

# Teaching Science in Australia

Results from the TIMSS 1999 Video Study

TIMSS Australia Monograph No. 8

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## FOREWORD

Australia, through the Australian Council for Educational Research (ACER), has taken part in many 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 happens in classrooms. What content are students exposed to, and what strategies are used to teach it? Intuitively, it seems these aspects of teaching should be important influences on achievement.

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 samples of 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.

Since that time, both the international and Australian reports of the mathematics component of the 1999 TIMSS Video Study have been released. The 1999 study was broader than the 1995 study not simply in the expanded number of participating countries, but in examining science teaching as well as mathematics teaching. This report describes and presents results from Australia's participation in the 1999 science component of the study.

## ACKNOWLEDGMENTS

The TIMSS 1999 Video Study was conducted by LessonLab, Inc. (Santa Monica, California, now known as LessonLab Research Institute) under contract to the National Center for Education Statistics (NCES), United States Department of Education. The United States National Science Foundation and some of the participating countries provided additional funding for the study. Half of the funding for Australia's participation in the mathematics component of the study was provided by NCES, with the other half provided jointly by the Australian Commonwealth, State and Territory governments. Some of the additional funding needed for Australia's participation in the science component was also provided by NCES, supplemented by contributions from the Commonwealth, State and Territory governments and the Australian Council for Educational Research (ACER).

ACER was contracted by the Commonwealth, State and Territory governments to manage Australia's participation in the study. ACER and the various Australian governments thank NCES for its generosity in making Australia's participation in this innovative and important project possible.

As in the mathematics component of the study, 87 Australian teachers and about 2000 Australian Year 8 students, from all regions and school sectors, participated in the science component. 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 five Australian teachers, and the principals of the schools involved, who agreed that their videotaped science lessons could be publicly released.

Thanks are also due to Silvia McCormack, who so capably recruited the schools and carried out the complex tasks of sampling and of arranging the schedule for the filming of the classes, and to Stephen Skok and Rowan Humphries, of *Pixelworks*, who travelled widely to film all of the Australian lessons.

Much of this report is drawn, with permission, from the international report of the study, *Teaching Science in Five Countries: Results from the TIMSS 1999 Video Study of Eighth-Grade Science Teaching: Statistical Analysis Report*, by Kathleen Roth, Stephen Druker, Helen Garnier, Meike Lemmens, Catherine Chen, Takako Kawanaka, David Rasmussen, Svetlana Trubacova, Dagmar Warvi, Yukari Okamoto, Patrick Gonzales, James Stigler and Ronald Gallimore.<sup>1</sup> ACER and the authors of this Australian report acknowledge with thanks the contribution of the international report authors to the Australian report.

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<sup>1</sup> This can be accessed from the NCES website: <http://nces.ed.gov/timss> or ordered from <http://www.edpubs.org>

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## EXECUTIVE SUMMARY

The purpose of the Third International Mathematics and Science Study (TIMSS) 1999 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,<sup>2</sup> Japan, the Netherlands, Switzerland and the United States. All seven countries took part in the mathematics component, while Hong Kong SAR and Switzerland chose not to participate in the science component. The initial TIMSS pen-and-paper assessments 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 and science assessments by students from the other countries that participated in the 1999 video study.

The TIMSS 1999 Video Study was conducted by LessonLab, Inc. (Santa Monica, California, now known as LessonLab Research Institute) under contract to the National Center for Education Statistics (NCES), United States Department of Education. The United States National Science Foundation and the participating countries provided additional funding for the study. As already acknowledged, a considerable proportion of the funding for Australia's participation was provided from United States sources, with most of the remainder coming from the Australian Commonwealth, State and Territory governments. The Australian Council for Educational Research (ACER) was contracted by the governments to coordinate Australia's participation.

The international report of the science component of the TIMSS 1999 Video Study is due for release early in 2006.<sup>3</sup> This Australian report, *Teaching Science in Australia*, includes many of the international results, but focuses on making comparisons and commentary from an Australian perspective. It also includes additional information on the Australian data. The report is accompanied by a DVD containing nine lessons (five from Australia, and one each from the Czech Republic, Japan, the Netherlands and the United States), which is being released publicly to illustrate the Australian 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 science 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 science teaching in Australian lower secondary classes;

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<sup>2</sup> 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.

<sup>3</sup> The international report, entitled *Teaching Science in Five Countries: Results from the TIMSS 1999 Video Study of Eighth-Grade Science Teaching: Statistical Analysis Report*, can be accessed from the NCES website (<http://nces.ed.gov/timss>) or ordered from <http://www.edpubs.org>, as can the international report of the mathematics component, *Teaching Mathematics in Seven Countries*.

- ascertaining the extent to which Australian science teaching in 1999 reflected emphases in curriculum documents developed during the 1990s;
- viewing Australian teaching practices in relation to those in some of the countries that were among the highest achieving countries on the TIMSS 1995 science 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.

### **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 for their students. 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 science component of the TIMSS 1999 Video Study included a total of 439 Year 8 lessons collected from the five participating countries. The designed sample size in 1999 was 100 lessons per country (although only one country achieved this). One lesson per school was randomly selected within each of 100 randomly selected schools per country.<sup>4</sup>

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 the teachers of their randomly selected Year 8 science lessons agreed to take part in the study.

In each school the teacher of the selected lesson was filmed for one complete Year 8 science lesson, and, in each country, the attempt was made to collect videotapes throughout the year to try and capture the range of topics and activities that can occur across a whole school year. If the selected lesson covered a double period, it was filmed in its entirety. To obtain justifiable 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 consistently 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. Two Australian researchers were based at LessonLab for most of the duration of this work, together with colleagues in a similar role from the other countries.

### **Major International Findings**

Internationally, the TIMSS 1999 Video Study of Year 8 science teaching showed in general terms that there is no one single best way to undertake successful teaching of science. 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 while at the same time displaying

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<sup>4</sup> The weighted response rate reached the desired 85 per cent or more in three countries. The exceptions were the Netherlands and the United States, both of which achieved a weighted response rate of between 80 and 85 per cent.

distinct patterns and features, supporting the proposition that teaching is culturally based. However, the four countries that had performed better than the United States on the TIMSS written assessments of science learning in 1995 and 1999 were found to share some characteristics that were different from the pattern observed in that country, as described later in this summary.

### ***Common features of year 8 science teaching across countries***

Common features observed across all five countries participating in the study included:

- Teachers in all countries were qualified to teach, and most were well qualified to teach science at Year 8 level.
- A very high percentage of lesson time, on average, was spent on science instruction and other activities pertaining to science.
- Virtually all of the lessons in all countries developed new content, worked on for two-thirds or more of the lesson time. Lessons devoted entirely to review of previous content were rare.
- Time was allocated to practical activities in 70 per cent or more of the lessons in all countries, although there were differences in the amounts of time spent on these activities.
- Most of the time, lessons included a mixture of public, whole-class work and private, individual or small group work.
- A high percentage of lessons included ‘public’ attention (when the intended audience of a teacher or other speaker was the whole class) to ‘canonical knowledge’ of science – that is, the generally accepted facts, ideas, concepts and theories shared within the scientific community.
- Attention to broader aspects of science, such as its values, limitations, social implications or history, or metacognitive issues such as strategies for learning or reflecting on one’s learning, received very little emphasis in any country.
- 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 7:1. Teachers tended to speak in phrases or sentences that were at least 5 words long while students mostly spoke in short phrases of four or fewer words.
- During whole-class interactions, students in all countries participated in some form of discussion in at least 80 per cent of the lessons.
- During their independent work on practical activities, students in all countries were more likely to observe phenomena than to design their own experiments, make their own models, carry out dissection or classification activities or conduct controlled experiments.
- Students rarely wrote text of a paragraph or more during their science instruction time.

### ***Distinctive features of Year 8 science teaching across countries***

In addition to the commonalities presented above, each of the countries was found to have a characteristic, distinct approach to science teaching. These approaches are summarised later, following some contextual comments and discussion of findings from an Australian perspective.

Year 8 science is taught as an integrated subject in Australia, Japan and the United States, but as three or four separate subjects in the Czech Republic and the Netherlands. Regardless of which way the subject matter was organised, distinctive features found related to the topics covered, the ways new content was introduced, the extent of emphasis on review of previous content, the level of challenge of the subject matter and the extent of time used for practical activities. They also included the use of various strategies to make lessons more coherent, the use of motivational strategies 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 Findings?**

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

illustrative figures for the country names are: Australia (AU); the Czech Republic (CZ); Japan (JP); the Netherlands (NL); and the United States (US).

### ***Contextual information***

- All of the Australian teachers were qualified to teach, although a very small percentage had training for primary level only. About 90 per cent had taken at least one science subject as a major or minor component of their tertiary studies. Echoing other studies in which concern at teachers' lack of expertise in the 'hard sciences' has been expressed, about half the Australian teachers had studied life sciences compared with about a third who had studied chemistry and only about a sixth who had studied physics.
- On average, the Australian teachers had been teaching science for 14 years and all but a small percentage considered themselves to be effective teachers.
- Three-quarters considered that they were familiar with current ideas in science teaching and learning.
- Over 80 per cent agreed that their videotaped lesson was typical or very typical of their teaching methods and 95 per cent agreed that their students' behaviour was about the same or better than usual (27 per cent replied 'better than usual'). About three-quarters said that the presence of the camera in the classroom did not affect the quality of their teaching, while 10 per cent said their teaching was better than usual and 18 per cent said it was worse than usual.
- As in all countries except the United States, a higher percentage of the Australian teachers said they spent more time planning for their videotaped lesson (39 minutes, on average) than for similar lessons (26 minutes, on average). Planning times were roughly similar in all countries except Japan, where teachers said they spent 135 minutes, on average, planning for their videotaped lesson compared with 92 minutes, on average, for similar lessons.
- Three-quarters or more of the Australian teachers considered that they had sufficient access to laboratories, teaching supplies and reference materials for their science lessons, but only a quarter were satisfied with their access to computers, software and Internet connections.

### ***Observations from the videotapes***

Concerning resources:

- Ninety per cent of the Australian lessons took place in science laboratories, significantly more than in any of the other countries except Japan (76%).
- Textbooks or workbooks were used in only 31 per cent of the Australian lessons, significantly fewer than in all countries except the United States; the Netherlands, where textbooks were used by students in 90 per cent of the lessons, stood out in this respect.

Concerning subject matter:

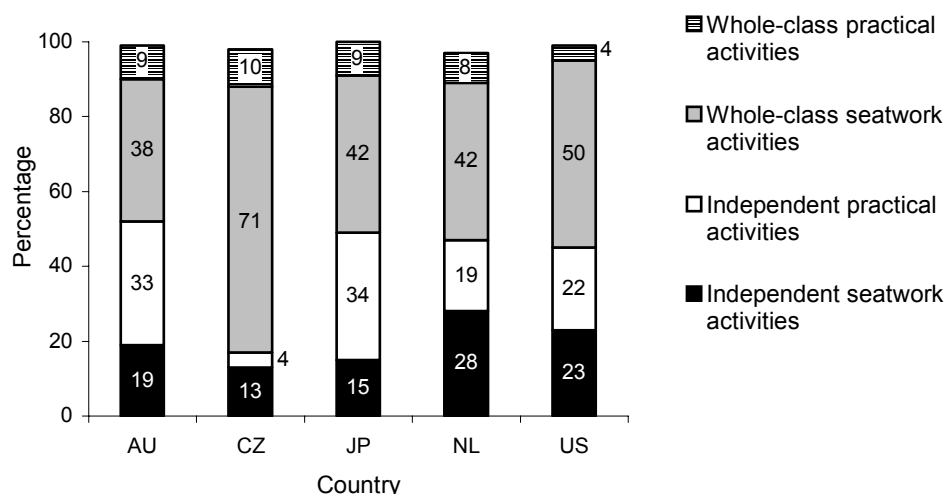
- Almost half the Australian lessons focused on physics topics, about the same as in the Netherlands, and a further quarter addressed life science topics. The emphasis on physics was not expected from a knowledge of Australian Year 8 curricula, and was probably an artefact of the time of year when the majority of Australian lessons were filmed (see the section, 'The sample', in Chapter 1).

Concerning lesson purposes:

- Introduction of new content was by far the most common lesson activity in all countries, consuming two-thirds or more of the lesson time on average (85 and 93 per cent in Australia and Japan, respectively). Other types of activity varied, but were rare in Australia, including review of previous content, going over homework in class and assessing student learning. The Czech Republic stood out in its emphasis on review and the Netherlands stood out in its emphasis on going over homework.
- The partition of lesson time into whole-class versus 'independent' work was approximately equal in all countries except the Czech Republic, where 80 per cent of the time on average was used for whole-class work.

- Australia and Japan had the closest to equal divisions of lesson time devoted to seatwork (such as making notes, completing written exercises and reading textbooks) and practical activities (on average, just over 40 per cent for practical activities). In the other countries, 70 per cent or more of the lesson time on average was spent on seatwork.

**Percentage distributions of science instruction time in Year 8 science lessons devoted to each combination of activity and lesson organisation type**



Whole-class practical activities: AU, CZ, JP>US

Whole-class seatwork activities: CZ>AU, JP, NL, US; US>AU

Independent practical activities: AU, JP, NL, US>CZ; AU, JP>NL

Independent seatwork activities: NL>CZ, JP; US>CZ

*Note:* Total may not sum to 100 because of rounding and data not presented for 'divided class work'. Analysis is limited to the 91 per cent or more of lesson time focused on science instruction per country.

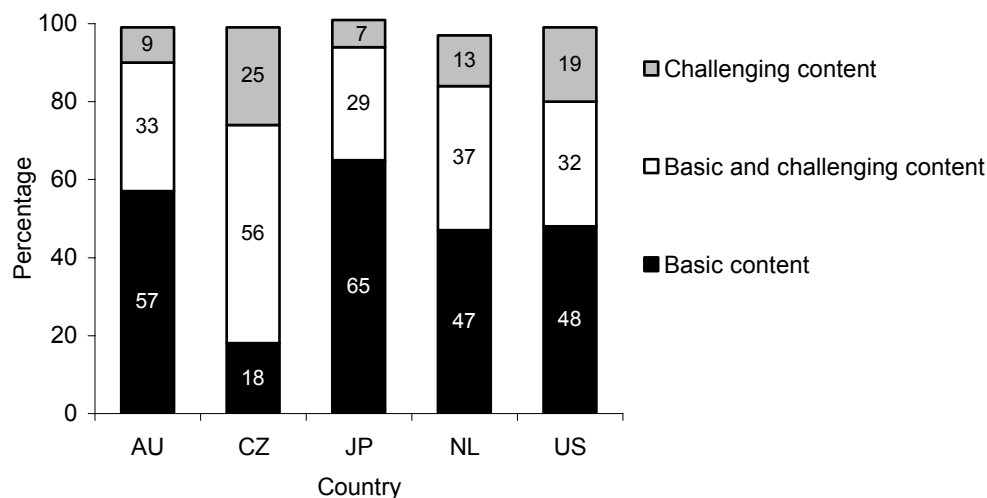
### Concerning lesson content

- Different types of knowledge were addressed in the science lessons. Considering 'public talk' time only (time when the whole class was the intended audience of a teacher or student), Australian lessons on average spent 35 per cent of the time on presenting and discussing canonical scientific knowledge, 17 per cent of the time on procedural and experimental knowledge, 12 per cent of the time on science-related real-life issues, 19 per cent of the time on strategies for learning, 2 per cent on safety knowledge and 4 per cent on discussing aspects of the nature of science. Remaining public talk time was spent on demonstrations of practical activities, presentations by students (rare in Australia) and organising students for various aspects of the lessons.
- The Czech Republic stood out in its emphasis on presenting canonical knowledge, which occupied on average almost 60 per cent of the public talk time in their lessons.

### Concerning level of challenge of scientific content:

- Countries were similar in the extent of use of scientific terms and highly technical scientific terms during their science lessons (about 20 and 10 terms, respectively), except for the Czech Republic where an average of 56 scientific terms was observed per lesson, 33 of which were judged to be highly technical.
- The majority of Australian and Japanese lessons were judged to contain content at basic level only. The distribution of basic, challenging and a mixture of basic and challenging content was similar in Australia, Japan, the Netherlands and the United States. Only in the Czech Republic, where 82 per cent of lessons were judged to be above basic level, was the content generally more advanced.

**Percentage distributions of Year 8 science lessons according to experts' judgments of the level of challenge of their scientific content**



Challenging content: CZ>JP

Basic and challenging content: CZ>AU, JP, US

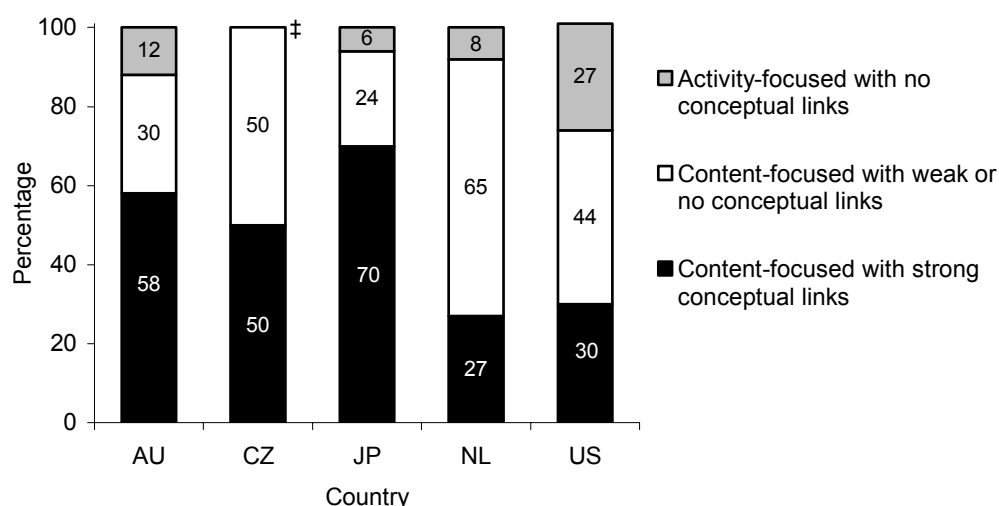
Basic content: AU, JP, NL, US>CZ

*Note:* Totals may not sum to 100 because of rounding.

Concerning lesson coherence:

- Australia and Japan were the only countries found to have strong conceptual links in the material presented in the majority of content-focused lessons. Only 12 per cent of Australian lessons and 6 per cent of Japanese lessons were activity-focused with no conceptual links.

**Percentage distributions of Year 8 science lessons by focus and strength of conceptual links**



† Fewer than three cases reported (country excluded from the relevant analysis)

Activity-focused with no conceptual links: US>JP, NL

Content-focused with weak or no conceptual links: CZ>JP; NL>AU, JP

Content-focused with strong conceptual links: AU, JP>NL, US; CZ>NL

*Note:* Totals may not sum to 100 because of rounding and data not reported.

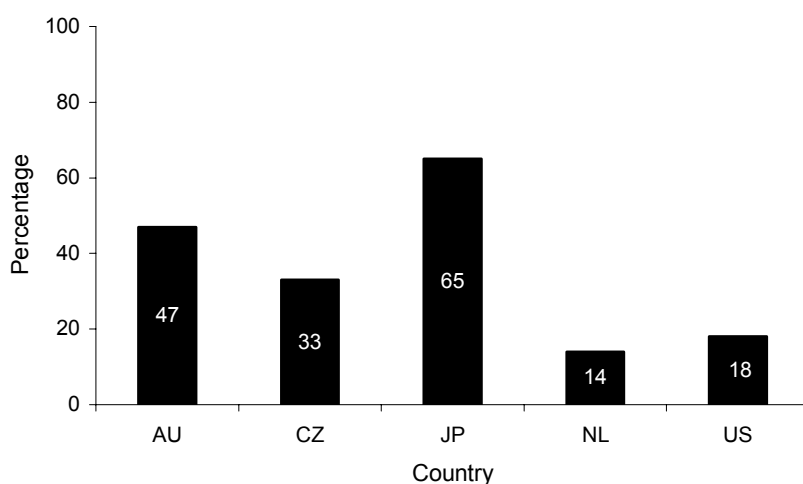


- Australia (58%) and Japan (72%) had the highest incidence of lessons in which ‘making connections’ rather than ‘acquiring facts’ was the main method of developing scientific content, significantly more than in the other three countries. In both Australia and Japan, the most common approach was to make connections through inquiry activities.
- Australia fared relatively well on aspects of coherence such as use of goal statements, which occurred in 95 per cent of the lessons. However, summary statements were used in only about a quarter of the lessons, midway between Japan (41%) and the Netherlands (6%).

Concerning use of evidence:

- All countries used first-hand data, observations of phenomena and visual representations to support the development of scientific concepts, though Australia and Japan used more than one set of the various types of evidence more often than occurred in the other countries.

**Percentages of Year 8 science lessons in which all main ideas were supported with all three of first-hand data, phenomena and visual representations**



*Note:* AU>NL, US; CZ>NL; JP>AU, CZ, NL, US

- Real-life examples were often used to help both in developing and supporting concepts. They were discussed in 79 per cent of Australian lessons.

Concerning homework:

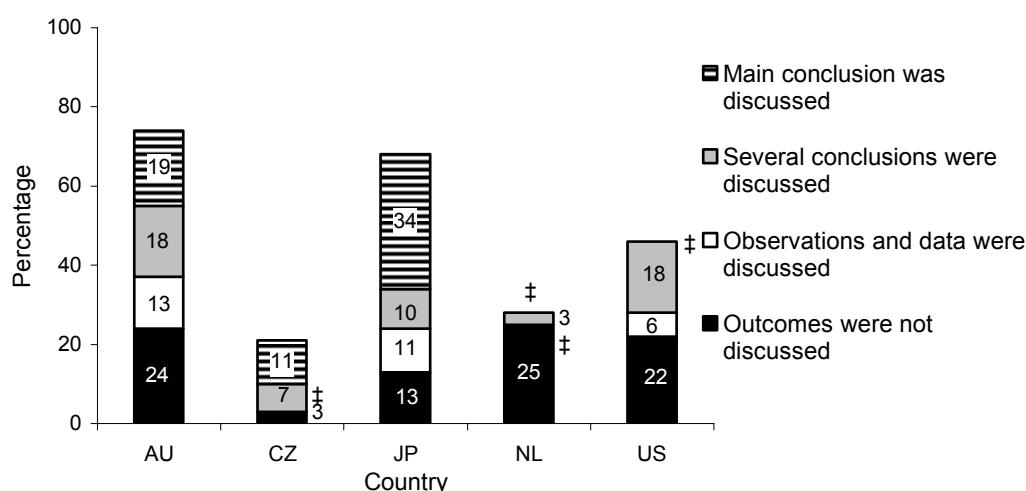
- Homework was assigned in about half the lessons in Australia, the Czech Republic and the United States and in two-thirds of the lessons in the Netherlands, but in only one-sixth of the lessons in Japan. This does not mean that Japanese students do less science outside the classroom than their counterparts in other countries, as many Japanese students take part in supplementary private lessons. It is encouraging that most of the homework set in Australia, as in the United States, involved working on new content only. The Czech Republic was the only country where students were expected to review previously covered content to any extent.
- In the Netherlands and Australia, students worked on homework during class time in 40 per cent or more of the lessons (although for only a very short time, on average, in Australia).

