HK, JP, SW, US; JP>AU; HK>AU, SW, US
Note: For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons.

In all the countries the vast majority of class time was spent in either public or private interaction; but countries divided their time between them somewhat differently. In Australia, there was no significant difference between the percentage of lesson time spent in public and private interaction. In Hong Kong SAR, a greater percentage of lesson time was spent in public interaction (75%) than in all of the other countries except the United States. In the Netherlands, a greater percentage of time (55%) was spent in private interaction compared to all of the other countries except Australia. The Czech Republic was the only country to spend a substantial portion of time (18%) in the mixed type referred to as 'optional, student presents information.' An example of this mixed type of interaction can be viewed in *CZ PRL 1 (00:01:35–00:06:52)*. Almost no time was spent in this interaction type in Australia.

Varying the type of classroom interaction provides one way for teachers to structure the lesson and to emphasise different kinds of experiences. By shifting between interaction types, the teacher can modify the environment and ask students to work on mathematics in different ways. How often did Australian Year 8 mathematics teachers change interaction types (i.e., switch among the five defined categories) during a lesson?

- *Australian mathematics teachers made shifts in interaction types, on average, five times per Year 8 mathematics lesson.*

Shifts in interaction types during lessons ranged across the countries from three in the Netherlands to eight in Japan.[1] Teachers in Japan and the Czech Republic made more shifts than teachers in all the other countries, changing interaction types between seven and eight times per lesson, respectively. For all the countries, the number of interaction shifts was significantly greater than the number of purpose shifts (Australia: two purpose shifts, five interaction shifts). It appears that teachers in all the countries used changes in interaction types to vary the learning environment more often than they used changes in the purpose of the activity.

Group work

As noted earlier, private interaction was defined as the time when students were working individually, in pairs, or in small groups. How often did Australian students work alone? How often did they work with their peers?

- *In all countries, students worked individually more often than they worked in pairs or groups during private interaction time. The percentage of lesson time devoted to working in pairs or groups was highest in Australia (about 13 per cent).*

Figure 3.9 displays the average percentage of private interaction time during which students worked individually, or in pairs and groups. Across all the countries, on average, at least 73 per cent of private work time involved students completing tasks individually. The percentages ranged from 73 per cent in Australia to 95 per cent in Hong Kong SAR. Comparing percentages of time within countries shows that working individually was a more common activity for students in all the countries than was working together during private work time.

Australian students spent significantly more private interaction time in pairs or groups than students in the Czech Republic and Hong Kong SAR. The percentage of *total lesson time* devoted to pair and group work, an objective advocated in *A National Statement on Mathematics for Australian Schools* (Australian Education Council, 1991, p. 49), was highest in Australia (about 13 per cent[2]).

Group work was observed in all four of the Australian public release lessons.

> Working at the computer in groups of two… allows for student discussion, interaction, peer tutoring. Having a third person in a group is sometimes necessary but not ideal as they may not participate fully. Here the groups are chosen by the students. *(AU PRL 1, Teacher Commentary, 00:19:05)*

> The maths coordinator at our school encourages the teachers to do group activities in their lessons. This is in line with current practice... I chose this lesson as a group activity because one of the other teachers at my school had used this lesson quite successfully, although I had not done it myself. I allow the students to choose their own groups where possible, because they are comfortable sharing ideas with their friends. They also tend to choose friends with

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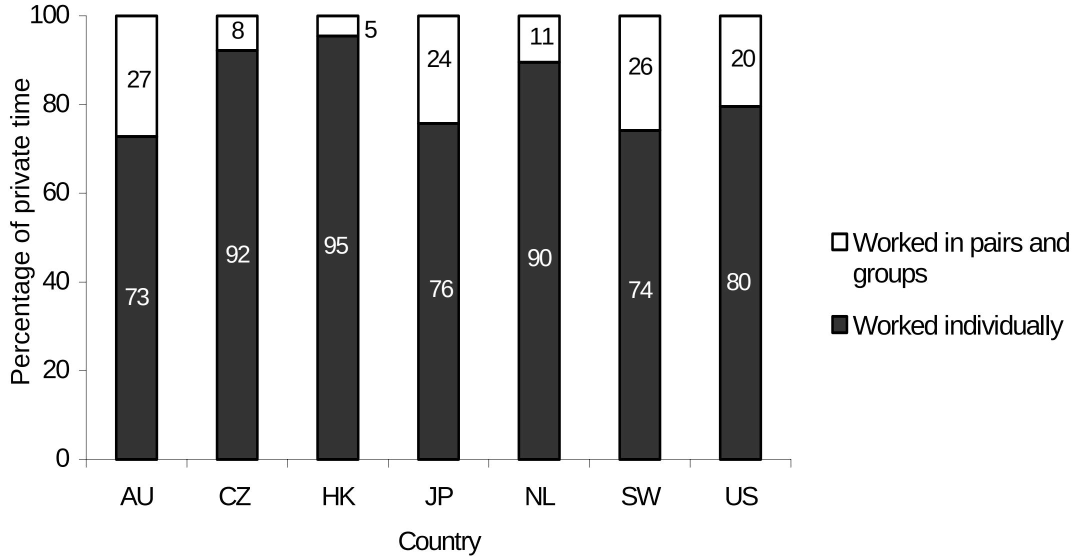
[1] Data not shown: see Hiebert et al. (2003), Table 3.7

[2] Calculated by combining data from Table 3.2 and Figure 3.9

similar ability, which extends the advanced students and helps with the self-esteem of the less able students. I believe that students learn better when they are able to collaborate. *(AU PRL 2, Teacher Commentary, 00:04:51)*

Figure 3.9 Average percentage of private interaction time that students worked individually or in pairs and groups



Worked individually: CZ>AU, JP, SW; HK>AU, JP, SW, US; NL>SW
Worked in pairs and groups: AU, JP, SW>CZ, HK; US>HK
Note: For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons.

Pedagogical Features that Influence Lesson Clarity and Flow

Another set of pedagogical elements of a lesson concerns lesson flow and clarity. These include lesson features that seem to highlight the major points of the lesson for the students or, on the other hand, might interrupt the flow of the lesson.

Goal statements and lesson summary statements

Two ways that teachers can help students identify the key mathematical points of a lesson are 1) to describe the goal of the lesson, and 2) to provide a lesson summary.

Goal statements were defined as explicit written or verbal statements by the teacher about the specific mathematical topic(s) that would be covered during the lesson. To count as a goal statement, the statement had to preview the mathematics that students encountered during at least one-third of the lesson time. How often did Australian teachers present goal statements in lessons?

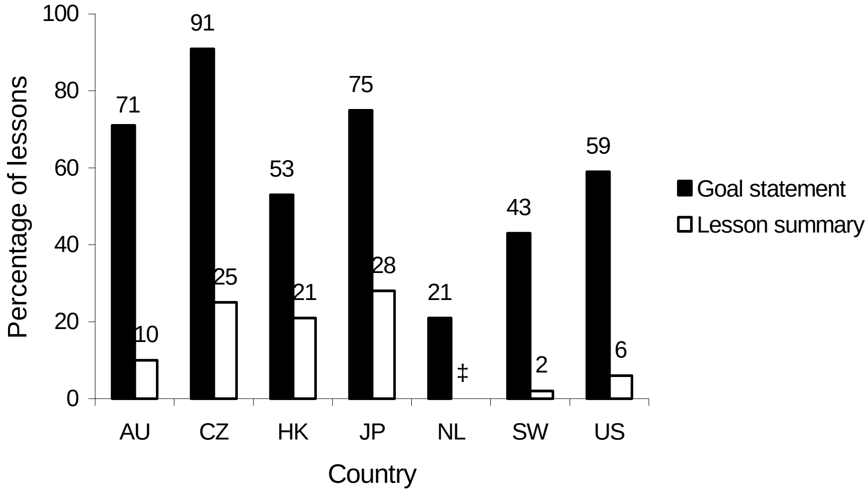
- *Seventy-one per cent of the Australian Year 8 mathematics lessons contained at least one goal statement.*

A second kind of aid to help students recognise the key ideas in a lesson is a *summary statement*. Summary statements highlight points that have just been studied in the lesson. They were defined as statements that occurred near the end of the public portions of the lesson and described the mathematical point(s) of the lesson. How often were lesson summary statements made in Australian lessons?

- *For all of the participating countries, lesson summaries were less common than goal statements. Lesson summaries were found in 10 per cent of lessons in Australia.*

Figure 3.10 displays the percentage of lessons that contained goal statements and lesson summary statements. A higher percentage of lessons in the Czech Republic contained goal statements provided by the teacher (91%) than in all the other countries except Japan. By contrast, goal statements were provided in a lower percentage of lessons (21%) in the Netherlands than in all the other countries.

Figure 3.10 Percentages of lessons that contained goal statements and lesson summary statements



‡ Fewer than three cases reported
Lessons contained at least one goal statement: AU>NL, SW; CZ>AU, HK, NL, SW, US; HK, JP, SW, US>NL
Lessons contained at least one summary statement: CZ> SW, US; HK, JP>SW (NL excluded from the analysis)

Lesson summaries were found in at least 21 per cent of Year 8 mathematics lessons in Japan, the Czech Republic and Hong Kong SAR, and in 10 per cent of lessons in Australia. In the other countries, less than 6 per cent of lessons included summary statements. Given the emphasis on summarising lessons in teacher training in Australia, the number of lessons in which lesson summary statements were made may seem lower than expected. One possible reason for this may be that teachers did not complete their lessons, as planned, during the time available. A comment in one of the Australian public release lessons indicates that the teacher 'unfortunately… was unable to complete the lesson' *(AU PRL 3, Teacher Commentary)*. In addition, some teachers indicated in their questionnaire responses that 'insufficient time to finish what I planned to teach' was a limitation of the videotaped lesson compared to how they would ideally like to teach that lesson.

An example of an Australian teacher providing a goal statement can be viewed in *AU PRL 2*. Following is the teacher's commentary related to that segment:

> I explained the aim of the lesson so that the students would understand the goal that they were trying to achieve… *(AU PRL 2, Teacher Commentary, 00:07:02)*

An example of an Australian teacher presenting a lesson summary statement can be viewed in *AU PRL 1*. According to the teacher:

> I wanted the students to get a feel for the results that the class had found. I knew that this activity would take more than one class period. Not all students have yet written a satisfactorily worded conclusion about the exterior angles of a pentagon. All students then need to see what happens for exterior angles of other polygons, and write a more general conclusion. These issues will be taken up in the next class. *(AU PRL 1, Teacher Commentary, 00:42:26)*

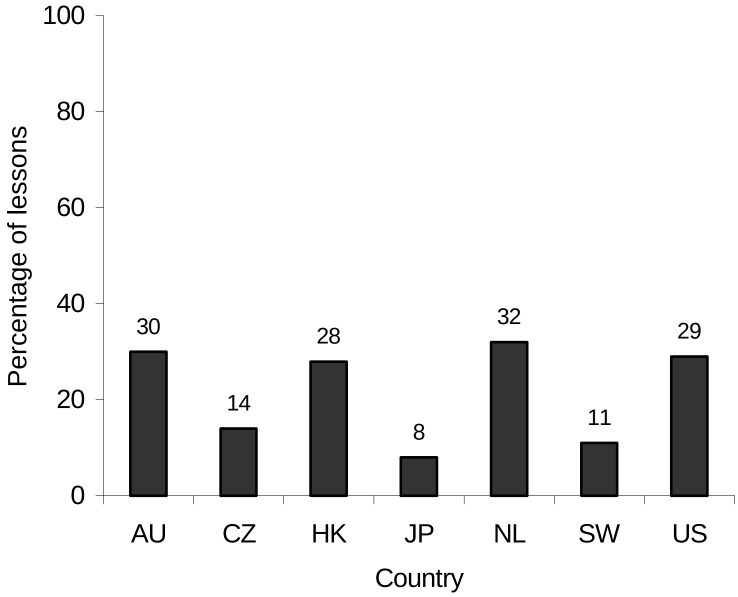
Outside interruptions

Whereas goal statements and summary statements can enhance the clarity of the key lesson ideas, interruptions to the lesson can break its flow and, perhaps, interfere with or delay developing the key ideas (Stigler & Hiebert, 1999). One kind of interruption comes from outside the classroom. Examples of outside interruptions include announcements over the intercom, individuals from outside the class requiring the teacher's attention, and talking to a student who has arrived late. How often were Australian lessons interrupted?

- *In Australia, 30 per cent of lessons were interrupted. However, on average, such interruptions occupied less than one minute of lesson time in total.*

Figure 3.11 displays the percentage of Year 8 mathematics lessons in which at least one outside interruption occurred. Around 30 per cent of lessons were interrupted in Australia, Hong Kong SAR, the Netherlands, and the United States. A larger percentage of lessons were interrupted in the Netherlands than in Japan. Other apparent differences between countries are not significant.

Figure 3.11 Percentage of lessons with outside interruptions



NL>JP

Thirty per cent of Australian lessons with interruptions may seem like a large number. However, outside interruptions were classified as non-mathematical work and, as reported earlier in the chapter (Figure 3.1), on average, only 1 per cent of lesson time (less than one minute) in Australia involved non-mathematical work. Hence, although there is no available direct measure of their length, on average, outside interruptions did not take much lesson time. Often they consisted of only an announcement made over the intercom, or one comment made by the teacher (for example, to a late student or a messenger from another class). On the other hand, it could be that the extent of outside interruptions was less than usual because filming was taking place.

Classroom Talk

The ways in which active student participation in classroom discourse affects learning is an enduring controversy in teaching research (Goldenberg, 1992/1993). Although most studies show that teachers talk the majority of the time while their students are listeners (Goodlad, 1984; Hoetker & Ahlbrand, 1969), there is disagreement over the effect of this pattern on learning. Advocates of student talk argue that limited student talk reduces learning opportunities towards low-level skills and factually oriented instruction (Bunyi, 1997; Cazden, 1988). They suggest that student interaction increases opportunities for students to elaborate, clarify, and reorganise their own thinking (Ball, 1993; Hatano, 1988). Others argue that student learning is best fostered by explicit or direct teaching, where teachers necessarily have substantially more talk opportunities than students (Gage, 1978; Walberg, 1986). A third view suggests the optimum ratio of teacher to student talk is a function of the content students are to learn (Goldenberg, 1992/1993). In summary, there is no broad consensus regarding the impact of student participation in classroom discourse.

Classroom discourse research suggests that students must utter more than single words or short phrases before their participation can qualify as active or be indicative of opportunities for extended discussion of academic content (Cazden, 1988). Word-based measures provide a proxy indication of whether that is the case, and to what extent classroom discourse is teacher-dominated in terms of opportunities to talk.

In Australia, active involvement of students, including a focus on student talk, is encouraged in *A National Statement on Mathematics for Australian Schools* (Australian Education Council, 1991, pp.17 & 19). How often did students talk publicly in the Australian Year 8 mathematics lessons?

➢ *In all the participating countries, including Australia, teachers spoke more words publicly per lesson than students (a ratio of at least 8:1 words). In Australian lessons, on average, teachers spoke 9 words to every one student word, 79 per cent of teacher utterances consisted of at least 5 words, and 71 per cent of student utterances consisted of fewer than 5 words.*

Computer-assisted text analyses were applied by the specialist Text Analysis Group (see Appendix A) to English transcripts of all segments of public interaction to quantify how often Year 8 students talked during mathematics lessons.[3] To account for the variation in lesson durations and average public interaction time, comparisons examined teacher and student talk standardised for 50 minutes of lesson time. A first indicator of how talk was shared between teachers and students is the total number of words spoken by teachers and students during public interaction. The average number of teacher and student words per lesson was relatively uniform across countries. The number of teacher words ranged from 5148 in Japan to 5902 in the United States. Australian teachers spoke, on average, 5536 words per lesson. The number of student words ranged from 640 in Hong Kong SAR to 1018 in the United States. Australian students spoke, on average, 810 words.[4]

A second indicator of the relative share of talk time afforded to students during public interaction is the ratio of teacher to student talk. Figure 3.12 shows the ratio of teacher to student talk per lesson. In all the countries teachers spoke more words than did students per lesson, at a ratio of at least 8:1. Hong Kong SAR Year 8 mathematics teachers spoke significantly more words relative to their students (16:1) than did teachers in Australia (9:1), the Czech Republic (9:1), and the United States (8:1).

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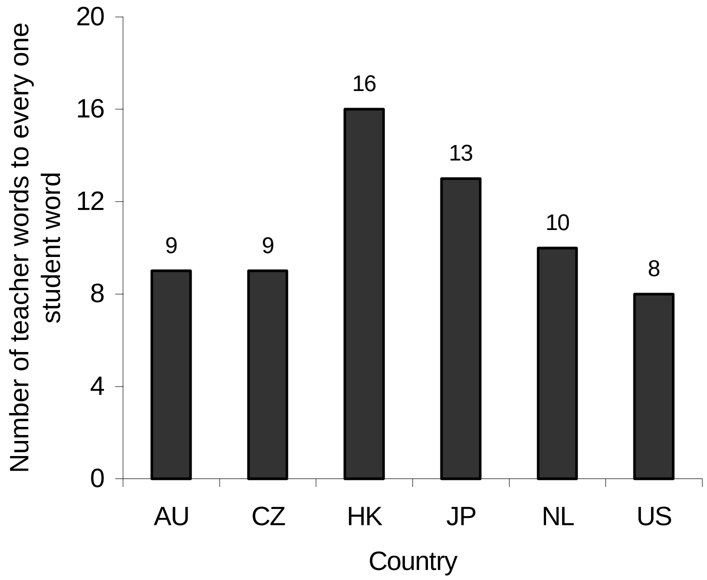
[3] English transcriptions of Swiss lessons were not available for text analyses.

[4] Data not shown: see Hiebert et al. (2003), Figure 5.14

Figure 3.12 Average number of teacher words to every one student word per lesson



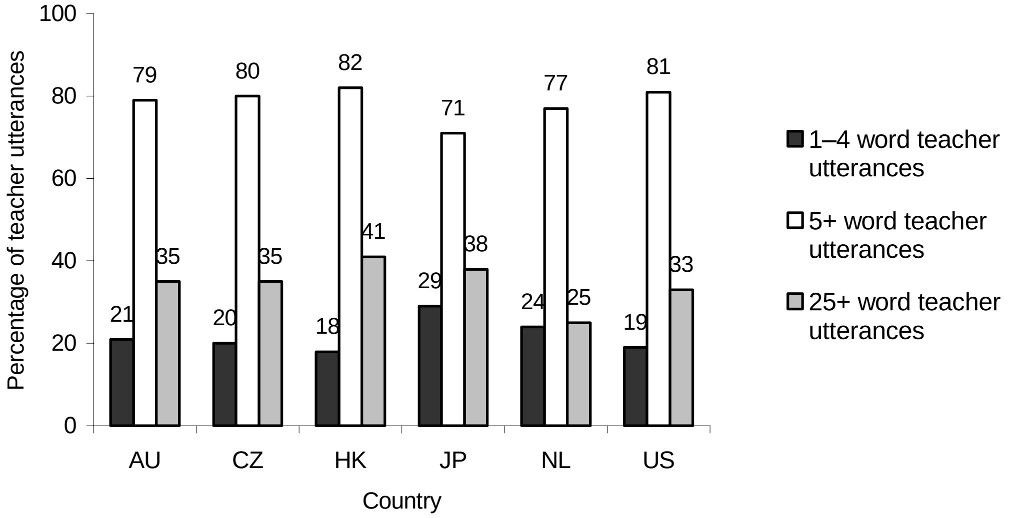
HK>AU, CZ, US

Note: Analyses were based on English transcripts of public interaction segments of lessons. English transcriptions of Swiss lessons were not available for text analyses.

A third indicator of opportunity to talk during lessons is the length of each utterance. For purposes of this analysis, an utterance was defined as talk by one speaker uninterrupted by another speaker. Overlapping speech was transcribed with each speaker's contribution recorded as a separate utterance, if audible. Transcribers were instructed to identify a new utterance any time a new speaker began talking, and to note who was speaking (e.g., teacher or student). Longer student utterances are often interpreted as indicators of opportunities for fuller student participation in classroom discussions, whereas short utterances often reflect faster-paced 'back and forth' exchanges between teachers and students. In faster-paced exchanges, students are typically restricted to single words or short phrases (Cazden, 1988; Goldenberg, 1992/1993).

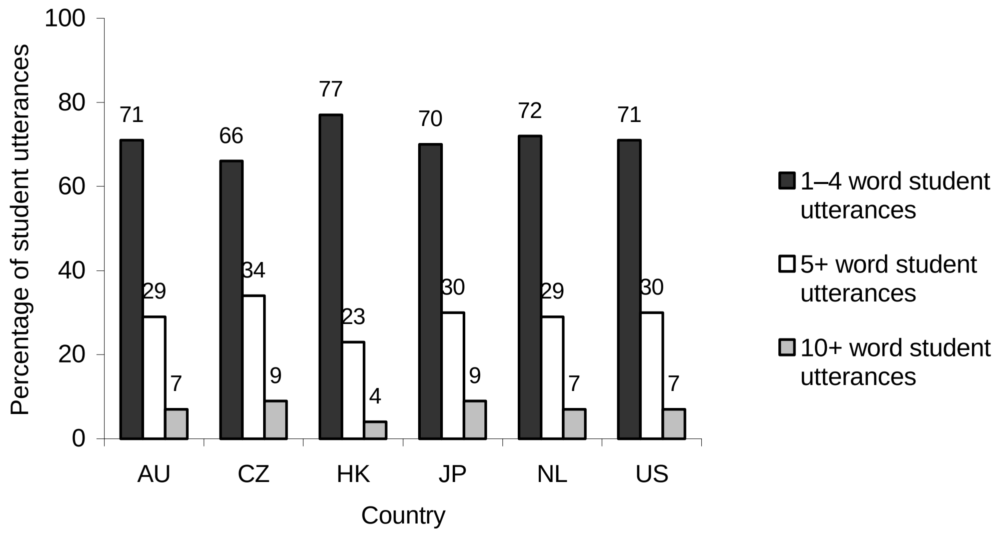
Figures 3.13 and 3.14 display the average percentage of teacher and student utterances of different lengths per lesson. Between 71 and 82 per cent of all teacher utterances on average per lesson contained at least 5 words (Figure 3.13). In contrast, between 66 and 77 per cent of student utterances on average per lesson contained fewer than 5 words (Figure 3.14). In none of the countries did the number of longer student utterances (10+ words) exceed 9 per cent. However, there were differences between countries on specific dimensions, indicating that lessons in some countries provided different opportunities than others, although in absolute terms none of these differences is large.

Figure 3.13 Average percentage of teacher utterances of each length per lesson



Percentage of teacher utterances that were 1–4 words: JP>AU, CZ, HK, US; NL>CZ, HK, US
Percentage of teacher utterances that were 5+ words: AU, CZ, HK, US>JP; HK>NL
Percentage of teacher utterances that were 25+ words: AU, CZ, JP, US>NL; HK>AU, CZ, NL, US
Note: Percentage of teacher utterances that were 25+ words is a subset of teacher utterances that were 5+ words. Analyses were based on English transcripts of public interaction segments of lessons. For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons. Percentages of 1–4 word teacher utterances and 5+ word teacher utterances may not sum to 100 because of rounding.

Figure 3.14 Average percentage of student utterances of each length per lesson



Percentage of student utterances that were 1–4 words: HK>AU, CZ, JP, NL, US; NL, US>CZ
Percentage of student utterances that were 5+ words: AU, JP, NL, US>HK; CZ>HK, NL, US
Percentage of student utterances that were 10+ words: AU, CZ, JP, NL, US>HK
Note: Percentage of student utterances that were 10+ words is a subset of student utterances that were 5+ words. Analyses were based on English transcripts of public interaction segments of lessons. For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons. Percentages of 1–4 word student utterances and 5+ word student utterances may not sum to 100 because of rounding.

What were some of the differences between Australia and the other countries? Year 8 mathematics lessons taught by Japanese teachers had significantly more short utterances (1, 2, 3, or 4 words in length) by teachers, and significantly fewer 5+ word utterances by teachers, than those in Australia. Lessons taught by Dutch teachers had fewer 'mini-lectures' (utterances of 25+ words) than did lessons taught by mathematics teachers in Australia. By contrast, the mathematics lessons in Hong Kong SAR were distinct from lessons in Australia by having significantly more mini-lectures delivered by teachers. Lessons in Hong Kong SAR also had more short utterances (1, 2, 3, or 4 words), and fewer longer utterances (5+ and 10+ words), delivered by students than lessons in Australia and all the other countries for which these analyses were conducted.

An example of one Australian teacher's attempt to encourage student talk can be viewed in the segment *00:34:20-00:34:44* of *AU PRL 2*. Following is the teacher's commentary related to that segment:

> This was another example of where the student described the answer in her own words, which was different from the conventional maths description. I feel that it is important to listen carefully to a student's answer and not to judge it on what you expect to hear. *(AU PRL 2, Teacher Commentary, 00:34:35)*

In broad terms, the Year 8 mathematics lessons in all the countries revealed many brief opportunities for students to talk while mathematical work was being done, and very few long opportunities. This is similar to the pattern often reported in the literature, in which teachers talk and students listen (Cazden, 1988; Goodlad, 1984; Hoetker & Ahlbrand, 1969).

The Role of Homework

The decision to incorporate homework within a lesson can have a direct impact on how that lesson is organised. That is, teachers can review problems students completed prior to the lesson, allow students to begin homework problems assigned for a future lesson, or both. How frequently did Australian teachers assign homework?

- ➢ *Homework was assigned in 62 per cent of Australian Year 8 mathematics lessons.*

Figure 3.15 displays the percentage of lessons in which homework was assigned. Homework was assigned in at least 57 per cent of the lessons in all countries except Japan. However, the time spent by teachers and students working on, or discussing, homework assignments during the lesson varied. Students in the Netherlands spent an estimated 10 minutes per lesson, on average, beginning their homework assignment during the lesson.[5] This was significantly more time than in all the other countries (ranging from 1 minute in Japan to 4 minutes in Australia and Switzerland).[6]

The ways in which homework problems completed for the videotaped lesson were corrected and discussed also varied. In Australia, on average, teachers spent an estimated 1 minute per lesson correcting or discussing, on average, 3 problems that had been previously assigned as homework. This was significantly less time and significantly fewer problems than teachers and students in the Netherlands (an estimated 16 minutes per lesson and 12 problems per lesson). The average number of problems per lesson previously assigned as homework, and the average time spent going over this homework, were both more in the Netherlands than in Australia, the Czech Republic, Hong Kong SAR and Japan.[7]

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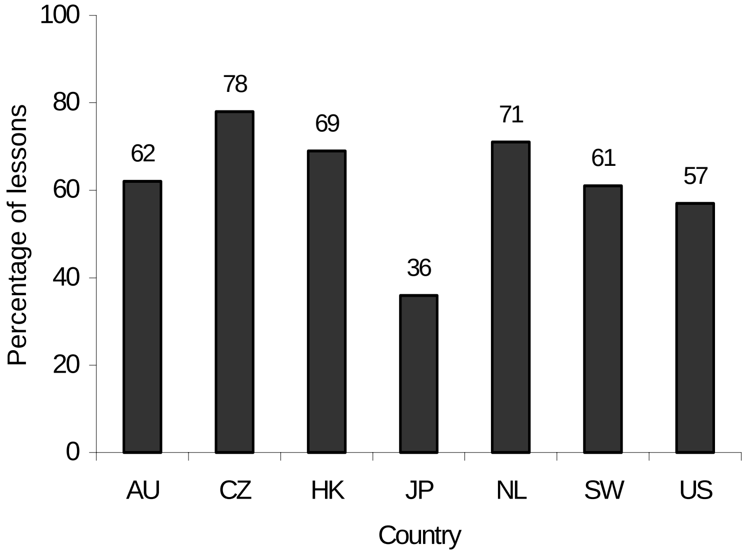
[5] This number includes the exact amount of time spent on all independent and answered-only problems assigned as homework, plus an estimate of the length of time spent on all concurrent problems previously assigned as homework. This estimate was calculated for each lesson by dividing the total length of time spent on concurrent problems by the number of concurrent problems, and multiplying the result by the number of concurrent problems assigned as future homework.

[6] Data not shown: see Hiebert et al. (2003), Table 3.8

[7] Data not shown: see Hiebert et al. (2003), Table 3.9

Figure 3.15 Percentage of lessons in which homework was assigned



AU, CZ, HK, NL, SW>JP

While homework played some role in Australian Year 8 mathematics lessons, it was not treated as a central part of the lessons as it was in the Netherlands. In some Australian lessons, homework assignments were monitored or collected at the beginning of lessons for later correction, instead of being discussed during the lesson. In other lessons, homework was monitored while students worked on other activities during the lesson. The teachers of the Australian public release lessons, as well as the Australian National Research Coordinator, made specific comments about the role of homework during lessons and how it is normally handled.

> For some lessons completion of assigned homework or other material would be monitored at this stage of the lesson, or students might place completed work in a designated place at the front of the room. *(AU PRL 1, Teacher Commentary, 00:02:50)*
>
> I check the homework and record who has done it. I do this when they are doing individual work so that I can answer any problems [questions] that they have on an individual basis. *(AU PRL 2, Teacher Commentary, 00:39:55)*
>
> The teacher is recording whether the student did the homework; she is not correcting it. It is up to the student to raise any difficulties that she had with the homework. This approach to checking homework becomes more and more common in later years in Australian schools. However, at Year 8 it is quite common for homework to be collected and marked by the teacher. *(AU PRL 2, National Research Coordinator Commentary, 00:41:40)*
>
> Our school policy encourages homework to be set and checked regularly (if not daily). Students can lose marks, get detentions, have letters [sent] home if there is a persistent problem with incomplete work. *(AU PRL 4, Teacher Commentary, 00:21:46)*

Homework was a relatively minor part of the lesson, on average, in the Czech Republic, Hong Kong SAR, and Japan. However, it should not be concluded that students in these countries do less mathematics outside of class than their counterparts in the other countries (see, for example, Schümer (1999) for a discussion of the role in Japan of voluntary studies at home and private supplementary lessons).

Resources Used

This chapter concludes by identifying the kinds of supportive materials that were used during the videotaped Year 8 mathematics lessons. Uses of the following kinds of resources were coded. In all cases, the resource was marked if it was used at any point in the lesson. If the materials and technology were present but not used, they were not included in these analyses.

- *Blackboard:* Included blackboards and whiteboards.
- *Projector:* Included overhead, video, and computer projectors.
- *Textbook/worksheets:* Included textbooks, review sheets, study sheets, and worksheets.
- *Special mathematics materials:* Included materials such as graph paper, graph boards, hundreds tables, geometric solids, base-ten blocks, rulers, measuring tape, compasses, protractors, and computer software that simulates constructions of models.
- *Real-world objects:* Included objects such as cans, beans, toothpicks, maps, dice, newspapers, magazines, and springs.
- *Calculators:* Included computational and graphing calculators, but each was marked separately.
- *Computers*.

How often were resources, other than calculators and computers, used in Australian Year 8 mathematics lessons?

➢ *At least 90 per cent of lessons in all countries, including Australia, used either a textbook or worksheet (Australia: 91%). Nearly all lessons (97%) in Australia used blackboards, but relatively few (16%) used overhead projectors.*

Table 3.3 depicts the percentage of Year 8 mathematics lessons during which a blackboard, a projector, a textbook or worksheet, special mathematical materials, and real-world objects were used. In the United States, less use was made of a blackboard, and more use of a projector, than in all the other countries. One obvious reason for the low percentage of projector use in the Netherlands is the relatively low amount of lesson time (44%) spent in public interaction (Table 3.2). In Australia, it appeared that in many cases where overhead projectors were used, they were set up permanently in the classroom.

The fact that real-world objects were used in 21 per cent of lessons in Australia, the numerically highest percentage of any country, may not be surprising given the emphasis placed on this in *A National Statement on Mathematics for Australian Schools* (Australian Education Council, 1991, p. 78).

Table 3.3 Percentage of lessons during which various resource materials were used

	Resources used				
	Blackboard	Projector	Textbook/ worksheet	Special mathematics materials	Real-world objects
Country	Per cent				
Australia (AU)	97	16	91	44	21
Czech Republic (CZ)	100	23	100	66	10
Hong Kong SAR (HK)	97	12	99	30	4
Japan (JP)[1]	98	11	92	86	19
Netherlands (NL)	96	3	100	81	7
Switzerland (SW)	90	49	95	32	20
United States (US)	71	59	98	44	15

[1] The Japanese sample contained a high percentage of two-dimensional geometry problems relative to the other countries.