Concerning practical activities:

- Ninety per cent of Australian lessons included some type of practical activity, sometimes demonstrated by the teacher and often undertaken by students working in pairs or small groups, which occurred in three-quarters of the lessons. Australia and Japan were the only countries where independent practical activities occurred in more than half of the lessons (74 and 67 per cent in Australia and Japan, respectively). The most common practical activity in all countries was producing or observing phenomena.

- In the lessons in which practical activities were performed by students, outcomes of their investigations were discussed in only about half the cases in Australia and the United States. Outcomes were rarely discussed in the Netherlands, while in Japan and the Czech Republic they were discussed in the majority of cases.
- The practical investigations performed by the students were usually directed or guided by the teacher or a worksheet. Students rarely designed their own investigations or formulated their own research questions. Sometimes they made predictions of the outcomes, particularly in Japan.

**Percentages of Year 8 science lessons in which outcomes of independent practical activities were discussed publicly**



‡ Fewer than three cases reported (country excluded from the relevant analysis)

Several conclusions were discussed: AU>NL

Main conclusion was discussed: JP>CZ

Outcomes were not discussed: AU, NL, US>CZ

*Note:* Totals may not sum to percentage of lessons with independent practical activities (shown in Figure 5.1) because of rounding and data not reported.

- Students in Australia and Japan commonly collected and recorded data, which occurred in 62 and 59 per cent of lessons, respectively, and also interpreted their data or observations in more lessons than occurred in the other countries.

Concerning student engagement, other than in practical activities:

- Teachers in all countries made use of motivating activities to stimulate students' interest. This occurred in about a third of the Australian lessons. The United States, where teachers used motivating activities in about two-thirds of the lessons, stood out in this respect.
- In all countries students were observed making public presentations of aspects of their work in about a third of the lessons.
- Students were sometimes expected to take notes during lessons, although this was relatively rare. In Australia and the Czech Republic students were expected to keep detailed notebooks about their lessons and the work that they had done (75 and 96 per cent of lessons, respectively). Some Australian teachers said that the students' notebooks would be assessed as part of their year's marks.

### Summary of Science Teaching Patterns by Country

For interest, a summarised pattern of teaching for each of the countries, derived from the more extensive summaries and charts in the final chapter of *Teaching Science in Five Countries* (Roth et

al., 2006) is presented here. The countries appear in alphabetical order except for Japan, which is placed after Australia because of the extent of similarities between the approaches to Year 8 science teaching in these two countries (in many respects the degree of similarity is quite striking, given the substantial differences in approaches to mathematics teaching reported by Hiebert et al. (2003) from the mathematics component of the study). The summaries are followed by a discussion of commonalities observed among the four higher-achieving countries.

***Australian pattern: Making connections between main ideas, evidence and real-life issues***

Australian Year 8 science lessons tended to focus on developing a limited number of canonical ideas (that is, generally-accepted scientific facts, ideas, concepts or theories) by making connections between ideas and evidence rather than by acquiring facts, definitions and algorithms. Ideas were developed through an inquiry, inductive approach in which data were collected during practical activities carried out independently by the students, more often in the area of physics than in other areas. During and after the practical work, Australian students were often guided, by the teacher or an instruction sheet, in manipulating and organising the data and in interpreting the data, although in some classes these activities were done without such guidance. Discussions of results and conclusions followed about half of the independent practical activities. Main ideas in Australian science lessons were supported by data or phenomena more often than in the lessons of some of the other countries. Textbooks were relied on considerably less than they were in the other countries.

Australian science lessons were found to be conceptually coherent, with frequent use of goal statements and an emphasis on developing content primarily by making connections between ideas and evidence rather than through acquisition of facts and definitions. However, the scientific content tended to be at a basic rather than a challenging level. The development of scientific ideas tended to be supported with real-life examples (69 per cent of lessons) and first-hand data (56 per cent of lessons). In addition, students in Australian lessons typically participated in two or more types of activity likely to be engaging to students (real-life issues, independent practical activities and motivating activities). Thus, Australian lessons appeared to have a strong focus on developing ideas through an inquiry, inductive process and supporting canonical ideas with examples of real-life issues while also providing multiple types of activities that had the potential to engage students' interest.

***Japanese pattern: Making connections between ideas and evidence***

Like the Australian Year 8 science lessons, Japanese lessons tended to focus on developing a few ideas by making connections between ideas and evidence. Ideas were developed through an inquiry, inductive approach in which data were collected and interpreted to build up to a main idea or conclusion. Also like Australian lessons, Japanese science lessons were found to be conceptually coherent, with an emphasis on identifying patterns in data and making connections among ideas and evidence.

Independent practical work played a central role in the development of main ideas in Japanese lessons, which were primarily in the areas of physics and chemistry. Before carrying out such activities, Japanese Year 8 students were typically informed of the question they would be exploring in the investigation, and were sometimes asked to make predictions. During and after practical work, Japanese students were guided by the teacher or textbook in manipulating and organising the data into graphs or charts and then interpreting the data. Discussions after independent practical activities typically led to the development of one main conclusion – the main idea of the lesson.

Few canonical ideas were presented publicly (that is, during time when the whole class was the intended audience of a teacher or student) in Japanese science lessons, and these ideas were judged to be basic rather than challenging or theoretical (similar to Australia). However, all of the main ideas in Japanese science lessons were developed with the use of data and/or phenomena. In fact, main ideas were often supported by more than one set of data or more than one phenomenon.

Thus, it appears that, although fewer ideas were developed in each Japanese science lesson, each idea was treated in depth, with multiple sources of supporting evidence.

### ***Czech pattern: Talking about scientific content***

Year 8 science lessons in the Czech Republic were characterised as whole-class events that focused on getting the content right. Instruction time focused on review, assessment and development of canonical scientific knowledge, with relatively little time allocated for students to work independently on practical activities. Review and the public oral assessment of students were prominent features of the Czech science lessons. The main topic areas were life science, physics and chemistry. The content was found to be challenging, dense and theoretical, organised more often around facts and definitions than making conceptual connections. Perhaps because of the high density of ideas and the high percentage of lessons organised as discrete pieces of information, half of the lessons were found to have weak or no conceptual links that tied ideas together. On the other hand, half of the lessons were strongly connected with conceptual links, and the presence of goal and summary statements also may have contributed to content coherence.

Main ideas in Czech science lessons were often developed with the use of visual representations. In fact, all of the main ideas in the lesson were supported by multiple visual representations in the majority of lessons. Czech Year 8 students engaged actively in the work of learning science primarily through frequent whole-class discussions, opportunities to present their work in front of the class and to take part in oral quizzes on scientific content in front of their peers. Students also kept organised science notebooks, into which they often copied notes.

### ***Dutch pattern: Learning science independently***

Year 8 science lessons in the Netherlands appeared to focus on students' independent learning of the scientific content. During independent seatwork activities, students read from their textbooks and generated written responses to questions (beyond selecting answers). Homework was typically assigned and was often observed to be the focus of either independent work in the lesson (working on assignments in class) or whole-class work (going over homework together). Students worked on homework tasks outside the lessons as well as during them. Students were expected to pace themselves on a long-term schedule of assignments, to check their own work in answer books, and to keep organised science notebooks. The main topic areas were physics and life science.

When Dutch science lessons included independent practical activities (30 per cent of lessons), students were sent off to work on their own for most of the lesson, with their only direction being procedural guidelines. Public discussion of the results of independent practical activities rarely occurred. Whole-class time in Dutch science lessons included going over homework assignments together in almost half the lessons, occupying a quarter of the lesson time on average. Dutch students also demonstrated responsibility for their own learning by initiating their own content-related comments during whole-class interactions.

### ***United States pattern: Variety of activities***

The data suggest that United States Year 8 science lessons were characterised by a variety of activities that may engage students in doing scientific work, with less focus on connecting these activities to the development of scientific content ideas. In terms of student activities, United States Year 8 science lessons kept students busy on a variety of activities, with a roughly equal emphasis on involving students in independent practical activities (for example, hands-on, laboratory work), independent seatwork activities (for example, reading, writing, small group discussions) and whole-class discussions. In addition, United States science teachers attempted to engage students' interest and active involvement through the use of real-life issues and motivating activities such as games, puzzles and role play – 23 per cent of United States instructional time was spent on such activities.

There was a variety of topics as well, across all major topic areas. Students in United States Year 8 science lessons had the opportunity to encounter some challenging content in the form of laws and theories, as well as some exposure to various forms of evidence (data, phenomena, visual representations and real-life examples). But these various sources of evidence were not frequently

linked to larger ideas to create coherent, connected, in-depth treatment of scientific content in the lessons. Instead, the various pieces of content were typically organised as discrete bits of factual information or problem-solving algorithms rather than as a set of connected ideas. For example, real-life issues were more often mentioned in United States lessons as interesting asides rather than being used as an integral part of developing the scientific content. Almost half the lessons were characterised as having weak or no conceptual links while a quarter of the lessons focused on carrying out activities rather than developing scientific content.

***Commonalities shared by the four higher-achieving countries: High content standards and a content-focused instructional approach***

The data suggest that the four relatively higher-achieving countries (based on the TIMSS 1995 written assessment and consistent with the 1999 written assessment) in Year 8 science that participated in this study – Australia, the Czech Republic, Japan and the Netherlands – shared two commonalities. First, Year 8 science lessons in these countries appeared to focus in some way on high content standards and expectations for student learning. Students in the higher-achieving countries were expected to engage with scientific content in some rigorous way, but there were varying definitions from country to country for what counts as high content standards. Second, instead of exposing students to a variety of pedagogical approaches and content, the science lessons in each of the four relatively higher-achieving countries appeared to reflect a common instructional approach that was content-focused.

In the Czech Republic the content standards were high in terms of the density and challenge of scientific ideas, and the instructional approach focused on talking in a whole-class setting about science. In Australia and Japan, the content standards were high in terms of developing ideas with the support of evidence in the form of first-hand data and phenomena, and the instructional approach focused on coherent connection of ideas and data through an inquiry, inductive process. In the Netherlands, content expectations for science were high in terms of students being held responsible for their own independent learning, and the instructional approach featured independent seatwork activities focused around textbook-centred reading and writing.

It is tempting to think that the high content standards and expectations for student science learning observed in the four higher-achieving countries might be linked to the specifications of national curricula, but, as Australian readers will know, the states and territories have independent authority over curricular matters. From the next section and the results of this study, however, the work of the Australian Education Council in the early 1990s, together with ongoing work by science educators, teachers and researchers, appear to have paved the way and ensured that all of our students benefit from good science teaching.

**Ideals for Science Education in Australia**

An ideal blueprint for effective science teaching in Australia was constructed from an analysis described in Goodrum, Hackling and Rennie (2001), the national professional standards developed by the Australian Science Teachers Association (2002) and the components identified by Tytler (2002) in the Victorian Science in Schools study. The following six characteristics were identified:

- Students experience a curriculum that is relevant to their lives and interests within a supportive and safe learning environment;
- Classroom science is linked to the broader community;
- Students are actively engaged with inquiry, evidence and ideas;
- Students are challenged to develop and extend meaningful understandings;
- Assessment facilitates learning and is focused on scientific literacy;
- ICTs are exploited to enhance students' learning of science.

To what extent does the actual picture revealed by the video data match the ideal?

The teachers were experienced and mostly not constrained by large class sizes or shortages of resources – their practices could therefore be expected to reflect the curriculum and their beliefs.

Their teaching was found to reflect the emphases of current Australian science curricula very well in many respects. Real-life objects and issues were often used or drawn on to make the science relevant to the students' lives and interests and other motivating activities were used in many of the lessons. Students' active engagement with inquiry, evidence and ideas was a strong feature of the Australian lessons, in which links between evidence and ideas were typically made in conceptually coherent ways.

Other aspects of the ideal picture, such as meaningful assessment activities, strong links to the broader community and use of technologies such as computers, were rarely or not observed in the sample of Australian lessons. These aspects may have been found in a larger sample of classes, or if the same classes had been observed over time. While the students were challenged to some extent through their hands-on involvement in data collection or observing and discussing phenomena, they were expected to generate their own research questions, design their own experiments or predict outcomes in only a few lessons. In carrying out their practical activities, they typically followed teachers' instructions or a worksheet. It seems likely that the need to cover curriculum content within the constraints of mostly single lesson periods would have contributed to this lack of opportunity for the students to learn and practise higher-level inquiry skills.

### **Summary and Educational Significance**

Science education in the compulsory years of schooling is expected to support the development of scientific literacy. Video records of what happens in science lessons can inform judgments about the extent to which that expectation is being achieved. The data from these video records of a representative sample of Australian Year 8 science lessons indicate, compared with other high-achieving countries, an emphasis on inquiry-based learning and strong connections to important scientific concepts that are consistent with that expectation. The data provide strong endorsement for the quality of Australian Year 8 science teaching both when the lessons are compared with lessons from other high-achieving countries and also when they are judged against the picture of ideal science teaching outlined above.

From the pictures of science teaching portrayed in the videotaped lessons, opportunities for the development of scientific literacy were missed in all the participating countries, however. There was limited scope for students to formulate their own research questions, devise their own experimental procedures and analyse their own data because practical work was largely teacher-directed. Furthermore, in half the Australian lessons in which students did practical work there was no public discussion of conclusions. These features of science lessons limit the opportunities for students to learn inquiry skills and develop scientific literacy. Given the centrality of inquiry-based learning in Australian science teaching, the commitment to scientific literacy and the emphasis on independent practical work, there appears to be a need to allow more student-directed investigations and public discussion of the results and conclusions arising from the practical work to ensure that scientific concepts underlying investigations can be developed.

In the first chapter, and also early in this Executive Summary, reasons are mentioned for studying science teaching across countries – to identify alternatives, to deepen educators' understanding of teaching and students' opportunities to learn science, to reveal one's own practices more clearly and to stimulate discussion about choices within a country. The study's success will ultimately be determined by the quality of the discussions it stimulates among scientists, science educators, teachers, policy makers and the general public, and the extent to which the discussions remain focused on the ultimate goal of improving students' opportunities to learn science.

### **Postscript**

In the most recent TIMSS written assessment of mathematics and science achievement, carried out in 2002/03, Australian Year 8 students continued to perform above the international average in science. Their result was similar to the Australian results in TIMSS 1995 and 1999. However, results in some other countries of interest to Australia improved, in some cases substantially, including in the United States. Thus it appears that Australia has been standing still, while other countries have been moving forward (Thomson & Fleming, 2004).

# Chapter 1

## INTRODUCTION

Researchers, policy makers and practitioners have long been interested in the systematic study of classroom practice. Several techniques have been used to study what happens in classrooms, including questionnaires completed by teachers, observations recorded by human observers of the extent and duration of various practices in lessons, log-book records completed by teachers at the end of each day and, more recently, the video-recording of classrooms in action. The study described in this report, the TIMSS 1999 Video Study, is the largest to use video-recording techniques for this purpose and, in so doing, both profited from the advantages and extended the benefits of this methodology as a tool for examining classroom teaching. This chapter describes the background, aims, scope and methods of the study (including a discussion of advantages and disadvantages of the video-recording methodology), and describes Australia's involvement in the science component of the project. It also outlines the contents of the remaining chapters in the report.

### **The TIMSS 1999 Video Study**

#### ***Background***

The purpose of the 1998–2000 Third International Mathematics and Science Study Video Study (hereafter referred to as the 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, itself a successor to TIMSS 1995.<sup>5</sup> The TIMSS 1999 Video Study expanded on the earlier 1994–1995 (hereafter 1995) TIMSS Video Study (Stigler, Gonzales, Kawanaka, Knoll & Serrano, 1999) by investigating teaching in science as well as mathematics, and sampling classroom lessons from more countries than took part in the TIMSS 1995 Video Study.

The 1999 study was conducted internationally by LessonLab, Inc. (Santa Monica, California, now known as LessonLab Research Institute) under contract to the National Center for Education Statistics (NCES), United States Department of Education. The United States National Science Foundation and the participating countries provided additional funding for the study. The Australian component of the study was conducted by the Australian Council for Educational Research (ACER).

The results of the mathematics component of the TIMSS 1999 Video Study were published in 2003 in the international report, *Teaching Mathematics in Seven Countries: Results from the TIMSS 1999 Video Study* (Hiebert, Gallimore, Garnier, Givvin, Hollingsworth, Jacobs, Chui, Wearne, Smith, Kersting, Manaster, A., Tseng, Etterbeek, Manaster, C., Gonzales & Stigler, 2003). A detailed description of technical aspects of the study was published in an accompanying report (Jacobs, Garnier, Gallimore, Hollingsworth, Givvin, Rust, Kawanaka, Smith, Wearne, Manaster, Etterbeek, Hiebert & Stigler, 2003). Australia's involvement in the mathematics component of the study and Australian perspectives on the results were published by ACER as *Teaching Mathematics in Australia* (Hollingsworth, Lokan & McCrae, 2003).

The present report, *Teaching Science in Australia* (Lokan, Hollingsworth & Hackling, 2005) has been prepared to present Australian perspectives on the science component of the 1999 video study, following publication of the international report, *Teaching Science in Five Countries:*

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<sup>5</sup> 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 some other documents, TIMSS 1995 is also referred to as TIMSS 1994, and TIMSS 1999 is also referred to as TIMSS 1998 or TIMSS-R (TIMSS-Repeat). While the 'T' in 'TIMSS' stands for 'Third' in the 1995 and 1999 studies, it stands for 'Trends' in studies since 1999.

*Results from the TIMSS 1999 Video Study of Eighth-Grade Science Teaching: Statistical Analysis Report* (Roth, Druker, Garnier, Lemmens, Chen, Kawanaka, Rasmussen, Trubacova, Warvi, Okamoto, Gonzales, Stigler & Gallimore, 2006). A supplementary technical report that addresses additional details specific to the science portion of the international study is to be released separately (Lemmens, Druker, Garnier, Chen & Roth, in press, 2006).

### **Participating countries**

The TIMSS 1995 Video Study included only one country, Japan, with a relatively high score in Year 8 mathematics as measured by TIMSS. Given that noticeably different patterns of teaching were observed between Japan and the two lower-achieving countries studied (Germany and the United States), it was tempting for some audiences to conclude prematurely that high mathematics achievement is possible only by adopting teaching practices like those used in Japan. The TIMSS 1999 Video Study addressed this issue for mathematics by sampling Year 8 lessons in more countries – both Asian and non-Asian countries – where students had performed well on the TIMSS 1995 mathematics assessment. A similar rationale was used in the selection of countries to participate in the TIMSS 1999 Science Video Study. Countries selected were Australia, the Czech Republic, Japan, the Netherlands and the United States.<sup>6</sup> The United States was particularly interested to study its own teaching practices in relation to those used in higher achieving countries, since its achievement on the written assessment was at about the international average only. Students in the United States performed significantly below students in all four of the other selected countries on the TIMSS 1995 written assessments.

Table 1.1 lists the countries that participated in the TIMSS 1999 Science Video Study along with their scores on the TIMSS 1995 and TIMSS 1999 science assessments. In 1995, the Czech and Japanese students, on average, performed significantly above the students from the other three countries. The TIMSS 1999 written assessment was administered after the TIMSS 1999 Video Study was underway and played no role in the selection of countries for the video study. However, the TIMSS 1999 science assessment results show that, on average, the United States students continued to perform significantly below their peers in the other four participating countries (although all five countries achieved results above the international average of 488).

**Table 1.1 Average scale scores on TIMSS 1995 and TIMSS 1999 science assessments of TIMSS 1999 Video Study participating countries<sup>1</sup>**

Country	1995 <sup>2</sup>	1999
	Average score	Average score
Australia <sup>3</sup> (AU)	527	540
Czech Republic (CZ)	555	539
Japan (JP)	554	550
Netherlands <sup>3</sup> (NL)	541	545
United States (US)	513	515

<sup>1</sup> There was no significant difference in science achievement at the .05 level in any of these five countries between the 1995 and 1999 assessments, though the improvement in absolute scores in Australia and the decline in absolute scores in the Czech Republic were among the largest that did not reach significance.

<sup>2</sup> Rescaled TIMSS 1995 science scores are reported here.

<sup>3</sup> 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, Martin, Mullis, Gonzalez, Smith & Kelly, 1996).

SOURCE: Gonzales, P., Calsyn, C., Jocelyn, L., Mak, K., Kastberg, D., Arafeh, S., Williams, T. & 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.

<sup>6</sup> A few other countries were approached but did not wish to take part.



### ***Goals of the study***

In addition to the broad purpose of describing science teaching in five countries, including some with records of high achievement in Year 8 science, the TIMSS 1999 Science 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;
- To compare teaching practices among countries and identify similar or different lesson features across countries, with a focus on differences between higher and lower achieving 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.

### ***Scope and methods***<sup>7</sup>

The TIMSS 1999 Science Video Study included a final sample of 439 Year 8 science lessons collected from the five participating countries. For each country, the lessons were randomly selected to be representative of Year 8 science lessons overall. In each case, a teacher was videotaped for one complete lesson and videotapes were collected across the school year in each country in an attempt to capture the range of topics and activities that can take place throughout an entire school year. 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 science 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 valid comparisons among the participating nations, the data were appropriately weighted to account for the sampling design.

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, which was usually the teacher. During private work time, that camera followed the teacher's and sampled students' activities. A second camera was stationary throughout the lesson 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 science and science education.<sup>8</sup> 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 science education specialist oversaw the science 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 science education researchers.

### **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

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<sup>7</sup> More information about the methodology used in the study can be found in Appendix A of this report and in Volume 2 of the *TIMSS 1999 Video Study Technical Report* (Lemmens et al., in press).

<sup>8</sup> Native English speakers coded the Australian lessons.

classroom is the place intentionally designed to facilitate students' learning. Although relationships between classroom teaching and learning are complicated and many factors outside the classroom are known to have an impact on student achievement, it is also well documented that teaching makes a difference in students' learning (e.g., Brophy & Good, 1986; Hiebert, 1999; Department of Education, Science and Training (DEST), 2003; OECD, 2005).

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 tend to enhance student learning opportunities and, by extension, student achievement. By providing rich descriptions of what actually takes place in science classrooms, the video study can contribute to further research into features of teaching that are most likely to 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 their knowledge of possibilities. In addition to examining how teachers in their own country approach mathematics or science in their classrooms, opening up the lens to include consideration of how teachers in another country approach the same topics can make one's own teaching practices more visible by contrast (Stigler & Hiebert, 1999; Stigler, Gallimore & Hiebert, 2000). Seeing one's own practices is a first step towards reflecting on them (Carver & Scheier, 1981; Tharp & Gallimore, 1989), which in turn is a step towards improving them.
- 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 can lead to hypotheses about ways different instructional practices may influence student learning that can be tested in carefully crafted follow-up research. Both the observations and any later 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. Year 8 students' achievement in science is the culmination of many past and current factors, both inside and outside of their schools. 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 (Martin, Mullis, Gonzalez, Gregory, Smith, Chrostowski, Garden & O'Connor, 2000). Moreover, in the countries involved in the 1999 science video study the videotaped classrooms were not the same ones in which students took the achievement tests as part of the TIMSS written assessment. The sample was a random sample of lessons meant to represent the practices within a country, not to obtain a reliable estimate of the average practice of any individual teacher.

### **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 can usually be transformed easily into data files that are ready for statistical analysis. However, using questionnaires to study classroom practices is inadequate 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 large samples are involved, 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 does not suffer from the above limitations and therefore offers a promising alternative for studying teaching (Stigler et al., 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 that it can be slowed down and viewed multiple times, by many people with different kinds of expertise, making possible detailed descriptions of many facets of many classroom lessons.
- Collecting a national random sample provides information about students' experiences across a range of conditions, rather than focusing on exceptional experiences. The ability to generalise nationally can provide the stimulus to 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., 2003), 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.

## **Particular Challenges in Studying Science Teaching**

### ***Science as separate disciplines or as an integrated subject***

The lessons in the TIMSS 1999 Science Video Study cover a wide range of topics drawn from the science disciplines of biology, chemistry, earth science, health, physical science, and, in some countries, technology and geography. Because of the range of content and the small number of lessons collected on any given topic within a science discipline, descriptions in this report can focus only on what is the average experience of Year 8 students in their science lessons. That is, it is not possible to describe the average chemistry or physics lessons, for example. This is an important limitation of the video study in relation to descriptions of science teaching, since some of the cross-country differences observed in science teaching practices may be an artefact of the disciplines emphasised in Year 8.

For example, it might be argued that physics and chemistry lend themselves more easily to production of phenomena that can be observed first-hand during a typical class period, whereas in biology, for example, the phenomena of interest typically require observations over a longer time. In a cross-national study there is the added complexity that some countries, for example, Australia, Japan and the United States, teach science as a single integrated subject at Year 8 level, while in others, such as the Czech Republic and the Netherlands, Year 8 science is offered through separate subject courses in physics, chemistry, life science and earth science (Martin et al., 2000). The present study did not attempt to quantify differences in emphasis of topics and teaching methods that might arise because of these two different approaches to science. Rather, readers need to bear in mind that the two approaches may have had some impact on the reported results.

### ***How should science lessons be described?***

There have been relatively few observational studies of science lessons, and certainly none on the scale of the TIMSS 1999 Science Video Study. To accomplish the challenging task of producing descriptions of science teaching that would be reliable, valid, interpretable and useful, the researchers had to ask many questions of themselves. How should the lessons be analysed? What questions would be most important to investigate? What kind of coding language would support analyses of important questions with an acceptable level of inter-rater agreement, and how could the language be developed to ensure that it would be sensitive to validity issues that sometimes

plague international comparisons?<sup>9</sup> These issues were relevant to the mathematics video study as well, of course, but there was more pre-existing research to use as a springboard.

The researchers began by conceptualising education as taking place within cultures, and science teaching as a process whereby teachers and students interact with knowledge, resources and expectations drawn from several communities, including the scientific community, within a culture. To say that science teaching is a cultural activity means that it is situated in a bed of routines, traditions, beliefs, expectations and values of students, parents, teachers, administrators, professional scientists and the interested public (Gallimore, 1996). For example, research has demonstrated that science teachers have deeply held beliefs about their students, about teaching and learning, about their roles as teachers, and about science (e.g., Carlsen, 1991; Gallagher, 1994; Hollon, Anderson & Roth, 1991). These beliefs influence how teachers represent science in their classrooms and the kinds of opportunities they provide for students to learn about science.

The guiding framework for the study acknowledges the importance of Schwab's four commonplaces of teaching (the teacher, the learners, the subject matter and the social milieu) (Schwab, 1969, 1971, 1973), but limits each of these to reflect the study's emphasis on observable features pertaining to the teachers' and students' actions, the students' opportunities for learning and the scientific content of the lessons, which are then aggregated and averaged to describe cultural patterns of teaching. It was expected that cultural differences in beliefs about science and teaching might be revealed through distinguishable country patterns emerging from observations of the teachers, the students and their science lessons. The framework emphasises the science lesson as the unit of analysis, but recognises the important influence of the larger culture on all aspects of the lesson.

## Research Questions

With the above broad conceptualisation of a framework of science teaching in mind, the researchers reviewed literature in science education, general education and curriculum, international education, psychology and the sociology and philosophy of science to aid their decisions about dimensions of science teaching to be analysed in the TIMSS 1999 Science Video Study.<sup>10</sup> In consultation with science and education experts from the participating countries, there was unanimous agreement that the overarching research question should be:

*'What opportunities did the lesson provide for students to learn science?'*

There was also agreement that analyses should look at the specific scientific content being taught, at science-specific teaching strategies and at the ways science itself was represented in the lessons (for example, science as inquiry, science as a body of knowledge).

Although this is a study of classroom teaching, the focus of analysis was placed on students and the ways in which teaching decisions provided different kinds of opportunities for students to learn science. This focus on student opportunity to learn fits well with the research literature on student thinking and learning, and with one of the main stimuli for the study – the discrepancies in student achievement as evidenced in the TIMSS 1995 and 1999 assessments (Martin et al., 2000). It is also

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<sup>9</sup> A description of how these aspects were coped with in the video study is given in Appendix A. More detail can be found in the technical reports of the study (Jacobs et al., 2003; Lemmens et al., in press, 2006).

<sup>10</sup> References consulted are given in the international report, *Teaching Science in Five Countries: Results from the TIMSS 1999 Video Study of Eighth-Grade Science Teaching: Statistical Analysis Report* (Roth et al., 2006). These include national curriculum documents from the Czech Republic, Japan and the Netherlands. The United States and Australia do not have national curricula, standards or guidelines; rather, decisions regarding curricula are taken at the state or local level. However, in both countries there are documents produced by nationally significant groups that have influenced curriculum decisions embodied in state or local curriculum guides. These influential documents are often cited in the international report and in this report, as they were the most widely referenced and distributed curricular and standards documents available at the time the study was conducted.

consistent with the ultimate goal of this study, which is the improvement of students' science learning.

Sets of indicative research questions were developed to guide the analyses undertaken. The three main guiding research questions are listed in Table 1.2 at the beginning of each set in the table.

**Table 1.2 Research questions for the TIMSS 1999 Video Study of Science Teaching**

Overarching question	<b>What opportunities did the lesson provide for students to learn science?</b>
Teacher actions: Instructional Organisation	<b>How did the teacher organise the lesson to support students' opportunities to learn science?</b> <ul style="list-style-type: none"> <li>▪ How much time was spent studying science?</li> <li>▪ What physical setting and resources supported science instruction?</li> <li>▪ How was the lesson organised for different instructional purposes?</li> <li>▪ How much did students work in pairs or groups versus individually?</li> <li>▪ How was the lesson organised for practical and seatwork activities?</li> <li>▪ How was the lesson organised for whole-class and independent work?</li> </ul>
Content	<b>How was science represented to students in the lesson?</b> <ul style="list-style-type: none"> <li>▪ Which scientific disciplines and topics were featured in the lessons?</li> <li>▪ What types of scientific knowledge were addressed in the lessons?</li> <li>▪ What was the source of the scientific content and its organisation?</li> <li>▪ How much scientific content was in the lesson?</li> <li>▪ How coherent was the scientific content?</li> <li>▪ How challenging was the scientific content?</li> <li>▪ What types of evidence were used in the lesson?</li> <li>▪ Were main ideas supported with multiple sets and types of evidence?</li> </ul>
Student actions	<b>What opportunities did students have to participate actively in science learning activities?</b> <ul style="list-style-type: none"> <li>▪ What were the features of independent practical activities?</li> <li>▪ What scientific inquiry actions did students practise during independent work and during whole-class work?</li> <li>▪ What features characterised students' collaboration during group work?</li> <li>▪ Did students have opportunities to read about science?</li> <li>▪ What opportunities did students have to communicate about science?</li> <li>▪ Did lessons include relevant issues for students?</li> <li>▪ Did lesson involve students in hands-on, practical work?</li> <li>▪ Did lessons involve different strategies to engage students?</li> <li>▪ What responsibilities did students have during the lesson?</li> <li>▪ What responsibilities did students have outside the lesson?</li> </ul>

The main guiding questions and the indicative sets of research questions were formulated and organised to keep the focus on students' opportunities to learn science. The guiding question regarding the teacher, for example, focused on the teacher's instructional organisation of the lesson: How did the teacher organise the lesson to support students' opportunities to learn science? Regarding the scientific content, the guiding question asked about how science was represented to students in the lesson. Regarding students, the focus was on students' actions related to science learning. The research questions listed in the table are indicative of the kinds of aspects that were investigated, not an exhaustive list of all analyses that were undertaken.

### **Australia's Participation in the TIMSS 1999 Science 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.

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

- Obtaining authentic and rich information on science teaching in Australian lower secondary classes, which, because of the study's design, could be aggregated to provide a national picture of teaching in this area;
- Ascertaining the extent to which science teaching in 1999 reflected emphases formalised in *A Statement on Science for Australian Schools* (Australian Education Council (AEC), 1994);<sup>11</sup>
- Examining Australian science teaching practices in relation to those in high-achieving Asian countries;<sup>12</sup>
- 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.

### ***The sample***

Detailed information on the designed and achieved Australian samples is provided in Appendix A. Briefly, 87 science classes were filmed. They were located in all states and territories, although the non-respondents were concentrated in New South Wales, which was experiencing protracted industrial problems at the time of the study.<sup>13</sup> Schools were selected with a probability proportional to their Year 8 enrolment. They came from all education 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 vast distance 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 going 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 second term of 2000. Inevitably, because of the need to use trained videographers and the cost of travel to other states from ACER's base in 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.

### **About This Report**

This report focuses on Australia's participation in the science component of the 1999 Video Study and the findings of particular relevance to Australia. In most instances, as the findings are

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<sup>11</sup> This document was the forerunner of similar, state-based documents developed during the 1990s that were current at the time of the study.

<sup>12</sup> 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'.

<sup>13</sup> 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.

presented and discussed, reference is inevitably made to all or some of the international results. The full results of the study can be found in the international report, *Teaching Science in Five Countries: Results from the TIMSS 1999 Video Study of Eighth-Grade Science Teaching: Statistical Analysis Report* (Roth et al., 2006),<sup>14</sup> hereinafter referred to as *Teaching Science in Five Countries*, from which much of the present report is drawn.

Chapter 2 discusses the context of the Australian 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 relates to the Teacher actions: Instructional Organisation section of Table 1.2 and provides information on the structure of the lessons and their main pedagogical components. The scientific content of the lessons is examined in Chapter 4, including both the nature of the content and how it is developed. Chapter 4 corresponds with the second section of Table 1.2. In relation to the third section of Table 1.2, Chapter 5 presents results and discussion about practical activities in science lessons, while Chapter 6 relates primarily to various other ways in which students actively participate in their science lessons.

The final chapter, Chapter 7, was prepared by one of Australia's foremost science educators, Professor Mark Hackling of Edith Cowan University. Professor Hackling draws on seminal and professional documents about science teaching and standards for highly accomplished science teachers in Australia to construct an ideal picture of science education for Australian students. He then uses results from the previous chapters of this report to describe key features of Year 8 science teaching in Australia in 1999-2000, as revealed by the study. In the context of the aims of science teaching in Australia, the ideal picture of science education that he has constructed and some of the international results, he then reflects on the findings and discusses their implications for Australian science education and teaching in the future.

### ***Statistical analyses***

Unless otherwise indicated, the source of all international data and statistics presented in this report is: the United States Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS) Video Study, 1999.<sup>15</sup> The complete set of tables and figures in the international report, *Teaching Science in Five Countries* (Roth et al., 2006), is not included here and the numbering of tables and figures often differs between this and the international report. To assist readers who wish to reconcile the two reports, Appendix B provides a list showing how the table and figure numbers correspond.

The following abbreviations are used throughout the report for the five participating countries: AU (Australia), CZ (Czech Republic), JP (Japan), NL (Netherlands), US (United States). Unless otherwise indicated, numbers and percentages presented by country in the tables and figures are weighted averages of data from all the lessons videotaped within each country. Since almost all tables and figures in the report pertain to the 1999 video study and display results by country, for parsimony these details have been omitted from the table headings and figure captions.

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 five countries). Weighted data were used in the significance tests. More detail of the analyses can be found in Appendix A.

Significance 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.<sup>16</sup> Because tests take into account the standard error for the reported differences, a large

<sup>14</sup> This can be accessed from the NCES website: <http://nces.ed.gov/timss> or ordered from [www.edpubs.org](http://www.edpubs.org)

<sup>15</sup> This wording is used under all tables and figures in *Teaching Science in Five Countries*.

<sup>16</sup> Note that, if fewer than three lessons within a country had an observed code, no pairwise comparison involving that country is reported – see Appendix A.

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

Extra caution is needed when interpreting small percentage results, as these sometimes have relatively large standard errors compared with the mean percentage values (especially for percentage values less than 5, which could well be rather different if measured in a different random sample from the same population). Complete tables of standard errors are included in an appendix to *Teaching Science in Five Countries* (Roth et al., 2006).

The purpose of this report is to introduce new survey data through the presentation of descriptive information. Readers are cautioned against drawing causal inferences based solely on the bivariate results presented. It is important to note that many of the variables examined in this report are related to one another, and complex interactions and relationships have not been explored here. Release of this and the international reports is intended to make the information available and to encourage more in-depth analysis of the data. Considering these limitations, the findings from the TIMSS 1999 Video Study of Year 8 science teaching are best interpreted alongside other sources of information, such as the TIMSS written assessments and other indicators that are broadly descriptive of education in the participating countries.

### ***Public release videos***

Accompanying this report is a DVD containing the five full-length public release lesson videos and associated materials from Australia, plus one full-length lesson from each of the Czech Republic, Japan, the Netherlands and the United States. Throughout Chapters 3 to 6, reference is made to various time segments of the Australian public release lessons to illustrate lesson features that are being discussed. For example, **AU PRL 4, 00:42:26** refers to the 42 minute 26 second point of the *TIMSS 1999 Video Study Australia Public Release Lesson 4*. (Note that the times cited can be expected to vary slightly on different computers.)

Altogether there are 25 TIMSS 1999 Science Video Study public release videos, five from each of the five participating countries. They are available as a set of CD-ROMs<sup>17</sup> 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 science teaching and how it can be improved.

### ***Highlights***

In addition to this report, highlights from the study for Australia are published in a separate document, available from the Australian Council for Educational Research in Melbourne via the ACER website: [www.timss.acer.edu.au](http://www.timss.acer.edu.au)

An international highlights document is available from the NCES website: <http://nces.ed.gov/timss> or can be ordered from <http://www.edpubs.org>

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<sup>17</sup> The CD-ROM package can be ordered online from the LessonLab Research Institute web site: [www.lessonlab.com](http://www.lessonlab.com) or from the NCES website cited above.



## Chapter 2

### CONTEXT OF THE AUSTRALIAN LESSONS

Many factors define the context of a school science lesson. These include, among other things, school conditions and resources, characteristics of the teachers, their expectations for science 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, as well as other aspects, were collected by means of questionnaires answered by the teachers and students of the videotaped classes.<sup>18</sup> This chapter describes the context of the sampled science lessons, in particular the Australian lessons.

Each of the 87 Australian teachers returned a completed Teacher Questionnaire. Student Questionnaires were returned from 82 of the 87 schools, although in a few schools not all students completed a questionnaire. According to enrolment data provided by the teachers, there were close to 2250 students enrolled in the videotaped classes. In total, 1854 Student Questionnaires were returned – a response rate of 82.4 per cent. Other studies suggest that between 5 and 10 per cent of students, depending on the time of year, would have been absent from school on the day of filming. The remaining 5–10 per cent of enrolments, about 110–230 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’, although 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 science teaching was provided by the teachers in their questionnaire responses. How well resourced were the Australian classrooms?

- *The Australian teachers and students were relatively very well provided with science laboratories, microscopes and reference materials. Teachers identified a shortage of computers and software, but this was also the case in the other countries in 1999.*

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<sup>18</sup> The Teacher Questionnaire is included in Lemmens et al. (in press, 2006) and the Student Questionnaire is included in the Technical Report of the mathematics component of the study (Jacobs et al., 2003, Appendix F). A description of the questionnaires is provided in Garnier (in press, 2006).

Only 9 per cent of the Australian science classes were taught by teachers who said that inadequate materials or 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 was felt most strongly, with only about a quarter of the Australian teachers indicating that they had sufficient access to these items in their classrooms.<sup>19</sup> By contrast, three-quarters or more said they had sufficient access to audio-visual equipment, teaching supplies, microscopes and reference materials (books, journals and magazines). Eighty-four per cent of the Australian teachers said they had sufficient access to a science laboratory. The range of access to resources across countries is shown in Table 2.1. The Australian schools were particularly well-resourced with respect to science laboratories and teaching and reference materials.

**Table 2.1 Percentages of Year 8 science lessons taught by teachers who reported sufficient access to resource items for use in their science classrooms**

Classroom resource	Country				
	AU	CZ	JP	NL	US
	Percentage of lessons				
Computers	27	34	40	29	48
Computer software	26	23	16	17	24
Computers with Internet connections	27	13	21	12	46
Audiovisual equipment	77	80	72	74	89
Teaching supplies and/or materials	79	93	78	85	49
Microscopes	79	78	80	59	54
Science laboratory	84	63	77	47	48
Reference materials	75	87	11	48	55

Computers with Internet connections: US>CZ, JP, NL

Teaching supplies and/or materials: AU, CZ, JP, NL>US

Microscopes: AU, JP>US

Science laboratory: AU>CZ, NL, US; JP>NL, US

Reference materials: AU, CZ, NL, US>JP; AU, CZ>NL; CZ>US

*Note:* Results based on science teachers’ reports. Percentages do not sum to 100 because more than one category could be selected.

In addition to asking teachers about the availability of equipment to teach science lessons, materials such as computers were noted in observations of the lessons. The percentages of lessons for which at least one computer was observed in the room were low except in the United States (4% in Japan, 5% in the Czech Republic, 10% in Australia and 22% in the Netherlands, compared with 59% in the United States). Whether the students were provided with the opportunity to use computers during the lesson is discussed in a later chapter.

## 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 are tabulated in this section, based on weighted data unless stated otherwise. Information about the classes is reported in the next section.

<sup>19</sup> 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.

### Gender

The weighted percentage of the Australian science lessons taught by males was 53 per cent (as compared to 63 per cent of the mathematics lessons). The TIMSS 1999 student assessment (Martin et al., 2000) reported that 57 per cent of Australian science students were in classes taught by males. Although the percentage of lessons is not the same statistic as the percentage of students in those lessons, a close relationship between these statistics would be expected and the data from the two studies are in fact reasonably consistent. A breakdown of teacher gender is not included by country in the TIMSS 1999 Video Study international report, *Teaching Science in Five Countries* (Roth et al., 2006). However, in the TIMSS 1999 student assessment, the majority of students were in science classes taught by a male teacher in each of the video study countries except for the Czech Republic (26%). The percentage of students taught by males in the United States was almost the same as that in Australia, but the corresponding percentages in Japan and the Netherlands, about 80 per cent in each case, were much higher (Martin et al., 2000).

### Educational preparation

How well prepared were the Australian teachers to teach science?

- *All but two of the Australian teachers had a university degree and all but five had studied science as a major or minor subject, with the overwhelming majority having studied it as a major subject. All were certified to teach, though three had primary training only. On average, they had been teaching for 15 years.*

Teachers identified the major and minor area(s) of study for their undergraduate degrees, and postgraduate studies where applicable. Only 2 per cent of the Australian teachers did not have at least a bachelor's degree, and 11 per cent had a postgraduate qualification, usually either a Graduate Diploma in Education or a Masters degree. All were qualified teachers, although three had training for primary level only. Across the participating countries, between 98 and 100 per cent of the lessons were taught by qualified teachers, although in the United States 10 per cent of the sampled lessons were taught by teachers who were certified to teach subjects other than science or science at lower grade levels than Year 8. In the Czech Republic, all teachers had a postgraduate degree, which is a pre-requisite for entering teaching there. In the Netherlands and the United States, almost 40 per cent of the sampled lessons' teachers had postgraduate qualifications, while the incidence of teachers of the sampled lessons with postgraduate degrees in Japan (8%) was similar to that in Australia.

Table 2.2 shows the percentage of lessons in each participating country taught by teachers who identified one or more major fields of study in their degree programs.<sup>20</sup> As the table indicates, except in Australia and the United States, all or almost all of the Year 8 science lessons were taught by teachers who reported having a major in science at tertiary level. Of the eleven Australian teachers who identified a major field other than science, six nominated an aspect of science as a minor field. Three of these had technology or mathematics as their major, two had physical education and one had sociology. One of the remaining five had graduated in civil engineering, one had a degree in human movement studies and three had undertaken primary training only. Most of the 36 per cent of teachers in the United States without a science major had qualifications in 'general education'.<sup>21</sup>

<sup>20</sup> These results differ slightly from those reported for Australia in *Teaching Science in Five Countries*; the Australian teachers' questionnaire responses showed that three teachers answered this question incorrectly and had actually studied science as a major (including one with a postgraduate degree in biology). Thus the 87 per cent showing for Australia for science overall in the international report was understated by about 3 per cent and the percentage for 'other than science' was overstated by the same amount.