Blackboard: AU, CZ, HK, JP, NL>US

Projector: CZ>NL; SW, US>AU, CZ, HK, JP, NL

Textbook/worksheet: HK>JP

Special mathematics materials: CZ>HK, SW; JP>AU, CZ, HK, SW, US; NL>AU, HK, SW, US

Real-world objects: AU, SW, US>HK

Note: Percentage of lessons reported for Japan with respect to blackboard, projector, and textbook/worksheet use differs from that reported in Stigler et al. (1999) because the definitions were changed for the current study.

Calculators and computers

With the increasing use of technology in all aspects of society, there is special interest in the use of calculators and computers in mathematics classes (Fey & Hirsch, 1992; Kaput, 1992; Ruthven, 1996). The use of calculators is a contested issue, with opponents concerned that calculator use, especially in the early grades, will limit students' computational fluency, and advocates arguing that calculators are an increasingly common tool that can be used in the classroom to facilitate students' learning (National Research Council, 2001).

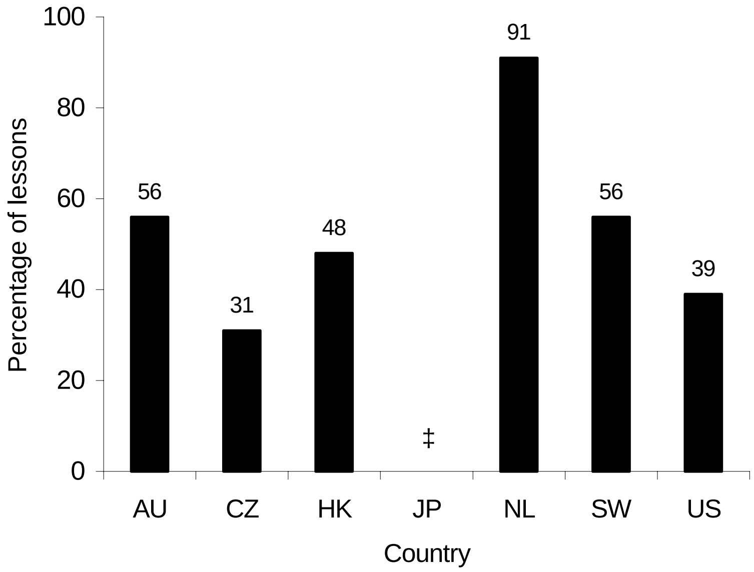
In 1987, all Australian education systems endorsed a national calculator policy that recommended all students use calculators at all year levels, K–12 (Curriculum Development Centre & Australian Association of Mathematics Teachers, 1986). The Australian Education Council further endorsed that recommendation in its *National Statement on Mathematics for Australian Schools* in 1991. How often were computational calculators (i.e., non-graphics calculators) used in the Australian Year 8 videotaped mathematics lessons?

➢ *Computational calculators were used in 56 per cent of lessons in Australia.*

Figure 3.16 displays the percentage of lessons during which computational calculators were used. Computational calculators were used more frequently in the Netherlands than in all the other countries. Calculators used for graphing were rarely seen in the Year 8 mathematics lessons in the participating countries, except in the United States where they were used in 6 per cent of the lessons. In all the other countries, including Australia, graphing calculators were observed too infrequently to calculate reliable estimates for their use.[8]

[8] It is likely that graphing calculators are used more frequently in Australian Year 8 mathematics classes nowadays than was the case in 1999–2000 when these data were collected.

Figure 3.16 Percentage of lessons during which computational calculators were used



‡ Fewer than three cases reported: the Japanese sample contained a high percentage of two-dimensional geometry problems relative to the other countries.
NL>AU, CZ, HK, SW, US; SW>CZ (JP excluded from the analysis)

How often were computers used in the videotaped Year 8 mathematics lessons?

- *Computers were used in relatively few of the lessons across the countries (Australia: 4 per cent of lessons).*

AU PRL 1 is an example of an Australian lesson that used computers. In the segment *00:13:10–00:42:12*, students use a software geometry package to investigate the exterior angles of polygons. Overall, however, it appears that the use of computers in 1999–2000 was lagging behind the expectations of *A National Statement on Mathematics for Australian Schools* (Australian Education Council, 1991, p. 14).

Summary

Teaching can be analysed from many perspectives. The approach taken in this study was to focus on features of teaching that seem likely to influence the learning opportunities for students (Brophy 1999; National Research Council, 1999, 2001; Stigler et al., 1999), and the way these features fit together.

In this chapter, results were presented on pedagogical elements of the videotaped Year 8 mathematics lessons. These elements helped shape the kinds of learning experiences that were likely to occur, and are direct indicators of the nature of the teaching. The results of this chapter represent some basic teaching choices that appeared in the lessons of Australia and the other participating countries.

At one level, it appears that educators in the seven countries made similar pedagogical choices. They used many of the same basic ingredients. Virtually all Year 8 lessons contained mathematical problems, and most of the instructional time was devoted to solving problems (Figure 3.2). Some problems were presented for class discussion and some were assigned as a set for working on privately (Table 3.1 and Figure 3.3). Across all lessons, teachers devoted some time to reviewing old content, introducing new content, and practising new content (Figure 3.7). Work was accomplished through two primary social structures: working together as a whole class and working privately (Table 3.2). In all countries teachers spoke more words publicly than students (Figure 3.12). Nearly all lessons used either a textbook or worksheet (Table 3.3), and computers were used in relatively few lessons across countries.

A closer look reveals, however, that there were detectable differences among countries in the relative emphasis they placed on different pedagogical elements. What were the pedagogical features and emphases of Australian lessons that were similar to and different from the other countries?

Key results concerning Australia reported in this chapter include the following:

- Australian Year 8 teachers and students, like those in every country, spent a very high percentage of lesson time engaged in mathematical work (Figure 3.1).
- Mathematics in Australian Year 8 classes, and classes in all other countries, was taught predominantly through solving problems (Figure 3.2).
- Australian Year 8 students spent more time working on sets of ‘concurrent problems’ than on ‘independent’ or ‘answered-only’ problems (Figure 3.3).
- Just under half of the problems presented in Australian Year 8 lessons were worked through relatively quickly (Figure 3.6), and significantly less time was spent working on each independent problem than in Japan (Figure 3.4).
- In Australia, a greater percentage of lesson time was spent either introducing or practising new content than reviewing previously introduced content (Figure 3.7).
- Australia and the United States had the highest percentage of lessons (28%) that were entirely review (Figure 3.8).
- Relatively equal amounts of time were devoted to public work and private work in Australian lessons (Table 3.2).
- The percentage of lesson time (13%) devoted to working in pairs or groups was highest in Australia (Table 3.2 and Figure 3.9).
- Goal statements occurred in 71 per cent of Australian lessons, but summary statements only occurred in 10 per cent of lessons (Figure 3.10).
- Australian Year 8 teachers spoke 9 words to every one word spoken by their students during ‘public interaction’ (Figure 3.12).
- Homework was assigned in 62 per cent of Australian Year 8 lessons (Figure 3.15), but very little public class time was devoted to discussing, or working on, homework problems.
- A blackboard or whiteboard was used in nearly all Australian lessons, and a textbook or worksheet was used in 91 per cent of lessons (Table 3.3).

Chapter 4

MATHEMATICAL CONTENT

Chapter 3 presented information on the way in which Year 8 mathematics lessons were organised, by examining some of the pedagogical elements of the videotaped lessons. The other main aspect of a lesson that influences students' opportunities to learn mathematics is, of course, its mathematical content. This chapter describes the mathematical content of the videotaped lessons, and the way in which that content was treated.

As reported in Chapter 3, most of the mathematics instruction in the participating countries occurred through presenting and solving problems (Figure 3.2). Accordingly, this activity is explored in detail. The following aspects are examined:

- The context in which problems were presented;
- The mathematical demands of problems;
- How problems in a lesson were related to each other;
- How problems were worked on during the lessons; and
- The kinds of mathematical processes that were used to solve problems.

Topics Covered During the Lessons

The filmed lessons in the TIMSS 1999 Video Study were obtained by sampling steadily over the school year (except for the 1995 Japanese sample[1]). This means it is reasonable to presume that each country's sample is somewhat representative of the topics covered during Year 8 as a whole. What topics were covered during the Australian lessons?

➢ *In Australian lessons, on average, 36 per cent of problems dealt with Number, 29 per cent with Geometry (Measurement and Space), 22 per cent with Algebra, and 9 per cent with Statistics. There were indications that the general curricular level of Australian Year 8 mathematics lessons was lower, and the algebra content less demanding, than in most of the other countries.*

One way of describing the topics included in the lessons was to label each mathematical problem dealt with in a lesson as pertaining to a specific topic. The topics addressed by the mathematical problems were grouped into five major categories and several sub-categories.

- *Number:* Whole numbers, fractions, decimals, ratio, proportion, percentage, and integers;
- *Geometry:* Measurement (perimeter and area), two-dimensional geometry (polygons, angles, lines, transformations and constructions), and three-dimensional geometry;
- *Statistics:* Probability, statistics, and graphical representation of data;
- *Algebra:* Operations with linear expressions, linear equations, inequalities and graphs of linear functions, and quadratic and higher degree equations; and
- *Trigonometry:* Trigonometric identities, equations with trigonometric expressions.

In some lessons, all of the problems were from one topic sub-category, such as linear equations, whereas in other lessons the problems were from more than one sub-category, and in some cases, more than one major category. Fifty per cent of the Australian lessons contained problems from more than one major content category.[2] Table 4.1 shows the average percentage per Year 8 lesson of mathematical problems within each major content category and within sub-categories for

[1] As noted in Chapter 1, Japanese data were collected over only a portion of the school year (in 1995).

[2] Data not shown: see Hiebert et al. (2003), Figure 4.8

number, geometry and algebra. Note, however, that because the sample was not chosen to represent systematically the curriculum in each country, no statistical comparisons were made.

In all seven countries, at least 82 per cent of the problems per lesson, on average, addressed three major curriculum areas: number, geometry, and algebra. In the Czech Republic, Hong Kong SAR, the Netherlands, and the United States, about 40 per cent of problems involved algebra. The percentages of problems involving algebra for Australia (22%), Japan (12%),[1] and Switzerland (22%) were much lower. In Hong Kong SAR, on average, 14 per cent of the problems per lesson involved trigonometry, but trigonometry problems occurred too infrequently to report reliable estimates in the other countries.

Table 4.1 Average percentage of problems per lesson within each topic area

	Country						
Topic area	AU	CZ	HK	JP	NL	SW	US
Number	*36*	*27*	*18*	‡	*16*	*42*	*30*
Whole numbers, fractions, decimals	15	13	5	‡	6	20	17
Ratio, proportion, percent	19	4	10	‡	6	19	6
Integers	2	9	3	‡	4	3	8
Geometry	*29*	*26*	*24*	*84*	*32*	*33*	*22*
Measurement (perimeter and area)	10	6	3	11	9	12	13
Two-dimensional geometry	14	15	17	73	15	17	4
Three-dimensional geometry	5	6	5	‡	9	4	5
Statistics	*9*	*3*	*2*	‡	*10*	*2*	*6*
Algebra	*22*	*43*	*40*	*12*	*41*	*22*	*41*
Linear expressions	7	16	11	‡	6	5	6
Solutions and graphs of linear equations and inequalities	15	21	23	12	33	14	27
Higher-order functions	‡	6	6	‡	3	3	8
Trigonometry	‡	‡	*14*	‡	‡	‡	‡
Other	‡	*1*	‡	‡	‡	*1*	*1*

‡ Fewer than three cases reported

Note: Percentages may not sum to 100 because of rounding and missing data. For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons.

In Australia, the number of mathematical problems per lesson varied widely. Two lessons contained no independent or concurrent problems, whereas in three lessons more than 100 problems were set. In one lesson, 135 problems were set for students to do, including 124 low procedural complexity algebra problems.[3] Another lesson contained 108 problems, including 101 low procedural complexity number problems. The mean number of problems per lesson in Australia was 27.4, with at least 50 problems set in 20 per cent of the videotaped lessons.

Because of the variation in numbers of problems per lesson, the data in Table 4.1 does not necessarily reflect the relative emphasis given to the various topic areas across the lessons within a country. In Australia, according to responses to the Teacher Questionnaire, the weighted percentage of lessons per major topic category was: Number 23%, Geometry 29%, Statistics 10%, Algebra 21% and Trigonometry 3%. The topics of the remaining 14 per cent of lessons were given as ‘problem solving and logical reasoning’ (10%), and ‘review’ (4%).

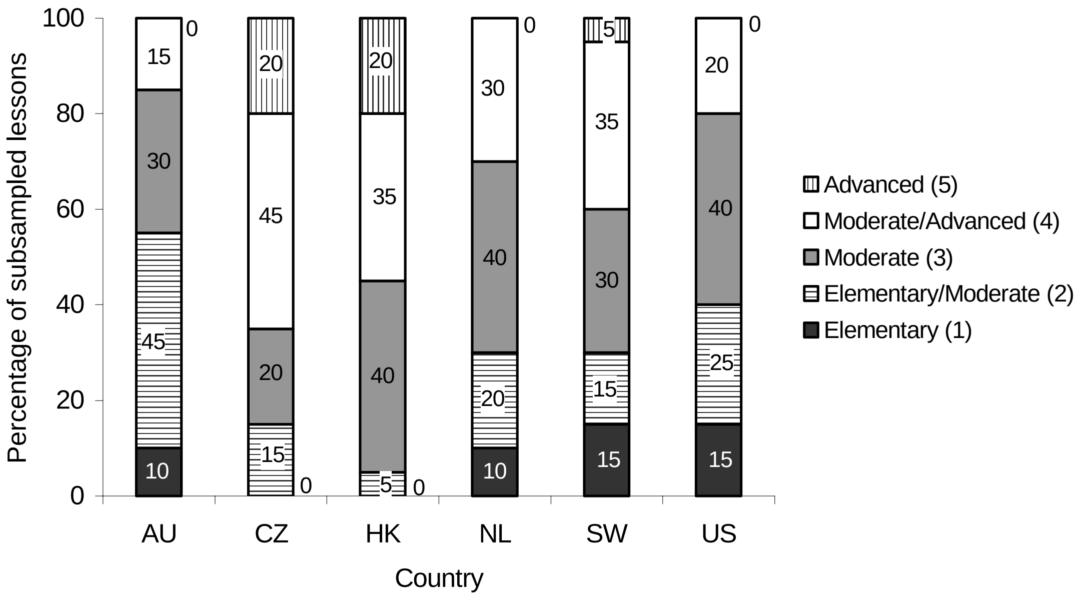
[3] See ‘Mathematical Demands of Problems’ later in this chapter for a discussion of procedural complexity.

Curricular level of the content

The Mathematical Quality Analysis Group (see Appendix A) examined country-blind written records of 20 lessons selected from each country's sample, except for Japan. One of the codes developed by the group placed each lesson in the subsample into one of five curricular levels, from elementary (1) to advanced (5). The moderate or mid level (3) was defined to include content that usually is encountered by students just prior to the standard topics of a beginning algebra course that often is taught in Year 8 in the United States. One rating was assigned to each lesson based on the rating that best described the content of the lesson, taken as a whole.

Figure 4.1 shows the percentage of Year 8 mathematics lessons assigned to each rating. Because these analyses were limited to a subset of the total sample of lessons, the percentages were not compared statistically and the results should be interpreted with caution as they may not be representative of the entire sample. However, it is of concern that 17 (85%) of the 20 Australian lessons were rated as having 'elementary', 'elementary/moderate', or 'moderate' content, while none of the lessons was given the 'advanced' content rating.

Figure 4.1 Percentage of lessons at each content level in subsample



Note: Lessons included here are a random subsample of lessons in each country. Results should be interpreted with caution because they might not be representative of the entire sample. A moderate ranking was defined to include content that usually is encountered by students just prior to the standard topics of a beginning algebra course that is often taught in Year 8 in the United States.

Problem Context

A National Statement on Mathematics for Australian Schools (Australian Education Council, 1991) states that 'All students should be involved in applying mathematics to practical problems.' (p. 59). How often were Australian students required to apply mathematics to real-life situations?

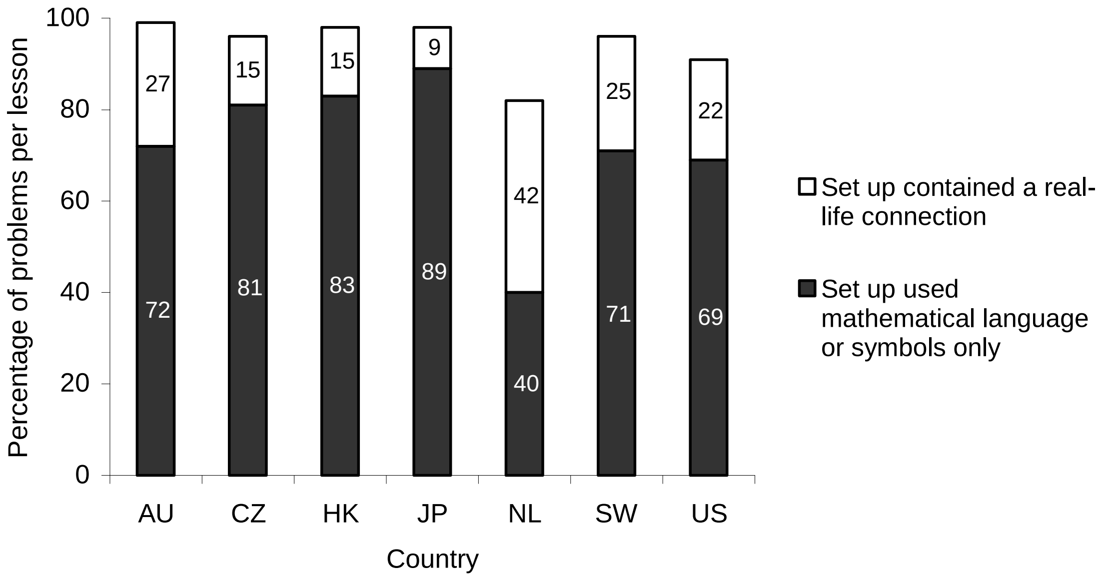
- *In Australia, on average, 45 per cent of problems per mathematics lesson were applications, but not necessarily real-life applications. On average, in Australia, 27 per cent of problems per lesson had a real-life setting.*

Real-life situations

Mathematical problems can be presented to students within a real-life context or by using only mathematical language with written symbols. The 'chocolate chip cookies' problem in *AU PRL 3 (00:03:34)* is an example of a problem with a real-life connection. Figure 4.2 shows the percentage of problems per Year 8 mathematics lesson that were presented or set up using real-life situations. If teachers brought in real-life connections later, when solving the problems, this was coded separately.

In Australia, on average, 27 per cent of problems per lesson were set up using real-life connections. This was a greater percentage than in Japan (9%), which, conversely, had a greater percentage (89%) of problems that were set up using mathematical symbols or language only than Australia (72%). The Netherlands had a smaller percentage (40 per cent per lesson, on average) of problems that were set up using mathematical symbols or language only than in any other country, and a higher percentage (42%) that were set with a real-life connection than in all the other countries except Australia and Switzerland.

Figure 4.2 Average percentage of problems per lesson set up with the use of a real-life connection, or set up using mathematical language or symbols only



Set up contained a real-life connection: AU, SW>JP; NL>CZ, HK, JP, US
Set up used mathematical language or symbols only: AU, CZ, HK, JP, SW, US>NL; JP>AU, SW, US
Note: Analyses do not include answered-only problems (i.e., problems that were completed prior to the videotaped lesson and only their answers were shared). Percentages may not sum to 100 because some problems were marked as 'unknown' and are not included here. For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons.

Applications

Working on mathematical problems can take a variety of forms. For example, students can be taught a particular procedure and then be asked to practise that procedure on a series of similar problems. These problems can be called exercises. Alternatively, students can be asked to apply procedures they have learned in one context in order to solve problems presented in a different context. These problems can be called *applications*. Applications often are presented using verbal descriptions, graphs, or diagrams rather than just mathematical symbols. They are important because they require students to make decisions about how and when to use procedures they may have already learned and practised. In this sense, applications are, by definition, more conceptually demanding than routine exercises for the same topic.

Applications might, or might not, be presented in real-life settings. Figure 4.3 shows a problem set up without a real-life connection that was classified as an application.

Figure 4.3 Example of an application problem: 'Find the measure of angle *x*.'

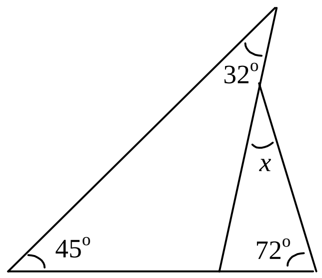
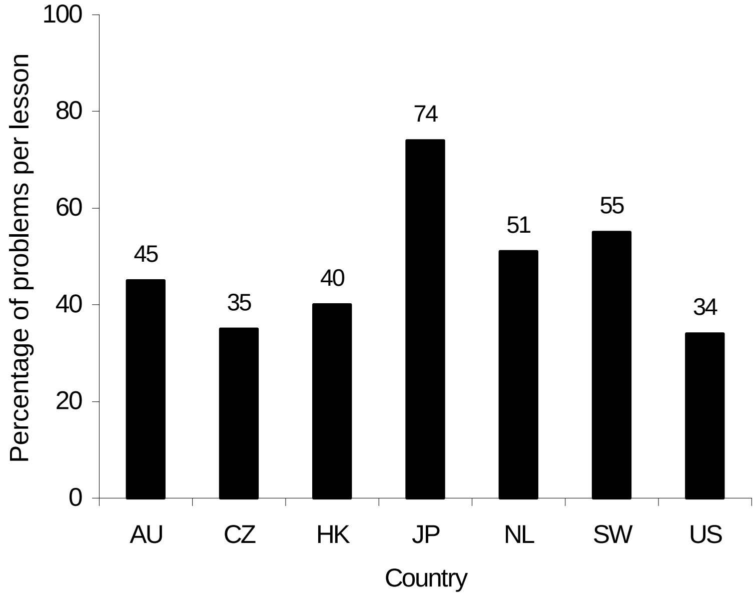


Figure 4.4 shows the percentages of problems per lesson, on average, classified as applications across the participating countries. Japanese lessons contained a higher percentage of applications per lesson (74%) than did lessons from Australia (45%) and all the other countries except Switzerland (55%).

Figure 4.4 Average percentage of problems per lesson that were applications



JP>AU, CZ, HK, NL, US; NL>US; SW>CZ

Note: Analyses do not include answered-only problems (i.e., problems that were completed prior to the videotaped lesson and only their answers were shared). For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons.

Mathematical Demands of Problems

Two characteristics of the mathematics presented during lessons are its complexity, and the kind of reasoning that is involved when doing the mathematics.

Procedural complexity

The complexity of a problem depends on a number of factors, including the experience and capability of the student. One kind of complexity that can be defined independent of the student is procedural complexity – the number of steps it takes to solve a problem using a common solution method. How complex were the problems presented in the Australian lessons?

➢ *Like all the other countries except Japan, most of the problems (77%) presented in the Australian lessons were of low procedural complexity, and few (8%) were of high procedural complexity.*

Every independent or concurrent problem worked on or assigned during each lesson was classified as low, moderate, or high procedural complexity according to the following definitions:

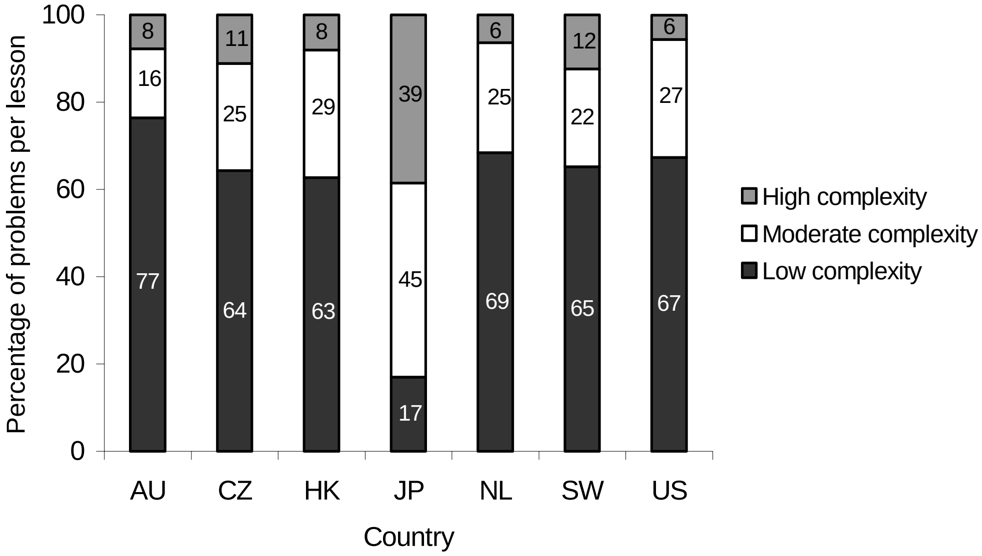
- Low complexity: Solving the problem, using conventional procedures, requires four or fewer decisions (small steps) by the students. The problem contains no sub-problems, or tasks embedded in larger problems that could themselves be coded as problems.
  - Example: Solve the equation: $2x + 7 = 2$.
- Moderate complexity: Solving the problem, using conventional procedures, requires more than four decisions by the students and can contain one sub-problem..
  - Example: Solve the set of equations for x and y: $2y = 3x – 4$; $2x + y = 5$.
- High complexity: Solving the problem, using conventional procedures, requires more than four decisions by the students and contains two or more sub-problems.
  - Example: Graph the following linear inequalities and find the area of intersection: $y \geq –1$; $y \leq x + 4$; $x \leq 2$.

Figure 4.5 shows the average percentage of problems per Year 8 mathematics lesson that were of each complexity level. In each country, except Japan, at least 63 per cent of the mathematical problems per lesson, on average, were of low procedural complexity and no more than 12 per cent of the problems were of high procedural complexity. Japanese lessons contained fewer problems (17%) of low complexity than Australia (77%) and all the other countries, and more problems (39%) of high complexity (Australia: 8%).

An example of a low complexity problem can be found in *AU PRL 4 (00:03:23)*. An example of a high complexity problem can be found in *AU PRL 2 (00:06:52)*.

Because the Japanese sample contained lessons with high percentages of two-dimensional geometry problems relative to the other countries, a question is raised about whether the relatively high complexity profile in Japan was due to the topic sample. In fact, when comparing just two-dimensional geometry problems, the procedural complexity of problems in Japanese lessons is more like those in the other countries. However, there still are a smaller percentage of low complexity problems in Japan than in Australia, Hong Kong SAR, and the Netherlands, and a larger percentage of high complexity problems in Japan than in Australia and Hong Kong SAR.

Figure 4.5 Average percentage of problems per lesson at each level of procedural complexity



High complexity: JP>AU, CZ, HK, NL, SW, US
Moderate complexity: HK>AU; JP>AU, SW
Low complexity: AU, CZ, HK, NL, SW, US>JP
Note: Percentages may not sum to 100 because of rounding. For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons.

Mathematical reasoning

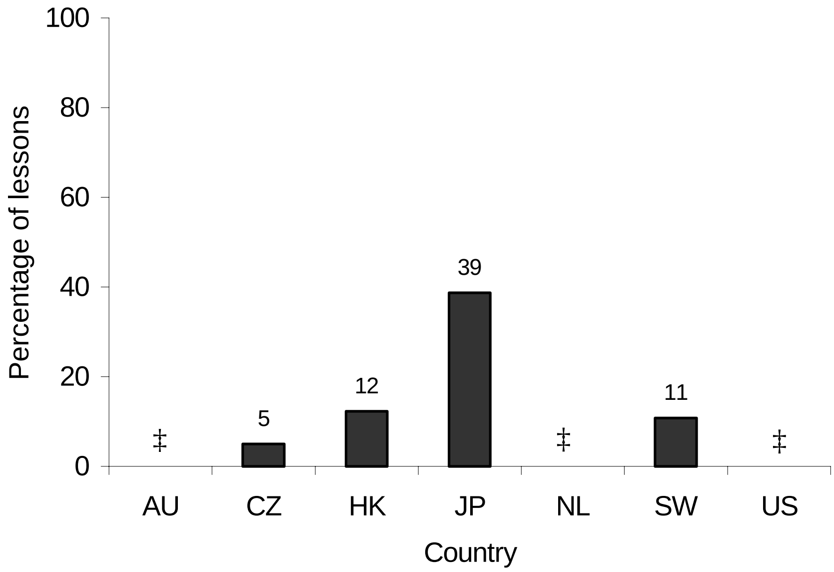
One of the features that distinguish mathematics from other school subjects is the special forms of reasoning that can be involved in solving problems (National Research Council, 2001). One such form of special reasoning is deductive reasoning, the kind of reasoning required to complete a mathematical proof. How often were mathematical proofs present in Australian lessons?

- *Fewer than 3 of the 87 Australian Year 8 mathematics lessons contained a formal, or informal, mathematical proof.*

All independent and concurrent mathematical problems were examined for whether they involved proofs. A problem was coded as a proof if the teacher or students verified, or demonstrated, that the result must be true by reasoning from the given conditions to the result using a logically connected sequence of steps. Figure 4.6 shows that proofs were evident to a substantial degree only in Japanese lessons, and practically not at all in Australian, Dutch and United States lessons. Similar results were found when comparing, across countries, the average percentages of all problems per lesson that included proofs, and when comparing just two-dimensional geometry problems.[4]

[4] Data not shown: see Hiebert et al. (2003), Figures 4.3 & 4.5

Figure 4.6 Percentage of lessons that contained at least one proof



‡ Fewer than three cases reported
JP>CZ, HK, SW (AU, NL and US excluded from the analysis)
Note: The percentage reported for Japan differs from that reported in Stigler et al. (1999) because the definition for proof was changed for the current study.

The apparent lack of occurrence of deductive reasoning in Australian Year 8 mathematics lessons was supported by an analysis of the Mathematics Quality Analysis Group which found that none of the subsample of 20 Australian lessons contained instances of deductive reasoning. With regard to other special forms of mathematical reasoning, the group found that 25 per cent of the Australian subsample lessons contained instances of 'developing a rationale',[5] 10 per cent contained instances of generalisations, and 10 per cent involved demonstrating that a conjecture cannot be true by showing a counter-example.

Relationships Among Problems

Because mathematical problems were used as vehicles for much of the content of the videotaped lessons, the mathematical coherence of a lesson depended, at least in part, on the way in which the problems within the lesson were related to each other. How were the problems in Australian lessons related?

➢ *Three-quarters of the problems presented in Australian lessons were repetitions of preceding problems. Very few (4%) were unrelated to any preceding problem.*

The mathematical relationships among all the problems (both independent and concurrent problems) presented during the videotaped lessons were coded. Each problem, except the first problem in the lesson, was classified as having one (and only one) of four kinds of relationships:

- <u>Repetition</u>: The problem was the same, or mostly the same, as a preceding problem in the lesson. It required essentially the same operations to solve although the numerical or algebraic expression might be different.
- <u>Mathematically related</u>: The problem was related to a preceding problem in the lesson in a mathematically significant way. This included using the solution to a previous problem for

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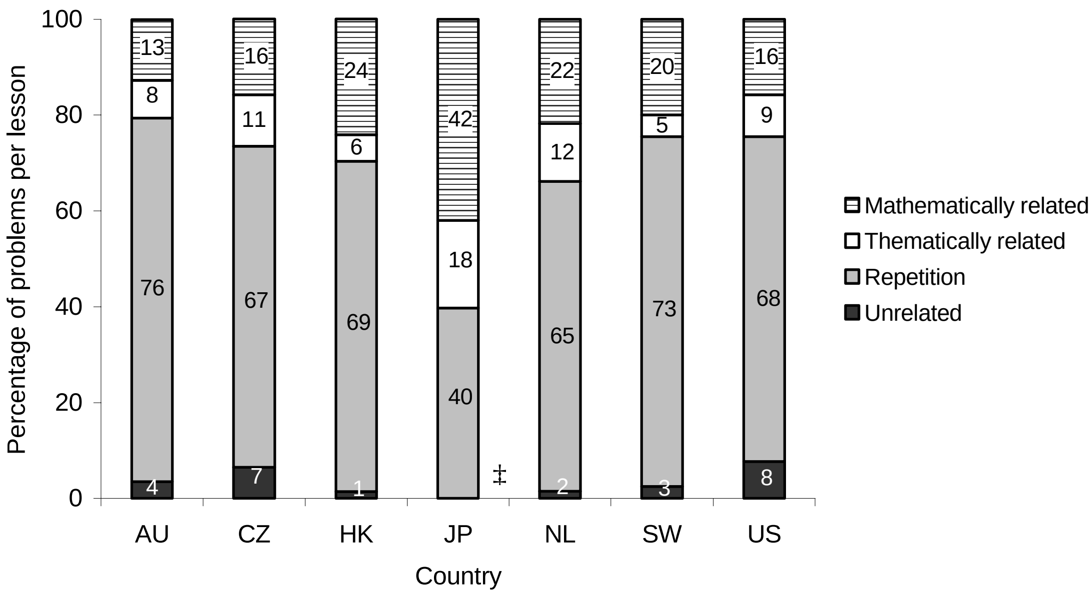
[5] This was defined as 'explaining or motivating, in broad mathematical terms, a mathematical assertion or procedure'. If such explanations took 'a systematic logical form', they were coded as deductive reasoning.

solving this problem, extending a previous problem by requiring additional operations, highlighting some operations of a previous problem by considering a simpler example, or elaborating a previous problem by solving a similar problem in a different way.