<sup>21</sup> 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. However, 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 87 per cent of the students were taught by teachers having science as a major area of study in their BA, MA, or teacher training program (Zammit, Routitsky & Greenwood, 2002).

**Table 2.2 Percentages of Year 8 science lessons taught by teachers identifying one or more major fields of science studied at tertiary level**

Major field	Country				
	AU <sup>2</sup>	CZ	JP	NL	US
	Percentage of lessons				
Science <sup>1</sup>	90	95	100	99	64
Life sciences	47	48	20	41	46
Physics	15	33	30	44	‡
Chemistry	29	32	31	37	4
Earth sciences	11	48	10	6	6
General science	4	‡	100	‡	11
Other than science	10	5	‡	‡	36

<sup>1</sup> Science includes teachers' responses indicating a major field of study in general science, science education, or any of the various fields of science (e.g., physics, chemistry, biology).

<sup>2</sup> See Footnote 20 on the previous page for a comment about the Australian results.

‡ Fewer than three cases reported (country excluded from the relevant analysis)

Science: AU, CZ, JP, NL>US; JP, NL>AU

Life sciences: AU, CZ, US>JP

Physics: CZ, JP, NL>AU

Chemistry: AU, CZ, JP, NL>US

Earth sciences: CZ>AU, JP, NL, US

General science: JP>AU, US

Other than science: US>AU, CZ

*Note:* Percentages for a country may not sum to 100 because teachers could identify more than one major area of science. 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 science (not limited to Year 8). Their responses are summarised in Table 2.3. On average, Year 8 science lessons in Australia, Japan and the Netherlands were taught by teachers who reported they had been teaching between 12 and 15 years, both in general and specifically for science. Teachers in the Czech Republic were significantly more experienced than the teachers from any of the other four countries. In both the Netherlands and the United States the median number of years' experience was three or more years less than the average for both teaching science and teaching in general. Thus, in those two countries, the distributions of teaching experience were skewed somewhat towards teachers with relatively more experience (if there were no skewing, the mean and the median would coincide for each distribution).

The data on teaching experience is consistent with that reported from TIMSS 1995 (Beaton et al., 1996).<sup>22</sup> On that occasion, between 55 and 77 per cent of the students in the five video study countries were taught by teachers with at least 10 years' experience. In Australia, Japan, the Netherlands and the United States, a quarter to a third of the students were taught by teachers with more than 20 years' experience, while in the Czech Republic the corresponding fraction of students was two-thirds. 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).

<sup>22</sup> Corresponding information was not reported from the TIMSS 1999 student assessment.

**Table 2.3 Mean, median and range of number of years that Year 8 science teachers reported teaching in general and teaching science**

Teaching experience	Country				
	AU	CZ	JP	NL	US
<i>Years teaching</i>					
Mean	15	21	15	14	12
Median	16	21	15	11	7
Range	0–39	1–41	1–34	1–36	1–35
<i>Years teaching science</i>					
Mean	14	19	14	12	10
Median	15	18	15	9	7
Range	0–39	1–39	1–34	1–33	1–35

Years teaching (mean): CZ>AU, JP, NL, US

Years teaching science (mean): CZ>AU, JP, NL, US

*Note:* Mean years per country are calculated as the sum of the number of years reported by its teachers 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. A response of zero (0) indicates that a teacher was in the first year of teaching at the time of data collection.

### ***Professional development activities***

Teachers' educational and professional experiences are not limited to formal degrees and years of teaching experience, but also include participation in professional development activities. Teachers were asked in the questionnaire to indicate, from a given list, the kinds of activities they had undertaken during the two years up to the day of videotaping.

- *More than 90 per cent of the Australian science classes were taught by teachers who had undertaken some kind of professional development activity in the previous two years. The professional development undertaken was usually of direct relevance to their day-to-day classroom teaching.*

The teachers' responses to the professional development items are summarised in Table 2.4. Clearly, fewer of the Australian lessons were taught by teachers who had taken at least one university course in science or science education in the previous two years than in any of the other four countries. It may be that some Australian teachers misinterpreted the word 'course', which was used in the Australian questionnaire as it was in the other countries – perhaps in our case 'subject' would have been a better choice of word. Nevertheless it is not common for Australian teachers to obtain release time to enable them to undertake further academic studies, and opportunities to upgrade qualifications through university summer school programs in Australia do not occur in the way they do in the United States.

In terms of the less theoretical, more immediately relevant professional development activities they were asked about, the Australian teachers reported undertaking an average of three such activities each, compared with an average of five each in the United States and two each in each of the other three countries. Within Australia, there were only six teachers who said they had not taken part in any professional development in the past two years. Seven teachers had undertaken one activity, 30 had undertaken two or three activities and 44 had taken part in more than three activities (the maximum was nine of the listed activities). As shown in Table 2.4, use of technology was clearly the most common professional development activity focus for the Australian teachers, followed by classroom management and organisation, science instructional techniques and standards-based teaching.

Although there is no indication in the responses about the duration of the professional development activities, the data in Table 2.4 show that, in various ways, the teachers from all five countries were active in undertaking professional development with implications for improving their pedagogical knowledge and skills.

**Table 2.4 Percentages of Year 8 science lessons taught by teachers who undertook professional development activities during the previous two years**

Professional development activity	Country				
	AU	CZ	JP	NL	US
	Percentage of lessons				
University science or science education course	9	56	38	50	49
Classroom management and organisation	37	6	19	16	21
Cooperative group instruction	29	7	12	36	48
Interdisciplinary instruction	14	5	‡	3	48
Science instructional techniques	36	36	50	43	66
Standards-based teaching	36	--	29	22	52
Teaching higher-order thinking skills	22	‡	‡	11	44
Teaching students from different cultural backgrounds	13	‡	‡	8	31
Teaching students with special needs	23	7	6	12	36
Use of technology	79	45	42	68	84
Other professional development issues	46	42	18	25	44

‡ Fewer than three cases reported (country excluded from the relevant analysis)

-- Not applicable

University science or science education course: CZ, JP, NL, US>AU

Classroom management and organisation: AU, US>CZ

Cooperative group instruction: AU, NL, US>CZ; NL, US>JP

Interdisciplinary instruction: US>AU, CZ, NL

Science instructional techniques: US>AU, CZ

Standards-based teaching: US>NL

Teaching higher-order thinking skills: US>AU, NL

Teaching students from different cultural backgrounds: US>AU, NL

Teaching students with special needs: AU>JP; US>CZ, JP, NL

Use of technology: AU, NL, US>CZ, JP

Other professional development activities: AU, CZ, US>JP

*Note:* Results based on science teachers' reports. Totals do not sum to 100 because more than one category could be selected. The option 'standards-based teaching' was not appropriate for the Czech Republic. 'Use of technology' includes but is not limited to use of computers.

### **Work responsibilities**

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

Table 2.5 shows that Year 8 science lessons differed in the amount of time teachers reported allocating to teaching science on average across countries. Lessons in the Netherlands and the United States were taught by teachers who reported spending the largest amount of time, 19 to 20 hours a week on average, in teaching science. Australian lessons were taught by teachers who reported spending less time on average in teaching science than lessons in Japan, the Netherlands and the United States. Japanese lessons were taught by teachers who reported teaching other classes for a smaller amount of time, and spending more time doing other school-related activities, compared with teachers in the other four countries, on average. The Australian teachers were similar to the teachers from the Czech Republic and the United States in the amount of time they reported spending on work related to teaching science, both at home and at school. They reported spending more time than the Dutch teachers in working at school and more time than the Japanese teachers in working at home on activities related to their science teaching.

**Table 2.5** Average hours per week that Year 8 science teachers reported spending on teaching and other school-related activities

Activity	Country				
	AU	CZ	JP	NL	US
	Hours per week				
Teaching science classes	14	16	16	19	20
Teaching other classes	3	6	1	4	4
Meeting with other teachers to work on curriculum and planning issues	2	1	1	1	2
Work at school related to science teaching	7	6	6	4	7
Work at home related to science teaching	6	6	4	7	6
Other school-related activities	5	7	12	5	6
Total	38	42	40	40	45

Teaching science classes: JP, NL, US>AU; NL>CZ

Teaching other classes: AU, CZ, NL, US>JP; CZ>AU

Meeting with other teachers to work on curriculum and planning issues: US>CZ, JP

Work at school related to teaching science: AU, CZ, JP, US>NL

Work at home related to teaching science: AU, CZ, NL, US>JP

Other school-related activities: JP>AU, CZ, NL, US

Total teaching and other school-related activities: No measurable differences detected

*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.

Some of the results for Australia seem low and warrant additional comment, especially in that the teachers were not asked about full-time or part-time teaching status. Inspection of the Australian data suggests that a quarter or more 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 30 or fewer hours in total, which would probably not have constituted a full-time workload, and 9 per cent reported spending fewer than 25 hours in total, certainly not a full-time workload. The average number of hours teaching science classes together with classes in other subjects shown in the table is particularly low in Australia compared with that reported by teachers from the other countries (except Japan). 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.

### **Confidence**

Teachers were asked several questions about their attitudes to teaching in general and to teaching science. Comparative data on these questions were not reported internationally, 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. Fifty-one per cent of lessons were taught by teachers who strongly agreed, and a further 37 per cent by teachers who agreed, that they had ‘a strong science background’ in the subject areas they were teaching. Two who had primary training only were among the three teachers who strongly disagreed that they had a strong science background. Among the remainder who did not agree that they had a strong science background all but one had at least one science subject as their major area of university study.

In contrast with the mathematics video study, 12 per cent of the Australian science lessons, compared with only 5 per cent in mathematics (Hollingsworth et al., 2003), were taught by teachers who said they were not proud of the quality of their teaching and believed that they were not effective teachers. This lack of confidence in their teaching skills had little to do with whether they regarded their background in science as strong – only two teachers who believed they were not effective teachers considered that their background in the science subject areas they were

teaching was not strong. All three respondents with primary training only judged themselves to be effective teachers.

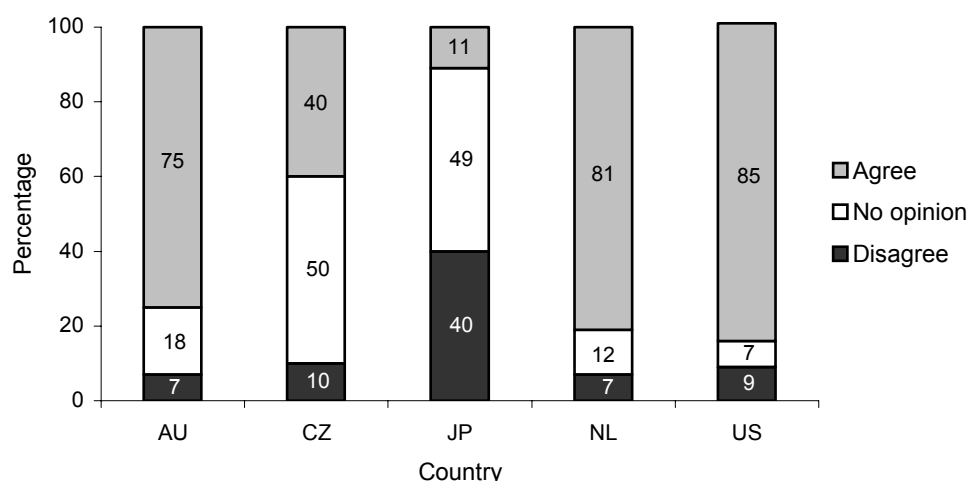
That student achievement is not necessarily related to teachers' perceptions of their preparation to teach is indicated by data from the TIMSS 1999 written assessment. Martin et al. (2000) show that, averaged over all the areas of science mentioned, 46 per cent of students internationally were taught by teachers who judged themselves to be very well prepared. The percentages of students in this category in Australia (55%), the Czech Republic (64%) and the United States (58%) were all significantly above the international average. The corresponding percentage in the Netherlands (50%) was no different from the international average. The percentage of students in Japan whose teachers judged themselves to be very well prepared to teach science, at only 17 per cent, was anomalous, echoing the results from the mathematics assessment study. These results for Japan, a country with high student achievement, highlight that factors other than teachers' beliefs about how well they are prepared are involved in good teaching.

### ***Familiarity with current ideas***

Several questionnaire items were designed to identify how teachers might have been influenced by current ideas about teaching and learning science. 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 the questions within their own context. First, teachers were asked if they agreed or disagreed that they were familiar with current ideas in science teaching and learning, or if they had no opinion. The distributions of their responses are shown in Figure 2.1.

The figure shows some contrasting results. On average, more Australian, Dutch and United States lessons, with at least 75 per cent agreement, were taught by teachers who believed they were familiar with current ideas. By contrast, half of Japanese lessons were taught by teachers who had no opinion about their familiarity with current ideas. In fact, 40 per cent of Japanese lessons were taught by teachers who reported that they were *not* familiar with current ideas, a much larger percentage than in any of the other countries.

**Figure 2.1** Percentage distributions of Year 8 science lessons taught by teachers who reported being familiar with current ideas in science teaching and learning



Agree: AU, NL, US > CZ, JP; CZ > JP

No opinion: CZ, JP > AU, NL, US

Disagree: JP > AU, CZ, NL, US

Note: Results based on science teachers' reports. Totals may not sum to 100 because of rounding.



One objective for Australia of participating in the video study was ascertaining the extent to which science teaching in 1999 reflected emphases formalised in *A Statement on Science for Australian Schools* (AEC, 1994), given that this document was influential in most of the state-based curriculum documents produced in the ensuing five years. 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 science teaching and learning, and only three teachers specifically mentioned the national *Statement*.<sup>23</sup> Most commonly, state-based and national journals and magazines, other teachers, science teachers' associations and professional development days were mentioned in relation to sources of current ideas. Reference to textbooks was less common and a few teachers said they used websites. Ten teachers responded that they did not read about new ideas in science teaching at all.

## 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 equal numbers of boys (930) and girls (924) in the Australian classes. Those who identified themselves as Indigenous Australians comprised 3.2 per cent of the students, which is what would be expected in a representative sample. Eighty-six per cent of the students, 68 per cent of their mothers, and 65 per cent of their fathers were born in Australia, while 92 per cent of the students said they spoke English at home at least half the time. These data correspond closely to the Australian data reported for TIMSS 1995 and TIMSS 1999 (Lokan et al., 1996; Zammit et al., 2002) and to the data reported for the mathematics video study (Hollingsworth et al., 2003).

'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 under 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 and science 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 scientific content and pedagogy which are the foci of separate chapters.

### *Class size*

Class sizes in the Australian science sample ranged from 13 to 32. Using weighted data, the average class size was 25.6 students, with a median of 26. Ten per cent of classes had 20 or fewer

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<sup>23</sup> It is likely that more teachers would mention their state's curriculum documents nowadays.

students, a further 38 per cent had between 21 and 25 students, 46 per cent had between 26 and 30 students, and only 6 per cent had more than 30 students. The most common class sizes were 24, 25, 28 and 30.

Teachers were asked whether the number of students in their class limited them from reaching their ideal for the videotaped lesson. Eight per cent of the lessons were taught by teachers who answered that the size of their class limited their teaching either 'a lot' or 'a great deal'. The actual sizes of the classes thought to be too large varied from 22 to 32 students, though all but two were above the Australian median of 26.

### ***Overall instructional time for science***

Before the data on lesson duration for the sampled lessons are presented, it is useful to consider the amount of instruction time in science 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, as demonstrated in the report of the TIMSS 1999 written assessment (Martin et al., 2000). Differences also occur within countries like Australia, where education is organised on a state by state basis.

Data on annual science instruction time were not collected in the TIMSS 1999 Science Video Study, but an indication can be obtained from the data collected from school principals in larger national random samples of schools for the TIMSS 1999 written assessment. As Martin et al. (2000) observed, students in countries where science was taught as several separate subjects generally had more instructional hours in science than in countries where it was taught as a single integrated subject. Most countries in the former category had over 150 hours of science instruction per year and many had over 200 hours. In contrast, most countries in the latter category reported between 90 and 150 science hours per year. The estimated average times for the five science video study countries are shown in Table 2.6.

The estimates in Table 2.6 should be considered indicative rather than definitive, particularly as they are limited to in-school instruction and therefore will not accurately reflect the amount of instruction that students may receive in other settings.<sup>24</sup> For this reason, it was deemed inappropriate to compare them statistically. Nonetheless, the data in the table serve as a reminder that it is not appropriate to presume that the individual lesson duration reported in the next section describes the relative time spent by students in each country in studying school science.

**Table 2.6 Average annual in-school time spent on Year 8 science instruction<sup>1</sup>**

<b>Country</b>	<b>Estimated average instructional time (hours)</b>
Australia (AU)	129
Czech Republic (CZ) <sup>2</sup>	236
Japan (JP)	94
Netherlands (NL) <sup>2</sup>	181
United States (US)	144

<sup>1</sup> Data from Exhibit 6.4 in Martin, Mullis, Gonzalez, Gregory, Smith, Chrostowski, Garden & O'Connor, 2000

<sup>2</sup> In the Czech Republic in 1999 Year 8 science was taught as four separate subjects (Earth Science, Biology, Physics and Chemistry); in the Netherlands it was taught as three separate subjects (Earth Science, Biology and Physics). In the other three countries in 1999 Year 8 science was taught as a single integrated subject.

<sup>24</sup> 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.

**Duration**

The length of a science 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 (NRC), 2000) and is therefore a good starting point for describing lessons. How the teachers and students filled in the lesson time with scientific content and work will become apparent in later chapters of this report.

To ensure that the science 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 science lesson, decisions had to be made about when a lesson began and ended. The beginning of the lesson was marked as the point when all or most of the students were in the room and the teacher verbally or physically signalled his or her intention to begin the lesson. When there was no such signal from the teacher, the beginning of the lesson was marked when all or most of the students were in the room and had begun to do what they were supposed to do (for example, they began working on a task that was written on the board). The end of the lesson was marked at the end of the teacher's signal to stop instructional work. 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 the first student packed up materials and left the classroom.

The mean, median, range, and standard deviation of the length of the videotaped science lessons in each country are displayed in Table 2.7.

**Table 2.7 Mean, median, range, and standard deviation (in minutes) of the duration of the videotaped lessons**

Country	Mean	Median	Range	Standard deviation
	Minutes			
Australia (AU)	49	45	21–92	14
Czech Republic (CZ)	46	45	39–52	1
Japan (JP)	50	51	40–65	4
Netherlands (NL)	47	46	37–90	8
United States (US)	51	46	33–119	16

Mean: JP, US>CZ; JP>NL

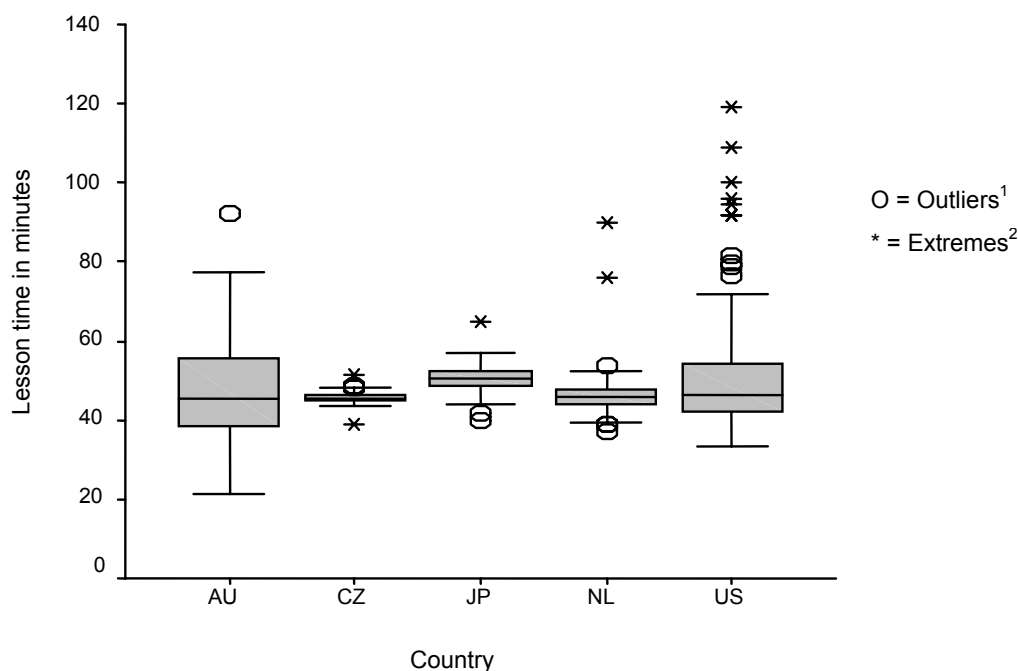
Standard deviation: AU, JP, NL, US>CZ; US>JP, NL; AU>JP

*Note:* For each country, the mean was calculated as the sum of the number of minutes in each lesson divided by the number of lessons filmed in 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 and the highest number of minutes observed within the country.

While the mean durations vary by only five minutes across countries, the use of 'double lessons' in some countries, particularly in Australia and the United States, has distorted the means a little, as can be seen from the difference between the mean and median lesson lengths. The median length is therefore a better measure for gauging the length of a typical lesson. The standard deviations and the ranges in the table show that lesson length varied less in the Czech Republic than in the other countries, suggesting a fairly standardised period of instruction for science in that country. In Australia, 13 of the 87 filmed science lessons were double periods. Three lessons were shorter than 30 minutes (but were intended to be 35 or 40 minutes long). One of these was short because the teacher administered the Student Questionnaire during the lesson. In the other two, students came several minutes late from their previous class and in one of these still more time was used while the teacher deployed students who had not returned permission slips.

In general, the data in Table 2.7 for science are similar to the data observed for mathematics in these five countries (Hiebert et al., 2003). 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. The figure provides a more detailed look at the variation in lesson length across countries. Whereas Table 2.7 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 fell within a narrower range, though the range in the United States was still broad compared with that in the other three countries.

**Figure 2.2 Box and whisker plot showing the distributions of videotaped science lesson durations**



<sup>1</sup> Outliers are values from 1.5 to 3.0 box lengths from the upper or lower edge of the box.

<sup>2</sup> 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 (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).