- Thematically related: The problem was related to a preceding problem only by virtue of it being a problem of a similar topic or a problem treated under a larger cover story or real-life scenario introduced by the teacher or the curriculum materials. If the problem was mathematically related as well, it was coded only as mathematically related.
- Unrelated: The problem was none of the above. That is, the problem required a completely different set of operations to solve than previous problems and was not related thematically to any of the previous problems in the lesson.

Mathematically related problems, by definition, tie the content of the lesson together through a variety of mathematical relationships. Sequences of such problems might provide good opportunities for students to construct mathematical relationships and to see the mathematical structure in the topic they are studying (Hiebert et al., 1997; National Research Council, 2001). Repetition problems require little change in students' thinking if students can solve the first problem in the series. These problems often are used for students to practise procedures for solving problems of particular kinds. Unrelated problems, by definition, divide the lesson into mathematically unrelated segments. Figure 4.7 shows the average percentage per Year 8 mathematics lesson of problems having each kind of relationship.

Figure 4.7 Average percentage of problems per lesson related to previous problems



‡ Fewer than three cases reported
Mathematically related: HK>AU; JP>AU, CZ, HK, NL, SW, US
Thematically related: CZ, JP>SW; NL>HK, SW
Repetition: AU, CZ, HK, NL, SW, US>JP
Unrelated: CZ>HK, NL, SW (JP excluded from the analysis)
Note: The first problem in each lesson was excluded. Percentages may not sum to 100 because of rounding. For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons.

On average, across all the countries, at least 93 per cent of problems per lesson were related in some way to preceding problems, and, except for Japan, at least 65 per cent of the problems per lesson were repetitions. Japanese lessons contained a lower percentage of problems per lesson (40%) that were repetitions than lessons in Australia (76%) and all the other countries, and a higher percentage of problems per lesson (42%) that were mathematically related (Australia: 13%).

Overall, the results on mathematical relationships indicated that, in all the participating countries, most of the mathematics discussed and studied within the videotaped Year 8 lessons was related. For many lessons in most of the countries, including Australia, however, the relatedness seems to have been achieved, in large part, through repetition. Only in Japan were the majority of problems per lesson related mathematically in ways other than repetition.

Examples of problems related in two different ways can be found in *HK PRL 1*. At *00:12:18*, the class goes over five problems; the latter four problems were each coded as repetitions. At *00:21:05*, the class works on three problems; the third problem was coded as 'mathematically related' to the preceding problems. The nine short review exercises at the start of *AU PRL 3 (00:00:33)* are examples of unrelated problems.

Presentation of Solutions

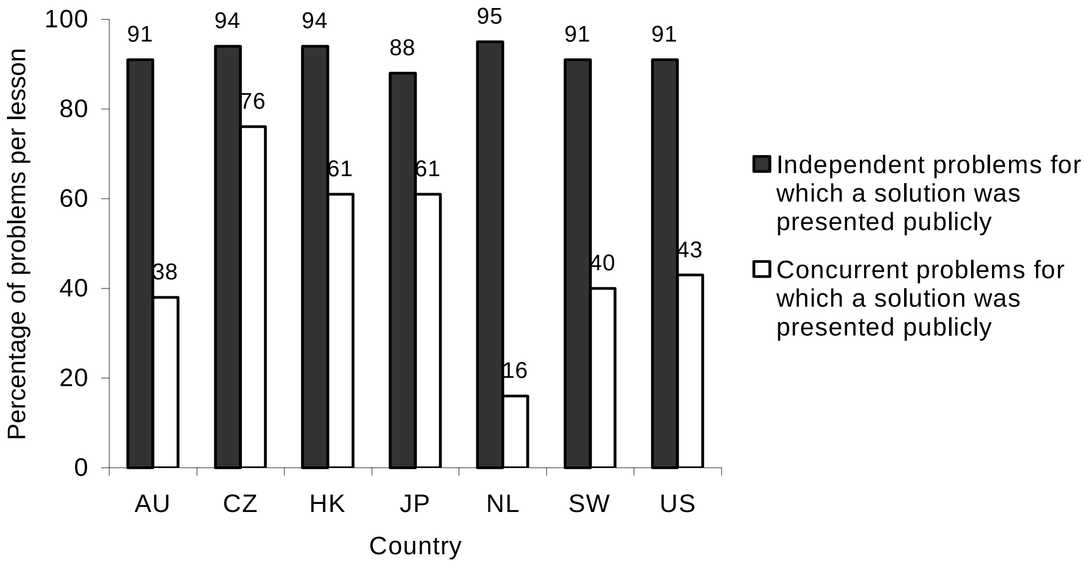
Public discussion of solutions to problems presented during a lesson suggests that the whole class was working on the same problem and allows the possibility that the teacher and students might have discussed the problem. On the other hand, no public presentation means that students were expected to complete the problem privately, with no follow-up discussion during the lesson. Different students might, or might not, be solving the same problems. Were answers to problems presented publicly in Australian Year 8 mathematics lessons?

- *Answers were presented publicly to most (91%) independent problems in Australian lessons, but answers were presented publicly to less than one-half (38%) of concurrent problems.*

Figure 4.8 shows the percentage of problems per lesson whose solutions were presented publicly, with independent and concurrent problems displayed separately. On average, across all the countries, at least 88 per cent of independent problems per lesson included the public presentation of a solution (Australia: 91%). This finding is not surprising because independent problems were defined as problems presented individually, worked on for a clearly definable period of time, and with the possibility that they would be solved through a whole class activity.

Concurrent problems, on the other hand, were defined as a set of problems to be worked on privately, perhaps over the span of several days. They could have been set from a textbook, with the answers given 'at the back' of the textbook. Understandably therefore, in all countries, a smaller percentage of concurrent problems than independent problems included the public presentation of a solution. The Netherlands had the lowest percentage (16%), significantly lower than the percentages in all the other countries. Australia had the second lowest percentage (38%), but only the Czech Republic (76%) and Hong Kong SAR (61%) had significantly higher percentages.

Figure 4.8 Average percentage of problems per lesson for which a solution was presented publicly



Independent problems: No difference detected

Concurrent problems: AU, CZ, HK, JP, SW, US>NL; CZ>AU, SW, US; HK>AU, SW

Note: For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons.

Alternative solution methods

In solving problems, key learning opportunities are created by the ways in which methods for solving problems are developed and discussed (Hiebert et al., 1996; Schoenfeld, 1985). One approach is for the teacher to demonstrate one method for solving a problem and then for the students to practise the method on similar problems. This is a common approach in the United States (Fey, 1979; Stigler & Hiebert, 1999), as well as in other countries (Leung, 1995). However, there are some compelling theoretical arguments, along with some empirical data, to suggest that students can benefit from both examining alternative solution methods and being allowed some choice in how they solve problems (Brophy, 1999; National Research Council, 2001).

Were alternative solution methods presented in Australian lessons, and were students encouraged to choose their own method when solving a problem?

- *In Australia, and in all the other countries except Japan, alternative methods of solution were rarely presented or encouraged.*

A solution method was defined as a sequence of mathematical steps used to produce a solution. Solution methods could be presented in written or verbal form solely by the teacher, worked out collaboratively with students, or presented solely by students. To count as an alternative solution method, each method needed to 1) be distinctly different from other methods presented; 2) have enough detail so that an attentive student could follow the steps and use the method to produce a solution; and 3) be accepted by the teacher as a distinct and legitimate method, rather than as a correction or elaboration of another method.

Allowing student choice of solution method when solving a problem was coded when either of the following events occurred: 1) the teacher (or textbook) explicitly stated that students were allowed to use whatever method they wished to solve the problem, or 2) two or more solution methods were identified and students were explicitly asked to choose one of the identified methods. However, situations where there might have been an unspoken understanding in the classroom that students were free to choose their own solution methods, if they occurred, were not included. Hence, this code is more an indication of when students were encouraged to choose their own method of solution than it is of when students were allowed to do so.

Table 4.2 shows that in Australia and all the countries, except Japan, 5 per cent or fewer of the problems per Year 8 mathematics lesson, on average, included the public presentation of alternative solution methods. The percentage for Japan (17%) was higher than that for Australia (2%), the Czech Republic (2%), and Hong Kong SAR (4%). Table 4.2 also shows that no more than 9 per cent of problems per lesson in all the countries, except Japan (15%), were accompanied with a clear indication that students could select their own solution method.

Table 4.2 Average percentage of problems per lesson for which more than one solution method was presented, and for which choice of method was encouraged

Country	Average percentage of problems per lesson with more than one solution method presented	Average percentage of problems per lesson in which student choice of solution method was encouraged
Australia (AU)	2	8
Czech Republic (CZ)	2	4
Hong Kong SAR (HK)	4	3
Japan (JP)	17	15
Netherlands (NL)	5	‡
Switzerland (SW)	4	7
United States (US)	5	9

‡ Fewer than three cases reported (NL excluded from the relevant analysis)
Problems per lesson with more than one solution method presented: JP>AU, CZ, HK
Problems per lesson in which student choice of solution method was encouraged: No difference detected
Note: Analyses do not include answered-only problems (i.e., problems that were completed prior to the videotaped lesson and only their answers were shared). For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons.

An example of an Australian teacher's presentation of an alternative method of solution, to one presented earlier in the lesson (at *00:14:04)*, can be viewed at *00:43:18* of *AU PRL 4*. Following is the teacher's perspective on presenting a choice of solution methods:

> If a class is struggling with a concept I will only give one method of approaching a problem. Wherever possible I present a choice of methods to a class. We often take a vote or a survey to see which method each student prefers. I like more able students to see that there are choices and a variety of correct methods to solve problems, though care must be taken not to confuse with information overload. (AU PRL 4, Teacher's Commentary, 00:43:33)

Problem summaries

After a problem has been solved, teachers might summarise the mathematical points that the problem illustrates. This is one way of clarifying for students what they have just learned by solving the problem, or what mathematical concepts or procedures are important to remember for future work. Did Australian teachers summarise problems after they had been solved?

➢ *On average, only 9 per cent of problems per lesson were summarised by Australian teachers.*

A problem was counted as including a summary if the teacher (or, on rare occasions, a student) restated the major steps used in the solution method or drew attention to a critical mathematical rule or property in the problem. The summary must have been provided after the solution was reached. All independent problems were included in this analysis along with concurrent problems for which a solution was stated publicly. Note that problem summaries are different from lesson summaries discussed earlier (in Chapter 3).

Table 4.3 shows that in Japanese Year 8 mathematics lessons, a higher percentage (27 per cent, on average) of problems per lesson were summarised by the teacher compared to lessons from Australia (9%) and all the other countries.

Table 4.3 Average percentage of problems per lesson that were summarised

Country	Average percentage
Australia (AU)	9
Czech Republic (CZ)	11
Hong Kong SAR (HK)	13
Japan (JP)	27
Netherlands (NL)	5
Switzerland (SW)	13
United States (US)	6

CZ, HK>NL; HK>US; JP>AU, CZ, HK, NL, SW, US; SW>NL, US

Note: Analyses do not include answered-only problems (i.e., problems that were completed prior to the videotaped lesson and only their answers were shared). Analyses do not include concurrent problems for which a solution was not publicly presented. For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons.

An example of a problem summary can be viewed at *00:27:31* in *HK PRL 1*. In this example, the teacher summarises three problems the class have just worked on. She explains that in the first case the answer is positive or negative, in the second case the answer is positive, and in the third case there is no solution.

Mathematical Processes Involved with Problems

Previous research has shown that problem statements can be examined for the nature of the mathematical work that is implied, and then compared with the mathematical work that actually is performed – and made explicit for the students – while the problems are being solved (Stein, Grover & Henningsen, 1996; Stein & Lane, 1996; Smith, 2000).

Mathematical processes implied by problem statements

The statements of problems imply that particular kinds of mathematical processes will be engaged in their solution. What kind of mathematical process was the focus of problems set for Australian students?

- *In Australia, and all other countries except Japan, the majority of problems per lesson (for which a solution was reached publicly) focused on using procedures.*

The problem statements were classified as one of three types based on the kinds of mathematical processes implied by the statements: *using procedures*, *stating concepts*, and *making connections*. Because some public interaction was needed to examine the way in which the same problems were solved, this analysis was only applied to all independent and concurrent problems *for which a solution was reached publicly*.[6]

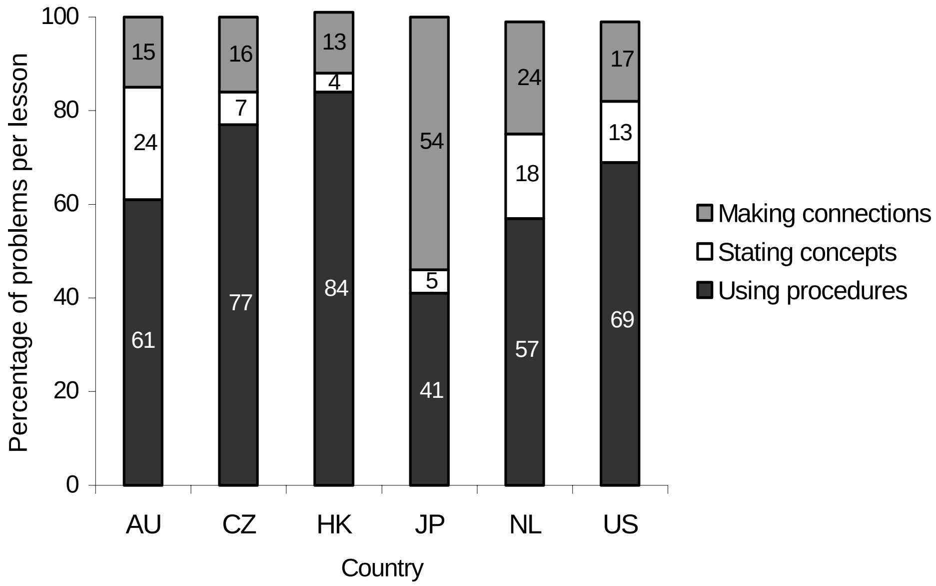
The three types of problem statements were defined as follows:

[6] Switzerland was not included in this analysis because English transcripts were not available for all lessons as some of the coding was conducted in Switzerland.

- Using procedures: Problem statements that suggested the problem was typically solved by applying a procedure or set of procedures. These include arithmetic with whole numbers, fractions, and decimals, manipulating algebraic symbols to simplify expressions and solve equations, finding areas and perimeters of simple plane figures, and so on. Problem statements such as 'Solve for x in the equation $2x + 5 = 6 – x$' were classified as using procedures.
- Stating concepts: Problem statements that called for a mathematical convention or an example of a mathematical concept. Problem statements such as 'Plot the point (3, 2) on a coordinate plane' or 'Draw an isosceles right triangle' were classified as stating concepts.
- Making connections: Problem statements that implied the focus of the problem was on constructing relationships among mathematical ideas, facts, or procedures. Often, the problem statement suggested that students would engage in special forms of mathematical reasoning, such as conjecturing, generalising, and verifying. Problem statements such as 'Graph the equations $y = 2x + 3$, $2y = x – 2$, and $y = –4x$, and examine the role played by the numbers in determining the position and slope of the associated lines' were classified as making connections.

The average percentage of problems per lesson of each statement type are shown in Figure 4.9 for each participating country where data were available.

Figure 4.9 Average percentage of problems per lesson of each problem statement type



Making connections: JP>AU, CZ, HK, US
Stating concepts: AU>CZ, HK, JP; NL, US>HK, JP
Using procedures: CZ>JP, NL; HK >AU, JP, NL, US; US>JP
Note: Analyses do not include answered-only problems (i.e., problems that were completed prior to the videotaped lesson and only their answers were shared). For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons. Percentages may not sum to 100 because of rounding.

Figure 4.9 shows that in all the countries, except Japan, more than one-half of the problem statements per Year 8 mathematics lesson focused on using procedures. Hong Kong SAR lessons contained a larger percentage (84%) of problem statements classified as using procedures than Australia (61%) and all the other countries except the Czech Republic (77%). Problem statements that focused on stating concepts were found in Australian lessons (24%) more frequently than in the Czech, Hong Kong SAR, and Japanese lessons (which ranged from 4 to 7 per cent). Although mathematics lessons in all the countries included problem statements that focused on making connections, the lessons from Japan contained a larger percentage of these problems (54%) than Australia (15%) and all the other countries except the Netherlands (24%).

Using the same information in another way, an examination within each country of the relative emphases of the types of problems per lesson implied by the problem statements shows that in five of the six countries, including Australia, a greater percentage of problems per lesson were presented as using procedures than either making connections or stating concepts. The exception to this pattern was Japan, where there was no detectable difference in the percentage of problems per lesson that were presented as using procedures compared to those presented as making connections.

Mathematical processes used when solving problems

When teachers work through problems, the kinds of processes that students actually engage in, or see others use, might be different from those implied by the problem statements. It is these mathematical processes used when solving problems that appear to shape the kind of learning opportunities available for students, and that have been shown to influence the nature of students' learning outcomes (Stein & Lane, 1996).

What mathematical processes were actually used when problems were solved publicly in Australian classes?

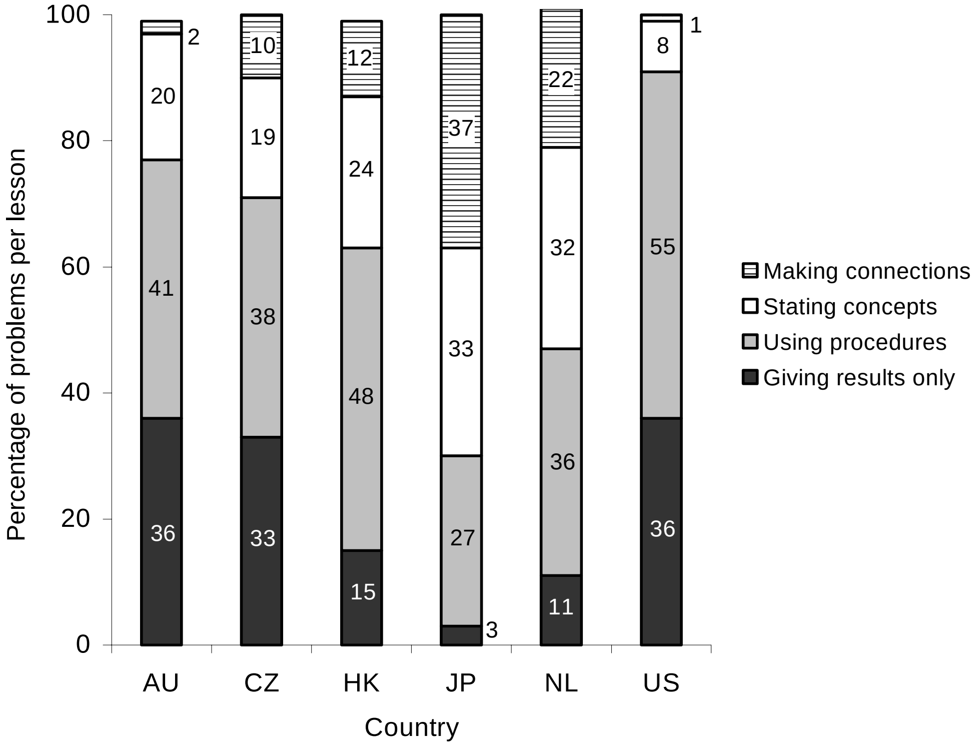
➢ *In Australian classes, problems were most often solved publicly by stating procedures (41%) or by giving the results only (36%). Only 2 per cent of problems were solved by referring to the mathematical relationships or reasoning involved.*

Each problem was classified into exactly one of four categories based on the mathematical processes that were made explicit during the problem-solving phase. This phase began after the problem was stated and lasted until the discussion about the problem ended. The categories for solving problems were the three types of processes defined for problem statements, plus an additional category – giving results only.

- Giving results only: The public work consisted solely of stating an answer to the problem without any discussion of how or why it was attained.
- Using procedures: The problem was completed algorithmically, with the discussion focusing on steps and rules rather than the underlying mathematical concepts.
- Stating concepts: Mathematical properties or definitions were identified while solving the problem, with no discussion about mathematical relationships or reasoning. This included, for example, stating the name of a property as the justification for a response, but not stating why this property would be appropriate for the current situation.
- Making connections: Explicit references were made to the mathematical relationships and/or mathematical reasoning involved while solving the problem.

Figure 4.10 shows that, in Australia (36%), the Czech Republic, and the United States, a larger percentage of problems per lesson, on average, were completed publicly by 'giving results only' than in the other three countries included in this analysis. 'Giving results only' occurred least frequently (3 per cent, on average) in Japanese lessons. 'Using procedures' ranged from 27 per cent to 55 per cent of problems per lesson across all the countries (Australia: 41%), and from 8 to 33 per cent of problems per lesson were solved and discussed publicly by 'stating concepts' (Australia: 20%). A higher percentage (37%) of problems per lesson were solved publicly through 'making connections' in Japanese lessons than in all the other countries except the Netherlands. Australian and United States lessons contained the smallest percentages of problems implemented as 'making connections' (2 per cent and 1 per cent of problems per lesson, respectively).

Figure 4.10 Average percentage of problems per lesson solved publicly by explicitly using processes of each type



Making connections: CZ, HK, NL>AU, US; JP>AU, CZ, HK, US
Stating concepts: AU, CZ, HK, JP>US; NL>CZ, US
Using procedures: HK>JP; US>CZ, JP, NL
Giving results only: AU, CZ, US>HK, JP, NL; HK, NL>JP
Note: Analyses only include problems with a publicly presented solution. Analyses do not include answered-only problems (i.e., problems that were completed prior to the videotaped lesson and only their answers were shared). For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons. Percentages may not sum to 100 because of rounding.

Comparing Figures 4.9 and 4.10 indicates that the processes made explicit for students while solving problems publicly were not necessarily identical to those suggested by the problem statements. By tracing each problem through the lesson, it was possible to see what happened to problems of various types as they were being solved.

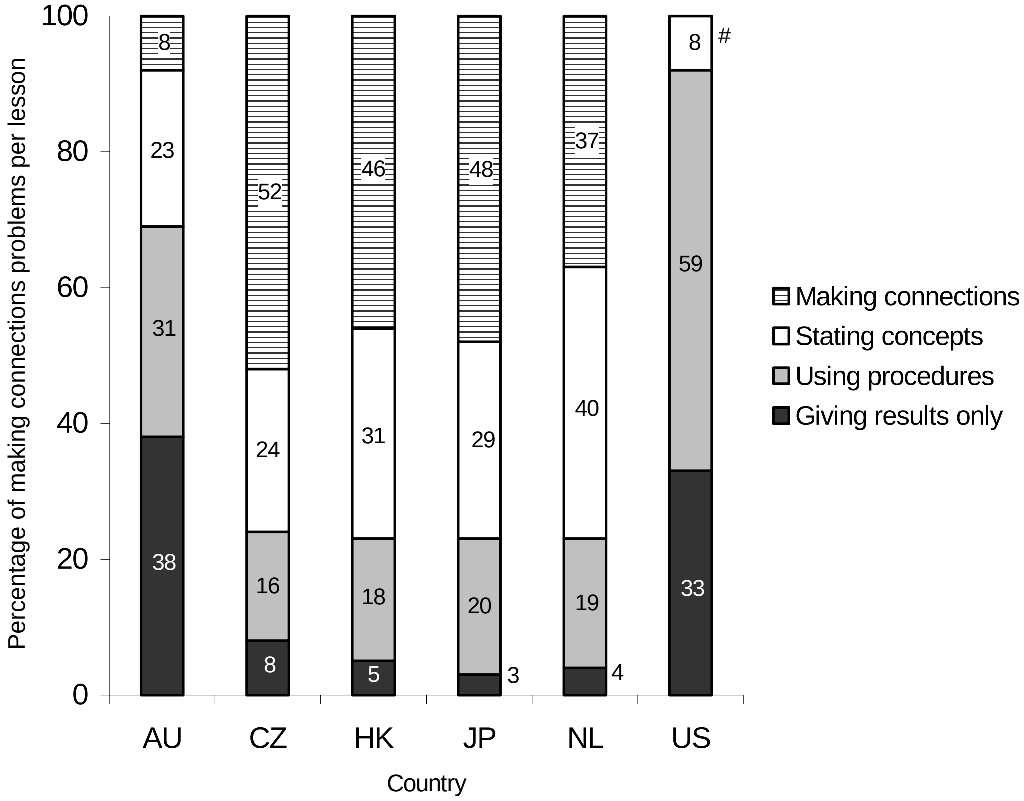
For problems solved publicly in Australian Year 8 mathematics lessons, it was found that, on average, the majority of both ‘using procedures’ problems and ‘stating concepts’ problems were in fact solved using the types of mathematical processes implied by the problem statements.[7] However, as is shown in Figure 4.11, in Australia only 8 per cent of ‘making connections’ problems were in fact solved that way, a lower percentage than all the other countries except for the United States. Thirty-eight per cent of ‘making connections’ problems were solved by ‘giving results only’, a higher percentage than all the other countries except for the United States.

An example of a ‘making connections’ problem that is solved publicly by using procedures can be viewed in *AU PRL 4 (00:18:25)*. Although the problem statement asks students to justify a particular mathematical relationship, they do not reason about why this mathematical relationship

[7] Data not shown: see Hiebert et al. (2003), Figures 5.10 & 5.11

holds true. The public discussion consists only of a procedural verification based on the given examples.

Figure 4.11 Average percentage of 'making connections' problems per lesson solved publicly by explicitly using processes of each type



[#] Rounds to zero
Making connections: CZ, HK, JP, NL>AU, US
Stating concepts: JP, NL>US
Using procedures: US>CZ, HK, JP, NL
Giving results only: AU, US>CZ, HK, JP, NL
Note: Analyses only include problems with a publicly presented solution. Analyses do not include answered-only problems (i.e., problems that were completed prior to the videotaped lesson and only their answers were shared). Lessons with no making connections problem statements were excluded from these analyses. For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons. Percentages may not sum to 100 because of rounding.

Mathematical processes involved in private work

In all the countries, between 20 and 55 per cent of lesson time, on average, was devoted to private work (Table 3.2). That is, Year 8 students were asked to complete mathematical problems by working on their own or in small groups. How did Australian students spend their private work time?

- *As in all countries except Japan, Australian students spent the majority of private time during lessons working on problems that required them to repeat procedures.*

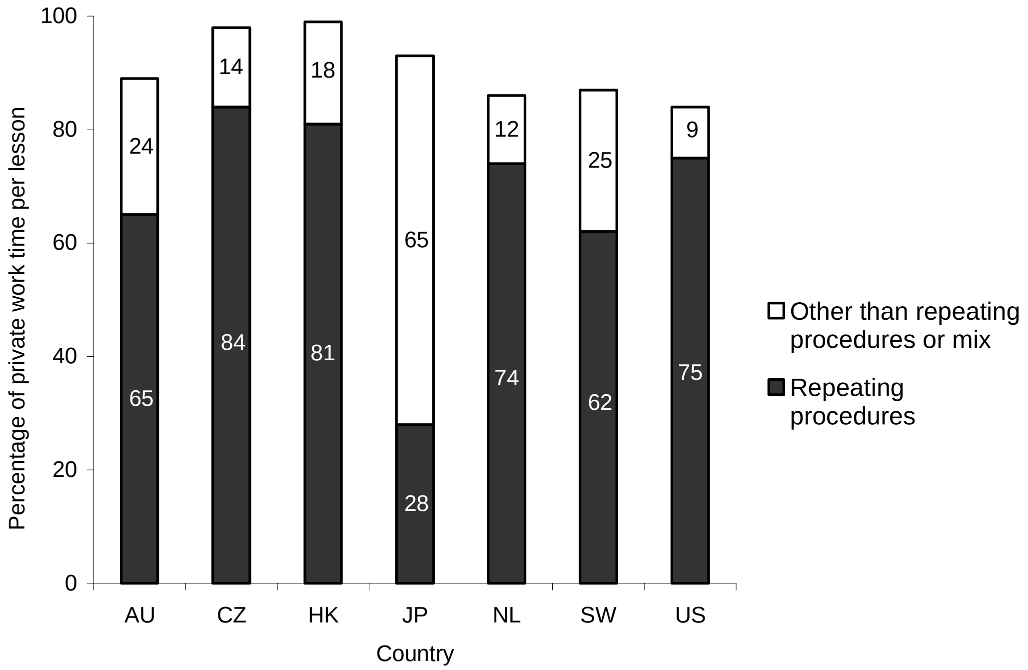
Less information was available to evaluate the mathematical processes in which students engaged during private time than public time, but it was possible to classify students' private work into one of two categories: 1) repeating procedures that had been demonstrated earlier in the lesson or learned in previous lessons, or 2) doing something other than repeating learned procedures.

'Something other' might have been developing solution procedures that were new for the students or modifying solution procedures they already had learned.

Each private work segment was marked for whether students worked on an assignment with problems that required them to repeat procedures, do something other than repetition, or do a mix of repetition and something other than repetition.[8] An assignment was considered mixed when it contained several problems, at least one of which required repetition and at least one of which required something other than repetition.

Figure 4.12 shows that in Japan, on average, a larger percentage (65%) of private work time per lesson was devoted to doing something other than repeating procedures, or doing a mix of repeating and something other than repeating, than in Australia (24%) and the other five countries. Japanese students spent 28 per cent of private work time repeating procedures, a smaller percentage than in Australia (65%) and the other countries.

Figure 4.12 Average percentage of private work time per lesson devoted to repeating procedures, and to something other than repetition or a mix of both



Other than repeating procedures or mixed: JP>AU, CZ, HK, NL, SW, US; AU, SW>US
Repeating procedures: AU, NL, SW, US>JP; CZ, HK>JP, SW
Note: For each country, average percentage was calculated as the sum of the percentages within each lesson, divided by the number of lessons. Percentages may not sum to 100 because some private work segments were marked as 'not able to make judgment'.

Taking the percentages of lesson time devoted to private work (see Table 3.2) into account shows that Australian students spent about 31 per cent of lesson time working privately on problems that required them to repeat procedures, and about 12 per cent of lesson time working privately on problems that required them to do something other than repetition, or a mix of repetition and something other than repetition. The corresponding percentages for Japan were about 10 per cent and 22 per cent, respectively. An example of a private work assignment requiring something other than repeating procedures can be viewed in *AU PRL 1* at *00:16:11*. In this example,

[8] Switzerland was included in this analysis.

students have to construct a pentagon on the computer, and then move the vertices or sides of the pentagon to see if the sum of the exterior angles changes. They conjecture what the sum might be and then see if their conjecture holds true.

Prior to this exercise, students examined a five-point star inscribed in a circle and concluded that the sum of the angles does not change when you move the points around the circle, and that the sum of the inscribed angles is always 180 degrees. Therefore, in their examination of the exterior angles of a pentagon, students are doing something more than repeating procedures they have already learned.

Summary

In this chapter, results were presented on the mathematical topics covered during the videotaped Year 8 mathematics lessons, and on the ways in which mathematical problems – the main vehicles for conveying mathematical content across the seven participating countries – were posed and worked on during the lessons.

In all the countries, three major topic areas – number, geometry, and algebra – were the subject of at least four-fifths of the problems presented during the lessons (Table 4.1). Up to 10 per cent of problems dealt with statistics, and, in Hong Kong SAR, an average of 14 per cent of problems per lesson concerned trigonometry. A common finding across countries regarding the problems worked on publicly during the lessons was that the mathematical processes used were often different from those implied by the problem statements – in particular, problems were solved ‘at a lower level’ (e.g., by giving the results only).