In Australia's case, it can be seen that a quarter of the videotaped lessons were shorter than about 40 minutes while another quarter were longer than about 57 minutes. As noted above, in 13 cases the videotaped lesson was a 'double lesson'. In 15 of the schools in the Australian sample science was taught in a mixture of single and double periods. Altogether, 22 of the schools had at least one double period for science each week and a further eight schools had single lessons of 60-65 minutes' duration, allowing time for apparatus to be set up for practical work. Four of the Australian public release lessons were single lessons (33, 34, 43 and 61 minutes from intended times of 38 to 64 minutes). The other was a double lesson (74 minutes from an intended time of 80 minutes). The National Research Coordinator explained:

This is a double lesson that extends well over one hour. Within a normal school week a class might typically have one double lesson. Teachers often take advantage of these lessons to do extended practical work. (AU PRL 4, National Research Coordinator's Comments, 00:00:52)

If only the single periods are considered in the full Australian sample, the mean and median lesson times were 45 and 44 minutes, respectively, but the standard deviation (9 minutes) was still large compared with that in the Czech Republic and Japan. The double periods had a mean and median

length of 72 minutes, with a standard deviation of 8 minutes. As in the mathematics video study, variations in lesson duration between states within Australia were noticeable, possibly carried forward from years ago when most schools were centrally administered and had much less autonomy in determining their day-to-day procedures.

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 science portion of the lesson. In many cases, lessons began or ended with non-science activities. These activities were included in the lesson and later marked as 'non-science 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 actual duration observed for the videotaped lessons showed about a quarter differing by no more than three minutes. A further fifth differed by between three and five minutes. All the others, more than half of the videotaped lessons, differed in duration by at least six minutes from the designated lesson time, several by up to ten minutes and seven by more than 10 minutes. While some of these differences were probably due to the unusual circumstance of having cameras and visitors in the classroom, they may also 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 towards which the teacher is working (Hiebert, Carpenter, Fennema, Wearne, Murray, Olivier & Human, 1997). What learning goals did the Australian teachers hold?

- *Overall learning goals held by the Australian teachers for their Year 8 science students emphasised awareness of the usefulness of science, developing an interest in science, using scientific inquiry skills and understanding the nature of science. For the videotaped lesson in particular, however, the learning goals were less broad. The main goal for the sampled lesson was conceptual understanding of scientific ideas.*

### Learning goals for the year

In one section of the questionnaire teachers were asked to list the three most important things they would like their students to learn from studying science this year. The Australian teachers tended to emphasise contextual and affective aspects such as awareness of the usefulness of science in life and developing a positive attitude towards or interest in science rather than the acquisition of scientific knowledge or conceptual understanding. As well, they wanted their students to use scientific inquiry skills and to understand the nature of science. Forty per cent or more of the lessons in Australia, Japan and the United States were taught by teachers who had an overall goal of having their students use scientific inquiry skills, compared with 14 per cent in the Netherlands and fewer than three cases in the Czech Republic. To have their students understand the nature of science was more important to Australian teachers than to the teachers in the Czech Republic, Japan and the Netherlands. Acquisition of scientific knowledge was all-important in the Czech Republic, where 86 per cent of the sampled lessons were taught by teachers who emphasised this goal, more than in any other country except the Netherlands (66%).

### Learning goals for the videotaped lesson

Early in their questionnaire the teachers were asked to identify, in their own words, the 'main thing' they wanted their students to learn from the videotaped lesson. The question followed immediately on from another that had asked about the ideas and skills taught in the lesson that were new to the students and those that were being reviewed. Given the sequence of questions, teachers tended to focus on knowledge and skills in their replies about their main objective for the lesson rather than on more general aspects of science. Some did mention more general aspects, as can be seen from Table 2.8. More typical responses in Australia were to mention a general topic goal, such as 'learning about characteristics of living things', or more detailed goals, such as

‘understanding that a force is a push or a pull on an object, how a force can change an object, how force is measured, how to use a spring balance’.

Teachers’ responses were coded according to aspects of the three main performance expectations of ‘knowing science’, ‘doing science’ and goals related to the ‘context of science’. These are similar to the goal dimensions of content, process, and perspective developed for the TIMSS science curriculum framework (Robitaille, Schmidt, Raizen, McKnight, Britton & Nicol, 1993). Content goals were identified by statements describing scientific concepts or topics. Process goals were defined as descriptions about how teachers wanted their students to do or use science, such as designing and/or conducting investigations or applying science to everyday situations. Perspective goals included those aimed at promoting students’ attitudes towards and interest in science and developing students’ awareness of the usefulness of science.

**Table 2.8 Percentages of Year 8 videotaped science lessons by teacher-identified science goals for the lesson**

Goal for videotaped lesson	Country				
	AU	CZ	JP	NL	US
	Percentage of lessons				
Performance expectations for science					
Knowing science					
Knowing scientific information	20	59	14	23	23
Understanding scientific ideas	51	7	70	27	23
Understanding the nature of science	4	‡	‡	‡	4
Doing science					
Carrying out a scientific experiment, project, or activity	4	6	10	15	17
Developing generic thinking skills	‡	‡	3	8	5
Learning laboratory skills	11	10	15	12	6
Using scientific inquiry skills	13	6	8	11	22
Context of science					
Awareness of the usefulness of science in life	19	12	9	17	22
Collaborative work in groups	‡	‡	‡	10	8
Independent work	5	‡	3	11	7

‡ Fewer than three cases reported (country excluded from the relevant analysis)

Knowing scientific information: CZ>AU, JP, NL, US

Understanding scientific ideas: AU, JP, NL, US >CZ; AU>US; JP>NL, US

*Note:* Results based on science teachers’ reports. Totals do not sum to 100 because responses could be coded into more than one goal for the videotaped lesson.

Countries differed on only two performance goals for the videotaped lesson, as can be seen from Table 2.8. More Czech lessons were taught by teachers whose stated goal for the lesson was knowing scientific information (59%) compared with all the other countries (14 to 23%). This result is consistent with the Czech teachers’ overall goals for the year discussed above. Also consistent with their overall goals is the result that fewer Czech lessons were taught by teachers whose goal for the lesson included understanding scientific ideas (7%), compared with 23 per cent to 70 per cent in the other countries. Despite the Australian teachers’ relatively low emphasis on the overall goal of having their students understand scientific ideas, half of the Australian lessons were taught by teachers who endorsed this goal as their main goal for the videotaped lesson. Comparisons within countries on goals for knowing science indicated that the main stated goal of more Year 8 lessons was for students to know scientific information and to understand scientific

ideas than to understand the nature of science. Within Australia and Japan, more lessons were taught by teachers who also wanted students to understand scientific ideas rather than to know scientific information, whereas within the Czech Republic the goal of teachers in more lessons was for students to know scientific information rather than to understand scientific ideas.

### Did teachers believe their lesson goals were achieved?

A lesson does not always proceed as intended. Interruptions, the need to revisit topics, difficulties with equipment or apparatus, and so on, 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 but Japan, the teachers were similarly satisfied that their lessons played out as they had intended, with between 87 per cent (Australia) and 94 per cent (United States) responding that they were satisfied in this respect. By contrast, 38 per cent of the Japanese lessons were taught by teachers who were not satisfied that their lessons had proceeded as intended, in most cases because the teachers believed that they had not achieved their lesson plan (24%) or their students had not learned the lesson content (12%). In all countries the most common reason for satisfaction given was that the students had learned the lesson content. Except in the Netherlands (27%), few lessons were taught by teachers who believed that they had achieved their lesson plan, but only the Japanese teachers indicated concern about this (data not shown).

### What influenced teachers in their decision to teach the content of the videotaped lesson?

The teachers were asked to identify the extent to which various factors contributed to their decision to teach the content captured in the videotaped lesson. The six response options listed in Table 2.9 were provided together with response boxes for 'no role', 'small role' or 'major role'.

**Table 2.9 Percentages of videotaped Year 8 science lessons taught by teachers who reported various factors playing a 'major role' in their decision to teach the lesson content**

Factor	Country				
	AU	CZ	JP	NL	US
	Percentage of lessons				
Cooperative work with other teachers	32	6	5	44	25
Curriculum guidelines	60	93	20	41	84
External examinations or standardised tests	--	3	5	7	23
Mandated textbook	32	67	52	74	26
Teacher's comfort with/interest in the topic	27	47	15	37	41
Teacher's assessment of students' interests or needs	47	39	44	25	74

-- Item not used in Australian questionnaire

Cooperative work with other teachers: AU, NL, US>CZ, JP

Curriculum guidelines: CZ, US>AU, JP, NL; AU>JP

External examinations or standardized tests: US>CZ, JP, NL

Mandated textbook: CZ, NL>AU, US; JP>US

Teacher's comfort/interest: CZ, NL, US>JP

Teacher's assessment of students' needs: US>AU, CZ, JP, NL

*Note:* Results based on science teachers' reports. Totals do not sum to 100 because more than one category could be selected.

Countries varied on many of the listed factors, as shown in the table. Curriculum guidelines played a major role in teachers' decisions in more Czech and United States lessons than in Australian, Dutch and Japanese lessons. More teachers of the United States' sampled lessons indicated students' needs than in any of the other countries. Even so, about 40 per cent or more of the

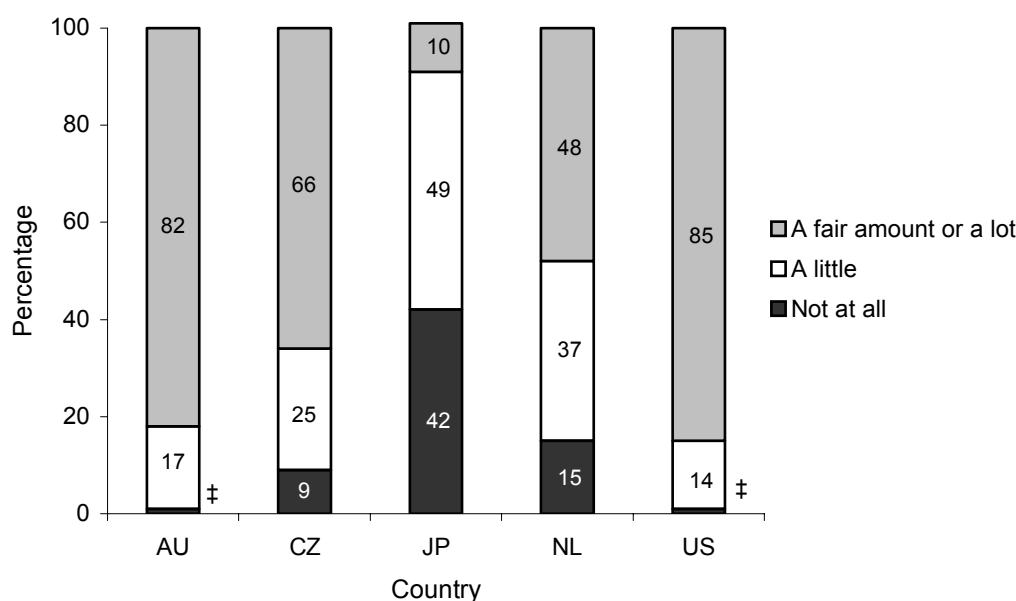
lessons in all but the Netherlands (25%) were taught by teachers who nominated students' needs as guiding their selection of lesson content. Cooperative work with other teachers was more important in guiding the content of the videotaped lessons in Australia, the Netherlands and the United States than in the Czech Republic or Japan.

As expected from the results of the TIMSS written assessment (Lokan et al., 1996), mandated textbooks did not play a major role in the majority of lessons in Australia. Together with the United States, fewer lessons in Australia were taught by teachers who said they were guided by mandated textbooks than in the other three countries. Within each of these latter three countries, more lessons were taught by teachers who said that the mandated textbook was a major influence on the content of the videotaped lesson than all or almost all other available options, along with curriculum guidelines in the Czech Republic and the teachers' assessment of students' needs in Japan. Within Australia and the United States, more lessons were taught by teachers who indicated that curriculum guidelines were the major influence on the videotaped lessons along with teachers' assessment of their students' needs.

### *Embodiment of current ideas*

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 science. Their responses are summarised in Figure 2.3.

**Figure 2.3** Percentage distributions of Year 8 science lessons by teachers' ratings of the extent to which the videotaped lesson was in accord with current ideas about teaching and learning science



† Fewer than three cases reported (country excluded from the relevant analysis)

A fair amount or a lot: AU, CZ, NL, US > JP; AU, US > NL

A little: JP > AU, CZ, US

Not at all: JP > CZ, NL

Note: Results based on science teachers' reports. Totals may not sum to 100 because of rounding and data not reported.

As seen earlier in the chapter (see Figure 2.1), 75 per cent or more of the lessons in Australia, the Netherlands and the United States were taught by teachers who believed that they were familiar with current ideas in science teaching and learning, while this was the case for only 40 per cent of the lessons in the Czech Republic and only 11 per cent in Japan. It is not surprising, then, to see in Figure 2.3 that teachers of fewer Japanese lessons described the videotaped lessons as being in



accord with current ideas to a fair or large degree compared with lessons in the other four countries.

There was some ‘spillage’ in Australia and the Czech Republic where more teachers believed their videotaped lessons were in accord with current ideas than those who said they were familiar with such ideas. Perhaps some who answered ‘no opinion’ to the familiarity question realised that they did have some knowledge of current ideas when thinking about their sampled lesson. The Netherlands result is in the reverse direction – whereas over 80 per cent of the lessons were taught by respondents who said that they were familiar with current ideas about science teaching and learning, only 48 per cent of the videotaped lessons were deemed by their teachers to be in accord with such ideas.

### **Typicality**

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

- *In general, the Australian teachers believed that their lessons were about the same as usual with regard to their teaching, their students’ behaviour and the difficulty of the content. 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 were also asked about the course of which the videotaped lesson was a part. Other questions asked about the typicality of the lesson content, the teaching methods used, and the students’ behaviour.

#### The course of which the videotaped lesson was part

Teachers were asked if all Year 8 students in the school took the same science course as the one in the videotaped lesson. In all Dutch lessons, the teachers responded that students in the school were required to take the same science course (data not shown). Between 84 and 97 per cent of lessons in the other four countries were in schools that required Year 8 students to take the same science course. These data suggest that, overall, Year 8 students in the participating countries were not streamed into different levels or types of science based on ability levels, at least within their schools.

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 or more 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 science is one. It is rare for students to be grouped into classes of different ability levels for science instruction at Year 8. Seven of the Australian teachers in the study said that all Year 8 students in their school did *not* study the same science course, but six of these said that whatever other science course the students took, it was no more nor less challenging than ‘the typical Year 8 science course of study/pathway in this school’. The other teacher said there was a class that studied the same material but also had extension work.

#### Content of the lesson

Between 81 per cent (United States) and 91 per cent (Australia) of the lessons were taught by teachers who said that the videotaped lesson was at about the same level of difficulty as most lessons the students were taking. Of the Australian lessons, 3 per cent were judged to be more difficult and 6 per cent were judged to be less difficult than usual. Internationally there were no measurable differences between countries in the teachers’ judgments of the level of difficulty of the lesson content (data not shown).

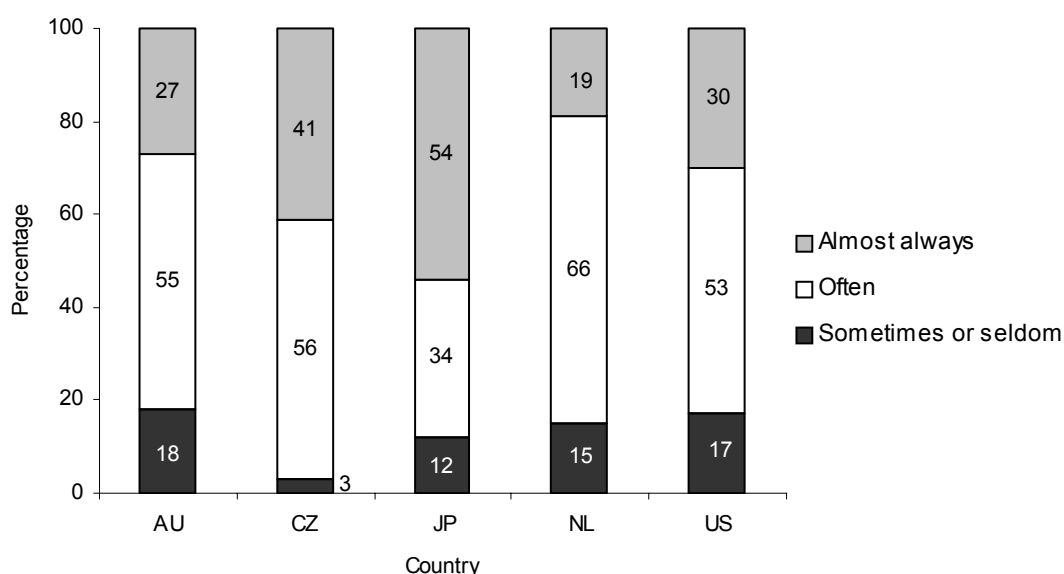
#### Teaching methods

According to the teachers’ reports, the Year 8 videotaped science lessons provide a picture of typical science teaching. With respect to pedagogy, the teachers were asked, ‘How often do you

use the teaching methods that are in the videotaped lesson?’ Their responses are summarised in Figure 2.4.

The two response options of ‘often’ and ‘almost always’ accounted for between 82 and 97 per cent of the responses in each of the five countries. The only cross-country differences were in the distributions of these two response categories. The lessons in Japan were taught by teachers who used the ‘almost always’ response category significantly more than was the case in the United States, Australia and the Netherlands, while teachers in the Netherlands and the Czech Republic responded ‘often’ significantly more than teachers in Japan.

**Figure 2.4** Percentage distributions of Year 8 science lessons by teachers’ ratings of how often they used the teaching methods in the videotaped lesson



Almost always: JP>AU, NL, US

Often: CZ, NL>JP

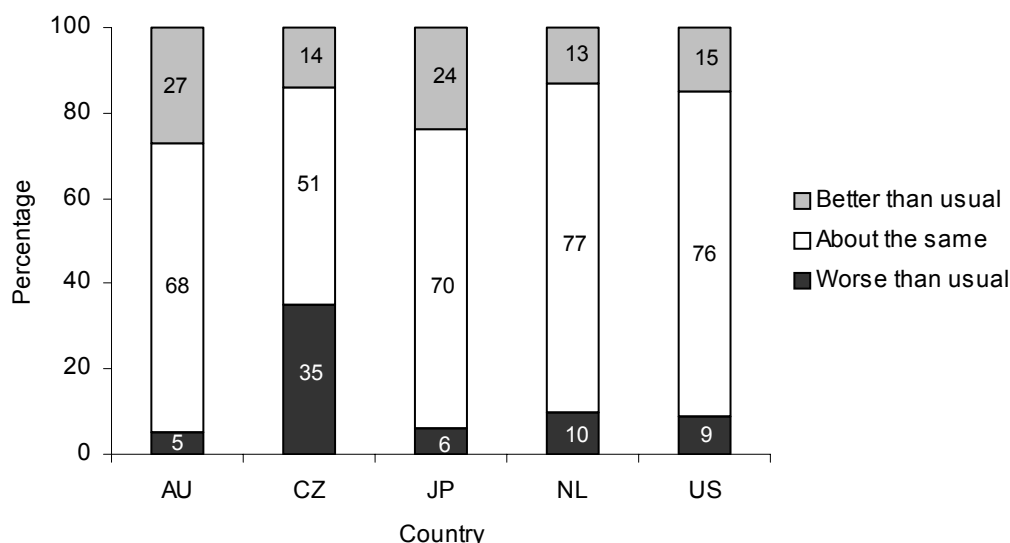
Note: Results based on science teachers’ reports

### Students’ behaviour

A teacher’s ability to conduct a successful lesson is related, in part, to students’ behaviour. A further 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 65 per cent of the lessons in each country were taught by teachers who reported that the students behaved about the same as or better than usual, the lowest percentage being in the Czech Republic.

Twenty-seven per cent of Australian lessons were taught by teachers who replied that their students’ behaviour was better than usual while 35 per cent of Czech lessons were taught by teachers who said 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 (47%), more shy, insecure or afraid to give wrong answers (45%), 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.<sup>25</sup> The Australian teachers who said their students behaved better than usual described behaviours such as students being more attentive and/or less noisy, ‘the attention seekers became shy’, ‘less disruption from some individuals’ and politeness when asking questions.

<sup>25</sup> Similar results were reported for the Czech Republic and Australia in the 1999 mathematics video study (Hiebert et al., 2003).

**Figure 2.5** Percentage distributions of Year 8 science lessons by teachers' ratings of their students' behaviour in the videotaped lessons

Better than usual: No measurable differences detected

About the same: NL, US > CZ

Worse than usual: CZ > AU, JP, NL, US

Note: Results based on science teachers' reports

### Influence of videotaping

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 whether the camera caused them to teach a lesson that was worse than usual, about the same, or better than usual. Between 72 and 90 per cent of the videotaped lessons in Australia, the Netherlands and the United States were taught by teachers who reported that their lesson was 'about the same' (72 per cent in Australia). Fewer Czech teachers (39%) than in all the other countries thought their lesson was 'about the same', whereas more teachers in the Czech Republic (37%) than in Japan, the Netherlands and the United States (17, 7 and 5 per cent, respectively) thought their lesson was 'worse than usual'. Comments from the Australian teachers who thought their teaching was worse than usual (18%) included that they 'weren't able to work as much with individual students' or 'weren't able to have as wide a range of activities' as usual, or simply were nervous and not as relaxed as usual, causing them to do 'silly things' such as 'forgetting to hand out the day's homework sheet'. About a quarter of the Czech and Japanese teachers considered that their teaching of the videotaped lesson was 'better than usual', significantly more than in the other three countries (5, 6 and 10 per cent in the United States, the Netherlands and Australia, respectively) (data not shown).

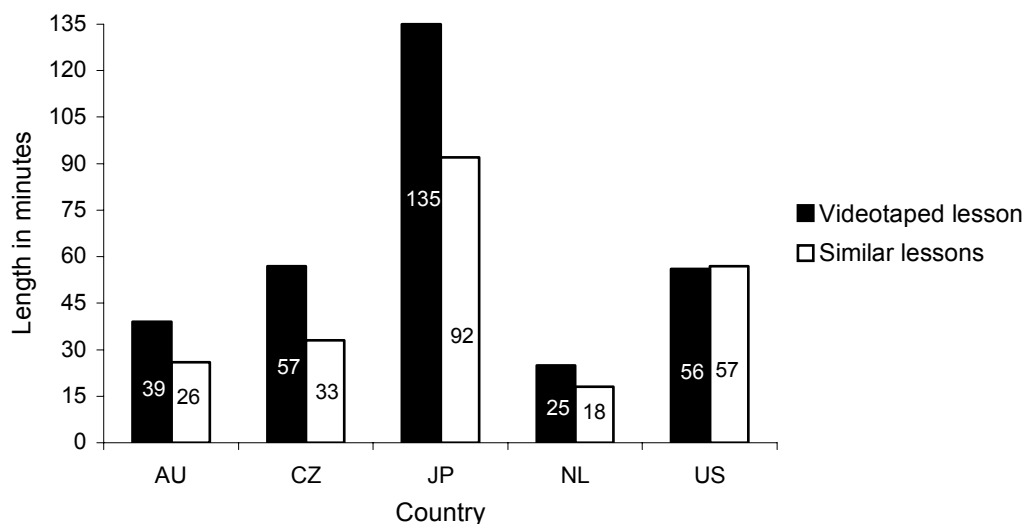
### Amount of planning

Teacher reports of how many minutes they spent planning for the videotaped lesson and how many minutes they typically spent planning for a similar science lesson are shown in Figure 2.6. Although they were asked to do nothing special, it was expected that, in anticipation of being filmed, the teachers might have invested more effort in planning their lessons, potentially altering how they would teach.

The results in Figure 2.6 together with within-country significance tests indicated this expectation to be borne out in all countries except the United States. Across countries Japanese teachers reported spending significantly more time in planning for the filmed lesson than teachers in the other four countries. They also reported spending more time in planning for similar lessons than teachers in Australia, the Netherlands and the Czech Republic. On average, the Japanese teachers

said they spent between three and four times as long on lesson planning as the Australian teachers and about five times as long as the Dutch teachers. The average planning times reported by the Australian science teachers were almost identical to those reported by the teachers in the mathematics component of the study (Hollingsworth et al., 2003).

**Figure 2.6 Average length of time Year 8 science teachers reported planning for the videotaped lesson and for similar science lessons**



Videotaped lesson: JP>AU, CZ, NL, US; CZ, US>NL

Similar lessons: CZ, JP, US>AU, NL; JP, US>CZ

*Note:* Results based on science teachers' reports. Average length of time per country was calculated as the sum of minutes reported for each lesson divided by the number of lessons within a country.

### Fit of lesson in curricular sequence

An individual science 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 96 and 99 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.

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). On average, the total number of lessons in the larger unit of which the videotaped lesson was a part ranged from 9 in the Czech Republic to 15 in Australia. On average, the lessons captured on videotape were located within the middle third of the lessons within a unit.

### **Summary**

The Australian sample for the TIMSS 1999 Science 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 439 Year 8 classes from five 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. 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. Some information is

also given about the students in the sampled Australian classes, derived from their responses to the Student Questionnaire.

A finding common to all 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 science at Year 8 level. A general goal for teaching and learning in Year 8 science that was common across countries was developing students' awareness of the usefulness of science in life. Other general goals, such as having students use scientific inquiry skills and having them acquire scientific knowledge and understanding, were important in some countries but much less so in others.

The median observed duration of lessons was around 45 minutes in all countries, except Japan (50 minutes) (Table 2.7). In all countries except Australia and, to a lesser extent, the United States, there was relatively little variation in the duration 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 science teaching, especially with regard to teaching methods, difficulty of content, and the lesson's fit within a curriculum unit. In all countries except the Czech Republic, the majority of teachers thought that their lesson and their students' behaviour were about the same as usual (Figures 2.4 and 2.5). However, teachers in Australia, the Czech Republic, Japan and the Netherlands spent more time than usual planning for the videotaped lesson (Figure 2.6).

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

- In Australia, about 90 per cent of the lessons were taught by teachers who had a major study in either science or science education (Table 2.2 and footnote 20); 94 per cent of the lessons' teachers had at least a minor study in one of these areas, and all were qualified to teach. However, three teachers had primary training only.
- The number of years that the Australian teachers had been teaching science ranged from 0 to 39 years (one teacher was in his first year of teaching), with a mean of 15 years and a median of 16 years (Table 2.3). Fifty-three per cent of the lessons were taught by males.
- More than 90 per cent of the Australian science lessons were taught by teachers who had undertaken at least one professional development activity in the previous two years. About half the teachers had undertaken three or more activities. The professional development undertaken was usually directly relevant to day-to-day classroom teaching. In contrast with the other countries, only about 10 per cent of the Australian teachers had pursued further academic studies in the previous two years (Table 2.4).
- Australian teachers reported spending, on average, 38 hours per week either teaching or engaging in other school-related activities, including 14 hours actually teaching science. However, no account was taken of whether they were employed full- or part-time (Table 2.5).
- Three-quarters of the Australian teachers agreed that they were familiar with 'current ideas' in science teaching and learning, and a slightly higher percentage said that the videotaped lesson was 'a fair amount or a lot' in accord with such ideas (Figures 2.1 and 2.3). However, several Australian teachers said they were not familiar with current ideas and that they were not aware of sources of information about them. A few were aware of information sources but said they had never read them.
- Three-quarters or more of the Australian teachers reported that they had sufficient access to facilities and equipment, apart from computers, for use in their science lessons. Only one quarter reported sufficient access to computers (Table 2.1).
- Thirteen of the 87 videotaped Australian lessons were 'double periods'. The mean and median observed durations of single-period lessons were 45 minutes and 44 minutes, respectively, with a standard deviation of 9 minutes.

- Goals concerned with ‘knowing science’ were identified for a large majority of the Australian lessons. Goals concerned with ‘doing science’ and goals related to the context of science were relevant for about a quarter of the Australian lessons (Table 2.8). Eighty-seven per cent of the Australian lessons were taught by teachers who were satisfied that their goal or goals for the lesson were achieved.
- Over 80 per cent of Australian teachers thought that their teaching of the videotaped lesson and the difficulty of the content were about the same as usual. Eighty-two per cent of the lessons were taught by teachers who reported that they often used the teaching methods they employed in the videotaped lesson (Figure 2.4), and 68 per cent who reported that their students’ behaviour was about the same as usual (Figure 2.5). Taking into account the lessons where the students’ behaviour was reported to be better than usual, only 5 per cent of the Australian lessons had students whose behaviour was worse than usual.
- Australian teachers spent more time (39 minutes, on average) than usual (26 minutes, on average) in planning their lessons (Figure 2.6). Japanese teachers, who spent about four times as long as Australian teachers and about five times as long as Dutch teachers in planning their lessons, stood out in this respect.

## Chapter 3

# TEACHING STRATEGIES

The way a lesson is organised can enable or limit both the content that is taught and the ways in which it is taught. It is useful to analyse lesson organisation and structure as sources of indicators of potential learning time for students. Efficient use of learning time, particularly when students are engaged in academic tasks, has been identified in the research literature as one of the most consistent factors in academic learning (e.g., Denham & Lieberman, 1980; Scheerens & Bosker, 1997). As an example with particular relevance for science, lessons that include time for practical hands-on science activities and lessons that focus entirely on whole-class lecture and discussion provide students with different images of science and different opportunities for learning science (e.g., Monk & Dillon, 2000). Chapter 2 presented contextual information as background to the videotaped lessons. This chapter presents information on the ways in which the teachers organised and structured the lessons.

The following pedagogical elements of the videotaped lessons are examined in the chapter:

- The proportion of time spent studying science during classroom lessons;
- The physical settings for science lessons and the resources used;
- The ways in which lessons were organised for different instructional purposes, such as reviewing old material, introducing new material and practising new material;
- The ways in which lessons were organised for practical activities and seatwork;
- The grouping structures used to study science during practical activities and seatwork;
- The ways in which key ideas were clarified and lesson flow was enhanced or interrupted; and
- The role of homework.

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 most suited to achieving the learning goals they hold for their students.

### Time Spent Studying Science

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 science. How much of the time did Australian Year 8 students spend studying science?

- *In all the countries, including Australia, most lessons were spent almost entirely on science instruction (at least 91 per cent of lesson time).*

Because lesson time can be spent on other things, such as carrying out administrative tasks or chatting about a musical concert the students attended the night before, it was important to mark the segments of the lesson devoted to scientific work. To measure the amount of time during which the students had opportunity to learn science, the following four categories were defined to segment the lessons:

- Science instruction: Time in the lesson when the teacher and at least one student engage in activities that provide opportunities for students to learn science: for example, the teacher explaining scientific concepts, the class conducting and discussing experiments, students working on written assignments.
- Science organisation: Time in the lesson used by the teacher for organisational activities and discussions that are related to studying science: for example, activities and discussions about

preparing or putting away apparatus, or time spent distributing materials or worksheets, discussing the marking scheme to be used on a test, or having students rearrange themselves to watch a science demonstration. (See [AU PRL 2, 00:06:10 - 00:07:30](#), for an example.)

- **Non-science:** Time in the lesson when no science-related activities or discussions take place: for example, talking about a social function, disciplining a student while other students wait, or listening to school announcements on a public address system.
- **Technical difficulty:** Time in the lesson when there is a technical problem with the video (such as lack of audio) that prevents accurate categorising.

These four categories of lesson segment were mutually exclusive and exhaustive. That is, every second of a lesson was coded into one of the four categories. In general, at least 30 continuous seconds were required to code a segment as science instruction, science organisation or non-science. A short science instruction segment, lasting for less than 30 seconds, was coded only if it was the first or last segment of the lesson. When science organisation and non-science activities occurred at the same time as science instructional activities (for example, if some students were doing an assignment at the same time as the organisation or non-science occurred), priority was given to science instruction because at least some students had an opportunity to learn science.

All five countries devoted the large majority of lesson time to science instruction, ranging from 91 per cent in Australia and the Netherlands to 97 per cent in the Czech Republic. Technical difficulties rarely occurred, and time spent on non-science was no more than 3 per cent of lesson time across the countries. From 2 to 7 per cent of lesson time was devoted to science organisation, with the Czech Republic devoting the smallest proportion of time to science organisation compared with the other four countries. Lessons in Australia and the Netherlands both had more time used for science organisation than Japan. To some extent these results may have arisen from the relative proportions of time spent on practical activities, which are discussed later in the chapter.

### **Physical Settings and Resources Used**

In this section the physical settings for the science lessons are described in terms of features of the classroom space. Physical resources used during the lessons, such as overhead projectors, computers and other technology to enhance the visibility of instructional materials, are also described.

#### ***Room types***

Science classrooms were described using the following categories:

- **Regular classrooms:** Regular classrooms contain movable desks/tables that can be adapted for purposes other than science. There is no obvious special science equipment, such as a teacher demonstration area with access to water and power or gas, built into the design of the room. Little science equipment is visible in the room, although there may be science posters and science work displayed on the walls.
- **Science rooms:** Science rooms have a few more science facilities than regular classrooms but are not obviously equipped to allow students to undertake a full range of practical work themselves. Typically, a large teacher bench at the front includes power, water, and/or gas and may be elevated to allow students to see demonstrations. Students' desks/tables are usually moveable and do not have sinks or power. There may be access to water and power at side or back work counters without gas outlets for student use.
- **Science laboratories:** Science laboratories provide work spaces for students to have easy access to water, power, and gas. A wide range of activities can be done in this kind of room. Student work spaces are either at the students' desks/tables or along rows of benches, or at multiple work stations at side and back benches. Usually a large teacher's bench with power, water, and/or gas is fixed at the front of the room. Science equipment is typically present in or on cupboards and shelves.



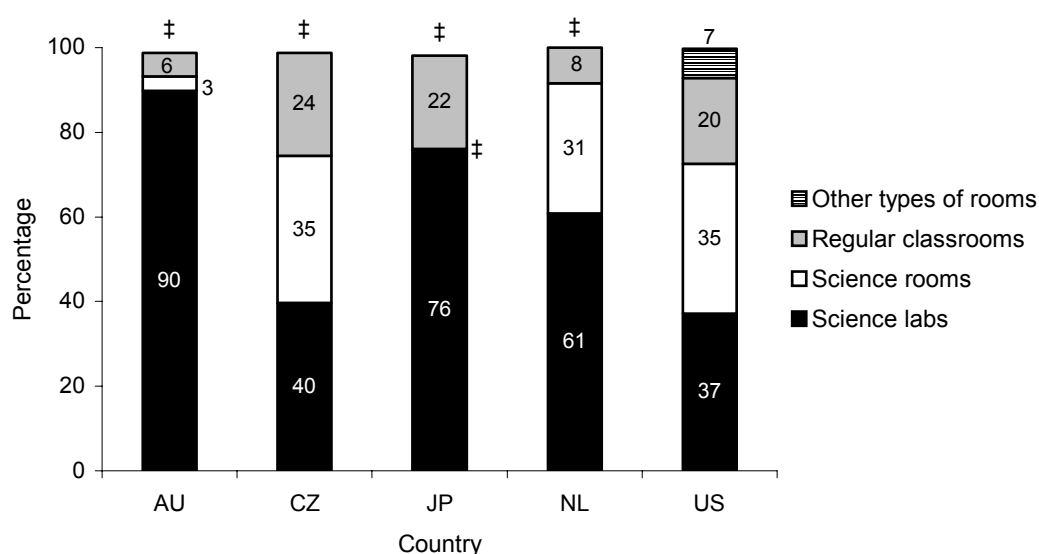
- Other types of room: This category includes computer laboratories, libraries, and outdoor spaces.

What settings were used for science instruction in Australia?

- *Ninety per cent of the Australian lessons were conducted in science laboratories, significantly more than in any of the other countries except Japan.*

We saw in Chapter 2 (Table 2.1) that the sampled schools in Australia were relatively very well provided with science laboratories and equipment for use at Year 8. Figure 3.1 indicates that these resources were being utilised for the videotaped lessons.

**Figure 3.1** Percentage distributions of Year 8 science lessons by type of classroom setting



† Fewer than three cases reported (country excluded from the relevant analysis)

Regular classrooms: CZ, JP>AU

Science rooms: CZ, NL, US>AU

Science laboratories: AU, JP, NL>CZ, US; AU>NL

Note: Total may not sum to 100 because of rounding and data not reported

Within countries, Australian, Dutch and Japanese Year 8 science lessons were more likely to be taught in science laboratories than in any other type of room. Within the Czech Republic and the United States, no measurable difference in use of the three main room types was found. In the United States, 7 per cent of lessons were held in another type of room, most commonly a computer laboratory or a media centre.

Not unexpectedly, the observations revealed in Figure 3.1 reflect the teachers' comments about access to facilities in their country, although more than 60 per cent of the Czech lessons and only 47 per cent of the Dutch lessons were taught by teachers who said they had sufficient access to science laboratories. Variations such as these are also to be expected, given that the teachers' responses about facilities related to their school across the year, whereas the samples of lessons were taped on a single occasion.

### **Science-related displays**

In addition to providing science equipment and furniture, classrooms can communicate information to students about the nature and other aspects of science through displays of materials such as posters, models, maps, photographs and natural object specimens in the room. At least 93 per cent of the videotaped classrooms in all countries but Japan (72%) had these kinds of materials displayed. Natural objects observed in the videotaped classrooms included such items as living or

non-living animals or animal parts, plants, seeds, rocks and sea shells. Displays of natural objects were less common than posters, charts and so on in all countries, ranging from being present in 63 per cent of Czech classrooms to 36 per cent of Japanese classrooms. Fifty-eight per cent of the Australian classrooms had natural objects on display (data not shown).

### ***Use of equipment and materials***

The percentages of teachers who said they had access to various kinds of equipment and resources for use in their science classrooms are provided in Table 2.1 in Chapter 2. The following sections describe the resources used during the videotaped lessons.

#### Computers

In all countries but the United States, the main lack of equipment identified by the teachers was computers (Japanese teachers also identified a severe lack of reference materials, with only 11 per cent saying that they had sufficient of these). It is also reported in Chapter 2 that computers were observed in 10 per cent or fewer classrooms except in the Netherlands (22%) and the United States (59%). How often were computers used by students during the videotaped lesson?

- *Computers were used by students in too few lessons to provide reliable estimates in three countries, including Australia. Highest usage was in the United States, where computers were used in 9 per cent of the lessons.*

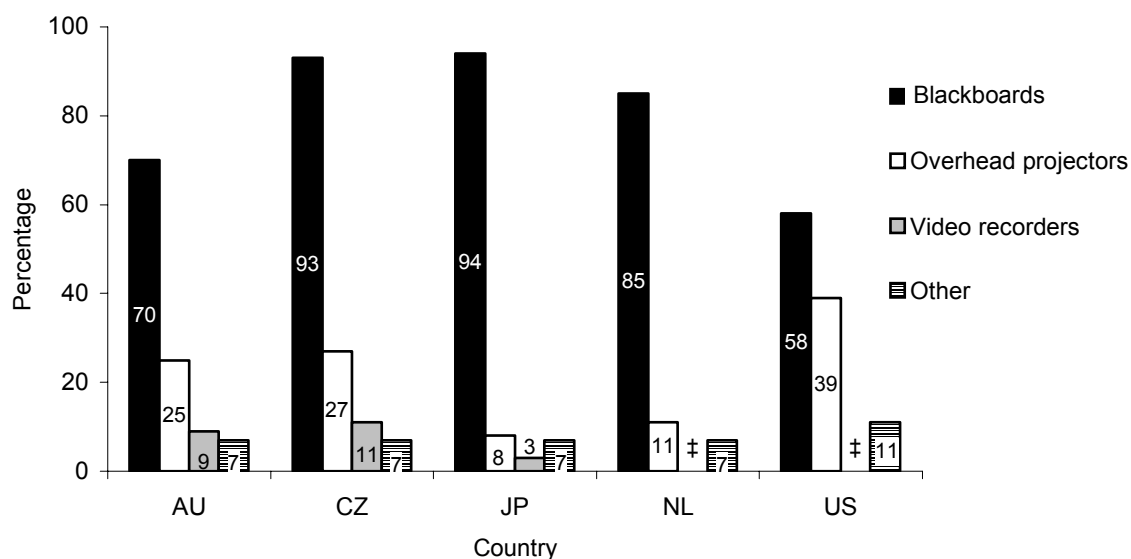
It is not possible to say whether the lack of computer use was governed by shortage of equipment or by curriculum guides and teaching procedures that were not yet prepared for incorporation of multi-media resources to the extent that would be expected in 2005. Most likely it would have been a combination of both. The data in Chapter 2 on professional development (Table 2.4), where 'use of technology' was the most common activity recently undertaken by teachers of the Australian, Dutch and United States lessons (79, 68 and 84 per cent, respectively), reveal the teachers' desire to update themselves in this regard. It is also possible that students would have been more likely to use computers when doing homework assignments, rather than within the time constraints of a classroom lesson.

#### Blackboards, overhead projectors, video recorders, and other visualisation aids

A variety of tools and technologies can help make text, images, and objects more visible to the whole class during a science lesson. Examples of resources used for this purpose in the Year 8 science lessons included blackboards (or whiteboards), overhead projectors, video recorders and other specialised visual technologies such as projecting microscopes, computer-projected images, and closed circuit televisions. Figure 3.2 shows the percentage of sampled science lessons in which these resources were used (not merely present) during the lesson.

- *In all countries, blackboards were the most commonly used vehicle for presenting information visually during science lessons. Highest usage of blackboards was in the Czech Republic and the Netherlands, each with usage in more than 90 per cent of the lessons. Seventy per cent of the Australian lessons involved use of blackboards.*

Within countries, blackboards were much more commonly used than other resources to assist in science teaching and learning, except in the United States where overhead projectors were used in almost 40 per cent of the lessons and blackboards were used in 58 per cent of the lessons (not significantly different). More Year 8 science lessons in the Czech Republic, Japan and the Netherlands involved the use of a blackboard than lessons in the United States. Blackboard use was also higher during Czech and Japanese lessons than in Australian lessons.

**Figure 3.2 Percentages of Year 8 science lessons in which blackboards, overhead projectors, video recorders and other visualisation aids were used**

‡ Fewer than three cases reported (country excluded from the relevant analysis)

Blackboards: CZ, JP>AU, US; NL>US

Overhead projectors: CZ>JP; US>JP, NL

Note: 'Other' includes specialised visual technologies such as closed circuit televisions and microscopes connected to a television

Overhead projectors were used in 39 per cent of United States lessons and about a quarter of the lessons in Australia and the Czech Republic. Usage of overhead projectors was significantly higher in the United States than in the Netherlands and Japan. Video recorders and other specialised visual technologies were each used in no more than 11 per cent of the lessons in all of the countries. (AU PRL 3, approx. 00:08:00 - 00:11:30, is an example of the teacher using a specialised visual aid – a camera connected to a television – in this case to demonstrate a kidney dissection). As shown in Table 2.1 in Chapter 2, teachers were generally satisfied with the availability of audio-visual resources for their science lessons, with three-quarters or more per country reporting that they had sufficient access to these items. For most teachers, it appears that the blackboard or whiteboard is still the preferred vehicle for presenting lesson information visually.

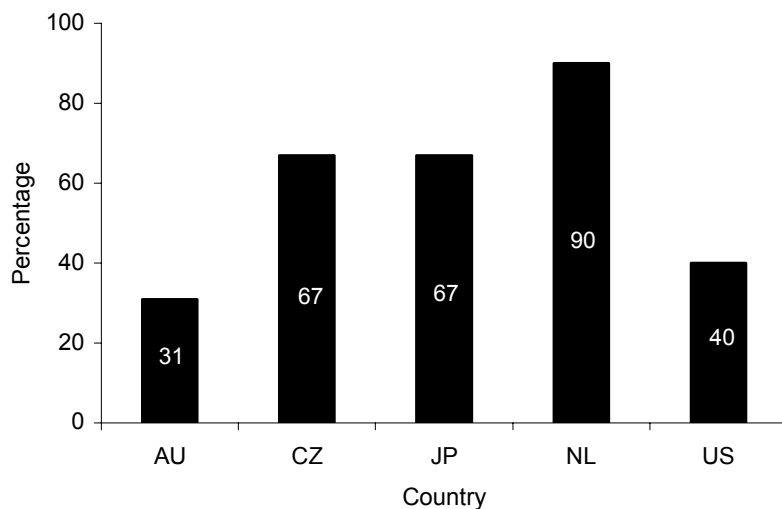
### Textbooks

Students' use of textbooks/workbooks observed during the sampled Year 8 lessons was generally consistent with teachers' responses in the Teacher Questionnaire about their use of textbooks in lesson planning. Only a third of the Australian lessons were taught by teachers who said that mandated textbooks played a major role in their decision to teach the content of the lesson, compared with 52 to 74 per cent of teachers in the Czech Republic, Japan and the Netherlands. Teachers in the United States were similar to the Australian teachers in this respect (see Table 2.9 in Chapter 2). To what extent were students observed to use textbooks in the Australian lessons?