The results in this chapter suggest that the purpose segments found to characterise lessons in Chapter 3 (Figure 3.7) were filled with mathematical problems that, in general, were consistent with the relative emphasis on particular purposes found in several countries. Japan’s relative emphasis on introducing new content is consistent with its relatively high percentage of mathematically related problems per lesson and relatively low percentage of repetition problems (Figure 4.7). Hong Kong SAR’s relative emphasis on practising new content, and the Czech Republic’s and the United States’ relative emphasis on review, are consistent with the relatively large percentage of repetition problems per lesson in these countries. A large percentage of repetition problems were also found, however, in the other countries – Australia, the Netherlands, and Switzerland. It is reasonable to conjecture that repetition becomes the most common problem-related activity for teaching Year 8 mathematics unless there is a clear emphasis on introducing new concepts or procedures.

The results in Chapter 3 showed that, on average, Japanese Year 8 mathematics lessons were characterised by devoting lesson time to solving relatively few problems (Table 3.1) and spending a relatively long time on each one (Figure 3.4). It appears that this structure was filled with problems possessing a unique content character, compared to all the other countries, based on a number of features. The problems in Japanese Year 8 mathematics lessons were of higher procedural complexity (Figure 4.5), they included proofs more often (Figure 4.6), they were related to each other more often in mathematically significant ways (Figure 4.7), and they focused on making connections (Figure 4.9). Further, these problems were solved publicly in a relatively distinctive manner. Alternative solutions were presented more often (Table 4.2), as were problem summaries (Table 4.3), and, for over one-third of the problems, the teachers made reference to the mathematical relationships or mathematical reasoning involved in the solutions (Figure 4.10).

Key results concerning Australia reported in this chapter include the following. *Unless Australia is specifically mentioned, a similar finding applies to all countries except Japan*.

- There were indications that the general curricular level of Australian Year 8 mathematics lessons was lower, and the algebra content less demanding, than in most of the other participating countries (Figure 4.1 and Table 4.1).
- In Australia, just over one-quarter of problems per lesson had a real-life setting, and approaching one-half could be regarded as applications (Figures 4.2 & 4.4).
- Most of the problems presented were of low procedural complexity, and few were of high procedural complexity (Figure 4.5).
- Proofs were hardly ever required (Figure 4.6), and instances of deductive reasoning were very hard to find in general.
- The majority of problems per lesson were essentially the same as a preceding problem in the lesson (Figure 4.7).
- Alternative methods of solving problems, and problem summaries, were rarely presented or encouraged (Tables 4.2 & 4.3).
- The majority of problems presented publicly were worded to suggest that they should be solved by using procedures (Figure 4.9), and the majority of private time was spent working on problems that required students to repeat procedures (Figure 4.12).
- When problems were solved publicly, most often they were solved by using procedures or by giving results only. In Australia, over one-third of problems were solved publicly by giving results only, and only 2 per cent were solved by making reference to the mathematical relationships or reasoning involved (Figure 4.10).

Chapter 5

MATHEMATICS TEACHING IN HIGHER AND LOWER ACHIEVING CLASSES

One of Australia's aims for participating in the TIMSS 1999 Video Study was to gain understanding of any differences found between Year 8 mathematics teaching practices in Australia and those in the high achieving Asian countries in the TIMSS 1995 and 1999 assessment studies (see Chapter 1). Another perspective on teaching practices in relation to achievement can be gained from extensions to the 1999 Video Study that were undertaken in both Australia and Switzerland, where measures of mathematics achievement were administered to the students in the videotaped classes. In both countries it was thought that achievement data would enhance the study by providing the opportunity to look at teaching practices in relation to the quality of student outcomes, even though there would be only one snapshot of teaching and learning for each videotaped class.

In their extended study, Switzerland used the full 'Population 2' (Year 8 in most countries) mathematics tests from the TIMSS 1995 and TIMSS 1999 assessments, as well as additional questionnaires for teachers and students. In Australia, because a full TIMSS mathematics test at this level would require 90 minutes of testing time, a subset of 50 items from the TIMSS 1995 assessment was administered. The 50 items were assembled into what is known in Australia as the *International Benchmark Test in Mathematics* (IBT-M), Level 2, published by the Australian Council for Educational Research.[1] This test is designed to be completed in one hour.

The analyses reported in this chapter, where teaching practices are examined in groups of classes contrasted by achievement level, are at best exploratory because each class was looked at on only one occasion and variation between lessons for any given teacher would be expected. Further, it is not possible to conclude from the single occasion data that any difference between teaching practices in classrooms contrasted by achievement level is a determining factor in the students' achievement. It is equally plausible that differences found could be a consequence of differences in students' ability levels. Either way, however, it is interesting to identify differences in teaching practices associated with differences in student achievement. Other studies can ask the question 'Are there differences in teaching practices that help some classes of students to achieve better than others?', while this study asks 'Do teachers tend to use different strategies when teaching classes of different skill levels?'.

Nature of the Data

Data on lesson content and teaching practices arising from the TIMSS 1999 Video Study involve judgments made by coders, but these are predominantly 'low inference' in nature, documenting events rather than offering judgments on quality. However, as explained in Appendix A, specialist coding groups provided higher inference data on some aspects for all or some of the videotaped lessons. Judgments were made of the procedural complexity of every problem dealt with in all of the lessons, and of the relationship among problems within lessons. Ratings on several dimensions of lesson quality were assigned in a subsample of 20 lessons per country, but these data were not included in the analyses undertaken for this chapter because of the small sample size.

As we saw in Chapter 4, 'procedural complexity' was defined as 'the number of steps it takes to solve a problem using a common solution method'. This kind of complexity was coded because it is less dependent on students' prior experience or ability than would be, for example, level of

[1] This test, and an equivalent one in science, were constructed and published with permission from the International Association for the Evaluation of Educational Achievement (IEA) in Amsterdam.

mathematical content. Procedural complexity was rated as low if four or fewer decisions needed to be made to solve the problem; as moderate if more than four decisions were needed and up to one sub-problem was present; and as high if more than four decisions were needed and two or more sub-problems were present. Procedural complexity is of interest because it is an aspect of whether the students would have been challenged by their mathematics lesson.

The relationship among problems within a lesson was described by classifying second and later problems worked on according to whether they were: 1) a 'repetition' of the previous problem; 2) 'mathematically related' to a prior problem in a significant way; 3) 'thematically related' in that they were on a similar topic or part of a larger cover story; or 4) 'unrelated'. A problem that was both mathematically and thematically related was coded as the former. The dimension of how problems are related is of interest because it is an indicator of the clarity and coherence of the lesson.

Apart from the ratings on these variables, most other data from the videotaped lessons are not evaluative in nature. However, among the large number of variables pertaining to teachers' pedagogical strategies and the structure and content of lessons available from the video study, are many that could be expected, based on mathematics education research literature, to be characteristic of good mathematics teaching. In terms of classes contrasted on mathematics achievement, it is of course desirable that both higher and lower achieving students experience good teaching. Many variables would be expected to be similar in the two groups of classes, including teacher qualifications and experience, time spent on lesson planning, and aspects such as lesson clarity and coherence.

Hypothesised Differences

It is also recognised as good pedagogy to adjust one's teaching methods to cater for students' current skills and abilities. Variables where a difference between higher and lower achieving classes might be expected include:

- *Higher in higher achieving classes:* type and level of mathematical content; procedural complexity of problems; incidence of longer duration problems; problems involving mathematical thinking; use of mathematical language and symbols; incidence of new topics; homework requirements; and time spent by students in working independently.
- *Higher in lower achieving classes:* use of real-life connections and concrete materials; incidence of problems that are repetitions; problems focusing on correct use of procedures; percentage of time spent in review; time spent on new material; time spent in group work; discussion of homework during class time; and extent of student and teacher talk.

These, and other, variables were examined for significant differences after the Australian classes were assigned to two groups based on mathematics achievement. Given the exploratory nature of the analyses and the relatively small sample of classes, differences significant at the .10 level are regarded as worthy of consideration. However, most of the differences identified here were significant at least at the .05 level.

Unless stated otherwise, all results presented in the chapter are based on weighted data. Significance tests were simple *t*-tests or chi-squared tests with adjustments made to standard errors for design effects arising from the two-stage sampling.

Classes Contrasted on Mathematics Achievement

Mathematics achievement data were available for 75 of the 87 classes in the Australian video study sample. Teachers could choose whether to administer the IBT-M test on the same day as the lesson was videotaped or on a day shortly afterwards. A few teachers did not want their students to give up lesson time to do the test and some, having agreed to administer it, were not able to fit it in. Given the industrial situation in many schools at the time, the researchers did not press the issue.

Class means on the 50-item test ranged from 13.5 to 43.8. Two classes identified by their teachers as remedial classes did not do the test. The highest scoring three classes were all identified by their teachers as accelerated or extension classes. The class means were approximately normally distributed, with a mean of 28.7 and median of 27.9. Given a desired minimum of 30 classes per achievement group for further analysis, there were not enough classes with data to form high, medium and low groups. Two contrasting groups were set up containing 32 classes each. Eleven classes scoring around the median were omitted, to minimise incorrect allocation of classes to groups. Class means in the higher group ranged from 29.5 to 43.8, and those in the lower group ranged from 13.5 to 26.9.

Results of Analyses of the Teacher Questionnaire

Teacher characteristics, workloads and attitudes

As hoped, the teachers of higher and lower achieving classes did not differ in their qualifications and years of teaching experience. As seen in Chapter 2, the teachers of the whole sample of Australian classes in the video study had been teaching for a median of 17 years. It is known from official records that median teacher age in Australian secondary schools would have been about 47 years in 1999, which suggests that the video study sample teachers were younger and possibly less experienced than the Australian average. The most likely scenario is that schools were deploying their more experienced teachers to teach mathematics at higher year levels. As indicated here, though, they were not deploying more experienced teachers differentially, on average, to teach higher or lower stream classes at Year 8.

Some significant differences were found in teaching responsibilities, however, and also in teachers' attitudes and beliefs. The teachers of classes in the higher achieving group taught mathematics for 14 hours a week on average, while their colleagues responsible for the lower achieving classes taught mathematics for only 10.5 hours per week on average (difference significant at $p < .05$). A corollary of these data, as might be expected, is that teachers of the lower achieving classes tended to spend more time teaching other subjects than teachers of the higher achieving classes. The former spent 12.9 hours a week and the latter spent 9.7 hours a week, on average, which was significantly different at the .10 level. A few of the lower achieving classes were remedial classes, who may have had Special Education teachers with responsibilities for teaching in several subject areas. If this were the case, it would help explain the differences in teaching responsibilities between the two groups of classes.

No difference between the teachers of the higher and lower achieving Australian classes was found in the amount of time spent in planning for the videotaped lesson or in the amount of time per lesson normally spent in planning. In all seven countries, teachers spent more time in planning for the videotaped lesson than for a normal lesson, though the difference in the Netherlands and Switzerland was small (about 5 minutes). In Australia the difference was 15 minutes per lesson in the whole sample (averages of 39 minutes for the videotaped lesson and 24 minutes for a normal lesson). The teachers of the higher and lower achieving class groups did not differ from each other in lesson planning times.

Teachers were asked several questions about their attitudes to teaching in general, to mathematics teaching, and to mathematics. A 4-point scale, from 'strongly disagree' to 'strongly agree', was used. The means on a selection of the attitude questions for the teachers of the higher and lower achieving groups of classes are presented in Table 5.1. The questions were randomly placed in a list of 30 statements.

Table 5.1 Mean scores of teachers of Australian higher and lower achieving classes on selected attitude items

Item[1]	High group mean	Low group mean
Teaching mathematics is rewarding work.	3.1	3.4
I have a strong mathematics background in the areas I teach.[2]	3.4	3.8
I am enthusiastic about teaching mathematics.	3.6	3.7
I am often impressed with the quality of thinking of my students.	3.3	3.0
If I had to choose, I would become a teacher again.	3.1	3.3
I enjoy teaching students of this age level.[2]	3.4	3.8
I prefer to teach a class that has students of different ability levels.[2]	2.1	2.6
I am proud of the quality of my teaching.	3.4	3.2
I think that I am an effective teacher.	3.3	3.2

1 A 4-point scale was used, with 4 indicating strong agreement.
2 Difference significant at $p < .05$

The differences in mean scores are quite small, but teachers' responses within a group were fairly uniform on some items, leading to very small standard errors. No difference was found between the groups on several important variables, such as attitude to teaching in general and belief in one's ability as a teacher. Teachers of the lower achieving classes were more likely to enjoy teaching students of this age level than teachers of the higher achieving classes were, though they also had a stronger preference for teaching classes of mixed ability. In addition, they were more likely to agree that they had a strong mathematics background than did the teachers of the higher achieving classes. The differences for 'teaching mathematics is rewarding work' and for being 'often impressed with the quality of their students' thinking' did not quite reach significance at the .10 level.

Aims for the lessons

Teachers were asked to identify the topic(s) of their videotaped lesson by ticking as many as were relevant from a given list. The list of 22 topics, many of which were sub-topics rather than broader areas, was compiled from curriculum documents supplied from each country to the questionnaire developers. Teachers were also asked to give a brief description of the unit or sequence of lessons of which the taped lesson was part, and the main thing(s) that students were expected to learn from the unit.

The majority of teachers ticked more than one of the 22 topics as the intended focus of their videotaped lesson. Occasionally the topics a teacher ticked came from different main areas (e.g., algebra and geometry), but usually this was not the case. No difference was found between higher and lower achieving classes in the number of topic goals indicated by the teachers (on average, 3.2 goals per lesson compared with 2.5). There was also no difference at the .05 level between the two groups of classes in the main topic areas nominated by the teachers, though there was a trend (significant at the .10 level) for more focus on algebra in the higher achieving group (29 per cent of teachers compared with 14 per cent in the lower achieving group). There was a difference similar in magnitude for geometry goals (45 per cent in the higher group and 31 per cent in the lower) but this was not statistically significant.

Teachers' responses concerning the 'main thing' they wanted their students to learn from the sampled lesson were coded on three dimensions – content, processes, and perspectives. 'Processes' included 'knowing', 'operations or calculations', 'mathematical thinking', and so on, and 'perspectives' included such aspects as developing 'interest', 'awareness' and 'confidence'. In the international coding, 25 per cent of the Australian teachers apparently did not nominate a content goal in answering this question. When looking at their actual questionnaires, however, it is clear that several teachers thought they did not need to mention a content area again, as they had already written it in other places. For example, one teacher wrote that the most important thing was for students ‘to understand the concept and its applications’ in a lesson that was clearly on the topic of ratios.

Table 5.2 shows the percentages of classes in the higher and lower achieving groups whose teachers identified the various content, process, and perspective goals as most important for their lesson. Most pairs of percentages were not significantly different. There is some evidence of less difficult content in the lower achieving group in that there was significantly more focus on measurement, which is categorised as lower level geometry in *Teaching Mathematics in Seven Countries* (p. 69). The percentages focusing on other geometry and algebra were numerically higher in the higher achieving classes but the differences were not significant.

Table 5.2 Incidence of goals identified as most important for the Australian higher and lower achieving classes

Content goal	%	Process goal	%	Perspective goal	%
Number		Knowing mathematical content		Developing mathematical dispositions[1]	
High group	25	High group	16	High group	4
Low group	12	Low group	17	Low group	15
Measurement[2]		Using routine operations		Awareness of mathematics in life	
High group	2	High group	44	High group	0
Low group	17	Low group	31	Low group	6
Geometry		Using maths in real world problems		Increasing students’ confidence	
High group	28	High group	13	High group	0
Low group	16	Low group	11	Low group	3
Algebra		Developing problem solving skills		Encouraging good attitude to maths	
High group	27	High group	9	High group	5
Low group	14	Low group	9	Low group	0
Statistics/Data		Thinking mathematically		None, or ‘other’[3]	
High group	8	High group	7	High group	91
Low group	12	Low group	8	Low group	76
None, or ‘other’[3]		None, or ‘other’[3]			
High group	10	High group	10		
Low group	29	Low group	23		

[1] Difference significant at $p < .10$
[2] Difference significant at $p < .05$
[3] In each case there were a small percentage of goals categorised as ‘other’ (between 1 and 6 per cent).

It was expected that there would be more emphasis on higher-level skills, such as thinking mathematically and developing problem solving capabilities, in the higher achieving group, and relatively more emphasis on use of routine operations in the lower achieving group. The data did not support this expectation. The table also shows a tendency for more emphasis on attitudinal goals in the lower achieving classes than in the higher achieving classes – for example, ‘developing mathematical dispositions’ such as objectivity, inventiveness and curiosity.

To provide further information on the videotaped lessons, teachers indicated which ideas and skills taught in the lessons were ‘mainly review’ and which were ‘mainly new’ to the students.

Six variables were derived from their responses, according to whether a content, process, or perspective idea or skill was mentioned as mainly review, and likewise as mainly new. Mentions of each type of review idea or skill occurred in more than 90 per cent of the classes in each achievement group. Table 5.3 shows the percentage of classes by achievement group for the 'mainly new' ideas and skills, which occurred significantly more often for content (p = .07) and processes (p = .06) in the higher achieving than the lower achieving classes. Teachers of the lower achieving classes may have introduced less new content into their sampled lessons than teachers of the higher achieving classes, but they said they were significantly more comfortable in trying new teaching techniques (p < .05), as revealed by their responses to another question.

Table 5.3 Incidence of 'new ideas and skills' in the Australian higher and lower achieving classes

New idea or skill category	High group %	Low group %
Content[1]	94	75
Process[1]	94	78
Perspective	94	80

[1] Difference significant at p < .10

The teachers' descriptions of the unit of lessons of which the sampled lesson was a part also provided relevant information on the mathematics the students were experiencing (stand-alone lessons were rare). Some units did not fit within a mathematics topic area, being described by their teachers as, for example, 'problem solving and communication of results – developing the courage to try', or 'applied maths in a variety of investigations'. Where the descriptions did fit into a content category, the differences identified above were supported: there was significantly more emphasis on algebra in the higher achieving classes and on measurement in the lower achieving classes.

At a broader level, teachers were asked to list the three most important things they wanted their students to learn from 'studying mathematics this year'. Their responses were once again coded on the three dimensions of content, processes and perspectives. Considering the year as a whole, there was no difference between the higher and lower achieving groups in content goals mentioned by their teachers, or in most of the process goals. A difference was found (p = .06) for the process of communicating mathematics – becoming familiar with mathematical language and 'being able to talk and write mathematics'. More value was placed on this process by the teachers of the lower achieving classes than by the teachers of the higher achieving classes.

Perspective goals played a larger part in teachers' aims for the year than for the videotaped lesson, as can be seen by comparing the percentages in Table 5.4 with those in Table 5.2.

Table 5.4 Incidence of perspective goals identified as important for the year in the Australian higher and lower achieving classes

Perspective goal	High group %[1]	Low group %[1]
Developing mathematical dispositions[2]	42	18
Increasing awareness of mathematics in life	34	23
Increasing students' confidence[2]	32	59
Encouraging positive attitudes to maths	49	33

[1] Percentages do not add to 100 because teachers could nominate up to three goals.
[2] Difference significant at p < .05

What is most interesting about the results in Table 5.4 is the change in emphasis on perspectives to the higher achieving classes from the lower achieving classes. When the year as a whole was considered, significantly more teachers of the higher achievers stated the goal of developing mathematical dispositions in their students than did teachers of the lower achievers, which is a reversal of the situation from the videotaped lesson. The strong emphasis on increasing the confidence of students in the lower achieving classes compared with the higher achieving classes is also noteworthy.

Tailoring the lessons: teachers' intentions

To what extent do the teachers' questionnaire responses indicate differences in the teachers' intentions for their higher and lower achieving classes?

- *Teachers of the higher achieving classes indicated more focus on algebra and teachers of the lower achieving classes indicated more focus on measurement, in some contexts. Teachers of the higher achieving classes indicated more introduction of new material, while teachers of the lower achieving classes indicated more consideration of their students' interests, thinking and difficulties.*

Some of the results described in the previous section suggest that teachers were tailoring their lessons to the likely higher and lower skill levels, on average, of the students in higher and lower achieving groups of classes. For example, there was a tendency (significant at the .10 level) for more focus on algebra in the higher achieving group than in the lower achieving group. In terms of the most important thing the teachers wanted their students to learn from the lesson, significantly more of the lower achieving group teachers mentioned a measurement topic, which was characterised internationally as lower level geometry. Teachers claimed to have introduced more new material to students in the higher than in the lower achieving classes. There was also a difference on an item embedded in a list of sources of ideas for the videotaped lesson, most of which were resources such as teacher guides, which asked to what extent the teachers used 'knowledge about your students' interests, thinking, or difficulties' when planning their lesson. Teachers of the lower achieving classes acknowledged that they used this factor significantly more often than did teachers of the higher achieving classes ($p < .05$).

It was expected that more emphasis might have been placed on higher-level skills, such as mathematical thinking and conceptual understanding, in the higher achieving group and on lower-level skills, such as carrying out routine operations, in the lower achieving group. The teachers' responses did not support these expectations. A comparatively greater emphasis on mathematics in real world contexts was hypothesised for the lower achieving group, but was not borne out by the teachers' responses either.

What was Observed in the Videotaped Lessons?

The variables discussed in this chapter so far have arisen from the Teacher Questionnaire. Coded observations of events in the videotaped lessons will now be drawn on to describe what actually happened in the groups of classes. Results on many of the variables included in this section are presented in Chapters 3 and 4 for Australia as a whole and discussed in relation to the other countries' results. In this section, results for higher and lower achieving classes are described for lesson structure and coherence, lesson events, mathematical problems worked on, and use of resources and contexts. The lessons of the higher and lower achieving Australian classes did not differ significantly in length, but nevertheless there was a numerical difference of 6 minutes in average time, considered sufficient to make comparisons of frequencies dubious. For this reason, most of the analyses undertaken for this section are based on percentages.

Lesson structure and coherence

As mentioned in Chapter 3, 95 per cent of the lesson time in Australia, on average, was spent in mathematical work and a further 4 per cent was used for organisational tasks connected with the mathematics that the students would be or were doing – distributing worksheets, for example. The higher and lower achieving Australian classes did not differ from each other in these aspects.

We also saw in Chapter 3 that mathematical work time was mainly spent in working on problems but also could be, for example, the teacher giving a lecture or demonstration or the students reading material from a textbook. The percentage of lesson time devoted to working on problems in the higher achieving classes (84 per cent) was significantly greater (p = .07) than that in the lower achieving classes (75 per cent), although time working on problems was clearly the dominant element in all classes.

Another aspect of lesson structure reflects whether students spent their mathematical work time in public interaction (whole class interacting publicly with the teacher) or private interaction (students working individually, or in small groups, who could interact with the teacher on an individual basis). Together with the Netherlands and Switzerland, Australia had the closest to equal allocation of time to public and private interaction, 52 and 48 per cent, respectively (Table 3.2). In the higher and lower achieving Australian classes, there was a tendency for more private interaction in the lower group than in the higher group (51 per cent compared with 43 per cent of the time, $p < .10$). This would have allowed teachers to work more extensively with their students on an individual basis in the lower achieving classes.

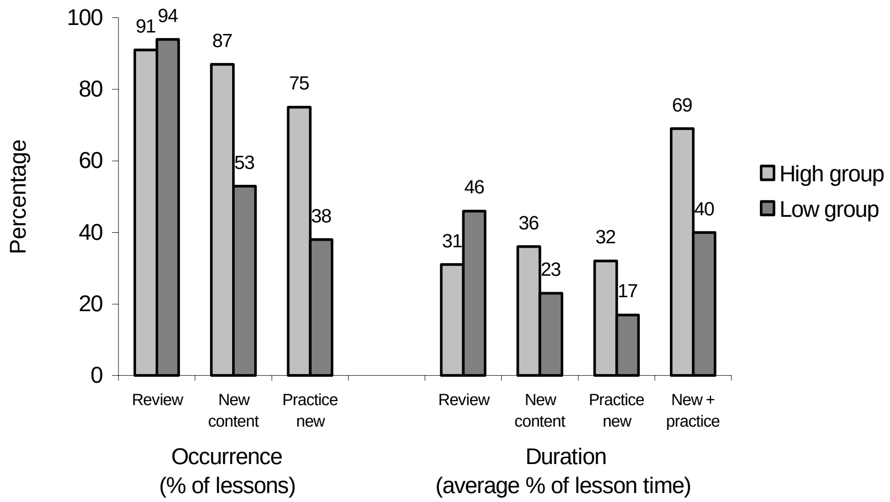
During private interaction time in the Australian lessons, students on average worked individually for 73 per cent of the time and in pairs or small groups for 27 per cent of the time (Figure 3.9). The corresponding statistics were 80 per cent working individually and 20 per cent working in pairs or small groups in the Australian higher achieving classes, while in the lower achieving classes it was 64 per cent working individually and 36 per cent working with one or more group members. These differences were statistically significant at the .10 level.

There is agreement in the literature that lessons are easier for students to follow and learn from if they are well structured and coherent. Lessons are more coherent if teachers provide ‘advance organisers’ to orient the students about what is going be covered and summaries to review what was covered, and do not switch much from topic to topic. Overall, at least one goal statement was given in more than 70 per cent of the Australian video study lessons but summary statements were provided in only 10 per cent (Figure 3.10). While numerically more of the lower achieving than the higher achieving Australian lessons included a goal statement (75 and 60 per cent, respectively), and more of the higher than the lower achieving lessons included a summary (17 and 8 per cent, respectively), the differences were not statistically significant. The higher and lower achieving class groups also did not differ in the extent of outside interruptions that would have disturbed the lesson flow – such interruptions occurred in about 30 per cent of each group’s lessons. Nor was there was any difference between the higher and lower achieving classes in the percentage of lessons in which all problems were on the same topic (46 and 52 per cent of lessons, respectively).

Other lesson events

A further aspect of the division of time within lessons is whether the lessons’ tasks involved review of previously presented material, or coverage and practice of new material. Along with most other countries, relatively more time was spent working on new material than reviewing previously learned content in the Australian lessons as a whole (Figure 3.7). Figure 5.1 shows the breakdown of the higher and lower achieving Australian class groups on variables pertaining to the various purpose types of lessons. The differences in average percentage of lesson time spent on previous and new content in the two groups of classes just failed to reach significance at the .10 level. In terms of occurrence, rather than time spent, significantly more lessons in the higher achieving class group involved the introduction of new content than lessons in the lower achieving class group ($p < .01$). If practising new content is considered as well, there was clearly a greater focus on new material in the higher achieving classes than in the lower achieving classes (also $p < .01$).

Figure 5.1 Occurrence and duration of lesson purpose types in the Australian higher and lower achieving classes



Another important element of classroom instruction that was monitored in the video study is the nature and extent of classroom talk. While there is no consensus from research on the role that teacher and student classroom talk plays in students' learning (see Chapter 3), current views on mathematics teaching in Australia advocate student participation in lessons, including involvement in classroom talk as well as other aspects such as hands-on use of equipment. In their video study questionnaire, teachers were asked if their lesson was 'in accord with current ideas about the teaching and learning of mathematics', and if so, in what way. Their answers had to be written in, with no prompts supplied. Many aspects were mentioned, but the one most commonly stated was 'students actively involved'. There was a highly significant difference between the percentages of teachers in the higher and lower achieving class groups who gave this response (7 per cent and 36 per cent, respectively). That is, the teachers of the lower achieving classes believed their lessons embodied this feature much more than did the teachers of the higher achieving classes.

One perspective on student involvement is available from the Text Analysis Group's quantitative analysis of public classroom talk in the videotaped lessons. Some of their data are included in Chapter 3, in Figures 3.12 to 3.14. To account for variations in lesson length, variables were created that standardised student and teacher talk to a lesson length of 50 minutes. As mentioned in Chapter 3, Australian teachers spoke 5536 words per lesson, and Australian students spoke 810 words per lesson, on average.

How student and teacher talk was distributed in the higher and lower achieving Australian classes is shown in Table 5.5. The groups of classes did not differ on teacher talk but there were clearly significant differences between the groups in numbers of words spoken by the students. The differences found agreed with the claims made by significantly more of the teachers of classes in the lower achieving group, reported in the preceding paragraph but one, that their lessons were structured to provide opportunity for student involvement.

Table 5.5 Average numbers of words spoken during public interaction by teachers and students in the Australian higher and lower achieving classes

Words spoken per lesson[1]	High group	Low group
Overall number of teacher words	5496	5284
Number of teacher words – mathematical content	3784	3635
Overall number of student words[2]	617	900
Number of student words – mathematical content[2]	437	629
Proportion of overall student to teacher words[2]	0.10	0.15

[1] Normalised to a lesson length of 50 minutes
[2] Difference significant at $p < .05$

Work on mathematical problems

The most important component of mathematics lessons in all countries in the TIMSS 1999 Video Study was time devoted to working on solving problems. Eighty per cent or more of lesson time in each country was spent in this way (Figure 3.2). Early in Chapter 3, the three ways in which problems were categorised for analysis were explained – as ‘independent’ or self-contained problems that could be worked on either by the whole class or by students working independently; as ‘concurrent’ problems given to students as a set to work on privately; and as ‘answered only’ problems, usually from homework or a test. For Australia, the average numbers of independent and answered-only problems per lesson were 7 and 1, respectively (Table 3.1). Although the number of concurrent problems assigned to students was determined, it was often not clear how many were worked on in any given lesson. Nevertheless, the time taken for this activity could be measured. The percentage of lesson time devoted to each of the three kinds of problem is given in Figure 3.3. This shows that Australia had one of the highest percentages of lesson time spent on concurrent problems (54%) and correspondingly one of the lowest percentages of lesson time spent on independent problems (26%). The incidence of answered-only problems was very small in Australia, rounding to 0 per cent.

In the groups of Australian higher and lower achieving classes, there were substantial differences in the use of lesson time for independent and concurrent problems, and also in the average length of time per problem, as shown in Table 5.6.

Table 5.6 Allocation of lesson time by problem type in the Australian higher and lower achieving classes

Time use	High group	Low group
Percentage of lesson time on IPs[1]	44	13
Percentage of lesson time on CPs[1]	40	61
Percentage of problem time on CPs[1]	48	85
Average duration per IP (minutes)[1]	5.2	1.5

[1] Difference significant at $p < .01$
Note: IP = independent problem; CP = concurrent problem, as defined in Chapter 3

Working on an independent problem could mean several things, including solving the problem publicly in whole class discussion with the teacher; solving it independently or perhaps in pairs, followed by class discussion; or students solving it, with the teacher then just giving the answer. The latter occurred very little in Australia, as mentioned above. The longer average duration per independent problem in the higher achieving Australian classes may mean that the problems were discussed for longer in the class as a whole, or were more challenging and required more time to solve, or a mixture of both.

Table 5.5 shows that there was more student talk in the lower achieving classes than the higher achieving classes as a whole and no difference between them in amount of teacher talk. If the analysis is restricted to the lesson segments devoted to independent problems only, there is no difference in student talk but a significant difference in teacher talk (standardised to a lesson length of 50 minutes) between the two groups of classes, with more teacher talk in the higher achieving group. This can probably be explained by the difference in time devoted to independent problems. However, it is interesting to note that the ratio of teacher to student talk in the higher achieving classes while working on independent problems was 8 to 1, but it was only 5 to 1 in the lower achieving classes. These ratios imply that there was relatively more student involvement in public discussion of independent problems in the lower achieving classes than in the higher achieving classes.

The emphasis on having students solve problems from worksheets or a textbook in the lower achieving classes is clear from the data shown in Table 5.6 on time spent on concurrent problems. Concurrent problems would not necessarily be easier than independent problems, though the concentration of lesson time on them in the lower achieving classes suggests that in Australia they may have been. Further perspectives on the findings discussed in relation to Table 5.6 are given in the following paragraphs, where various characteristics of the independent and concurrent problems within the higher and lower achieving class groups are examined and discussed in relation to the differential emphasis on the two problem types.

Table 5.7 provides several insights into aspects of the independent and concurrent problems, and the way that the two problem types were used in the higher and lower achieving class groups.