- *Textbooks or workbooks were used relatively rarely by students in the Australian science lessons. They were used by students in three times as many Dutch lessons and twice as many Czech and Japanese lessons as in the Australian lessons.*

Textbook use by students during the videotaped lessons is summarised in Figure 3.3. The data include use of textbooks (pre-printed materials designed to provide information) and workbooks (also pre-printed and presenting information, but designed in addition for students to write notes, answer questions, draw diagrams and so on in relation to the printed material).

**Figure 3.3 Percentages of Year 8 science lessons in which students used textbooks and/or workbooks**



Note: NL>AU, CZ, JP, US; CZ, JP>AU, US

**AU PRL 1** provides an example of Australian students using a printed book for reference. As the teacher explained:

Students do not have a general textbook. They have a topic, 'Forensic Science', booklet and a workbook for entering their written work during the class. (*AU PRL 1, Teacher's Comments, 00:00:00*)

The topic book mentioned by the teacher is small in the number of pages it contains, but it would have been categorised as a textbook for analysis purposes. This lesson was one of only 31 per cent of Australian Year 8 science lessons where students were observed to use a textbook of some kind. Australian and United States science lessons were similar with regard to the incidence of textbook and/or workbook use by students, closely matching the teachers' responses about the relative role of textbooks in their decisions about the content taught in the videotaped lesson. Students in the Netherlands clearly used textbooks and/or workbooks in their Year 8 science lessons more than the students in any of the other countries. Further, students used textbooks and/or workbooks in more Czech and Japanese lessons than they did in Australian and United States lessons.

### Lesson Segments for Different Instructional Purposes



Teachers plan and organise a variety of activities during lessons for different instructional purposes. Based on the observed behaviours of teachers and students and the nature of the science work that they engaged in, the purposes of different lesson segments in the sampled Year 8 science lessons were described. For example, three instructional purposes would be described for a lesson that began with a review of previously introduced content, then continued for the majority of the lesson with the introduction of new content and ended with a short test to assess students' learning.

#### *Categories of instructional purposes*

To capture various purposes of lesson parts, the following five categories were developed and defined (each moment of a lesson is categorised by only one of these codes):

- Developing new content: a continuous time period<sup>26</sup> during the lesson when the main instructional activity takes place. The purpose of such activities is to present, develop, elaborate or apply scientific concepts, ideas and/or procedures.

<sup>26</sup> To be categorised, a continuous time period had to be at least 30 seconds long.

- Reviewing previous content: a continuous time period during the lesson when the content presented to students in previous lessons is repeated or revisited. No new content information is provided during this time except for simple referencing ('We will learn more about this process of testing for acids and bases later in the lesson.'). (See  AU PRL 2, 00:00:04 - 00:03:30, for an example.)
- Going over homework: a continuous time period during the lesson that the teacher sets aside to correct, check, or go over students' homework after they had worked on or completed the assignment at home (this did not occur in the AU PRL examples).
- Assessing student learning: a continuous time period during the lesson that the teacher sets aside to formally assess students' work individually, as a small group, or as a whole class, either orally or in writing, or to check and/or go over tests or other assessments that were previously completed (in the videotaped lessons or in previous lessons). ( AU PRL 3, approx. 00:27:45 - 00:31:55, is an example, including marks being read out.)
- Other purposes: A period during the lesson that the teacher sets aside for other purposes such as assigning homework or completing administrative tasks. In addition, time that could not be categorised into one of the four functions above, or time that could be categorised into one of the four functions above but was less than 30 seconds long, is included here.

What pattern of lesson time use was found in Australia for Year 8 science?

- *In Australia, 60 per cent of the lessons were devoted entirely to the development of new content, compared with 16 per cent of Czech lessons and 91 per cent of Dutch lessons. On average, all of the countries spent more science lesson time on new content than on all of the other lesson purposes combined.*

### Incidence

In all the countries, from 96 to 100 per cent of the science lessons contained at least one segment of lesson time devoted to developing new content (97 per cent in Australia) and from 92 to 100 per cent contained a segment used for purposes other than the four defined above (99 per cent in Australia). The incidences of review, going over homework and assessing student learning were more varied across countries. At least one segment of review occurred in from 8 per cent of lessons in the Netherlands to 84 per cent in the Czech Republic (41 per cent in Australia); at least one segment of going over homework occurred in from 2 per cent of lessons in Australia to 45 per cent in the Netherlands; and at least one segment of assessing student learning occurred in from 5 per cent of lessons in Japan to 50 per cent in the Czech Republic (data not shown). There were too few instances of assessing student learning in the Australian lessons to form a reliable estimate.

### Percentage of lesson time

The amount of time spent on a lesson purpose may be quite different from merely noting that at least one segment of time was devoted to it. The average percentages of science lesson time spent on each type of lesson purpose are summarised in Table 3.1. The highest percentage of time on reviewing previous content also occurred in the Czech Republic, but whereas this lesson purpose featured in more than four-fifths of the Czech lessons, only about one-fifth of the time was occupied by it. The percentage of time spent on review was very small in both Japan and the Netherlands, at 3 per cent and 1 per cent, respectively. In Australia, while 41 per cent of the lessons included at least one segment of reviewing previous content, this activity occupied only 8 per cent of the lesson time, on average.

While 45 per cent of the Dutch lessons included time for going over homework, the average time percentage spent on this purpose across all the Dutch lessons was only 12 per cent – that is, in the lessons in which homework was reviewed, an average of about a quarter of the lesson time was focused on this purpose. The practice of assessing student learning both occurred more often and used more lesson time in the Czech Republic than in all the other countries, echoing the result from the TIMSS 1999 Mathematics Video Study (Hiebert et al., 2003).

**Table 3.1 Percentage distributions of Year 8 science lesson time devoted to various purposes**

Purpose	Country				
	AU	CZ	JP	NL	US
	Percentage of lesson time				
Developing new content	85	67	93	78	79
Reviewing previous content	8	19	3	1	8
Going over homework	#	1	‡	12	3
Assessing student learning	‡	9	1	2	3
Other purposes	7	4	3	7	8

# Rounds to zero

‡ Fewer than three cases reported (country excluded from the relevant analysis)

Developing new content: AU, JP, US>CZ; JP>NL, US

Reviewing previous content: CZ>AU, JP, NL, US; US>JP, NL

Going over homework: NL>AU, CZ, US

Assessing student learning: CZ> JP, NL, US; NL>JP

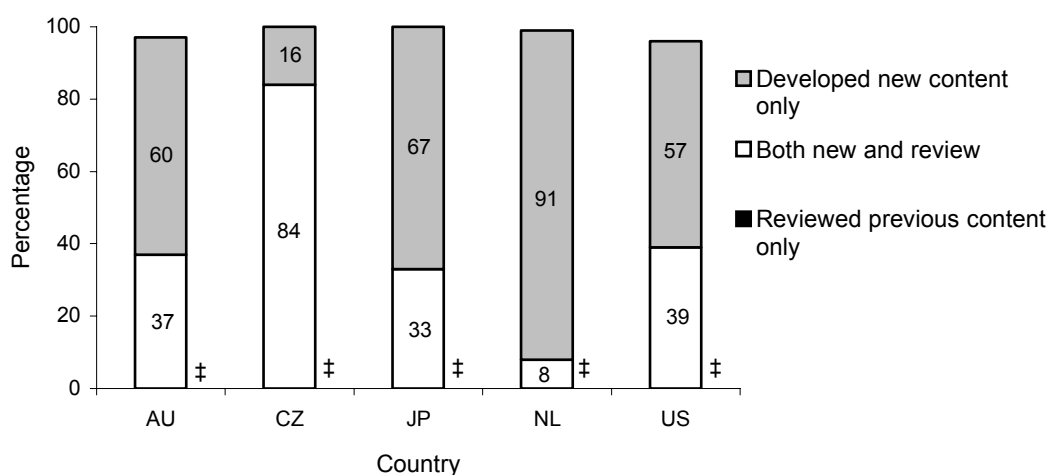
Other purposes: AU, NL, US>CZ, JP

Note: Total may not sum to 100 because of rounding and data not reported.

### *New and previously introduced content*

Table 3.1 shows that the five countries devoted a larger average proportion of science lesson time to developing new content than to reviewing previous content. The percentages of lessons devoted to developing new content only and to developing new content as well as discussing previously introduced content are shown in Figure 3.4. There were hardly any cases of lessons devoted entirely to review of previous content.

**Figure 3.4 Percentages of Year 8 science lessons devoted to developing new and reviewing previously introduced content, separately and in combination**



‡ Fewer than three cases reported (country excluded from the relevant analysis)

Developed new content only: AU, JP, NL, US>CZ; NL>AU, JP, US

Developed new content and reviewed previous content: CZ>AU, JP, NL, US; AU, JP, US>NL

Note: Totals sum to the percentages of lessons in which new content was introduced, since no country had enough cases of lessons devoted entirely to review for reliable estimates to be calculated.

Although at least 96 per cent of the science lessons in every country developed new content at some time during the lesson, as mentioned above, there were at least 57 per cent of lessons in all the countries except the Czech Republic that attended to new content only with no review of previous content. Only 16 per cent of Czech lessons developed new content only, without any attention given to reviewing previous content. On the other hand, science instruction in 84 per cent of Czech lessons both developed new content and reviewed previous learning, substantially more than in all the other countries. Only 8 per cent of the Dutch lessons and between 33 and 39 per cent of the Japanese, Australian and United States lessons featured a combination of new and reviewed content.

The observation that there were too few science lessons that focused on reviewing previous content only to be reliably reported in any country departs from the results of the 1999 mathematics video study, where there were between 19 and 28 per cent of lessons devoted entirely to review except in Hong Kong (8%) and Japan (5%). Australia, along with the United States, had numerically the highest percentage of lessons spent entirely on reviewing previous mathematics content (Hiebert et al., 2003).

The comparison between the amount of time spent on the development of new content and the amount of time spent on review activities is an issue of educational interest, particularly in light of the findings from the mathematics video study. In that study, Year 8 mathematics lessons in the Czech Republic and the United States allocated more than half of the lesson time for review (58 and 53 per cent, respectively) whereas Japanese lessons allocated only a quarter of the lesson time for review (Hiebert et al., 2003). This finding suggested two distinct approaches to teaching mathematics, one emphasising review and the other emphasising development of new content. Australia and the Netherlands were in between, with a little over a third of the mathematics lesson time spent on review.

Contrasting patterns across countries are also revealed by the videotaped lessons for Year 8 science teaching, but with a substantially lesser emphasis on review. Even in the Czech Republic, where more than four-fifths of the science lessons contained review segments, only one-fifth of the lesson time was allocated to these segments. In Year 8 science teaching, emphasis on developing new content was relatively high in all countries, though it was still higher in Japan than in all the other countries except Australia. The greatest contrast between countries in Year 8 science lessons was in the very high incidence of Dutch lessons devoted entirely to developing new content compared with all other countries, but particularly with the Czech Republic. Australia and the United States were noticeable in their lesser emphasis on review in science lessons than in mathematics lessons at Year 8.

Although review activities on their own occupied only 8 per cent of Year 8 science lesson time on average in Australia, a few minutes spent in reviewing previous content at the beginning of the lesson was a typical occurrence (see *AU PRL 3, 00:00:15*, for an example). The teacher commented:

My task here was to review students' current understanding of excretion. I wanted to do this in order to ensure that they understood this term correctly (... and) I wanted to create a link with a previous lesson. In class, we had looked at excretion in the lungs and I wanted to remind students of what substances were excreted (removed) from the body by the lungs before discussing the chemicals that were excreted by the kidneys.

### **Lesson Segments for Practical and Seatwork Activities**

Science lessons may include practical activities in which the teacher and/or students carry out experiments and other kinds of 'hands-on' activities in addition to 'seatwork' activities such as teacher lectures, class discussions, reading or writing. Many countries emphasise the importance of practical activities, whether they describe them as involving investigations, inquiry, replications, demonstrations, project- or problem-based studies, or experimental work (e.g., Beatty & Woolnough, 1982; Jenkins, 1999; NRC, 1996; Swain, Monk & Johnson, 1998; Watson, 2000; Watson & Prieto, 1994; White, 1996). Justification for inclusion of practical activities in science

instruction is presented in Chapter 5, together with results and discussion of what was actually done during periods of practical work in the sampled Year 8 science lessons. In this chapter the concern is to describe how science instruction time is organised into practical and seatwork activity structures.

‘Practical activities’ is a term used in some countries to describe what may be referred to in other countries as ‘hands-on’ or ‘laboratory’ activities. The term ‘practical’ is used in this report to denote a wider span of activities than might be suggested by ‘laboratory’. The distinction between practical and seatwork activities defined for this study is outlined below.

- **Practical activities:** those activities that provide students with the opportunity to observe and/or interact first-hand with objects and related phenomena. They include teacher demonstrations of phenomena and objects as well as student participation in traditional laboratory experiments and other hands-on interactions with objects. Producing and observing phenomena, building models, designing and testing technological solutions to problems and observing objects are all examples of practical activities.
- **Seatwork activities:** those activities seen in the videotaped science lessons that did not involve the use of objects. They include teacher lecture, class discussion, reading text, copying notes, and students’ work on paper-and-pencil activities. The term ‘seatwork’ should not be interpreted as meaning that students always stayed in their seats. For example, students might be out of their seats working on a large poster drawing on the floor. Also, while students are often in their seats while they are doing practical activities, for the purposes of this study such activities are not defined as seatwork.

The data in this section apply only to periods of science instruction. Lesson segments categorised as non-science or science organisation, together comprising no more than 9 per cent of the lesson time on average per country, are not included.

### ***Practical and seatwork activities***

#### **Incidence**

Practical activities occurred in at least 72 per cent of the Year 8 science lessons in each country, with more lessons containing practical activities in Australia (90%) than in the Netherlands (72%). They featured in 74 per cent of the United States lessons, 81 per cent of the Czech lessons and 83 per cent of the Japanese lessons. Seatwork activities occurred in all of the science lessons in all five countries – that is, no lesson was spent entirely on practical activities (data not shown).

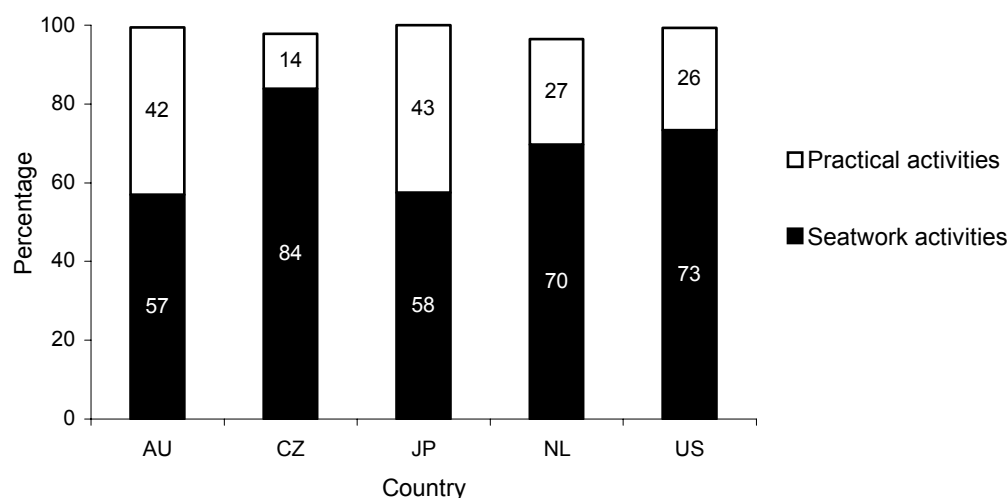
#### **Percentage of lesson time**

On average, all of the countries allocated a larger percentage of science instruction time to seatwork activities (57 to 84 per cent) than to practical activities (14 to 43 per cent), as shown in Figure 3.5. What percentage of lesson time was devoted to practical activities in Australia?

- *Australia, along with Japan, had the highest average percentage of lesson time allocated to practical activities (42%), activities which occurred in 90 per cent of the Australian lessons. Although practical activities featured in over 80 per cent of lessons in the Czech Republic, these activities occupied an average of only 14 per cent of the lesson time.*

Australian and Japanese lessons allocated larger percentages of science instruction time to practical activities than the three other countries’ lessons, and smaller percentages of time to seatwork activities than in the Czech Republic and the United States. The Czech Republic spent a larger percentage of time on seatwork activities than all of the other countries except the United States.



**Figure 3.5** Percentage distributions of science instruction time in Year 8 science lessons devoted to practical and seatwork activities

Practical activities: AU, JP>CZ, NL, US; US>CZ

Seatwork activities: CZ, US>AU, JP; CZ>NL

*Note:* Total may not sum to 100 because of rounding and data not presented for 'divided class work' (see Figure 3.6).

Analysis is limited to the 91 per cent or more of the lesson time focused on science instruction per country.

### ***Whole-class and independent work***

During both practical and seatwork activities, lesson segments were categorised by whether the students were working as a whole class or working independently, with 'independent' in this context meaning 'independent of the teacher'.

In *whole-class work*, all students are expected to pay attention to the same activity that is led by the teacher, a student, a small group of students, or another source (for example, a videotape or an assistant teacher). In *independent work*, students work on their own, either individually or in small groups. Occasionally, both lesson organisation structures occur at the same time, with part of the class working together under the direction of the teacher and part of the class working independently. For example, the teacher may have assigned half the class to work on answering questions individually on a worksheet, while she showed the rest of the class a demonstration. In this case, some students worked independently while the other students worked together under the direct supervision of the teacher.

### **Incidence**

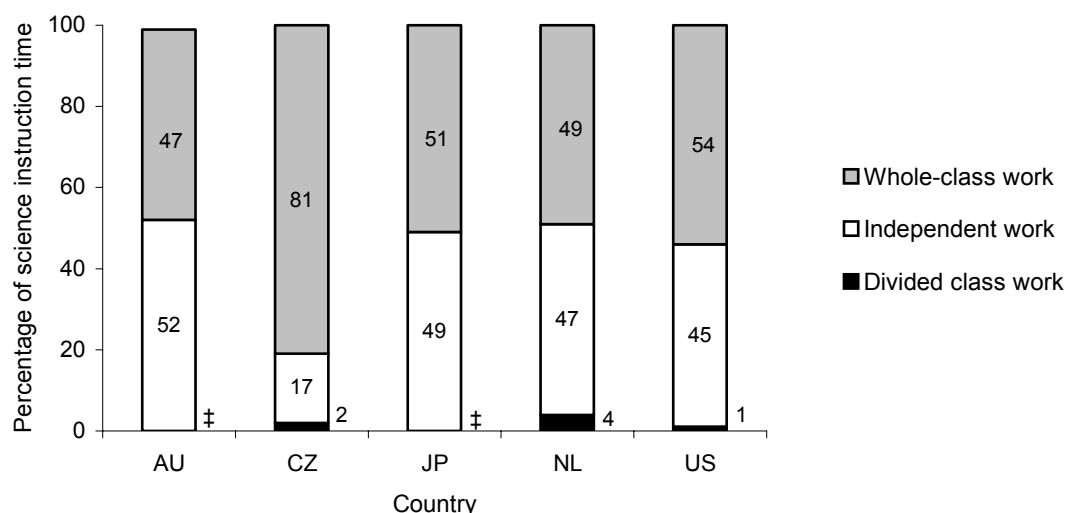
The vast majority of the sampled Year 8 science lessons contained at least one segment of independent work (ranging from 92 per cent of lessons in the Czech Republic to 100 per cent in Australia) and one segment of whole-class work (ranging from 98 per cent in the Netherlands to 100 per cent in the Czech Republic, Japan, and Australia; data not shown). By contrast, divided class work occurred in no more than 18 per cent of the Year 8 science lessons in all of the countries (ranging from 4 per cent in the United States to 18 per cent in the Czech Republic, with too few lessons with divided class work in Australia and Japan to calculate reliable estimates).

### **Percentage of science instruction time**

In all the participating countries except the Czech Republic, approximately the same percentages of science instruction time on average were spent with students working as a whole-class and working independently, as shown in Figure 3.6. As can be seen in the figure, time used for divided class work was very small across all countries, with no more than 4 per cent of time, which occurred in the Netherlands, spent on this type of class organisation. The Czech Republic differed

from all the other countries in allocating a much higher percentage of lesson time to whole-class work than to independent work.

**Figure 3.6** Percentage distributions of science instruction time in Year 8 science lessons devoted to whole-class work, independent work and divided class work



† Fewer than three cases reported (country excluded from the relevant analysis)

Whole-class work: CZ>AU, JP, NL, US

Independent work: AU, JP, NL, US>CZ


Note: Total may not sum to 100 because of rounding and data not reported. Analysis is limited to the 91 per cent or more of the lesson time focused on science instruction per country.



The relationship between periods of time devoted to whole-class or independent work and periods devoted to practical or seatwork activities is examined in the next section.

### ***Practical and seatwork activities during whole-class and independent work***

Practical activities can be done in a whole-class setting or while students work independently. To explore further the nature of science activities in Year 8 science lessons across the countries, the relationship between practical and seatwork activities and the organisation of the lessons in terms of whole-class and independent work was examined. To what extent were practical and seatwork activities done in a whole-class setting or carried out by students independently? The combinations of activity and lesson organisation types are described as follows:

- **Whole-class practical activities:** teacher demonstrations ranging from simple displays of science-related objects ('this is an ammeter' or 'this is a model of a heart') to displays of objects with related phenomena (for example, using objects to show a chemical reaction), to public demonstration of complete experiments. These activities do not include discussion time that precedes or follows the observations. (See *AU PRL 4, 00:11.58 - 00:13.58*.)
- **Whole-class seatwork activities:** oral lectures or discussions, often augmented by visual aids. Examples of whole-class seatwork activities include the teacher presenting a new idea by showing and talking about a diagram, graph, map or photograph; or the teacher playing a videotape that presents both audio and visual information about the scientific content (*AU PRL 5, 00:01:40 - 00:23:18*, a whole-class discussion, is an example).
- **Independent practical activities:** hands-on work such as students conducting a laboratory experiment. Students are working either individually or in small groups on tasks that involve observing, handling, or manipulating objects, materials, 3-dimensional models or organisms. The purposes of such activities include generating and/or gathering data; producing and/or

observing phenomena; observing and/or manipulating objects such as models or organisms; creating models; solving technological problems; or practising a skill that involves the manipulation of objects. Whole-class discussion time that precedes or follows the hands-on work is not included as part of the independent practical activity. (See  AU PRL 1, 00:12:15 - 00:18:58.)