Table 5.7 Characteristics of independent and concurrent problems worked on in the Australian higher and lower achieving classes

	Independent problems		Concurrent problems	
Problem characteristic	High group	Low group	High group	Low group
Percentage of problems:				
With no choice of solution method	92	91	82	97[1]
Worked on for less than 45 seconds	39[1]	22	88	88
Involving real-life context in set up	19	36[2]	21	36
Involving students' use of physical materials	7	2	14	5
Containing a table	8	5	10	33[2]
Containing math. symbols/language only	80[2]	61	79	64
With a problem summary	15[2]	6	3	3
Percentage of lessons with:				
At least one problem with more than one solution presented publicly, at least one of which was suggested by students	21[2]	5	8	4
At least one problem with more than one solution presented publicly, suggested by a student or the teacher	39[3]	5	8	5
At least one problem with a problem summary	51[3]	13	8	12

[1] Difference significant at $p < .05$
[2] Difference significant at $p < .10$
[3] Difference significant at $p < .001$

Table 5.7 shows that concurrent problems assigned to students on worksheets or from a textbook, which the students usually undertook as 'seatwork', were overwhelmingly short in duration and most offered no choice of solution method. Although there was a significant difference, at the .05 level, between the higher and lower groups of classes in the percentages of concurrent problems with no choice of solution method, the percentage was still high (82%) even in the higher achieving group. Smaller percentages of independent problems than concurrent problems took less than 45 seconds to solve on average, but, regardless of time taken, almost all the independent problems involved no choice of solution method. Although the percentage of problems with more than one solution method was very small, the percentage of lessons in which at least one problem had more than one solution method suggested was greater. More lessons had independent rather than concurrent problems with more than one solution, and significantly more such lessons occurred in the higher achieving classes. Although 18 per cent of the concurrent problems in the higher achieving classes had a choice of solution method, these were concentrated in only 8 per cent of the classes.

It was expected that more use would be made of real-life contexts in the lower achieving classes than in the higher achieving classes. This was borne out by the data for independent problems but was not significantly different for concurrent problems. It was also expected that more use of physical materials would be made in the lower achieving classes. However, the percentages of problems involving students' use of physical materials were numerically higher, for both kinds of problems, in the higher achieving classes compared with the lower achieving classes, although the differences were not statistically significant. A further aspect that differentiated problem types and also higher and lower achieving classes in the way that the problems were dealt with lay in the use of problem summaries. Just as learning may be enhanced through lesson content being summarised, it seems likely to be a good pedagogical strategy to summarise problems. The percentage of lessons containing at least one summarised problem was much higher than the actual percentage of problems that were summarised, as can be seen from the table. Not surprisingly given their definition, it was mostly independent problems that were summarised, but this occurred more commonly in the higher achieving classes than in the lower achieving classes.

The variety of problems within each problem type is shown in Table 5.8. Problems were coded according to whether they were a repetition of a prior problem (i.e., requiring the same operations to solve), mathematically related in a significant way, thematically related (i.e., on a similar topic or connected to other problems by a cover story), or unrelated. None of the comparisons of percentages between higher and lower achieving classes was significant, but the data extend the perspective from Table 5.7 that the majority of problems were short and likely to be tasks involving routine procedures, as was shown in Chapter 4 for the whole sample (Figure 4.9). About 70 per cent of students' private time working on problems in the lower achieving Australian classes was spent in doing no more than repeating procedures, and about 60 per cent was spent likewise in the higher achieving classes, adding further to the impression of emphasis on routine work.

Table 5.8 Relationship of problems to previous problems in the Australian higher and lower achieving classes

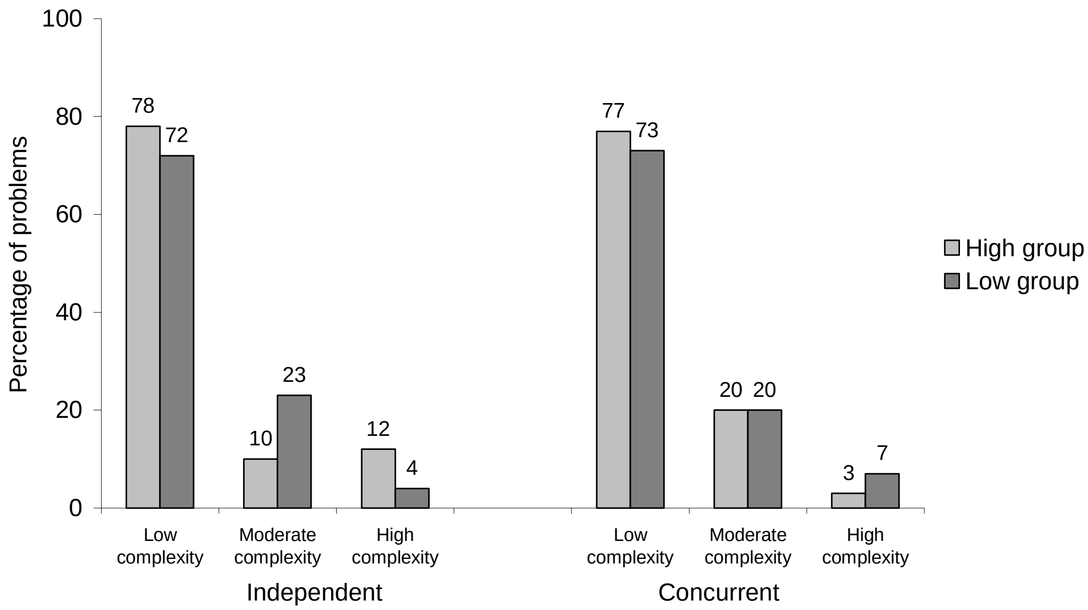
	Independent problems %		Concurrent problems %	
Relationship	High group	Low group	High group	Low group
Repetition	63	54	77	84
Mathematically related	14	18	14	8
Thematically related	15	16	5	6
Unrelated	8	11	3	1

Note: The first problem in each lesson was excluded.

Problems worked on publicly were also coded according to whether they were presented as 'using procedures', as 'stating concepts', or as 'making connections' problems. For the Australian lessons as a whole, as mentioned in Chapter 4, the majority of the first two kinds of problems were solved using the processes implied by the problem statements. However, fewer than one in ten of the 'making connections' problems were actually solved that way (Figure 4.11). It might be expected that 'making connections' processes would be more likely to be used in the higher than in the lower achieving classes, but this was not found. There was no difference in the percentages of problems in each of the three categories between the higher and lower achieving classes. Significantly more of the 'using procedures' problems were solved by using procedures in the lower achieving classes than in the higher achieving classes (71 per cent compared with 57 per cent, significant at $p < .05$). Almost 10 per cent of the 'using procedures' problems were actually solved by stating concepts in the higher achieving classes, which hardly ever occurred in the lower achieving classes (difference significant at $p < .01$).

Still further reinforcement of the view that mathematical problems assigned to Year 8 students in Australia, whether or not the students were in high achieving classes, were mostly straightforward, routine exercises with little to challenge the students, arises from the data presented in Figure 5.2. The procedural complexity categories are defined briefly earlier in this chapter (under 'Nature of the data') and more fully in Chapter 4.

Figure 5.2 Procedural complexity level of independent and concurrent problems in the Australian higher and lower achieving classes



The percentage of problems rated as low in complexity was 10 per cent higher in Australia than in any other country (though not always significantly different). There may be a case for focusing on routine problems in lower ability classes, to help students achieve some success in solving them. But what kinds of problems led to such a high percentage of low complexity ratings in the higher achieving classes? In fact, in eight of the 32 classes in the higher achieving group, the majority of problems were *not* rated as being of low complexity. Five of these were geometry lessons, two involved extended projects in statistics, and one was a number lesson with mostly conceptual work about relationships among fractions, decimals, ratios and so on.

However, in ten of the lessons, *all* problems were classified as being of low complexity. Six of these were algebra lessons, in which students were given large numbers (135 in one case) of expressions to simplify, factorise or expand, or simple equations to solve. Two were measurement lessons with 20 or more areas or volumes to calculate, one was a number lesson with many ratios to work on, and another was a number lesson with several problems where interest had to be calculated. In the remainder of the higher achieving classes, which had most but not all problems classified as being of low complexity, six were algebra lessons (again with many repetitive exercises); four were number lessons in ratio or rate; two were statistics lessons on constructing frequency distributions; and two were geometry lessons about congruent triangles.

It is true that only one lesson was filmed for each teacher and a lesson on a different day or topic may well have been different. On the other hand, lessons were filmed at different times of the year to ensure a cross-section of topics and stages in students' learning. The fact that many short, repetitive and low complexity tasks were so dominating in Australian Year 8 algebra lessons and, to a lesser extent, in number lessons, leaves a strong impression of mathematics lacking in both interest and challenge for students.

Homework

Chapter 3 presented findings on the incidence of homework in Australian lessons, both worked on during the videotaped lesson and set for the next lesson, in comparison with other countries. According to the Teacher Questionnaire responses, 24 of the 32 higher achieving classes had been set homework that was due on the day of the videotaped lesson, compared with only 12 of the 32 lower achieving classes. The weighted percentages observed for homework being set were 72 and 44 per cent, respectively, in the higher and lower achieving classes (significantly different at $p < .05$). Teachers who had set homework estimated that students would need 21 minutes, on average, to complete it in both the higher and lower achieving class groups. Very little time, only about a minute, was actually spent in both groups of classes on publicly reviewing homework problems set previously.

There was a significant difference ($p < .05$) in the percentage of lesson time, on average, spent in discussing problems for future homework in the higher achieving than in the lower achieving class group, though this represented only about 6 minutes per lesson in the higher group and about 2 minutes per lesson in the lower group. Clearly, working on homework during lesson time was not a major element of Australian mathematics lessons.

The type of homework exercise set, according to the teachers' descriptions, was similar in the higher and lower achieving classes. Completing worksheets or textbook exercises, or revising material for an exam or test, were the activities usually set by the teachers who assigned homework during the videotaped lessons. In only one case were students asked to do some reading related to the next lesson and in two cases students were asked to continue work on their class projects.

Tailoring the lessons: what was observed

It was noted earlier that there was some difference in teachers' *intentions* for the groups of classes categorised as higher and lower achievers in mathematics. To what extent were differences observed?

- *Differences were observed on several aspects where differences were expected, but not on several others that were expected. In particular, there was no difference observed in the level of procedural complexity of problems assigned in the higher and lower achieving classes. A large majority of the problems in both groups were rated by specialist mathematics coders as being of low procedural complexity.*

As intended, more focus was placed on algebra topics by the teachers of the higher achieving classes, but, as other analyses have shown, the material presented in these lessons was not necessarily more complex than material that was presented in lessons on other topics. The teachers of higher achieving classes were not found to emphasise higher-order skills such as mathematical thinking more extensively in their classes than were teachers of the lower achieving classes.

More use was made of lesson time in the higher achieving than in the lower achieving classes to work on problems, and proportionally more time was spent on problems classified as 'independent' rather than as 'concurrent'. The greater time spent working on concurrent problems in lower achieving classes allowed teachers more time to circulate and help students individually.

As expected, more time was spent in the higher achieving class group in practising new content, and in presenting and practising new content considered together, than in the lower achieving class group. Some element of challenge was revealed for the higher achieving group in that more of their concurrent problems involved a choice of solution method than in the lower achieving group, but the percentage of problems involving choice was still quite small (less than 20 per cent). There may have been more challenge in the independent problems presented in the higher achieving classes since they required more time to solve than in the lower achieving classes, but this was not the case for concurrent problems. Overall, there was evidence of problems that required sustained attention in only a handful of the Australian classes.

Teachers of the lower achieving classes believed that their students were more actively involved in their lessons and this was borne out by the analyses of classroom talk. There was relatively more class discussion of independent problems in the lower achieving than in the higher achieving classes, which could be considered appropriate in relation to ensuring that the students could understand what they were doing. As expected, more use was made of real-life contexts in independent problems presented to the lower achieving class group than in the higher achieving class group, but the expected difference in use of concrete materials was not found.

The lessons were not tailored to the different skill levels between the higher and lower achieving class groups in crucial aspects relating to the difficulty and complexity of the problems worked on during the lesson. Higher-level processes such as making reference to mathematical relationships or mathematical reasoning were rarely used for the problems solved publicly in Australian lessons, regardless of the achievement level of the class. Both independent and concurrent problems were overwhelmingly rated as being of low procedural complexity in both groups of classes.

Discussion and Summary

In general terms, the TIMSS 1999 Video Study has shown that there is no one way to undertake successful teaching of mathematics. As discussed in Chapter 1, results showed that teachers in the high achieving countries included in the study used a variety of methods and combined them in different ways, thereby providing several perspectives on effective teaching.

Data from the study are limited mostly to observational variables that describe factual aspects of classroom life. A few variables for the whole sample were coded in an evaluative way, but in addition it is useful to compare the observational data with established findings from the research literature.

Very briefly, lesson features that have been found to be positively associated with student learning outcomes, and that were measured in the video study, include:

- Lessons should be structured so that students have a variety of opportunities for learning, for example through time spent in whole class discussions and in working on their own or in cooperative group work (e.g., Brophy & Good, 1986; Good, Mulryan & McCaslin, 1992; Grouws & Cebulla, 2000).
- Lessons should be structured as a coherent whole, with clear goal statements and stated relationships of previous work to new material (e.g., Brophy & Good, 1986; Stigler & Perry, 1988).
- Teachers should sequence mathematical problems in such a way that students are encouraged to see mathematical connections, relationships and structure in the topic they are studying (e.g. Stein & Lane, 1996; Hiebert et al., 1997).

- Practice is an important aspect of classroom learning, but needs to include focus on applying new material to new situations (e.g., Hanna, 1987).
- Time should be invested in lesson planning (e.g., Sternberg & Horvath, 1995).
- Students should be encouraged to find their own solution methods and to examine different solution methods (e.g., Grouws & Cebulla, 2000).
- To be supportive of learning, classroom environments need to set high expectations, encourage students to be self-regulating, and to engage students in their learning (e.g., Nickerson, 1988; Gore, 2000; Lokan, Greenwood & Cresswell, 2001).
- For students to develop in their conceptual understanding and mathematical thinking, they must be given tasks that are mathematically challenging and significant (e.g. Askew, Brown, Rhodes, Johnson & Wiliam, 1997; Fraivillig, 2001).

These established findings provide a frame of reference against which to compare the results reported in this chapter concerning higher and lower achieving Year 8 mathematics classes in Australia.

- Most lessons were structured to provide students with both time spent in whole class discussions and time spent working on problems on their own or in small groups. Significantly more private interaction time (36 per cent, on average), was spent working in pairs or groups in the lower achieving classes than in the higher achieving classes (20 per cent, on average), which would allow teachers to interact more with their students in the lower achieving classes and would be considered an appropriate pedagogical strategy.
- The majority of lessons included at least one goal statement, but very few included summaries at the end of either a section or the lesson. Few connections of mathematical ideas or relationships were made – rather, most problems were connected by being repetitions of previous problems (Table 5.8). There was no difference in any of these variables between the higher and lower achieving classes, as would be expected for organisational aspects such as including goal and summary statements. However, the lack of emphasis on higher-level processes such as making connections and mathematical reasoning, even in the higher achieving classes, suggests that opportunities are being missed especially for these latter students.
- Students were provided with considerable opportunity to practise new material, but the large incidence of repetition in the problems set for them indicates that some of the practice time could have been more productively used. Significantly more lesson time was spent in presenting and practising new material in the higher achieving than in the lower achieving classes (69 per cent compared with 40 per cent, on average) (Figure 5.1). It is probably an appropriate pedagogical strategy to spend proportionately more time in review tasks, to consolidate concepts and procedures, in lower achieving classes.
- There was no difference, on average, in the time spent in lesson planning by teachers of the higher and lower achieving classes.
- Opportunity was provided for students to find and examine different solution methods for a small percentage of problems in a small percentage of lessons. While significantly more opportunity to do this was provided to students in the higher than in the lower achieving classes, more than 80 per cent of their problems still involved no choice of solution method (Table 5.7). The research literature suggests that students would benefit from more opportunity to view problems in different ways.
- Teachers of the lower achieving classes believed more strongly than teachers of the higher achieving classes that their students were engaged with their mathematics learning. Some support for this belief arises from the greater actual and relative student talk in the lower achieving class group (Table 5.5).

- The emphasis on problems of low procedural complexity (Figure 5.2) in the higher achieving classes as well as in the lower achieving classes suggests that opportunity is being missed to enhance students' performance by exposing them to more intellectually challenging topics and situations. Teachers' expectations for their students were not directly measured or observed in the video study, but the inference that expectations could be higher, especially in the higher achieving classes, is hard to avoid.

Caveats

The focus of this chapter has been on similarities and differences, in content and teaching practices, in groups of higher and lower achieving Year 8 mathematics classes. Comparisons have been made between the two groups of classes on a large number of variables considered one at a time. In larger samples of classes, it would be informative to carry out analyses of the likely important teaching practice variables, considered as an interacting set, at the same time taking home background into account. It was not feasible to perform such an analysis in the relatively small sample of contrasted Australian classes available in this study.

When reading this chapter, it needs to be remembered that the Australian sample as a whole was often quite similar to other countries in the study on many of the variables analysed for the contrasted groups of classes. In considering the results of these analyses, the comparisons presented in Chapters 3 and 4 also need to be borne in mind. Overall, the results do imply that our Year 8 students, particularly our better students, are not being challenged enough, but Australia is not alone in this respect.

Chapter 6

FEATURES OF MATHEMATICS TEACHING IN AUSTRALIA

The TIMSS 1999 Video Study set out to reveal similarities and differences in teaching practices among the seven participating countries, and to consider whether distinctive patterns of Year 8 mathematics teaching could be detected in each country. In earlier chapters, differences between Australia and the other countries have been reported feature by feature. Beyond comparing countries on individual features, another approach that can provide additional insight is to look inside each country, at constellations of features that describe the way in which lessons were constructed. The relationships among features of mathematics teaching in Australia are explored in this chapter.

Lesson Signatures

If there are features that characterise teaching in a particular country, there should be enough similarities across lessons within the country to reveal a particular pattern to the lessons in each country. If this were the case, then overlaying the features of all of the lessons within a country would reveal a pattern or, as labelled here, a *lesson signature*.

The analyses presented to this point in the report have focused on the presence of particular lesson features. In contrast, lesson signatures take into account when features occurred in the course of a lesson, and consider whether and how basic lesson features occurred concurrently. The lesson signature presented in this chapter was created by considering three dimensions that provide a dynamic structure to lessons: the purpose of the activities, the type of classroom interaction, and the nature of the content activity. These three dimensions each comprised selected lesson features analysed in the video study. To create a lesson signature, each Year 8 mathematics lesson was exhaustively subdivided along each of the three dimensions by marking the beginning and ending times for any shifts in features. In this way, the dimensions could be linked by time through the lesson. This allowed an investigation into the ways in which the purpose segments, classroom interaction phases, and content activities appeared, occurred concurrently, and changed, as the lessons proceeded.

The lesson signature for Australia shown later (Figure 6.1) was constructed by asking what was happening along the three dimensions during each minute of every Australian Year 8 mathematics lesson.[1] Each variable or feature within a dimension is listed separately, and is accompanied by its own histogram which represents the frequency of occurrence across all the lessons in Australia, expressed as a percentage of the Year 8 mathematics lessons. The histogram increases in height by one pixel[2] for every 5 per cent of lessons marked positively for a feature at any given moment during the lesson time, and disappears (due to technological limitations) when fewer than 5 per cent of lessons were marked positively.

Along the horizontal axis of the lesson signature is a time scale that represents the percentage of time that has elapsed in a given lesson, from the beginning to the end of a lesson. The percentage of lesson time was used to standardise the passing of time across lessons, which varied widely in length, from as little as 28 minutes to as much as 90 minutes in Australia (Table 2.5).

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[1] The analysis used to develop the lesson signatures divided each lesson into 250 segments, each representing 0.4 per cent of the total lesson length. For example, the analysis accounts for how a 50 minute lesson was coded approximately every 12 seconds.

[2] Pixel is short for ‘picture element’. A pixel is the smallest unit of visual information that can be used to build an image. In the case of the printed page, pixels are the little dots or squares that can be seen when a graphics image is enlarged or viewed up close.

Representing the passing of time in this way provides a sense of the point in a lesson that an activity or event occurred, relative to the point in another lesson that the same activity or event occurred. For example, if lesson *A* was twice as long as lesson *B*, and the first mathematical problem in lesson *A* was presented 6 minutes into the lesson and the first mathematical problem in lesson *B* was presented 3 minutes into the lesson, the lesson signature would show that the first mathematical problem in both lessons occurred at the same relative time.

To assist the reader in gauging the passing of time in the lessons, the lesson signature has vertical lines marking the start of the lesson, the 20, 40, 60, and 80 per cent marks of the lesson time, and the lesson end. By following the histogram of a particular feature from the zero to the 100 per cent of time markings, one can get a rough idea of the percentage of lessons that included the feature at various moments throughout the lesson. For example, a lesson signature may show that 100 per cent of lessons begin with review, but by the midpoint of a lesson, the percentage of lessons that are focused on review has decreased.

Because the signature displays 15 histograms, it is often difficult to assess the exact frequency of a given code at a particular moment in the lesson. Therefore, as an additional aid to the reader, a table that lists the percentage of lessons that included each feature from the zero to 100 per cent time marks (in increments of 20) is included in Appendix C (Table C.1).

Comparing the histograms of features within or across dimensions provides a sense of how those features were implemented as lesson time elapsed. Patterns may or may not be easily identified. Where patterns are readily apparent, this suggests that many lessons contained the same sequence of features. Where patterns are not readily apparent, this suggests variability within a country, either in terms of the presence of particular features or in terms of their sequencing. Furthermore, if the histograms of particular features are all relatively high at the same time in the lesson, this suggests that these features are likely to be happening at the same time. However, in any single lesson observed in a country, this may or may not be the case. Thus, the histograms provide a general sense of what occurs as lesson time passes rather than explicitly documenting how each lesson moved from one feature to the next.

As noted above, a set of features within each of three dimensions (i.e., purpose, classroom interaction, and content activity) are displayed along the left side of the lesson signature. Within each dimension, the features that are used to represent each dimension are mutually exclusive (that is, a lesson was coded as exhibiting only one of the features at any point in time). However, in the interest of space, some low frequency features in two of the dimensions are not shown. For classroom interaction, the features not shown are ‘optional, teacher presents information’ and ‘mixed private and public interaction’ (these two features, combined, accounted for less than one per cent of lesson time in Australia). For content activity, the feature not shown is ‘non-mathematical work’ (accounting for 1 per cent of lesson time in Australia, Figure 3.1).

Most of the features presented in the lesson signature are defined and described in detail in Chapters 3 and 4. The lesson signature shows additional detail about independent and concurrent problems. As stated earlier, independent problems were presented as single problems and worked on for a clearly recognisable period of time. Concurrent problems were presented as a set of problems that were worked on privately for a time. To provide the reader with a sense of the utilisation of independent problems in the lessons, independent problems are grouped into four categories: the first independent problem worked on in the lesson, the second to fifth independent problems worked on in the lesson, the sixth to tenth independent problems worked on in the lesson, and the eleventh and upwards independent problems worked on in the lesson. For concurrent problems, it was possible to distinguish between times when they were worked on as whole class, public discussion (concurrent problems, classwork), and times when they were worked on as individual or small group work (concurrent problems, seatwork). These two features are displayed in the lesson signature as well.

The Lesson Signature for Australia

The lesson signature shown in Figure 6.1 provides a view, at a glance, of how Australian Year 8 mathematics lessons were coded for each of the three dimensions shown to the left of the graph (i.e., purpose, classroom interaction, and content activities).[3] The following discussion of Australia's lesson signature is supplemented by findings reported in previous chapters. In this way, the lesson signature becomes a vehicle for pulling together the many pieces of information about Australian Year 8 mathematics lessons contained in this report.

Mention is made in the discussion of the 'hypothesised Australian country model'. At the outset of the study, hypothesised country models – holistic representations of a 'typical' mathematics lesson in each country – were developed to assist, in turn, with the development of the coding system. Six dimensions were used to create the models: Purpose, Classroom routine, Actions of participants, Content, Classroom talk, and Climate. The hypothesised Australian country model is presented in Appendix D (Figure D.1). The hypothesised models for the other participating countries are presented in Appendix E of *Teaching Mathematics in Seven Countries*, together with a description of the process by which they were developed.[4]

Purpose

Eighty-nine per cent of Year 8 Australian mathematics lessons included some portion of time during the class period devoted to review, representing an average of 36 per cent of time per lesson (Figure 3.7). Moreover, 28 per cent of mathematics lessons were found to spend the entire lesson time in review of previously learned content, among the highest percentages of all the countries (Figure 3.8). As visible on the lesson signature, 87 per cent of the Australian Year 8 mathematics lessons began with a review of previously learned content. A majority of Australian lessons focused on review through the first 20 per cent of lesson time, with a decreasing percentage of lessons going over previously learned content during the remainder of the lesson (Figure 6.1 and Table C.1).

Starting about 30 per cent of the way into the lesson, and continuing to the end, a majority of Australian lessons engaged students with new content, representing an average of 56 per cent of time per lesson (Figure 3.7), with the practising of new content becoming an increasing focus in the last quarter of the lesson.

Classroom interaction

In terms of the interaction format in which Year 8 students and teachers worked on mathematics, Australian lessons were found to show no detectable difference in the percentage of lesson time devoted to whole class, public interaction versus private, individual or small group interaction (52 and 48 per cent, on average, respectively, Table 3.2). The majority of Australian lessons were conducted through whole class, public interaction during roughly the first third of lesson time, and again at the very end of the lesson (Figure 6.1 and Table C.1). In between those two periods of time in the lesson, Year 8 Australian students were found to be engaged in private work in a majority of lessons, usually with students working individually on problems that asked them to repeat procedures that had been demonstrated earlier in the lesson (73 per cent of private interaction time per lesson was spent working individually, on average, Figure 3.9; 65 per cent of student private work time was spent repeating procedures that had been demonstrated earlier in the lesson, Figure 4.12).

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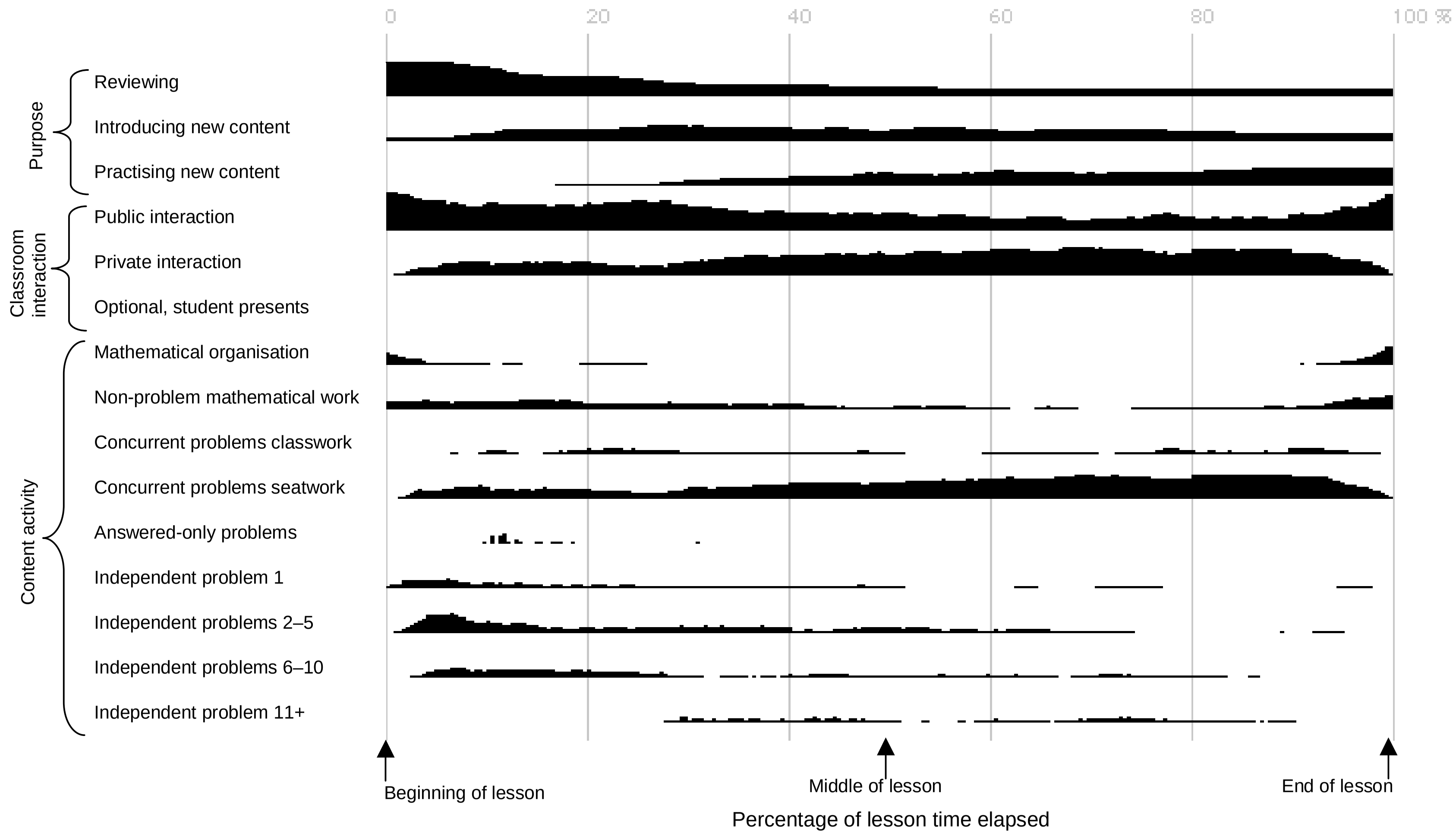
[3] For the lesson signatures of the other TIMSS 1999 Video Study countries, see Hiebert et al. (2003), ch. 6.

[4] No model is presented for Japan.

Figure 6.1 Australian Year 8 mathematics lesson signature



Note: The graph represents both the frequency of occurrence of a feature and the elapsing of time throughout a lesson. For each feature listed along the left side of the graph, the histogram (or bar) represents the percentage of Year 8 mathematics lessons that exhibited the feature – the thicker the histogram, the larger the percentage of lessons that exhibited the feature. From left to right, the percentage of elapsed time in a lesson is marked along the bottom of the graph. The histogram increases by one pixel (or printable dot) for every 5 per cent of lessons marked for a feature at any given moment during the lesson time, and disappears when fewer than 5 per cent of lessons were marked. By following each histogram from left to right, one can get an idea of the percentage of lessons that included the feature as lesson time elapsed. A listing of the percentage of lessons that included each feature by the elapsing of time is given in Table C.1. To create each histogram, each lesson was divided into 250 segments, each representing 0.4 per cent of lesson time. The codes applied to each lesson at the start of each segment were tabulated, using weighted data, and reported as the percentage of lessons exhibiting each feature at particular moments in time.

Source: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study, Video Study, 1999.

In the hypothesised Australian country model, experts posited that there would be a 'practice/application' period in the typical Year 8 Australian mathematics lesson during which students would often be assigned a task to complete privately while the teacher moved about the class assisting students (Figure D.1). As the lesson signature shows, during the time in the lesson when the main purpose of Australian lessons was the practice of new content (at least the last third of the lesson), a majority of Australian lessons were found to have students working individually or in small groups (private interaction; Figure 6.1 and Table C.1).

Content activities

A brief period of mathematical organisation work (e.g., distributing materials) was common at the beginning of Australian lessons. However, during the first half of the Australian mathematics lessons there does not appear to be any consistent pattern in the types of problems that are presented to students (Figure 6.1 and Table C.1). That is, teachers conveyed previously learned or new content to students by presenting mathematics outside the context of a problem (e.g., giving definitions or concepts, pointing out relationships among ideas, or providing an overview of the lesson), or by having their students work on independent problems, or sets of problems (concurrent problems), either as whole class or as seatwork.

During most of the last half of the Australian Year 8 mathematics lessons, however, a majority of lessons were found to employ sets of problems (concurrent problems) as a way to focus on new content. Year 8 Australian students were found to spend 54 per cent of lesson time working on concurrent problems (Figure 3.3), with 45 per cent of independent and concurrent problems (in total) worked on for less than 45 seconds each (Figure 3.6).

Almost half the Australian lessons ended with some mathematical organisation work (e.g., collecting materials, distributing a homework assignment).

Variability in Lessons

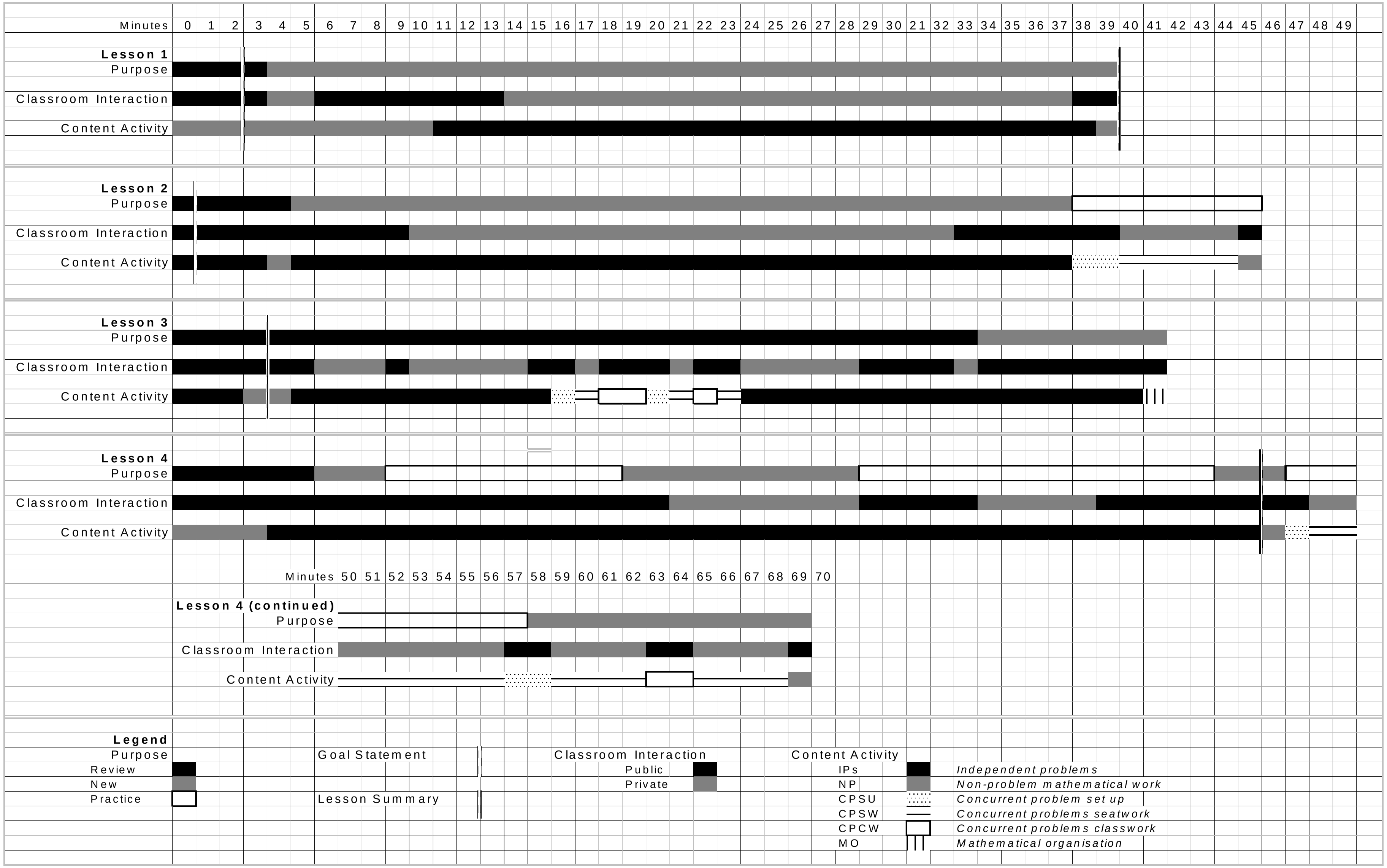
The lesson signature in Figure 6.1 illustrates 'the pattern' of Year 8 mathematics teaching across the 87 Australian lessons videotaped. However, as noted earlier, much variability occurs between individual lessons. One way to examine this variability is to look at some individual lesson displays. Figure 6.2 shows individual lesson displays for each of the four Australian public release lessons.

The displays in Figure 6.2 present the same three dimensions of lesson structure shown in the Australian lesson signature: the purpose of the activities, the type of classroom interaction, and the nature of the content activity. However, in contrast to the lesson signature, the scale for the lesson displays is elapsed time in minutes rather than per cent of time elapsed, allowing variability in lesson duration to be shown. Furthermore, two additional features analysed in the study have been added to the displays: goal statements and lesson summaries. These are marked on the displays by vertical lines at the time points in the lesson where they occurred.

How do the four lessons vary from one another? At the most obvious level, the range in lesson duration was from 39 minutes in Lesson 1, to 1 hour and 9 minutes in Lesson 4. Lessons 1, 2, and 3 were all relatively close to the average Australian lesson length of 47 minutes (39 minutes, 45 minutes, and 41 minutes respectively). In Lesson 1, there appeared to be a delay at the beginning of the lesson as the teacher waited for students to arrive; the actual videotaped portion of the lesson was around 43 minutes.[5]

[5] The duration of a lesson was calculated from the time when the teacher first engaged in talk intended for the entire class (see Chapter 2).

Figure 6.2 Lesson displays of the Australian Public Release Lessons 1–4



With respect to purpose, the profiles of each of the lessons look somewhat different. All four lessons began with a review segment of at least 3 minutes, but that was the extent of their similarity in this area. In Lesson 1, following a 3-minute review, the remainder of the lesson focused on new content. In Lesson 3, an almost opposite profile was apparent. The review segment in that lesson lasted for 33 minutes and was followed by an 8-minute segment focused on new material. The profile of Lesson 2 with respect to purpose most closely resembles the one reported as typical for Australia. Following a 4-minute review segment, new content was introduced for a period of 33 minutes and that was followed by an 8-minute segment of practice. In Lesson 4, following a 4-minute review segment, the lesson alternated six times between new and practice purpose segments during the remainder of the lesson.

Variability was also evident in regards to classroom interaction. The profiles of Lessons 1 and 2 have some similarity in that the lessons began with public interaction, had a substantial amount of time in private interaction, and concluded with a short period of public interaction. In Lesson 3, interaction types changed more frequently than in Lessons 1 and 2, and the periods of time in each interaction type were comparatively short. In Lesson 4, interaction types also changed more often than in Lessons 1 and 2, but the time spent in each interaction type was somewhat longer than in Lesson 3.

The four lessons also varied according to content activity. Lessons 2 and 4 look most alike on this dimension. They included a small amount of time on a non-problem segment towards the beginning of the lesson, then a large portion of lesson time on independent problems, followed by a smaller portion of time on concurrent problems toward the later part of the lesson. Lesson 1 had a unique profile regarding content activity for an Australian lesson. It began with a non-problem segment of about 10 minutes, during which the teacher reviewed previous work and introduced new material, while the remainder of the lesson was spent working on a single independent problem. In Lesson 3, most of the lesson was spent on independent problems, but there was an 8-minute segment of concurrent problem work in the middle of the lesson. Lesson 3 ended with a mathematical organisation segment (collection of calculators).[6]

Lessons 1, 2 and 3 each featured a goal statement soon after the start of the lesson. Lesson 1 finished with a summary statement, while there is a summary segment in Lesson 4 after about 60 per cent of the lesson time has elapsed, immediately prior to the class being set to work on some exercises.

How Mathematics was Worked On

The delivery of content in Australian lessons is revealed in analyses presented earlier in the report, but this is not readily evident in the lesson signature. For example, when taking into consideration all of the problems presented in the Year 8 Australian mathematics lessons, except for answered-only problems, 61 per cent of problems per lesson were found to be posed by the teacher with the apparent intent of using procedures – problems that are typically solved by applying a procedure or set of procedures. This is a higher percentage than the percentage posed by the teacher with the apparent intent of either eliciting a mathematical convention or concept, or making connections between ideas, facts, and procedures (‘stating concepts’ and ‘making connections’; 24 and 15 per cent, respectively, Figure 4.9).

Further, when the problems introduced in the lesson were examined a second time for processes made public while working through the problems, 77 per cent of the problems per lesson in Australia were found to have been solved by focusing on the procedures necessary to solve the problem, or by simply giving results only without discussion of how the answer was obtained (Figure 4.10). When the 15 per cent of problems per lesson that were posed to make mathematical connections were followed through to see whether the connections were stated or discussed publicly, only 8 per cent per lesson were found to be solved by explicitly and publicly

[6] Note that the teacher ran out of time to complete the lesson as planned – see *AU PRL 3, Teacher Commentary (00:40:51).*

making the connections (Figure 4.11). Overall, reference to the mathematical relationships or reasoning involved was made in only 2 per cent of problems solved publicly in Australian lessons (Figure 4.10). This was a significantly lower percentage than in the five other countries included in the analysis,[7] except for the United States.

Alternative methods of solution, and problem summaries, were rarely presented or encouraged in Australian Year 8 mathematics lessons (Tables 4.2 & 4.3). Further, problems requiring a formal, or informal, proof, or instances of deductive reasoning, hardly ever occurred (Figure 4.6).

Finally, when experts examined the problems worked on or assigned during each lesson for the level of procedural complexity – based on the number of steps it takes to solve a problem using common solution methods, 77 per cent of the problems per Year 8 mathematics lesson in Australia were found to be of low procedural complexity, among the highest percentages of all the countries (Figure 4.5). The emphasis on repetitive, low procedural complexity problems was observed in both higher and lower achieving Australian classes (Tables 5.8 and Figure 5.2).

Summary

The observations and findings discussed throughout this report suggest that, on average, Year 8 Australian mathematics lessons were conducted through a combination of whole class, public discussion and private, individual student work, with an increasing focus on students working individually on sets of short problems that were solved by using similar procedures as new content was introduced into the lesson and practised.

More specifically, a typical Australian lesson began with a review of previously learned content, conducted as a whole class activity led by the teacher. This was followed by the introduction of new content, through a mixture of public and private interaction, and finally the practising of new content by setting students to work individually (or, occasionally, in pairs or small groups) on sets of problems.

The features of a typical Australian Year 8 mathematics lesson are captured in the *lesson signature* for Australia (Figure 6.1). However, although the lesson signature illustrates the typical Australian lesson ‘pattern’, there was considerable variability between individual Australian lessons (as illustrated in Figure 6.2).

Like all seven countries that participated in the TIMSS 1999 Video Study, a majority of time in Australian lessons was spent working on mathematical problems (Figure 3.2). The results of the study suggest that Australian teachers could use this time more profitably by:

- setting fewer, more challenging problems for their students; and
- highlighting the mathematical connections and reasoning involved in their solution more often.

It appears also that higher ability students, at least, would be better served with some more challenging content – in particular, algebra beyond technique practice.

In the next and final chapter of this report, four Australian mathematics educators present their views on the implications of the results of the video study for mathematics teaching in Australia.

[7] As noted in Chapter 4, Switzerland was not included in this analysis.

Chapter 7

IMPLICATIONS FOR MATHEMATICS TEACHING IN AUSTRALIA

The TIMSS 1999 Video Study has revealed that there are many choices to make in Year 8 mathematics teaching: choices about pedagogy and lesson organisation, and choices about mathematical content and how it is presented. Most of these choices apply for mathematics teaching at any level of secondary schooling. *But what choices should be made?*

Four Australian mathematics educators, Associate Professor Alistair McIntosh (University of Tasmania), Sue Martin (a teacher participant in the study), Will Morony (Executive Officer, Australian Association of Mathematics Teachers), and Professor Kaye Stacey (University of Melbourne), were each invited to discuss (in about 1500 words) the implications of the findings of the TIMSS 1999 Video Study for mathematics teaching in Australia. They were provided with a copy of *Teaching Mathematics in Seven Countries*, the accompanying CD-ROM of illustrative video clips, and the twenty-eight public release videos. They worked independently of each other and were not aware of any additional information about the study contained in this report.

McIntosh hopes that the report will make people sit up and do something about a ‘depressing’ picture of how we ‘try to inculcate confidence, competence and enjoyment of mathematics in our young teenagers’. He contrasts the impression of ‘a lot of pretty boring, artificial, low-level, irrelevant, mentally stifling lessons being delivered round the globe’, with some ‘really stimulating and exciting examples of teaching’ among the public release videos.

While recognising that some aspects of current practice clearly need reviewing, Martin warns against an overreaction: ‘We should look at what is good practice and keep it’, and ‘Should teachers in Australia spend more time discussing solutions publicly? Some would argue that we are doing better because we spend more time with the individual.’ She discusses changes to school conditions that would facilitate different teaching practices, but demonstrates by reflecting on her own videotaped lesson that ‘Teachers can change their teaching practices without changing the whole world’. She shows there *is* a way ahead.

Martin’s note that she ‘felt analysed and examined within an inch of my utterances’ reminds us of the debt that we owe the participating teachers, as Morony comments at the end of his response. Morony begins by reminding us of the national context in which the results need to be considered, including the overall high performances of Australian students on the TIMSS 1995 and 1999, and PISA 2000, assessments. He notes that, although new alternatives to current practice emerge in the report, ‘whether these are useful in the context of Australian classrooms can only be determined by Australian teachers’. He also notes the need, when considering the results, to take into account how the various terms used in the report are defined. Morony highlights the usefulness of the report, and the public release videos in particular, for professional development purposes in relation to AAMT’s ongoing work on professional teaching standards.

Stacey argues that the report’s Australian findings expose ‘a syndrome of shallow teaching, where students are asked to follow procedures without reasons’. She notes the trade-off between time spent on procedural skills and time spent on higher-order thinking implicitly advocated in *A National Statement on Mathematics for Australian Schools*, but observes that the TIMSS assessments, which have shown some anticipated decrease in performance of routine skills, have not demonstrated the benefits. She cites research evidence to argue that ‘shallow teaching’ will not lead to the hoped-for corresponding increase in students’ conceptual understanding and problem solving ability. Instead, she argues, lessons must emphasise ‘the thinking processes that characterise mathematics’, and the study shows that ‘this can be done with Year 8 students better than is currently done in the average Australian classroom’.

A Typical Australian Year 8 Mathematics Lesson?

Alistair McIntosh
University of Tasmania

The TIMSS 1999 Video Study was a project of gigantic proportions and presumably correspondingly gigantic cost, involving as it did, for mathematics alone, the videoing of 638 Year 8 lessons collected from seven participating countries, followed by an extremely fine-detailed and multi-faceted analysis of these videos. We in Australia can never hope to reproduce such a vast project, and so we would be foolish not to reap all the benefits from it that we can.

What can we learn or, more practically, what fruitful discussions can arise from study of the 28 lesson videos that are being publicly released, and from the report *Teaching Mathematics in Seven Countries* of the results of the study?

Having read the report, and having viewed some half dozen of the videos, I have two somewhat conflicting feelings. My first reaction is that there are some absolutely fascinating data arising from the study, which, even if their implications are not clear, certainly resonate or conflict with impressions of my own about the state of secondary school mathematics, and have several times made me leave my desk to go and share them immediately with colleagues (for starters: ‘Teachers in all of the countries talked more than students, at a ratio of at least 8:1 words.’).

My second reaction, a depressing one, is that, if these videos and data represent fairly normal current practice in these countries (and the teachers involved and others say that they do), then there are a lot of pretty boring, artificial, low-level, irrelevant, mentally stifling lessons being delivered round the globe in the name of Year 8 mathematics, and it is not surprising that so many adults don’t want to know anything more about mathematics after they leave school. I have a feeling that if people in 100 years time view these videos, they will wonder how such rubbish was allowed to continue for so long. (Another chilling corner of my mind suspects that they are much more likely to say with relief: ‘Ah, nothing has changed!’). So perhaps, just perhaps, these videos and the study can act as a clarion call to sanity. Because amongst them are some really stimulating and exciting examples of teaching.

The report is careful not to be judgmental about the results, though it does make some even-handed reflections on the reasons for some of the results, and is very helpful in pointing out some dangers in drawing conclusions, because of the data. For example, because the Japanese data were all collected at a particular time in the school year, there is a preponderance of lessons on two-dimensional geometry. The study is therefore commendably scrupulous in doing additional comparisons between the Japanese lessons on two-dimensional geometry and the subset of lessons on two-dimensional geometry from the other countries. The report is also very careful to emphasise that the findings are much more diffuse than those of the TIMSS 1995 Video Study, and it warns repeatedly against the simplistic reaction of looking for features of ‘successful’ countries and then determining how to incorporate these into the practices of other countries. I found myself therefore, as I read, unusually willing to trust the data and the representation with the caveats given in the text, and allowed myself to put my own gloss on the data provided.

So I would like to comment on some of the findings which particularly resonated with me, and which in my view could lead to useful discussions amongst teachers and others. I hope I have not distorted the data, though I am certainly conscious of being as partial and biased as the next person in my interpretation. And that is the strength of the report as a basis for discussions. We will carry our own prejudices to the report, but we must emerge with them tempered by the actual data. So here goes.

Lesson goals were categorised as ‘content’, ‘process’ or ‘perspective’. Australia (Figure 2.1/*2.3*)[1] had the lowest percentage (75%) of teachers who identified a specific content goal for their

[1] That is, Figure 2.1 in the international report of the TIMSS 1999 Video Study (Hiebert et al., 2003), but Figure *2.3* in this Australian report of the study.

lessons. Almost no one anywhere thought of giving a perspective goal, which is a longer term goal, often an affective goal considering the cumulative effect of this and other lessons on students' confidence and interest in mathematics.

Teachers of all the lessons were asked (Figure 2.2/*2.1* and Figure 2.3/*2.4*) whether they were familiar with current ideas in mathematics teaching and learning, and were also asked to rate the extent to which they thought that their videoed lessons were in accord with current ideas in mathematics teaching and learning. For all countries except the Czech Republic and Hong Kong SAR, between 69 and 77 per cent of teachers thought that they were familiar with current ideas, whereas the figures for the Czech Republic and Hong Kong SAR were only 25 per cent and 22 per cent, respectively. Moreover only 22 per cent of Hong Kong SAR teachers thought their lessons were 'a fair amount or a lot' in accord with current ideas and 61 per cent said 'not at all'. Is this a case of false modesty, or a rejection of 'current ideas'? We are not told.

It is an interesting and, to me, totally unexpected finding (Figure 3.2/*3.1*) that the average percentage of lesson time in mathematics lessons devoted to mathematics work was at least 95 per cent in every country. So much for the common view that lessons are constantly interrupted by unruly students or external distractions and interruptions. Moreover (Figure 3.3/*3.2*) the average percentage of lesson time devoted to working on problems exceeded 80 per cent in all countries. However this is not as exciting as it sounds. A problem is defined as 'events that contained a statement asking for some unknown information that could be determined by applying a mathematical operation'. And looking further at the data, the picture of 'problem solving' in an Australian classroom seems pretty bleak.

First, when Australian students worked on 'independent problems' (that is, problems which were set one at a time rather than as a batch together) they spent an average of 3 minutes on each. Moreover only 55 per cent of these problems were worked on for longer than 45 seconds (the least of any country). The Japanese spent an average of 15 minutes on each problem and 98 per cent of all their problems lasted more than 45 seconds. The suspicion that this suggests that the Japanese problems might be more rich or involved is confirmed when one notes (Figure 4.1/*4.5*) that, when all problems are categorised as pitched at high, moderate or low procedural complexity, Australia has much the highest percentage (77%) of all its problems classified as 'low'.

Even worse, when each problem in a lesson was looked at (Figure 4.6/*4.7*) in relation to its predecessors and classified as mathematically related, thematically related, repetitions or unrelated, Australia had the highest percentage (76%) of problems categorised as 'repetitions'.

And finally in looking at lesson content, Australia and the United States (Figure 3.9/*3.8*) had the highest percentage of lessons (28%) *entirely* devoted to review of previous work.

In most countries, very few lessons involved use of materials other than paper, pencil and calculators. Australia was typical in that 97 per cent of lessons employed the chalkboard or whiteboard, and 91 per cent involved use of textbooks or worksheets.

Most lessons did not contain even one example of more than one solution being presented to a problem, or even one example of students having a choice of solution methods, and there were very few lessons indeed (Australia 8%) in which students presented and examined different solution methods.

When the ways the mathematical processes used in solving problems were examined (Figure 5.9/*4.10*) and categorised as making connections, stating concepts, using procedures or giving results only, Australia and the United States made least use (2% and 1%, respectively) of 'making connections' and had the highest percentages of problems solved by giving results only or using procedures (77% and 91%). In fact even when an Australian classroom was presented with problem statements that implied that the problem would focus on making connections, teachers and students only solved 8 per cent of problems in this way, and in 38 per cent of such problems the answer alone was given, while a further 31 per cent were solved by using procedures. So much for the finding elsewhere by Askew, Brown, Rhodes, Johnson and Wiliam (1997) that the teacher who makes connections is the most effective teacher of numeracy. One wonders whether teachers were aware of the difference, or whether they unwittingly turned a potentially rich mathematical situation into an impoverished one.

Finally back to the opportunities for teachers and students to talk. The researchers counted all the words spoken by teachers and students in each lesson and found that, on average, teachers in every country spoke at least 8 words (Australia 9, Hong Kong SAR 16) to every one word spoken by students. Moreover, over 70 per cent of all teacher utterances in each country contained over five words (Australia 79%), while at least 66 per cent of student utterances in each country were of four words or less (Australia 71%).

What overall picture does that give of a typical Australian Year 8 mathematics lesson? The teacher talks a lot, the students mainly reply with very few words, most of the time the students work, using only paper and pencil, on a repetitive set of low level problems, most presented via the board or textbooks or worksheets; discussion of solutions is mainly limited to giving the right answer or going through the one procedure taught. There is little or no opportunity for students to explain their thinking, to have a choice of solution methods or to realise that alternative solution methods are possible, and very few connections are drawn out between mathematical ideas, facts and procedures.

Now call me pessimistic, but I don’t think we should be satisfied by that picture of how we try to inculcate confidence, competence and enjoyment of mathematics in our young teenagers.

I think it is depressing: I am not sure that it isn’t frightening. And I hope this report makes people sit up and do something about it.

But I will end on a positive note: Calculators (not graphing calculators) were actually used in 56 per cent of the Australian lessons – as high a percentage as any country except the Netherlands.

Reference

Askew, M., Brown, M., Rhodes, V., Johnson, D., & Wiliam, D. (1997). *Effective Teachers of Numeracy. Final Report.* King’s College: London.

The Views of a Secondary Teacher Participant

Sue Martin
New South Wales

Introduction

This was a challenging assignment. The brief was not very clear so I have interpreted it in the way that gives meaning to my participation in the study and as a teacher in a secondary school.

I start by placing myself in the context of the study.

Next, I examine the four reasons given in the report, as answers to the question *Why study teaching in different countries?,* from the perspective of how the results of the study have meaning for a teacher in Australia. The reasons are:

- Reveal one's own practices more clearly;
- Discover new alternatives;
- Stimulate discussion about choices within each country; and
- Deepen educators' understanding of teaching.

I investigate the first two reasons together by looking at the three aspects of teaching defined in the report, and interpreting how the results of the study apply to mathematics teachers in Australia, particularly the state of NSW.

I then give my views about the third reason for studying teaching in different countries by discussing the choices that we have in Australia.

My conclusion puts the fourth and final reason into practice. It is a reflection on my lesson and how I now understand it, in terms of the findings of the study.

Setting myself in the context

I was involved in the TIMSS 1999 Video Study as a teacher whose Year 8 mathematics class was videotaped.

How did this all start? In 1999, I was approached by the Mathematics Coordinator (and Head Teacher) at my school and informed that my class had been chosen at random to be part of this study and then asked if I would be willing to take part in the research. Obviously I agreed.

The whole lesson was videotaped from the beginning to the end. Did this change my lesson? Yes and no.

Yes, in that it made me feel self conscious about the presence of the videographer and the video camera. The students were also very aware of this. I also did extra preparation for the lesson, in that I modified the worksheet a few times and also rehearsed the lesson a few times in my head, worried that I would overlook something under the pressure of scrutiny. Surprisingly, this did not happen much and the lesson went more or less according to plan.

No, this did not change my lesson plans. However I thought twice about whether I should give a lesson that I had never done before. I had taught the topic many times before, but not as a group lesson. This approach would give the students more opportunity to explore different results and to discuss these with each other. I wasn't worried at this stage as to whether the lesson would be successful, because the study emphasised that this should be a normal lesson. Some experiments work, some don't.

I could not choose the content to be taught, but I could choose how I taught it. The content of the lesson was ultimately determined by the syllabus written by the Board of Studies in NSW. This influenced the program of work, of which the lesson was part, which was written for Year 8 at my school by the Coordinator. I was expected to teach this unit at this time.

Why study teaching in different countries?: Reveal one's own practices more clearly, and discover new alternatives

These two reasons were investigated together by looking at the findings for Australia and comparing these to the other countries with regard to the three aspects of teaching defined in the report: the structure of lessons, the mathematical content of lessons, and instructional practices.

<u>The way that the learning environment was structured</u>

The length of lessons across the different countries was surprisingly similar. The only variation from a median of 36 to 50 minutes was that three countries had 'double lessons', which included Australia. This restricts the type of problems that can be studied if problems need to be within the time allocated.

The time spent per problem (Figure 3.5/*3.4*) should have reflected the length of the lessons. Australia, with double periods, should have been able to have much longer time spent on problems but it was significantly less than in Japan. All countries, other than Japan, spent less than 5 minutes per problem on average. As indicated in the report, the less time devoted to each problem could mean that the problems were less challenging. The rationale for the NSW Syllabus for Mathematics 7–10 supports more challenging problems. It states that 'The study of the subject enables students to develop a positive self concept as learners of mathematics, obtain enjoyment from mathematics and become self-motivated learners through inquiry and active participation in challenging and engaging experiences.' (Board of Studies, 2002b, p. 7). This cannot be achieved unless more time is spent on problems. Australian teachers are not giving challenging problems if the problems average only three minutes.

Australia also had a significantly lower percentage of problems that were worked on for longer than 45 seconds, again indicating that the problems are not challenging.

Australian teachers need to make the problems more challenging by working on fewer problems for longer. Students need to be able to examine the details of mathematical relationships and to discuss the reasons that solution methods work.

Australian teachers spend about the same time in public and private interaction but the proportion of public interaction was significantly lower than in all other countries except the Netherlands.

Private interaction was defined as 'the time when students were working individually, in pairs, or in small groups'. Australia was one of the countries that had a significantly higher percentage of time spent in private interaction (Table 3.6/*3.2*). The Key Competencies are generic competencies described in the syllabus as 'essential for the continuing development of those effective thinking skills which are necessary for further education, work and everyday life'. One of these competencies is 'working with others and in teams' (Board of Studies, 2002b, pp. 9,10). Teachers in Australia in all subjects are using group work as well as individual work to structure lessons. This is good. Teachers in Australia have been encouraged to give students individual attention according to their needs as is reflected in the statistics. Perhaps this is an area that needs to be reassessed. More students may benefit from the teacher's help through public discussion.

The role of homework was very interesting. Homework is an institution in Australia with both parents and teachers expecting homework to be set and done. In Australia, homework was assigned in 62 per cent of lessons (Figure 3.11/*3.15*). Teachers in Australia showed some indication of attending to homework in class, but it was a relatively minor part of the lesson in the Czech Republic, Hong Kong SAR or Japan. The students from Hong Kong SAR and Japan did very well in the TIMSS assessment (Table 1.1/*1.1*)[2], so is homework really an important tool in improving the mathematical ability of our students?[3]

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[2] That is, Table 1.1 in the international report of the TIMSS 1999 Video Study (Hiebert et al., 2003), and also Table *1.1* in this Australian report of the study.

[3] However, see discussion after Figure 3.15 in this report. *[Eds.]*

<u>The nature of the content</u>

In Australia the *Curriculum guidelines* play a major role in the content that the teacher can choose (Table 2.6)[4] compared to some other countries. In NSW, there is a new syllabus for Years 7–10, to be implemented in 2004, which incorporates content and outcomes. It is interesting to note that the aim of the syllabus is not about content, but about 'developing student's thinking, understanding, competence and confidence in the application of mathematics' (Board of Studies, 2002b, p. 11).

The hypothesised country model (Figure E.1/*D.1*) suggests that teachers rely on textbooks for content in the assignment of tasks, the practice/application and re-instruction, and the conclusion. Even though teachers say that they use the *Curriculum guidelines*, from this table (and my experiences), teachers rely on the textbooks for content, knowing that they are written to reflect the content demanded in the syllabus. In Australia we do not have mandated textbooks, and the teachers can choose which textbook they use. However in reality, this is an economic decision as only one textbook is usually used at each school and this textbook may be used for many years even after a better textbook becomes available. The textbooks do not vary in content but do vary in difficulty of problems and suggested teaching methodology. The teacher has the flexibility to choose the methodology even when they are using a textbook as a primary resource.

Australian teachers are not extending students as much as teachers in Japan, the Czech Republic, Hong Kong SAR and Switzerland. There were too few mathematics problems that involved proofs in Australia to calculate reliable estimates. Australian lessons had a large percentage of repetition problems, whereas in Japan new content was emphasised. Teachers need to consider giving fewer problems, of longer duration, that are more difficult and not repetitious.

<u>Instructional practices</u>

The problems should be related to real life situations so that students can 'apply mathematical knowledge, skills and understanding to everyday situations and the solution of everyday problems' (Board of Studies, 2002b, p. 11). Australian teachers are presenting mathematical problems in real life situations (Figure 5.1/*4.2*) as much as most other countries. They are using real-world objects more than other countries (Table 5.6/*3.3*). This is an important aspect of current teaching practices in Australia that is being achieved.

The report states that 'students can benefit from both examining alternative solution methods and being allowed some choice in how they solve the problem'. Australia performed poorly here as only 2 per cent of problems included a public presentation of alternative solutions (Table 5.2/*4.2*). Teachers need to present more than one solution when it exists. If a student has worked out a different solution, then they think that they are wrong if it is not discussed, when in fact they may not be wrong. The students need to have the opportunity to present their own solutions. Of course this takes more time and fewer problems can be solved.

Teachers in Australia are giving problems to students but not asking for the higher order thinking required to make connections, as is shown in Figure 5.9/*4.10* and Figure 5.12/*4.11*. Students need these skills to have a full understanding of the concepts and to be able to interpret and apply maths in a variety of contexts. However this is not being done as well as in other countries. Seventy-seven per cent of problems given were of low procedural complexity (Figure 4.1/*4.5*) and this was among the highest percentages in all the countries. This shows that there can be a substantial improvement here as other countries show that more complex problems can be given to Year 8 students. Are we, as teachers, underestimating students' ability?

Why study teaching in different countries?: Discuss choices for Australia

'Classroom practices are the result of choices; they are not inevitable' (*Teaching Mathematics in Seven Countries*, p. 4). This study is a statistical report on mathematics teaching in a variety of countries. It does compare practices across cultures but it does not identify which choices are

[4] Data not shown in Australian report

best. Hence, I propose my answers to these questions, based on my learning, my experiences and my philosophies about teaching.

Why are teaching practices so common?

Teachers in Australia generally have the same structure for lessons, which are, on average 47 minutes long. They review previous work. They then present new work and the students practise this using many short problems which do not extend the students' thinking. The students do this individually or in pairs. Then the students are given problems for homework. Teachers use this format because they were taught this during teacher training or have learned this from their peers. It has been passed down through generations of maths teachers for many years.

Within this framework, teachers in Australia are using real life examples and materials very well. They are also using many different resources such as calculators and computers.

Teachers complain that they do not have enough time to get through the content. As a result, they have no time for experimenting with lessons. The content of the lessons is driven by the curriculum. This is reflected in the textbooks which teachers rely on for lesson planning and class exercises.

Teachers do not have time to extend their lessons to consider alternative answers and to discuss the results. There is no time for promoting higher-order thinking, such as making connections. These skills and understandings are included in the syllabus but are overlooked in preference for getting through the content.

The same topics are often taught every year of a student's time at school, but with increasing difficulty. This means that previous learning must be revised each year and for many students, much of the work is not new. This seems a waste of precious time.

Should these methods be retained?

Students are doing well in Australia. We should look at what it is that is good practice and keep it. This includes the relevance of mathematics to real life and the use of a variety of resources.

Teachers are spending a substantial amount of time in helping students in 'private interaction', while the students are working individually, or in pairs and groups.

Some of the content being studied is best done as a series of short problems, which the students are able to learn and practise. This method is obviously successful in many countries and should not be discarded in the belief that it is not an acceptable teaching methodology.

However teachers need to look at the way the lessons are structured and also ways of allowing the students to construct their own knowledge and understanding.

What other choices can be made?

Teachers need to incorporate fewer problems and include some that are more difficult and involve more complex procedures. They need to allow more time to solve problems and consider alternative solutions. Students need to be given more choice in their solutions and need to be more responsible for their own learning.

There should be more group work with students discussing their problems and collaborating to find the solutions.

Should teachers in Australia spend more time discussing solutions publicly? Some would argue that we are doing better because we spend more time with the individual.

What conditions might support the move toward different teaching practices?

Schools can be restructured to include Kindergarten to Year 12. There is a lot of valuable teaching time lost in NSW because the students come into secondary school from many primary schools with different mathematics experiences. Much of Year 7 is spent revising maths that has already been taught in primary school. There are new schools in Queensland which are designed as K–12 schools and some NSW private schools have this approach.

The new NSW syllabus attempts to eradicate this problem by including a continuum of learning from Kindergarten to Year 10. This includes outcomes and content for Stages 2 and 3 to 'allow teachers to build on what students know and do' (Board of Studies, 2002a, p. 1). The intent may be there but the reality is as different as the schools that the students come from.

School timetables can be restructured. Lessons do not have to be of a short duration and of a fixed length. This would allow the solution of problems to be followed through to their conclusion. This can be done through double lessons, which some countries do have. Another solution involves restructuring the whole of the middle school so that lessons are longer and units of work can incorporate other subjects. Surprisingly, this was not common in any country.

Lessons can be restructured to use time in a different way. There are many ideas for bigger problems and group work in the textbooks. The teachers need to give a higher priority to these activities and not to only include them at the end of a lesson if there is enough time for fun.

Teachers have to let go of the textbooks that are content driven. In the new syllabus, the content can be covered over Stage 4, which is both Year 7 and Year 8. Units can be done in depth in either of these years. This gets rid of repetition and the students have an opportunity to gain a superior knowledge and understanding of the concepts. Most topics will be studied again in Stage 5. Of course, new textbooks could reflect this idea.

Conclusion

Why study teaching in different countries?: Deepen my understanding of teaching

The videotaped lesson that I taught was similar to and very different from the Australian lessons described in the report. It was similar in that I started with a short quiz which reviewed the previous lesson, I introduced a new concept, which was worked on privately, the solution was discussed publicly and then I asked the students to use the textbook to practise this. It was different because I gave the students one large problem which had four solutions. The students worked in small groups, finding and discussing their own solutions. Then the students presented their solutions using their own words and focused on constructing relationships between them.

By chance (it just happened to fall on the day of the video) it was a lesson that reflected my views on teaching.[5] I believe that the students should construct their own learning, built on their own experiences. I believe that this can be done well in a group, where students are able to discuss their ideas with each other and the teacher. It was an experiment and it worked. I allowed them to think for themselves and they did. I did not expect such good results and I was amazed at the ideas that they formulated.

The success of a lesson like this will depend on the ability of the students, but are teachers underestimating the ability of the students? If students in Japan can do this regularly, why can't Australian students?

This lesson was achieved within the framework of an average Australian school. The lesson was 53 minutes long and I had a work program to follow. Teachers can change their teaching practices without changing the whole world.

References

Board of Studies. (2002a) *Mathematics A Guide to the New Years 7–10 Syllabus*. Sydney: Author.
Board of Studies. (2002b). *Mathematics Years 7–10 Syllabus*. Sydney: Author.

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[5] I will add that I was horrified to watch myself. I stumbled. I missed words. I said the wrong thing. I didn't finish sentences. I sounded soooo Australian, and then when I realised that the study was so in depth that even the words that I said were counted, I felt analysed and examined within an inch of my utterances. I have to thank the students for being so great.

Windows on Others' Classrooms … Mirrors for Our Own

Will Morony
Executive Officer, Australian Association of Mathematics Teachers Inc.

The Australian Context

The release of the results of the TIMSS 1999 Video Study in the report *Teaching Mathematics in Seven Countries* is a major event in the world of research that focuses on international comparisons in education. It is likely a measure of increasing globalisation that interest and investment in making such comparisons has increased significantly over the past fifteen or so years. As important as these studies may be, results are inevitably viewed from within local contexts.

In Australia in 2003, the key aspects of the context of school mathematics in which the results need to be considered include:

- Australian students consistently perform well in studies of achievement, notably the two TIMSS studies (1995 and 1999), and the more recent Programme for International Student Assessment (PISA 2000);
- An emphasis on innovation as a key to maintaining Australia's competitive position in the knowledge economy;
- Developments in curriculum thinking that de-emphasise traditional focus on the disciplines;
- Concerns about the supply and retention of teachers of mathematics (and science and technology); and
- A range of efforts to improve the status, quality and professionalism of teachers.

These factors, and more, will colour the ways we look at the results, what we can take from them and how the findings assist teachers of mathematics in their work. Importantly, and particularly in relation to the last point above, the Australian Association of Mathematics Teachers (AAMT) has been a leader in efforts to come to grips with the issues around teacher professional standards. The publication of the *Standards for Excellence in the Teaching of Mathematics in Australian Schools* (AAMT, 2002), and subsequent work to exemplify these and to develop means for assessing teachers, is important Australian work to investigate and describe teaching.

Why is the TIMSS 1999 Video Study interesting and useful?

The first thing to note in assessing the usefulness of this work is that the teachers involved have, on the whole, assessed the lessons as fairly typical. No sample of around a hundred lessons can claim to be representative of the teaching in a given country, but these teachers' evaluations of the lessons as 'typical' means that some levels of generalisation can be made.

The whole concept of this study would seem to acknowledge a pervasive trait of teachers – most are voyeurs. The opportunity to look at the classroom 'next door' is always interesting and informative. The opportunity to have access to classrooms in other countries multiplies the potential. The results – including the twenty-eight public release lessons — will allow Australian teachers to look deeply at themselves. Teachers reflecting on their practice are known to be a powerful element in their professional development. These materials provide a range of prompts for teacher reflection – *Is that how I/we do it? How is it different? How is it the same? Why do I/we do it the way we do?* – on a huge range of topics.

It is important to note that the presence of information about other countries provides comparisons that will inform us about ourselves. New alternatives will also emerge, but whether these are useful in the context of Australian classrooms can only be determined by Australian teachers. Perhaps the core finding of the whole study is that there is no single method of teaching mathematics across the countries. Learning and teaching mathematics occurs in, and responds to, widely differing social, cultural and educational contexts. There isn't a 'silver bullet'!

An important consequence of the public release of videos of twenty-eight of the lessons is that teachers and others will have an unchanging record that can be looked at – studied – again and again for different purposes. Add to this the usability of the LessonLab software interface and the supporting resources that fill out the action on the videos – the Teacher Commentaries are particularly useful as they allow viewers to see the teacher's explanation of aspects of the lesson – and we have a resource that will be able to be 'mined' in different ways and for different purposes over many years.

A model for unpacking teaching of mathematics

The chapters in *Teaching Mathematics in Seven Countries* that report results provide a framework for dissecting mathematics lessons.

- Context: teachers' qualifications, experience and working week; goals and influences on these; teachers' familiarity with current trends.
- Structure of lessons: length; time on task; communication of lesson intentions; organisation of problems; purposes and types of interactions.
- Mathematical content of lessons: topics; complexity; occurrence of proofs; relationship between problems.
- Instructional practices: problem context, means of representation and materials used; development and discussion of different methods of solution; approaches required for solution of problem; use of private work time; classroom talk; resources used.

This summary does not do justice to the detail of the analysis that led to the development of this framework, of course. However, having it accessible, described and exemplified by video clips means that Australian teachers will be able to use it in thinking and talking about mathematics lessons. It points to components of teaching that can be focused on.

For example, reporting on the extent to which lessons contain a verbal or written goal statement and/or summary statement provided by the teacher highlights these as potential organisers for the lesson. These kinds of statements enable the students to better appreciate the purpose of the lesson. Add this to the finding that, of the Australian lessons studied, about 70 per cent contained at least one goal statement (i.e., statement of the lesson's intent; Figure 3.12/*3.10*)[6], while only 10 per cent contained at least one summary statement (i.e., statements highlighting points that had been studied in the lesson; Figure 3.13/*3.10*) and some of the potential for a teacher or group of teachers to use the framework and findings as prompts to useful consideration of their own practices becomes apparent.

The TIMSS Video Study raises questions for teachers and others

The above example is one of many of the same kind that can be identified in the data and the report. Several of these are discussed below. Some questions that could be prompted are then outlined. The major implication of *Teaching Mathematics in Seven Countries* for Australian teachers will be its capacity to prompt such questions, and to inform teachers' discussions of the questions and issues that arise.

What influences what teachers do?

Teachers reported that the following factors played a 'major role' in influencing their teaching decisions for the videotaped lesson: curriculum guidelines, 83 per cent; their assessment of students' interests or needs, 41 per cent; their own comfort or interest with the topic, 29 per cent (this is presumably lower for 'normal lessons'); mandated textbook, 28 per cent; cooperative work with other teachers, 26 per cent (Table 2.6)[7]. *Is this the right kind of mix? How are things*

[6] That is, Figure 3.12 in the international report of the TIMSS 1999 Video Study (Hiebert et al., 2003), but Figure *3.10* in this Australian report of the study.

[7] Data not shown in Australian report

different in the Netherlands where cooperative work with other teachers *was a major factor for nearly 60 per cent of the teachers involved?*

How is work assigned to students?

Australian students were found (Figure 3.4/*3.3*) to spend twice as much time working on a set of problems (these were called *concurrent problems* by the researchers) than they did as a class on a single problem (*independent problems*). The balance was found to be similar in the Netherlands and Switzerland. In the other countries the balance was in the other direction – more time on independent than concurrent problems. *What opportunities would greater use of independent problems provide, especially in relation to students verbalising mathematics when explaining their work on a problem that is a shared experience for the members of the class?*

What was working on problems like for the students?

Across the countries the average length of time spent working on independent problems was between two and five minutes (Australia: 3 minutes) except for Japan where the figure was 15 minutes (Figure 3.5/*3.4*). *Do I/we give complex enough problems to the whole class so that they can struggle a little? Do I/we give them enough time to try to work on problems? Achieving short-term goals can be motivating and rewarding, but is there anything in what and how our Japanese colleagues approach these sorts of whole class problems that can be adapted?*

Another finding that may be unexpected is that in these lessons the Australian students worked individually for around 75 per cent of the time they spend working on problems (Figure 3.10/*3.9*). *Is 25 per cent of the time my/our level of collaborative work?*

How complex were the problems set for students?

The researchers defined three levels of *procedural complexity*:

- *Low complexity* problems require four or fewer decisions, with no sub-problems (*eg solve* $2x + 7 = 2$).
- *Moderate complexity* problems require more than four decisions and can contain a sub-problem (*eg solve for x and y:* $2y = 3x - 4$; $2x + y = 5$).
- *High complexity* problems require more than four decisions and contain two or more sub-problems (eg graph the following inequalities and find the area of intersection: $y \leq x + 4$; $x \leq 2$; $y \geq -1$).

This classification is an example of the potential usefulness of the framework in prompting reflection on what is being done in our classrooms. The results were that in the Australian lessons 8 per cent of problems were *high procedural complexity*; 16 per cent *moderate complexity*; 77 per cent *low complexity* (Figure 4.1/*4.5*). This last figure was the highest numerically of all the countries, although statistically higher than only Japan. *Is this indicative of expecting enough of Year 8 students?*

How much mathematical reasoning is going on?

Proofs were defined as being present if ‘the teacher or students verified or demonstrated that the result must be true by reasoning from the given conditions to the result using a logically connected set of steps’. There were so few problems or lessons that contained *proofs* in the Australian lessons that researchers were unable to make reliable estimates of their occurrence (Figure 4.4/*4.6*). *Given the emphasis on thinking, analytical reasoning, communication and problem solving skills in education for life in the 21st century, am I/are we doing enough to build these through our focus on mathematical reasoning in the classroom? Are important opportunities to keep mathematics relevant being missed?* It is worth noting that most other countries seem to be similar. A significant component of proof was only found in the Japanese lessons.

How is the mathematics related through the lesson?

In the Australian lessons, some 76 per cent of the problems after the first were related to previous problems as *repetition* (as distinguished from being *thematically* (8%) or *mathematically* (13%) related, or *unrelated* (4%)) (Figure 4.6/*4.7*). A related result is that repetition took at least 65 per cent of the students' private work time (Figure 5.13/*4.12*). *Do I/we have a similar focus on repetition/practice? To what extent does this link to the 'I'm bored' response of some/many students?*

What were the problems like?

Researchers distinguished between problems that were set up with some *real-life connection*, and those that were wholly set up *using mathematical language or symbols*. The Australian lessons were found to have 27 per cent of the former and 72 per cent of the latter (Figure 5.1/*4.2*). *Is this around the mix I/we achieve? Is it an appropriate mix given the emphasis on 'making mathematics meaningful', middle schooling philosophy and the like?*

The classification of the actual problems set is again interesting and potentially useful for Australian teachers in their reflections on practice. More than 60 per cent of problems in the Australian lessons were about *using procedures*, with 15 per cent designed for *making connections* (Figure 5.8/*4.9*). *Should I/we have more emphasis on* making connections*? Is that important?…desirable?…achievable?*

What talk went on in the classrooms?

The ratio of words spoken by teachers to those spoken by students in the Australian lessons is 9:1, and this is fairly typical (Figure 5.14[8] and Figure 5.15/*3.12*). Given this, it is not surprising that teachers' talk was more in extended utterances (35 per cent being *more than 25 words*, as opposed to 7 per cent of the students' talk; Figure 5.16/*3.13* and Figure 5.17/*3.14*). *Do I/we talk that much? Should I/we?*

What resources were used in the lessons?

The lessons are analysed for the use of a wide variety of resources. The low use of computers in the Australian lessons (4%) may reflect the fact that these were 1999 lessons. A relatively low uptake is still likely, however. Certainly in 2003 *computer use* is unlikely to approach the 1999 figure of students using *computational calculators* in 56 per cent of the lessons. *Am I/are we using computers at this sort of level in Year 8 mathematics lessons? What factors might be inhibiting uptake…availability of hardware and/or suitable software and computer-based materials?…professional development?…bandwidth into schools?*

A note of caution

There is no doubt that the TIMSS 1999 Video Study is a highly professional piece of work, but as with all educational research readers need to look at the findings critically. As part of the framework the researchers have had to define a range of terms and these may be somewhat problematic. For example the term *problem* was defined as 'events that contained a statement asking for some unknown information that could be determined by applying a mathematical operation'. This is a very broad definition that encompasses what Australians might call 'exercises' or even 'calculations'. Similarly the idea of *process* is perhaps broader than is usual in discussions in this country. There are undoubtedly other definitional differences. These are likely to spark good professional discussion as teachers come to discuss the work and findings, and this is in itself worthwhile.

The researchers have also had to create other definitions as part of the development of the framework for unpacking teaching and learning. Some examples such as *procedural complexity* and categories for classifying problems have been outlined above. Again, it is likely that teachers

[8] Data not shown in Australian report

and others will differ in their views about the appropriateness of these, and this can and will lead to productive professional development.

Moving forward in the teaching of mathematics

The majority of this paper has dwelt on the ways in which the TIMSS 1999 Video Study has illuminated Australian mathematics classrooms. Making detailed comparisons with other countries can be useful, but only insofar as it assists with this illumination, and if it provides images of how things might be done differently.

No matter how the report and the public release lessons are used in teachers' professional development, the most productive focus will be on the core concern of teachers of mathematics – planning their teaching, structuring lessons, identifying the work students need to do, managing the learning, classroom interactions, resources and so on. In doing this, teachers will benefit from the work of the AAMT on its professional teaching standards, as these provide a common language for talking about teaching mathematics.

There is no doubt that the public release lessons, in particular, provide an engaging stimulus for teachers to reflect on components of the AAMT professional teaching standards in relation to their teaching of mathematics. Teachers in Australia and around the world will be indebted to these colleagues, for many years to come, for their generosity in sharing their work with others. Sincere thanks to them all from the mathematics teachers of Australia.

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The Need to Increase Attention to Mathematical Reasoning

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The international report of the TIMSS 1999 Video Study provides a fascinating insight into national differences and provides a high quality set of findings on teaching mathematics that will be analysed and discussed for many years. The strength of the sampling, the range of constructs observed, the detailed analysis and the clarity of presentation of results, all contribute to making the report extremely useful as a basis for professional development, for research and also for helping set future directions for improvement.

The results of the original TIMSS assessment study (TIMSS 1995) form a backdrop to the video study. That study tested mathematics achievement of 13-year-old, 9-year-old and Year 12 students, as well as collecting data on a wide range of variables that might be able to explain achievement. The international results showed Australia to be doing reasonably well in mathematics. The Australian 13-year-old students tied for ninth place with 14 countries, out of a total group of 41 countries tested in the written tests, and in the performance assessment Australian students were also clearly above average (Harmon et al., 1997; Lokan, Ford & Greenwood, 1996). Australia was one of the highest achieving of the western English-speaking countries, doing generally better than England, USA and New Zealand, but the results demonstrated clearly the possibilities for improvement.

As responsible scientists, the authors of the international video report carefully refrain from drawing conclusions about cause and effect from the data in this study: they cannot scientifically claim that the features of classrooms in the high achieving countries cause high achievement. In fact, the main conclusion drawn by the report is only that different methods of teaching can lead to high achievement. However, if Australia is to use the results of this research to improve its mathematics achievement, then we need to go beyond the scientifically proven links and 'join the dots' to make an interpretable picture. In this short piece, I will outline the main area needing attention in the joined-dots picture that I see.

The shallow teaching syndrome: procedures without reasons

The average lesson in Australia reveals a cluster of features that together constitute a syndrome of shallow teaching, where students are asked to follow procedures without reasons. The evidence for this syndrome lies in the low complexity of problems undertaken with excessive repetition, and an absence of mathematical reasoning in the classroom discourse.

Excessive repetition

The video study classified each problem according to its relationship to previous problems. On average, 76 per cent of problems in Australian classrooms were repetitions of previous problems (Figure 4.6/*4.7*)[9]. This was the highest percentage[10] of the seven countries. The definition of repetition means that the problems are indeed extremely similar, with only the numbers or other elements changed. For example, calculating $\sqrt{(-4)^2}$ after $\sqrt{(4)^2}$ is not regarded as repetition. Conversely, Australia had the lowest percentage[11] of problems (13%) that were 'mathematically related', where students had to extend a previous solution method even in a minor way, as in the example above. In Hong Kong SAR, which also had a high rate of repetition (69%), nearly twice

9 That is, Figure 4.6 in the international report of the TIMSS 1999 Video Study (Hiebert et al., 2003), but Figure *4.7* in this Australian report of the study.

10 In the international report, claims such as highest are made only where statistically significant. In this commentary, claims refer to the data and do not necessarily indicate statistical significance. In this example, Australia has the numerically highest percentage, but this is not significantly higher than any of the other countries except Japan.

11 Significantly lower than Hong Kong SAR and Japan

as many problems were mathematically related (24%). Australian students spent 65 per cent of their individual work time repeating procedures that had just been demonstrated.

Problems of low complexity

The video study classified all problems as being of high, moderate or low procedural complexity, according to how many (small) steps a typical solution might take. Solving the equation $2x+7 = 2$ is of low complexity, whereas solving a pair of simple simultaneous equations is of moderate complexity. On this measure, Australian lessons had an average of 77 per cent of problems of low complexity, again the highest of the seven countries (Figure 4.1/*4.5*).[12] Since this measure could well depend on the balance of topics studied, it was repeated for plane geometry. In this topic, fewer problems were of lower complexity, but again Australia had the highest percentage of the seven countries.

Absence of mathematical reasoning

The study looked for evidence of mathematical reasoning in two ways. Firstly, they identified all the lessons where some form of deductive reasoning, even very informal, was evident. Too few lessons were found in Australia to register (i.e., less than 1 per cent), along with the Netherlands and the United States (Figure 4.4/*4.6*). The four other countries ranged from 5 per cent to 39 per cent (Japan) of lessons.

Secondly, problems were classified, according to the mathematical processes expected to be used to solve them, as *using procedures* (e.g., solving a standard equation), *stating concepts* (giving an example or interpreting a convention – e.g., by plotting a point) and *making connections*. This final group included linking mathematical concepts, facts and procedures, and making generalisations and verifying them, all aspects of mathematical reasoning. Figure 5.8/*4.9* shows that 15 per cent of Australian problems were in this making connections category, a low figure but similar to that in three other countries.[13] The actual solutions presented in the class (by teachers or students) were then also analysed. This showed that in Australia, only 2 per cent of the total number of problems exhibited evidence of *making connections* when actually solved (Figure 5.9/*4.10*), and this included only 8 per cent of the problems specifically identified as *making connections*. More commonly the public solution was to state a concept, use a procedure or just give the result (Figure 5.12/*4.11*). Together these results point to an absence of mathematical reasoning in the average Australian Year 8 mathematics class.

Performance and valued goals

Observing that the average Australian lesson demonstrates shallow teaching is not important unless it means that it prevents Australia reaching goals that it wants to achieve. So what are Australian goals?

A central feature of the curriculum in all states over the last two decades and of *A National Statement on Mathematics for Australian Schools* (Australian Education Council, 1991) has been an implicit trade-off between time spent on procedural skills and time on higher-order thinking. Especially because of the advent of affordable technology, mathematics curriculum leaders judged that the ability to carry out detailed arithmetic or algebraic processes was no longer a highly prized skill. They saw an opportunity to work instead on the poor conceptual understanding of mathematics and the difficulty of applying mathematical knowledge to real world or unfamiliar mathematical problems; both of which research had consistently shown are prevalent around the world. Curriculum documents of the last decades therefore show a reduced emphasis on computational skill and algebraic procedures, and substantial emphasis on students' obtaining deep understanding of the underlying ideas and being able to use them in real contexts.

Australia's low emphasis on the development of computational skills was evident in internationally poor results. This was the only major area of the TIMSS 1995 mathematics tests

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[12] Significantly higher than Japan

[13] Significantly lower than Japan

where Australian students were consistently below the international average. To illustrate, the 13-year-old students had the lowest success rate in the world (25%) on the item $\frac{8}{35}$ divided by $\frac{4}{15}$. In all of these items, the Asian countries had high success rates, some over 90 per cent. These results are not, of themselves, particular cause for concern, provided that Australia can see benefits from the trade off of routine skill for conceptual understanding and problem solving.

Some TIMSS 1995 items tested conceptual understanding. On these items, Australia is generally above the international average, consistent with its overall position, but the gains on conceptual understanding seem small in comparison to the loss on the other items. For example, an item asking 13-year-old students to order three decimals and a fraction had an Australian success rate of 47 per cent, an international average of 44 per cent and a Singapore success rate of 84 per cent. Singapore students seem to develop a strong conceptual understanding of number (including large numbers, fractions and decimals) early and they apply this to achieve high success rates in most areas of mathematics. Fewer TIMSS written items assessed applying mathematics. However, a similar pattern is evident in the results and also in the performance assessment.

In summary, Australia has not achieved the gains that one might have expected. The reduction in goals for procedural skills is evident in TIMSS results, and in the video study in the dominance of low complexity items and possibly also in the relatively slow curriculum pace – only 56 per cent of lesson time is spent on new material (Figure 3.8/*3.7*). However, we do not have evidence that we have yet reaped the desired benefits of better conceptual understanding and problem solving ability, with real world problems or otherwise.

Linking learning outcomes to lessons with high-level reasoning

The video study demonstrates that the average Australian lesson now focuses on procedures, learned through repetition without making mathematical connections. In addition, Australia is only average in frequency of use of real world contexts. What evidence is there that this teaching method may be a reason for the less-than-expected performance on conceptual understanding and problem solving ability? The video study provides some indirect evidence (to be noted below), but the major evidence comes from other research.

In considering teachers' characteristics and their association with children's numeracy performance in Britain, Askew, Brown, Rhodes, Johnson and Wiliam (1997) identified teachers' recognition of deep connections between mathematical ideas as one of the few predictors of high learning gains by children. Effective teachers of numeracy saw mathematics as richly connected and adopted classroom strategies that helped children to make links. Teachers whose mathematics teaching style was oriented to 'transmission' or 'discovery' (where children worked out ideas with little teacher input) were less effective. Ma (1999) makes a similar claim, comparing Chinese and American teachers.

There are a number of quantitative and qualitative studies reporting that higher learning gains are associated with the classroom use of mathematical tasks that engage students in high-level cognitive reasoning, including the QUASAR project that substantially improved the achievement of middle school children in underachieving schools in the United States (see, for example, Stein & Lane, 1996; Henningsen & Stein, 1997). These studies highlighted, however, that although good tasks might seem to be the causal mechanism, the teacher influences the choice, timing, and detail of their implementation in classrooms. A lesson may be more or less successful in sustaining high level thinking, depending on the actions and pedagogical decisions of the teacher within the classroom. Ball (2000) also demonstrates how the mathematical climate in a class is the result of a myriad of teaching decisions, such as what questions to ask, what examples to choose, which methods to explain, and so on. Opportunities can therefore easily be missed.

Two models from the video study, with one conclusion

The video study demonstrates that the two highest achieving countries have different teaching methods. Stigler and Hiebert (1999) attribute the Japanese success to the way that Japanese teachers developed lesson plans with deep cognitive content and careful attention to lesson objectives and mathematical connections (see also Shimizu, 1999). They build lessons around a small number of rich problems and sustain an emphasis on mathematical reasoning. The Australian public release lessons show examples of rich problems being used in Australian schools, but the overall averages suggest that their potential for drawing out mathematical reasoning and connections is not being realised. Instead, rich problems are being reduced to problems that are solved by statements of facts or routine procedural work.

The high achievement in Hong Kong SAR is built on different foundations. Like Australian students, Hong Kong SAR students spend most of their time on problems emphasising procedures, although they have more problems of moderate complexity and spend more time on new material with less repetition. There is also more emphasis on mathematical connections than in Australia: more lessons have some evidence of proof, and the solutions of 12 per cent of problems involve making connections. These students seem to get more out of their primarily procedurally-oriented teaching.

In summary, whether Australia pursues the reform ideal of having students learn mathematics by deep engagement with rich problems or alternatively seeks to maximise outcomes obtained by emphasising standard sets of mathematical procedures, there needs to be a greater emphasis on explicit mathematical reasoning, deduction, connections and higher-order thinking in lessons. The research evidence indicates that this may increase achievement, but it is also of *a priori* importance since these are the thinking processes that characterise mathematics. The video study shows that this can be done with Year 8 students better than is currently done in the average Australian classroom.

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Appendix A

TECHNICAL INFORMATION

The TIMSS 1999 Video Study was carried out to the same high methodological standards as the TIMSS 1995 and 1999 assessments and other IEA studies. Procedures were developed to ensure that data were collected in standardised ways across countries, and that sampling was carried out according to specifications so that statistically reliable country estimates could be reported. Full technical details are contained in the technical report of the study (Jacobs et al., in press).

This appendix provides a summary for Australian readers of the technical details of the mathematics portion of the study. It is drawn largely from Appendix A of the international report, *Teaching Mathematics in Seven Countries* (Hiebert et al., 2003), but is supplemented with some relevant Australian data.

Sampling

The sampling objective was to obtain a representative sample of Year 8 mathematics lessons in each participating country, large enough to enable inferences to be made about the national populations of lessons for the countries. In general, the sampling plan followed the standards and procedures agreed to and implemented for the TIMSS 1999 assessments (see Martin, Gregory & Stemler, 2000). The school sample was required to be a 'Probability Proportional to Size' (PPS) sample. A PPS sample assigns a probability of selection to each school according to its enrolment of Year 8 students as a proportion of the number of Year 8 students in schools countrywide (thus, larger schools have a higher chance of being chosen). Once the schools were selected, one Year 8 mathematics class per school was sampled randomly from lists of classes and timetables provided by the schools.[1]

Most of the participating countries drew separate samples for the video study and the TIMSS 1999 student assessments. For this and other reasons, the TIMSS 1999 assessment data cannot be directly linked to the video database, although Australia and Switzerland both extended the study by having the videotaped students complete a written mathematics test.

Sample size

All of the TIMSS 1999 Video Study countries were required to include 100 schools in their initial selection of schools. Switzerland wished to analyse its data by language group, and therefore selected a nationally representative sample (156 schools) that would also be statistically reliable for their French-, Italian-, and German-language regions. The Japanese mathematics data, from the TIMSS 1995 Video Study, included only 50 schools.

The TIMSS 1999 Video Study final sample comprised 638 Year 8 mathematics lessons. Table A.1 indicates the sample size and participation rate for each country.

1 Some countries, including Australia, also selected and filmed science classes.

Table A.1 Sample size and participation rate for each country

Country	Number of schools that participated	Percentage of schools that participated, including replacements[1] – unweighted[2]	Percentage of schools that participated, including replacements[1] – weighted[3]
Australia[4]	87	85	85
Czech Republic[4]	100	100	100
Hong Kong SAR	100	100	100
Japan[5]	50	100	100
Netherlands[4]	85[6]	87	85
Switzerland[7]	140	93	93
United States	83	77	76

[1] The participation rate including replacement schools is the percentage of all schools (i.e., original and replacements) that participated.
[2] Unweighted participation rates were computed using the actual numbers of schools and reflect success in terms of getting schools to take part.
[3] Weighted participation rates reflect the probability of being selected into the sample and show success in terms of the population of schools to be represented.
[4] For Australia, the Czech Republic, and the Netherlands, these figures represent the participation rates for the combined mathematics and science samples.
[5] Japanese mathematics data were collected in 1995.
[6] In the Netherlands, a mathematics lesson was filmed in only 78 of the schools.
[7] In Switzerland, 74 schools participated from the German-language area (99 per cent unweighted and weighted participation rate), 39 schools participated from the French-language area (95 per cent unweighted and weighted participation rate), and 27 schools participated from the Italian-language area (77 per cent unweighted and weighted participation rate).

Sampling within each country

Within the specified guidelines, the participating countries each developed their own strategy for obtaining a random sample of Year 8 lessons to videotape for the study. For example, in the German-language area of Switzerland, the video sample was a sub-sample of the TIMSS 1995 assessment schools, and in Hong Kong SAR, most, but not all, of the video sample was a sub-sample of the TIMSS 1999 assessment schools. In the other countries, separate samples were drawn for the video and assessment studies.

National Research Coordinators were responsible for selecting or reviewing the selection of schools and lessons in their country. Identical instructions for sample selection, based on those used for the TIMSS 1999 assessment study, were provided to all countries. In all cases, countries provided the relevant sampling variables to Westat, so that they could appropriately weight the school samples.[2]

Australian sample

According to specifications, the designed Australian sample consisted of 100 schools. The sample was randomly selected by computer, with probability proportional to size of Year 8 enrolment, from the sampling frame of Australian schools maintained by the Australian Council for Educational Research (ACER).

Prior to selection, the sampling frame was stratified by state and territory. Within these strata, schools were listed by sector (government, Catholic and independent) in order of enrolment size,

[2] Since it was based on the TIMSS 1999 assessment sample, the Hong Kong SAR school sample was selected and checked by Statistics Canada. In the United States, Westat selected the school sample and LessonLab selected the classroom sample.

with government and independent schools in descending order and Catholic schools in ascending order. Within the five mainland states, schools were also stratified by metropolitan/non-metropolitan, based on their telephone codes. As was done for the TIMSS 1999 assessment, permission was obtained from the sampling referee to exclude schools in remote areas with five or fewer Year 8 students enrolled (the total number of Year 8 students in such schools across the country was very small).

The allocation of schools by state and territory was approximately proportional to the estimated number of students, except that there was some slight undersampling in the largest state, New South Wales, and a corresponding oversampling in Tasmania and the Northern Territory, both of which have relatively small enrolments. Permission was obtained from the sampling referee to slightly undersample non-metropolitan schools,[3] which meant that metropolitan schools were oversampled to maintain the approximate proportional sampling within the states. The 1998 enrolment figures and the designed sample are shown in Table A.2.

Table A.2 Year 8 enrolment and designed Australian sample

State	Year 8 enrolment[1]	Percentage of total Year 8 enrolment	Designed sample (no. of schools)
New South Wales	84 574	32.8	30
Victoria	61 518	23.8	24
Queensland	50 114	19.4	19
South Australia	19 994	7.8	8
Western Australia	27 471	10.7	11
Tasmania	7 084	2.7	4
Northern Territory	2 385	0.9	2
Australian Capital Territory	4 853	1.9	2
Total	258 003	100.0	100

[1] Source: *Schools Australia 1998*, Australian Bureau of Statistics, Catalogue 4221.0

The allocation of the designed sample by state and sector is shown in Table A.3, together with details of the achieved sample. As is customary in such studies, schools were initially approached through their principal. Given the possibly daunting prospect for teachers of having video cameras in their classrooms, most principals discussed the approach with their teachers before giving consent for the school to participate. Principals and teachers knew from the initial approach that a Year 8 mathematics class would be chosen at random, and so once the consent to take part was given, only one school was later lost to the study because the selected teacher did not wish to be filmed. Altogether, 61 of the originally selected schools participated and the remainder of the achieved sample was made up with replacement schools.

As can be seen in Table A.3, most of the refusals came from New South Wales, where industrial problems in both the government and Catholic sectors were experienced for several months prior to the time of the study. Apart from that circumstance, the response rate was generally excellent.[4] Non-metropolitan areas were represented in the achieved sample in all but the two territories (the Australian Capital Territory has no secondary schools in non-metropolitan areas). Of the 54 government schools where lessons were filmed, 40 were in metropolitan areas; of the 17 Catholic

[3] This was done to contain the costs of data collection, a very expensive undertaking in a large country like Australia when teams of videographers have to be sent to the participating schools.

[4] Disparities in representativeness of the achieved sample were compensated for in the analyses by statistical weighting.

schools, 14 were in metropolitan areas; and of the 16 independent schools, 13 were in metropolitan areas. Thus, in the total of 87 schools, 67 were in metropolitan areas and 20 in non-metropolitan areas. This breakdown is a reasonable reflection of the distribution of schools countrywide, allowing for the slight undersampling of schools from non-metropolitan areas.

Table A.3 Designed and achieved Australian samples, by state and sector

	State								
Sector	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	**Total**
Designed									
Government	20	14	12	5	6	3	1	1	62
Catholic	6	6	4	1	3	0	1	1	22
Independent	4	4	3	2	2	1	0	0	16
Total designed	30	24	19	8	11	4	2	2	100
Achieved									
Government	12	14	12	4	5	3	1	1	52
Catholic	3	6	4	0	2	0	1	1	17
Independent	4	4	3	2	2	1	0	0	16
Total achieved	19	24	19	6	9	4	2	2	85

Note: In addition to the numbers of schools shown in the table, classes in two extra government schools were filmed. This came about because in two instances the initially selected school at first refused to take part, and hence the replacement school was approached and agreed to be involved. Later, the originally selected school changed its mind, and was included in the filming as well. One of the two extra schools was in Queensland and the other was in the Northern Territory. The data for the two replacement schools were retained in the database and the weighting of schools in those states was adjusted to retain proportionality of representation.

Videotaped lessons

As noted earlier, only one mathematics class was randomly selected within each school. No substitution of a teacher or a class period was allowed. The designated class was videotaped once, in its entirety, without regard to the particular mathematics topic being taught or type of activity taking place. The only exception was that teachers were not videotaped on days they planned to give a test for the entire class period.

The complexities of scheduling meant that teachers had to be contacted a short while in advance of the filming, usually between one and five days ahead. Teachers were asked to do nothing special for the videotape session, and to conduct the class as they had planned. The scheduler and videographer in each country determined on which day the lesson would be filmed. If the class would have been doing a test at the nominated time, arrangements were made for the same class, taught by the same teacher, to be filmed on another day.

Most of the filming took place in 1999. In some countries filming began in 1998 and ended in 1999, and in other countries, including Australia, filming began in 1999 and ended in 2000. The goal was to sample lessons throughout a normal school year, while accommodating how academic years are organised in each country.

It is customary in Australia to inform parents when their children have been selected to take part in a research study and to provide them with the opportunity to refuse permission for their child to be involved. In this study, the requirement that each student return a signed permission slip from their parent(s), agreeing to the student's participation in the filming, was strictly adhered to by the researchers.

Questionnaires

Teacher Questionnaire

To help understand and interpret the videotaped mathematics lessons, questionnaires were collected from the teachers of these lessons. The Teacher Questionnaire was designed to elicit information about the professional background of the teacher, the nature of the mathematics course in which the lesson was filmed, the context and goal of the filmed lesson, and the teacher's perceptions of its typicality. Teacher Questionnaire response rates are shown in Table A.4.

Table A.4 Teacher Questionnaire response rates

	Teacher questionnaire response rate (unweighted)	
Country	Percentage	Sample size
Australia	100	87
Czech Republic	100	100
Hong Kong SAR	100	100
Netherlands	96	75
Switzerland	99	138
United States	100	83

Note: Japan did not collect a new mathematics sample for the TIMSS 1999 Video Study.

The Teacher Questionnaire was developed in English and consisted of 27 open-ended and 32 closed questions. Countries could modify the questionnaire items to make them culturally appropriate. In some cases, questions were deleted for reasons of sensitivity or appropriateness. Country-specific versions of the questionnaire were reviewed for comparability and accuracy.[5]

The open-ended items required development of quantitative codes, a procedure for training coders, and a procedure for calculating inter-coder reliability. An 85 per cent within-country inter-coder reliability criterion was used. The reliability procedures were similar to those used in the TIMSS 1995 assessment to code students' responses to the open-ended tasks (Mullis, Jones & Garden, 1996; Mullis & Martin, 1998).

Student Questionnaire

Short questionnaires were also distributed to the students in each videotaped lesson.[5] Student data are not presented in the international report, but some of the Australian data are reported in Chapter 2 of this Australian report.

Australian adaptations

Adaptations needed to the questionnaires for Australian use were minor to very minor. Vocabulary such as 'elementary school' and 'high school' was changed to 'primary school' and 'secondary school'; 'grade level' was changed to 'year level'; 'graduate school' was changed to 'postgraduate studies' and 'college courses' to 'university courses', and so on. Reference to District level curriculum guides was removed and reference to national curriculum documents was replaced by reference to 'your state's version of the National Mathematics Statement'. In the Student Questionnaire, questions referring to race and ethnicity were replaced by questions asking for country of birth and language(s) spoken at home most of the time, and a question asking about Aboriginal or Torres Strait Islander status was added.

[5] The questionnaires are available online at http://www.lessonlab.com

Video Data Coding

This section provides information about the teams involved in developing and applying codes to the video data. Group members are not specified in this Australian report, but can be found in Appendix B of *Teaching Mathematics in Seven Countries*. For validity and credibility of the study's findings, it is crucial that codes developed to describe the data could be applied reliably by a large team of coders. Thus, a great deal of time and effort was expended to ensure that the codes were clear and that coders could meet stringent criteria of consistency in their judgments when applying the codes.

The Mathematics Code Development Team

An international team was assembled to develop codes to apply to the TIMSS 1999 Video Study mathematics data. The team consisted of country associates (bilingual representatives from each country) and was directed by a mathematics education researcher.[6] The Mathematics Code Development Team was responsible for creating and overseeing the coding process, and for managing the International Video Coding Team (see below). The team discussed coding ideas, created code definitions, wrote a coding manual, gathered examples and practice materials, designed a coder training program, trained coders and established reliability, organised quality control measures, consulted on difficult coding decisions, and managed the analyses and write-up of the data.

The International Video Coding Team

Members of the International Video Coding Team represented all of the participating countries. They were fluently bilingual and so could watch the lessons in their original language, and not rely heavily on the English-language transcripts. In almost all cases, coders were born and raised in the country whose lessons they coded.

Coders in the International Video Coding Team applied 45 codes in seven coding passes through each of the videotaped lessons. They also created a lesson table for each video, which combined information from a number of codes. For example, the lesson tables noted when each mathematical problem began and ended, and included a description of the problem and the solution. These tables served several purposes: they acted as quick reference guides to each lesson, they were used in the development process for later codes, and they enabled problems to be further coded by specialist coding teams.[7]

Coding reliability

As with any study that relies on coding, it is important to establish clear reliability criteria. Based on procedures previously used and documented for the TIMSS 1995 Video Study and as described in the literature (Bakeman & Gottman, 1997), percentage agreement was used to estimate inter-rater reliability and the reliability of codes within and across countries for all variables presented in the report. Percentage agreement allows for consideration not only of whether coders applied the same codes to a specific action or behaviour, for example, but also allows for consideration of whether the coders applied the same codes within the same relative period of time during the lesson.

The calculation of 'percentage agreement' in this study is defined as the proportion of the number of agreements to the number of agreements plus disagreements. Coders established *initial reliability*, at or near the beginning of applying codes, on all codes in a coding pass prior to their actual implementation. After the coders had finished coding approximately half of their assigned set of lessons (in most cases about 40–50 lessons), they established *midpoint reliability*. The

6 The mathematics team did not include a representative from Japan because Japanese mathematics lessons were not filmed as part of the TIMSS 1999 video data collection.

7 A subset of these lesson tables, from all countries except Japan, was expanded and then coded by the Mathematics Quality Analysis Group, described below.

minimum acceptable reliability score for each code (averaging across coders) was 85 per cent. Individual coders or coder pairs had to reach at least 80 per cent reliability on each code.[8]

Initial reliability was computed as agreement between coders and a master document. A master document refers to a lesson or part of a lesson coded by consensus by the Mathematics Code Development Team. To create a master, the country associates independently coded the same lesson and then met to compare their coding and discuss disagreements until consensus was achieved. The method of establishing reliability via comparison with master documents is considered a rigorous and cost-effective alternative to inter-coder reliability (Bakeman & Gottman, 1997).

Midpoint reliability was computed as agreement between pairs of coders. By half way through the coding process, coders were considered to be more expert in the code definitions and applications than the Mathematics Code Development Team. Therefore, in general, the most appropriate assessment of their reliability was deemed in this study to be a comparison among coders rather than to a master document. Inter-rater agreement was also used to establish initial reliability in some of the later coding passes, but only for those codes for which coders helped to develop coding definitions.

A percentage agreement reliability statistic was computed for each coder by dividing the number of agreements by the sum of agreements and disagreements, as mentioned above. Average reliability was then calculated across coders and across countries for each code. In cases where coders did not reach the established reliability standard, they were re-trained and re-tested using a new set of lessons. Codes were dropped from the study if 85 per cent reliability could not be achieved (or if individual coders could not reach at least 80 per cent reliability).

What counted as an agreement or disagreement depended on the specific nature of each code, and is explained in detail in Jacobs et al. (in press). Some codes required coders to indicate a time. In these cases, coders' time markings had to fall within a predetermined margin of error. This margin of error varied depending on the nature of the code, ranging from 10 seconds to two minutes.

After coder training, and retraining as necessary, all assigned codes met, and usually exceeded, the minimum acceptable reliability standard established for the study. Over about 40 variables, the mean percentage agreement was just under 96 per cent for both initial and midpoint measurements. Least reliable, at 86 per cent agreement for both occasions, were judgments of what was or was not a 'public announcement'; most reliable, at almost 100 per cent, were the variables relating to use of various kinds of equipment. The largest discrepancy, of 10 percentage points, between initial and midpoint reliability was for judging what was or was not a 'goal statement', which was less easily agreed on after coders became more experienced. The obtained initial and midpoint reliability values are included in *Teaching Mathematics in Seven Countries.*

Specialist coding groups

The majority of codes for which analyses were conducted in this report were applied to the video data by members of the International Video Coding Team, who were cultural 'insiders' and fluent in the language of the lessons they coded. However, not all of them were experts in mathematics or teaching. Therefore, several specialist coding teams with different areas of expertise were employed to create and apply special codes concerned with the mathematical nature of the content, the pedagogy, and the discourse.

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[8] The minimum acceptable reliability score for all codes (across coders and countries) was 85 per cent. For coders and countries, the minimum acceptable reliability score was 80 per cent. That is, the reliability of an individual coder or the average of all coders within a particular country was occasionally between 80 and 85 per cent. In these cases clarification was provided, but re-testing for reliability was not deemed necessary.

Mathematics Problem Analysis Group

Members of the Mathematics Problem Analysis Group were individuals with expertise in mathematics and mathematics education. They developed and applied a series of codes to all of the mathematical problems in the videotaped lessons, using lesson tables that had been prepared by the International Video Coding Team.

From textbooks and curriculum materials provided by countries, the Mathematics Problem Analysis Group constructed a comprehensive, detailed, and structured list of mathematics topics covered in eighth grade in all participating countries. Each problem marked in a videotaped lesson was connected to a topic on the list.

In addition to coding the mathematics topics of problems, the group also coded the procedural complexity of each problem and the relationships among problems, and identified application problems (as defined in Chapter 4).

The members of this group each established reliability with the director of the group by coding a randomly selected set of lessons from each country. Their codes were then compared with those in a 'master' set prepared by the director. Both initial reliability and reliability after approximately two-thirds of the lessons had been coded were computed. The percentage agreement was above 85 per cent for each code.

Mathematics Quality Analysis Group

A second specialist group possessed special expertise in both mathematics and mathematics teaching at the post-secondary level. The same group had previously been commissioned to develop and apply codes for the TIMSS 1995 Video Study. The Mathematics Quality Analysis Group reviewed a randomly selected subset of 120 lessons (20 lessons from each country except Japan). Japan was not included because the group had already analysed a subsample of the Japanese lessons as part of the 1995 Video Study.

Specially trained members of the International Video Coding Team created expanded lesson tables for each of the 120 lessons in the subsample. The resulting tables all followed the same format: they included details about the classroom interaction, the nature of the mathematical problems worked on during class time, descriptions of time periods during which problems were not worked on, mathematical generalisations, labels, links, goal statements, lesson summaries, and other information relevant to understanding the content covered during the lesson. Furthermore, the tables were 'country-blind', with all indicators that might reveal the country removed. For example, proper names were changed to those deemed neutral to Americans, and lessons were identified only by an arbitrarily assigned ID number. The Mathematics Quality Analysis Group worked solely from these written records, and had no access to either the full transcripts or the video data.

The group created and applied a coding scheme that focused on mathematical reasoning, mathematical coherence, the nature and level of mathematical content, and the overall quality of the mathematics in the lessons. The scheme was reviewed by mathematics experts in each country and then revised based on the feedback received. The group applied their coding scheme by studying the written records of the lessons and reaching consensus about each judgment.

Because the subsample of 120 lessons contained relatively few lessons (20) from each country, it might not be representative of the full sample of Year 8 mathematics lessons in each country, and so only descriptive analyses of the group's coded data were included in *Teaching Mathematics in Seven Countries* (as Appendix D); no statistical comparisons were made.

The twenty Australian lessons selected for this analysis comprised two from New South Wales, seven from Victoria, six from Queensland, two from Western Australia, and one each from South Australia, Tasmania and the Northern Territory. Fourteen of the twenty schools involved were government schools, four were Catholic and two were independent. They were chosen from a random starting point on a list that was approximately in chronological order of filming. The selection is not in proportion to the stratified composition of the sample.

Problem Implementation Analysis Team

The Problem Implementation Analysis Team analysed a subset of mathematical problems and examined 1) the types of mathematical processes implied by the problem statement, and 2) the types of mathematical processes that were publicly addressed when solving the problem.

Using the video data, translated transcripts, and the same lesson tables provided to their problem analysis colleagues, the Problem Implementation Analysis Team analysed only those problems that were publicly completed during the videotaped lessons. The team did not analyse data from Switzerland, since most of the Swiss transcripts were not translated into English.

Reliability was established by comparing codes assigned by the director of the team for a set of 10 lessons from each country with codes assigned by one outside coder. This set of lessons was randomly selected from lessons that included at least one problem that was publicly completed during the lesson. Reliability of at least 85 per cent was achieved for all countries.

Text Analysis Group

The Text Analysis Group used all portions of the mathematics lesson transcripts designated as public interaction to conduct various discourse analyses. The group made use of specially designed computer software for these quantitative analyses of classroom talk.

Because of resource limitations, computer-assisted analyses were applied only to English translations of lesson transcripts.[9] In the case of the Czech Republic, Japan, and the Netherlands, all lessons were translated from the respective native languages, and in the case of Hong Kong SAR, 66 per cent were translated (34 per cent of the Hong Kong SAR lessons were conducted in English). English translations of Swiss lessons were not available and so were not analysed by the team.

Statistical Analyses

Most of the analyses presented in *Teaching Mathematics in Seven Countries* are comparisons of means or distributions across seven countries for video data and across six countries for questionnaire data. The TIMSS 1999 Video Study was designed to provide information about and compare mathematics instruction in Year 8 classrooms. For this reason, the lesson rather than the school, teacher, or student was the unit of analysis in all cases in the international report.

Analyses for the international report were conducted in two stages. First, means or distributions were compared across all available countries using either one-way ANOVA or Pearson Chi-square procedures. For some continuous data, additional dichotomous variables were created that identified either no occurrence of an event (code = 0) or one or more occurrences of an event (code = 1). Variables coded dichotomously were usually analysed using ANOVA, with asymptotic approximations.

Next, for each analysis that was significant overall, pairwise comparisons were computed and significance determined by the Bonferroni adjustment. However, if fewer than three lessons within a country had an observed code, all pairwise comparisons involving that country were first removed from the analysis.

The Bonferroni adjustment was made assuming all combinations of (the remaining) pairwise comparisons.[10] For continuous variables, Student's t values were computed on each pairwise

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[9] Transcribers/translators were fluent in both English and their native language, educated at least to Year 8 in the country whose lessons they translated, and had completed two weeks' training in the procedures detailed in the TIMSS 1999 Video Study Transcription and Translation Manual – see Jacobs et al. (in press). A glossary of terms was developed to help standardise translation within each country.

[10] See Appendix B.

contrast. Student's *t* was computed as the difference between the two sample means divided by the square root of the replication variance estimate for the difference. Determination that a pairwise contrast was statistically significant with $p < .05$ was made by consulting the Bonferroni *t* tables published by Bailey (1977). For categorical variables, the Bonferroni Chi-square tables published in Bailey were used.

The degrees of freedom were based on the numbers of replicate weights, which were 50 for each country. Thus, in any comparison between two countries there were 100 replicate weights, which were used as the degrees of freedom.

All tests were two-tailed. Statistical tests were conducted using unrounded estimates and standard errors, which also were computed for each estimate. The full set of standard errors for estimates shown in figures in *Teaching Mathematics in Seven Countries* are provided in Appendix C to that report. The analyses were conducted using data weighted with survey weights, which were calculated specifically for the classrooms in the TIMSS 1999 Video Study. A full description of the weighting procedures is included in Jacobs et al. (in press).

Appendix B

STATISTICAL SIGNIFICANCE AND MULTIPLE COMPARISONS

Throughout most of the body of this report, a difference between two observed values is labelled *significant* if it is statistically significant at the .05 level. That is, a difference is regarded as significant if a difference of that magnitude, or larger, would be observed less than 5 per cent of the time when, in fact, there was no difference in corresponding population values.

Although the probability that a particular difference will falsely be declared significant is low (5%) in each pairwise comparison, the probability of making such an error increases when *multiple comparisons* are made. For example, if six pairwise comparisons are made on a set of data, the probability that at least one will falsely be declared significant (at the .05 level) is just over one-quarter (0.26). For 14 comparisons, this probability rises to just over one-half (0.51), and for 21 comparisons it is nearly two-thirds (0.66). (Looking at it another way, on average, 5 per cent of multiple comparisons – one in twenty – will falsely be declared significant.)

It is possible, however, to make an adjustment when determining the significance of multiple comparisons that reduces to 0.05 (5%) the probability that *at least one* comparison will falsely be declared significant. Consistent with the international report of the video study, and previous international and Australian TIMSS reports, such an adjustment, based on the Bonferroni method, was used in determining significance when multiple comparisons were made between, and within, countries in this report.

The Bonferroni adjustment was made assuming *all possible combinations* of pairwise comparisons. Thus, for example, for comparisons between all seven participating countries on a particular variable, the adjustment for 21 comparisons was used; for comparisons between six countries, the adjustment for 15 comparisons was used; and for comparisons within a country on three levels of a variable, the adjustment for three comparisons was used.

Many readers of this report, however, may only be interested in how Australia compared with the other participating countries, and not in how the other countries compared among themselves. If this is the situation, a case can be made for making a 'limited' Bonferroni adjustment for comparisons between Australia and the other countries that assumes only all possible pairwise combinations that involve Australia. That is, for example, for comparisons between Australia and the six other participating countries on a particular variable, using the adjustment for six comparisons; for comparisons with five countries, using the adjustment for five comparisons.

Other readers may only be interested in comparing Australia with one other country on a few variables. In this situation, no Bonferroni adjustments may be appropriate, though readers should bear in mind the above warning that you can expect that 5 per cent of such results would falsely be identified as significant.

Table B.1 lists all the variables for which data are given in tables or figures in Chapters 2–4, and for which pairwise comparisons were made between Australia and other participating countries. For each variable, Table B.1 indicates the countries that were significantly different (at the 0.05 level) from Australia on that variable, using: 1) the 'full' Bonferroni adjustment;[1] 2) the 'limited' Bonferroni adjustment,[2] and 3) no adjustment to the critical *t*-value.[2]

[1] These are the results that are listed below the relevant table or figure in the report.

[2] This information is not provided in the international report.

Table B.1 Statistical significance for pairwise tests between Australia and the other participating countries, with and without Bonferroni adjustments

		Countries excluded		Countries significantly different to Australia ($p < .05$)[2]		
Reference[1]	**Test variable**	No data	Too few cases	'Full' Bonferroni adjustment	'Limited' Bonferroni adjustment	No Bonferroni adjustment
T2.1	Mathematics major	JP		CZ, NL	CZ, HK, NL	CZ, HK, NL
	Science major	JP				CZ, NL
	Education major	JP			US	HK, US
	Other major	JP				
T2.2	Mean years teaching	JP		HK, NL	HK, NL	CZ, HK, NL
	Mean years teaching maths	JP		CZ, HK, NL	CZ, HK, NL	CZ, HK, NL
T2.3	Teaching mathematics	JP		NL, US	NL, US	CZ, NL, US
	Teaching other classes	JP		CZ, SW	CZ, SW	CZ, SW
	Meetings with other teachers	JP		HK	HK	HK
	Maths-related work at school	JP		NL, SW	NL, SW	HK, NL, SW
	Maths-related work at home	JP				SW
	Other school-related activities	JP				NL, SW
F2.1	Agree	JP		CZ, HK	CZ, HK	CZ, HK
	No opinion	JP		CZ, HK	CZ, HK	CZ, HK
	Disagree	JP	NL			
T2.5	Mean lesson duration			HK	HK	HK, JP
	Standard deviation			CZ, JP	CZ, JP, SW	CZ, JP, NL, SW
F2.3	Content goal	JP			CZ	CZ, HK, NL
	Process goal	JP				
	Perspective goal	JP	HK			

T2.6	Using routine operations	JP				
	Reasoning mathematically	JP				HK, NL
	Applying mathematics	JP				
	Knowing mathematical content	JP				
	Other process goal	JP	HK			
	No process goal	JP	NL		na	na
F2.4	A fair amount or a lot	JP		CZ, HK	CZ, HK	CZ, HK, NL, US
	A little	JP				CZ
	Not at all	JP	AU, US			
F2.5	Better than usual	JP				NL
	About the same	JP		CZ	CZ, HK	CZ, HK
	Worse than usual	JP		CZ	CZ, HK, NL	CZ, HK, NL
F2.6	Better than usual	JP	HK, NL	CZ	CZ	CZ
	About the same	JP		CZ	CZ, HK	CZ, HK, US
	Worse than usual	JP		CZ, HK	CZ, HK, US	CZ, HK, US
F2.7	Videotaped lessons	JP		NL	NL	NL
	Similar lessons	JP		NL	NL	CZ, NL, SW, US
T2.7	No. of lessons in unit	JP		CZ	CZ	CZ
	Placement of lesson in unit	JP		CZ	CZ	CZ, HK
F3.1	Non-mathematical work				NL	NL
	Mathematical organisation			CZ, HK, JP, SW	CZ, HK, JP, SW	CZ, HK, JP, NL, SW
	Mathematical work			CZ, HK, JP, SW	CZ, HK, JP, SW	CZ, HK, JP, SW
F3.2	Non-problem segments			NL	NL	NL
	Problem segments			NL	NL	NL
T3.1	Number of independent problems				CZ	CZ, JP
	Number of answered-only problems		JP			

		Countries excluded		Countries significantly different to Australia ($p < .05$)[2]		
Reference[1]	**Test variable**	No data	Too few cases	'Full' Bonferroni adjustment	'Limited' Bonferroni adjustment	No Bonferroni adjustment
F3.3	Answered-only problems		JP	US	US	US, SW
	Concurrent problems			CZ, HK, JP, US	CZ, HK, JP, US	CZ, HK, JP, US
	Independent problems			CZ, HK, JP, US	CZ, HK, JP, US	CZ, HK, JP, US
F3.4	Time per independent problem			JP	JP	JP
F3.6	Problems worked on for 45+ secs			HK, JP, NL SW	HK, JP, NL SW	HK, JP, NL SW
F3.7	Practising new content					HK, JP
	Introducing new content			JP	JP	CZ, HK, JP, SW
	Reviewing			CZ	CZ	CZ, HK, JP, US
F3.8	Percentage entirely review				HK, JP	HK, JP
T3.2	Public interaction			HK, JP, US	HK, JP, US	CZ, HK, JP, NL, US
	Private interaction			CZ, HK, JP, US	CZ, HK, JP, US	CZ, HK, JP, US
	Optional, student presents information		NL	CZ, HK, JP	CZ, HK, JP	CZ, HK, JP
F3.9	Worked in pairs or groups					
	Worked individually					
F3.10	Goal statement			CZ, NL, SW	CZ, NL, SW	CZ, HK, NL ,SW
	Summary statement		NL		CZ	CZ, HK, JP, SW
F3.11	Lessons with outside interruptions				JP, SW	CZ, JP, SW
F3.12	Teacher words to student words	SW		HK	HK	HK
F3.13	1–4 word teacher utterances	SW		JP	JP	HK, JP
	5+ word teacher utterances	SW		JP	JP	HK, JP
	25+ word teacher utterances	SW		HK, NL	HK, NL	HK, NL
F3.14	1–4 word student utterances	SW		HK	CZ, HK	CZ, HK
	5+ word student utterances	SW		HK	CZ, HK	CZ, HK
	25+ word student utterances	SW		HK	CZ, HK	CZ, HK, JP

F3.15	Lessons in which homework assigned			JP	JP	CZ, JP
T3.3	Blackboard			US	US	US
	Projector			SW, US	SW, US	NL, SW, US
	Textbook/worksheet				CZ, NL	CZ, HK, NL
	Special mathematics material			JP, NL	CZ, JP, NL	CZ, HK, JP, NL
	Real-world objects			HK	HK	HK, NL
F3.16	Computational calculators used		JP	NL	CZ, NL	CZ, NL
F4.2	Set up with real-life connection			JP	CZ, HK, JP, NL	CZ, HK, JP, NL
	Set up with maths language			JP, NL	JP, NL	CZ, HK, JP, NL
F4.4	Problems that were applications			JP	JP	JP
F4.5	High procedural complexity			JP	JP	JP
	Moderate complexity			HK, JP	CZ, HK, JP, US	CZ, HK, JP, NL, US
	Low procedural complexity			JP	JP	CZ, HK, JP, SW
F4.6	Lesson contained at least one proof		AU, NL, US			
F4.7	Mathematically related			HK, JP	HK, JP, NL	HK, JP, NL, SW
	Thematically related					JP
	Repetition			JP	JP, NL	CZ, JP, NL, US
	Unrelated		JP			
F4.8	Independent problems solved publicly					
	Concurrent problems solved publicly			CZ, HK, NL	CZ, HK, NL	CZ, HK, NL
T4.2	More than one soln method presented			JP	JP	JP, HK
	Choice of solution method encouraged		NL			HK
T4.3	Problems summarised			JP	JP	JP, SW
F4.9	Making connections	SW		JP	JP	JP
	Stating concepts	SW		CZ, HK, JP	CZ, HK, JP	CZ, HK, JP, US
	Using procedures	SW		HK	CZ, HK,	CZ, HK, JP

		Countries excluded		Countries significantly different to Australia ($p < .05$)[2]		
Reference[1]	**Test variable**	No data	Too few cases	'Full' Bonferroni adjustment	'Limited' Bonferroni adjustment	No Bonferroni adjustment
F4.10	Making connections	SW		CZ, HK, JP, NL	CZ, HK, JP, NL	CZ, HK, JP, NL
	Stating concepts	SW		US	US	JP, NL, US
	Using procedures	SW				JP, US
	Giving results only	SW		HK, JP, NL	HK, JP, NL	HK, JP, NL
F4.11	Making connections	SW		CZ, HK, JP, NL	CZ, HK, JP, NL	CZ, HK, JP, NL
	Stating concepts	SW				
	Using procedures	SW				US
	Giving results only	SW		CZ, HK, JP, NL	CZ, HK, JP, NL	CZ, HK, JP, NL
F4.12	Other than repeating procedures or mix			JP, US	JP, US	JP, NL, US
	Repeating procedures			JP	CZ, JP	CZ, HK, JP

[1] Key: T = Table, F = Figure, na = *t*-value not available for comparison against critical values
AU=Australia; CZ=Czech Republic; HK=Hong Kong SAR; JP=Japan; NL=Netherlands; SW=Switzerland; and US=United States

[2] Check table or figure for the *direction* of the difference for *each* country. Direction of difference may vary from country to country.

Note: Source of *t*-values: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study, Video Study, 1999

Appendix C

NUMERIC VALUES FOR THE AUSTRALIAN LESSON SIGNATURE

Table C.1 Percentage of Australian lessons marked at each 10 per cent interval of the lessons

	Percentage interval (time) of the lessons										
	Beginning					Midpoint					End
	0	10	20	30	40	50	60	70	80	90	100
Review	87	77	52	37	32	27	23	23	22	23	23
Introduction of new content	12	23	33	40	36	31	33	33	29	23	23
Practice of new content	‡	‡	8	17	26	35	36	36	40	47	47
Public interaction	99	73	70	64	48	49	33	32	37	42	92
Private interaction	‡	36	37	40	52	54	67	72	66	59	9
Optional, student presents information	‡	‡	‡	‡	‡	‡	‡	‡	4	‡	‡
Mathematical organization	32	6	5	‡	‡	‡	‡	‡	‡	5	47
Non-problem	23	24	17	18	15	10	6	‡	7	10	36
Concurrent problem classwork	‡	14	15	10	7	8	5	6	14	17	‡
Concurrent problem seatwork	‡	31	26	30	40	43	54	62	62	56	6
Answered-only problems	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
Independent problem 1	6	18	9	6	7	6	‡	5	4	‡	‡
Independent problem 2–5	‡	31	17	17	16	16	10	10	‡	5	‡
Independent problem 6–10	‡	21	23	6	10	7	10	10	5	‡	‡
Independent problems 11+	‡	‡	‡	8	8	9	8	10	5	6	‡

‡ Fewer than three cases reported

Note: The percentage of lessons coded for a feature at any point in time was calculated by dividing each lesson into 250 segments representing 0.4 per cent of total lesson time. In a 50 minute lesson, this equates to segments of approximately 12 seconds each. Within each segment, the codes applied to the lessons are tabulated to derive the percentage of lessons exhibiting the feature. While many of the features listed above are mutually exclusive within each of the three dimensions (e.g., reviewing, introducing new content, and practising new content within the purpose dimension), the percentages may not sum to 100 within a dimension due to the possibility of a) a shift in codes within a segment in which case both codes would have been counted; b) a segment being coded as ‘unable to make a judgment’; c) missing data; d) momentary overlaps between the end of one feature and the start of another in which case both would be counted; and e) rounding.

Source: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study, Video Study, 1999

Appendix D

HYPOTHESISED AUSTRALIAN COUNTRY MODEL

Table D.1 Hypothesised country model for Australia

Purpose	Review	Introduction of new material	Assignment of task	Practice/application & re-instruction			Conclusion
				practice/ application	***reassignment of task***	***practice/ application***	
	reinforce knowledge; check/correct/ review homework; re-instruct	acquisition of knowledge;	assignment of task	application of knowledge	assignment of task	application of knowledge	reinforce knowledge
Classroom routine	review of relevant material previously worked on	presentation of new material	assignment of task	completion of task	assignment of task	completion of task	summary of new material; assignment of homework
Actions of participants	T – [at front] ask Ss questions; elicit/embellish responses; demonstrate examples on BB	T – [at front] provides information asking some Ss questions and using examples on BB	T – [at front] describes text book/ worksheet task	T – [roams room] provides assistance to Ss as needed and observes Ss progress on set task	T – [at front] re-explains text book/ worksheet task	T – [roams room] provides assistance to Ss as needed and observes Ss progress on set task	T – [at front] provides information and asks Ss questions
	Ss – [in seats] respond to & ask T questions; listen to T explanations, watch demonstrations	Ss – [in seats] listen to T explanations and respond to T questions	Ss – [in seats] listen to T descriptions	Ss – [in seats] work individually or in pairs on task	Ss – [in seats] listen to T descriptions	Ss – [in seats] work individually or in pairs on task	Ss – [in seats] listen to T descriptions; respond to and ask T questions
Content	related to previous lesson	definitions/ examples building on ideas previously worked on	description of task; focus on text/worksheet problems	text/worksheet problems	description of task; focus on text/ worksheet problems	text/worksheet problems	text/worksheet problems; homework problems
Classroom talk	T talks most; Ss one-word responses	Mix of T/S talk although discussion clearly T directed	T provides direct instructions	mix of T/S and S/S talk – including explanations & questions	T provides direct instructions	mix of T/S and S/S talk – including explanations and questions	mix of T & T/Ss talk – including explanations and questions
Climate	somewhat informal – relaxed yet focused						

Note: T = teacher, S = student, SS = students, BB = blackboard
Source: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study, Video Study, 1999