- **Independent seatwork activities:** students work individually or in small groups on assignments, copying notes, and/or reading silently. Examples of independent seatwork activities include answering questions in writing; writing an essay; drawing and/or labelling diagrams; completing worksheets; brainstorming ideas in a small group discussion; copying down or reading any information presented on the blackboard, an overhead transparency, the textbook or some other source. (See  AU PRL 1, 00:06:47 - 00:08:10 and  AU PRL 3, 00:02:05 - 00:04:10.)

### Incidence

The percentages of Year 8 science lessons that contained at least one segment of each combination of science activity type and lesson organisation type are presented in Table 3.2. The table shows that more than 60 per cent of science lessons in all of the countries included whole-class practical activities, while almost all lessons included whole-class seatwork activities and at least three-quarters included independent seatwork activities. There was a wider variation for independent practical activities, which occurred in fewer Czech and Dutch lessons (23 and 30 per cent, respectively) than Australian and Japanese lessons (74 and 67 per cent, respectively). In the United States, 47 per cent of lessons contained independent practical activities, more than the in Czech Republic but fewer than in Australia. No other difference was detected between countries.

**Table 3.2 Percentages of Year 8 science lessons by activity type and lesson organisation**

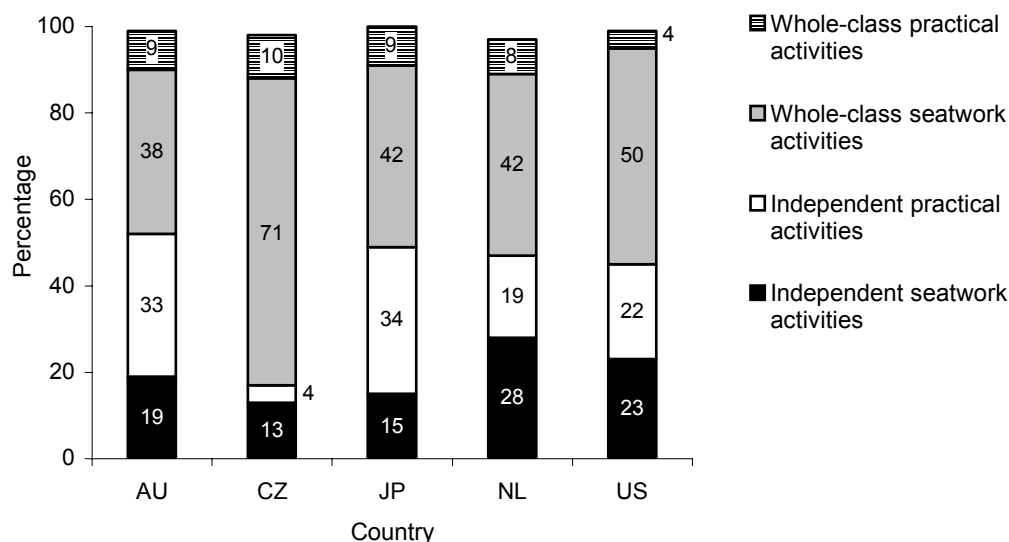
Lesson organ- isation type	Activity type	Examples of activities	Country				
			AU	CZ	JP	NL	US
			Percentage of lessons				
Whole-class	Practical	Discussing and showing objects to whole class; demonstrations	81	80	77	62	69
	Seatwork	Presentations; discussions	100	100	100	98	99
Independent	Practical	Experiments; model building	74	23	67	30	47
	Seatwork	Answering written questions; discussing in small groups; copying notes from board; reading textbook	88	88	81	77	86

Independent practical activities: AU, JP>CZ, NL; AU>US; US>CZ

### Percentage of instruction time

How the time spent in whole class and independent work was differentially allocated to practical and seatwork activities among the countries is illustrated in Figure 3.7. Although there was no difference across four of the countries in the percentages of time spent on whole-class and independent work overall (see Figure 3.6), practical and seatwork activities featured for different percentages of time within these two types of lesson organisation.

**Figure 3.7 Percentage distributions of science instruction time in Year 8 science lessons devoted to each combination of science activity and lesson organisation type**



Whole-class practical activities: AU, CZ, JP>US

Whole-class seatwork activities: CZ>AU, JP, NL, US; US>AU

Independent practical activities: AU, JP, NL, US>CZ; AU, JP>NL

Independent seatwork activities: NL>CZ, JP; US>CZ

*Note:* Total may not sum to 100 because of rounding and data not presented. Analysis is limited to the 91 per cent or more of lesson time focused on science instruction per country.

Practical activities were undertaken independently (white areas on the chart) by students for a greater percentage of time in Australian and Japanese lessons than in Dutch lessons and seatwork activities were done in whole-class work (grey areas on the chart) for a greater percentage of time in United States than in Australian lessons. Bringing the fifth country, the Czech Republic, into the picture, independent practical activities were clearly done for a lesser percentage of time here, and whole class seatwork activities for a greater percentage of time, than in all of the other countries.

Looking at patterns within countries, practical activities were more likely to be conducted during independent work (white areas on the chart) than during whole-class work (hatched areas on the chart) except in the Czech Republic, where a larger average proportion of science instruction time for practical activities was allocated during whole-class work (10 per cent) than during independent work (4 per cent). In all of the countries, seatwork activities were more likely to be conducted during whole-class work time (grey areas on the chart) than during independent work time (black areas on the chart).



### Grouping Structures

Having students work collaboratively in groups is a common pedagogical strategy in many school subjects, particularly in science where teachers often group students to work together on practical activities. Educational research supports the value of 'group work' or 'cooperative learning' as a tool to support student learning in science as well as in other subjects (e.g., Bandura, 1994; Owens & Barnes, 1992; Slavin, 1996). In the context of a group, students can encounter viewpoints and ideas that may not occur to them if they are left to work on their own. Group work is emphasised as an important goal in most of the curriculum and standards documents of the participating countries as an aid for students to learn to converse with each other and work as part of a team. Individual work and student independence are usually also given as important goals, especially in the Czech Republic and the Netherlands (Roth et al., 2006). Thus it was of particular interest to examine the extent of teachers' use of grouping structures in the videotaped lessons.

The descriptions of collaborative work in this chapter pertain to the periods of lesson time when students were working independently of the teacher; time spent on whole-class work is not included. We saw earlier in the chapter that at least 92 per cent of lessons, and all lessons in Australia, contained at least one segment of independent work. Further, as shown in Figure 3.6, about half the science instruction time in four countries, including Australia, was spent on independent work. The exception was the Czech Republic, where independent work was uncommon, using on average only 17 per cent of the science instruction time.

### ***Group versus individual work***

This section discusses the incidence and the percentage of science instruction time when students worked independently of their teacher, either individually or in pairs or small groups. Did the students engage in group work only during practical activities, or did group work also happen during seatwork activities such as completing paper-and-pencil tasks? Two predominant lesson organisation structures were defined to assess students' opportunities to collaborate in pairs or small groups:

- **Individual work:** the teacher instructs students to work alone, or the task is structured in a way that suggests that students should work alone – for example, 'Think for yourself about what the hypothesis might be, and write it down in your notebook'. At least half the students are observed to be working alone for more than half of the independent work time. (See  AU PRL 1, 00:38:38 - 00:44:15, when most students are independently organising the results of their practical activity into their notebooks.)
- **Pair or group work:** the teacher organises or instructs students to work in groups of two or more, or the task is structured in a way that suggests students should work together in pairs or small groups. At least half the students are observed to be working in pairs or small groups during more than half of the independent work time. (See  AU PRL 4, 00:24:40 - 00:25:50, when the teacher assigns students to groups, and 00:27:55 - 01:04:10 in the same lesson, when the students are doing practical activities in their assigned groups.)

A third structure, where students moved back-and-forth between individual and group work during independent work time, was observed in 3 per cent of Australian and United States lessons. Since there were not enough cases in the other three countries to determine reliable estimates, information on this structure is not included in this chapter.

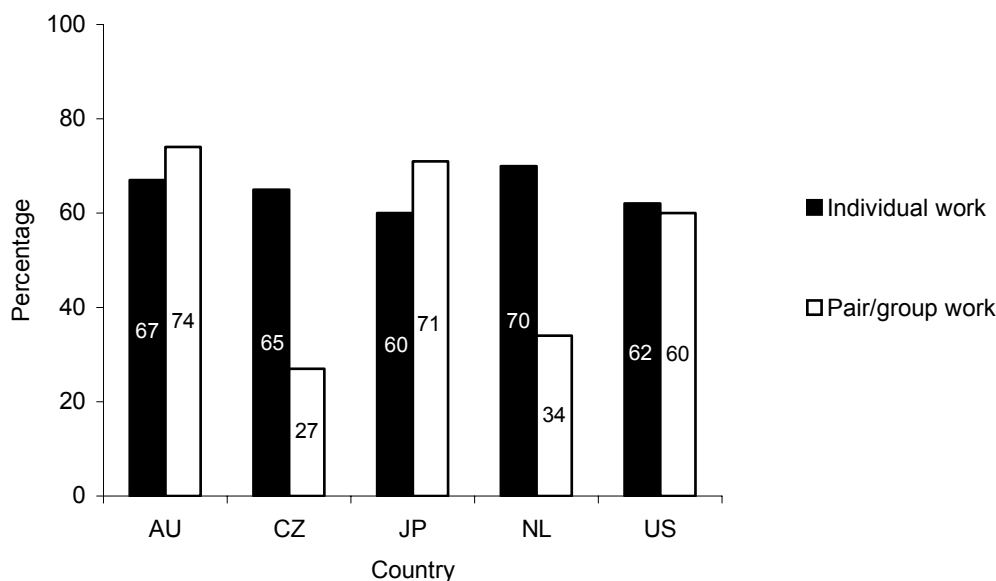
With regard to the definitions of individual and pair or group work given above, how often did Australian students work alone in their Year 8 science lessons? How often did they work with their peers?

- *In Australia, as in Japan and the United States, Year 8 science lessons were just as likely to involve students working in pairs or small groups as working individually. In terms of the proportion of time spent, however, group work predominated in these countries, occupying more than two-thirds of the independent work time. Group work was relatively less extensive as a proportion of independent work time in the Netherlands and much less extensive in the Czech Republic.*

### ***Incidence***

Figure 3.8 displays the average percentage of Year 8 science lessons per country that provided opportunities for individual and pair or group work. Students in more Australian, Japanese and United States lessons had opportunities to work in pairs or small groups than students in Czech and Dutch lessons. While no measurable difference was found across countries in the percentages of lessons in which students worked individually, within-country differences were found. Students were more likely to work individually than in pairs or groups within the Czech Republic and the Netherlands.

**Figure 3.8 Percentages of Year 8 science lessons with individual work and pair or group work independent of the teacher**



Pair/group work: AU, JP, US > CZ, NL

*Note:* Percentage of lessons does not include lessons where students moved freely between independent and pair/group work. This occurred in no more than 3 per cent of United States and Australian lessons, and was observed too infrequently in the other countries to produce reliable estimates.

#### Percentage of independent work time

The percentages of independent work time allocated to students' working in pairs or groups rather than individually<sup>27</sup> followed roughly the same pattern as the incidence of lessons, shown in Figure 3.8, where pair or group work was observed to occur (see Figure 3.7 for the overall average amount of time per country spent on independent work). Pair or group work occupied 82 per cent of the independent work time in Japanese lessons, 71 per cent of such time in Australian lessons and 69 per cent of such time in United States lessons. By contrast, students worked on their own for 64 per cent of the independent work time in Czech lessons, while the independent work time was divided evenly between individual and pair or group work in Dutch lessons. Except for the Czech Republic, these results for science are in sharp contrast to those revealed in the TIMSS 1999 Mathematics Video Study, when students worked individually for three-quarters or more of their independent work time during mathematics lessons (Hiebert et al., 2003).

#### ***Group work during independent practical and seatwork activities***

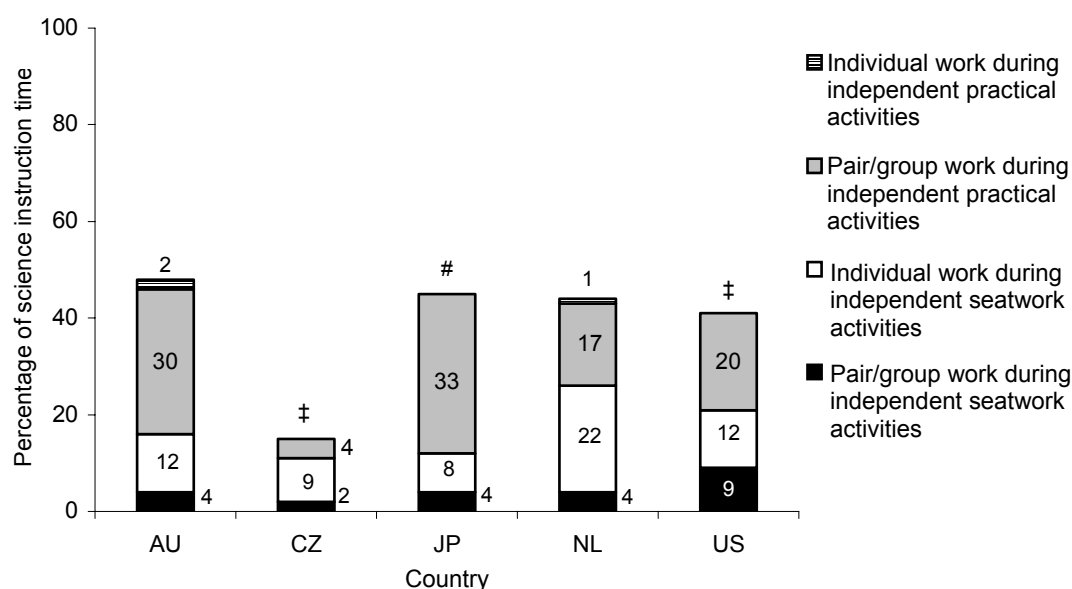
It was expected that students would work in pairs or groups rather than individually during hands-on practical activities. This and other deployments of individual and group structures during independent science instruction are shown in Figure 3.9. The expectation for hands-on activities was borne out in all countries, where a maximum of only 2 per cent of science instruction time was spent by students working individually on independent practical activities. Reflecting the small average percentage of lesson time spent in Czech lessons on independent work overall (see Figure 3.7), students in that country worked in pairs or groups for a smaller average percentage of science instruction time during independent practical work than students in the other countries.

The teacher of **AU PRL 4** explains some of the values of group work thus:

I get students to work in set groups. I group them by mixed ability to allow for peer tutoring within each group. I also group behaviour problem students so I am able to keep a closer eye on them. (*AU PRL 4, Teacher's Comments, 00:20:00*)

<sup>27</sup> Data not shown (see Figure 8.2 in Roth et al., 2006)

**Figure 3.9** Percentage distributions of science instruction time during Year 8 science lessons devoted to individual and pair or group work during independent practical and seatwork activities



# Rounds to zero

† Fewer than three cases reported (country excluded from the relevant analysis)

Pair/group work during independent practical activities: AU, JP, NL, US > CZ; JP > NL

Individual work during independent seatwork activities: NL > AU, CZ, JP

Note: Percentages of science instruction time devoted to changing grouping structures, copying notes and silent reading, divided class work and whole class work are not presented (see Figure 3.7).

During independent seatwork activities, students in Dutch Year 8 science lessons worked individually for a larger percentage of science instruction time on average (22 per cent) than students in all the other countries except the United States. No measurable difference was detected across countries in the percentages of science instruction time that students worked independently in pairs or groups on seatwork activities.

### 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 highlight or make explicit 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 points of a lesson are 1) to describe the goal(s) 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 topic(s) that would be covered in the lesson. To count as a goal statement, the statement had to preview the scientific content that students encountered during at least one-third of the lesson time. How often did Australian teachers present goal statements in the science lessons?

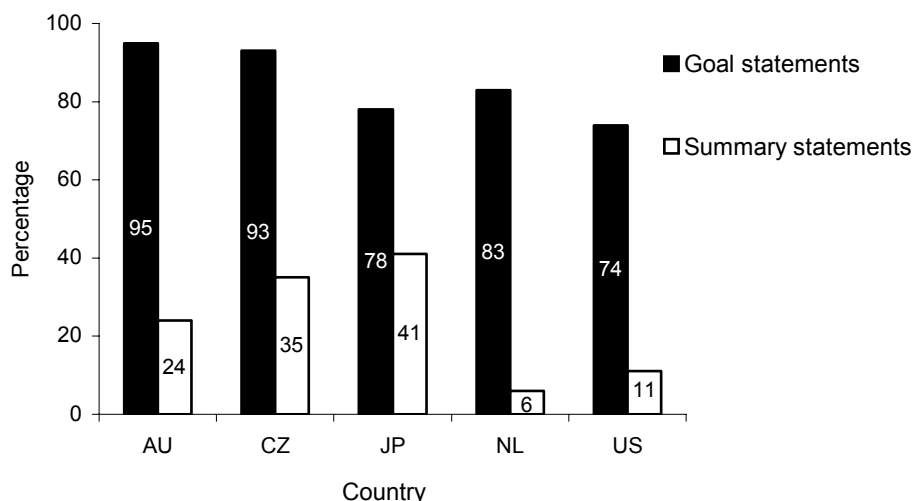
- *Ninety-five per cent of the Australian Year 8 science lessons contained at least one goal statement.*

A second kind of aid to help students recognise the key ideas in a lesson is a *summary statement*. This was defined as a statement that occurred near the end of either whole-class portions of the lesson or the lesson as a whole, and highlighted the main point(s) that had just been studied in the lesson. How often were lesson summary statements made in the Australian science lessons?

- Lesson summaries were provided in 24 per cent of lessons in Australia. In all of the participating countries, lesson summaries were less common than goal statements.

Figure 3.10 displays the percentages of lessons that contained goal statements and lesson summary statements for each country.

**Figure 3.10 Percentages of Year 8 science lessons with goal and summary statements**



Goal statements: AU>JP, US; CZ>US

Summary statements: AU, CZ, JP>NL; CZ, JP>US

Teachers in more Australian Year 8 science lessons explicitly conveyed the goal or goals of the lesson than did teachers in Japanese and United States lessons. On the other hand, summary statements were provided more commonly in Czech and Japanese lessons than they were in Dutch and United States lessons. A quarter of the Australian lessons provided lesson summary statements.

An example of an Australian teacher providing a goal statement can be viewed in [AU PRL 2](#). The following is the teacher's commentary related to that segment:

At this stage I wanted to define the objective of the lesson. (*AU PRL 2, Teacher's Comments, 00:06:07*)

The researchers commented:

The teacher gives a clear goal statement as he shifts from review to development of new content (...) This particular goal statement includes the main idea presented as a known outcome. (*AU PRL 2, Researchers' Comments, 00:04:41*)

An example of an Australian teacher presenting a lesson summary statement can be viewed in [AU PRL 4](#). According to the teacher:

I discuss the results and student observations to consolidate the lesson and clear up any confusion about the expected conclusions for the practical. (*AU PRL 4, Teacher's Comments, 01:13:02*)

From the perspective of the researchers:

The teacher calls the students' attention and begins summarizing the work they have done during the independent practical activities. Teachers made summary statements in 24% of the science lessons in the Australian data set. (*AU PRL 4, Researchers' Comments, 01:09:48*)

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, during the time available, teachers did not complete their lessons as



planned. A comment in one of the Australian public release lessons indicates that the teacher, who had said earlier that he would summarise the lesson, ‘would have preferred some more time at the end of the class so that the class and I could have had a brief discussion about what we all achieved’ (AU PRL 1, *Teacher’s Comments*). 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 with how they would ideally like to teach that lesson.

### ***Lesson 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). Interruptions from outside the classroom, or arising within the classroom from non-science or science organisation segments, were examined. Examples of outside interruptions include announcements over the intercom, individuals from outside the class requiring the teacher’s attention, talking to a student who has arrived late, and fire drills.

Non-science periods can occur at the beginning or end of the lesson without interrupting the lesson flow, but occurrences of three or more of these events would most likely involve a mid-lesson interruption of science instruction. Time spent on science organisation is sometimes needed to move the flow of the lesson from one activity to another and one or two such segments would not necessarily disrupt the lesson in the same way as an outside interruption would. When segments of science organisation occur multiple times during a lesson, however, it seems that they would be more likely to interrupt the overall lesson flow.

How often were the Australian lessons interrupted?

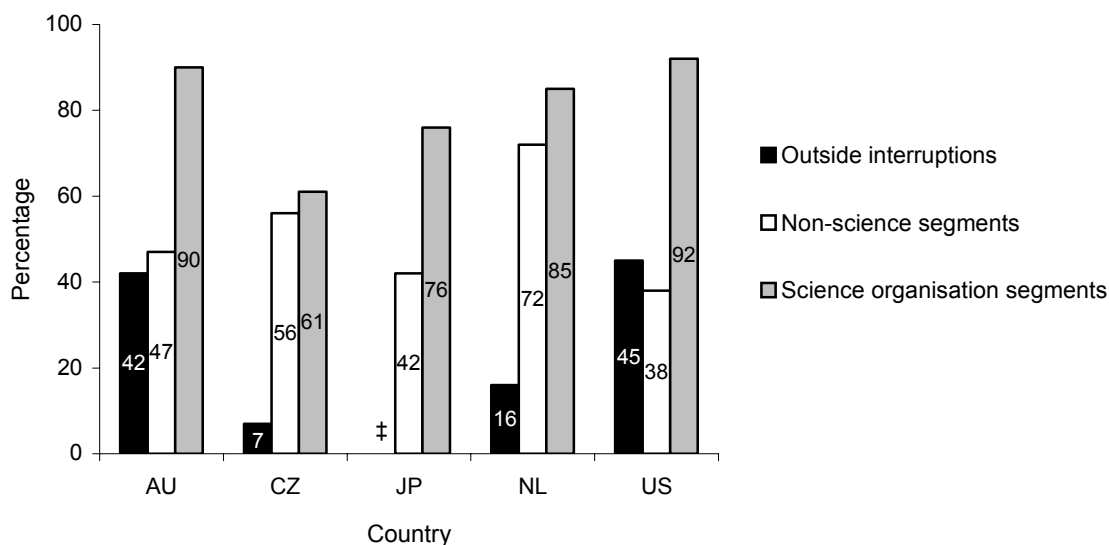
- *In Australia, 42 per cent of the Year 8 science lessons were interrupted by an outside source, more than in any other country except the United States. At least one segment of non-science occurred in 47 per cent, and at least one segment of science organisation in 90 per cent, of the Australian lessons. However, on average, only small percentages of lesson time were occupied by these events. Fifty-eight per cent of the Australian lessons featured three or more interruptions.*

The percentages of Year 8 science lessons per country during which the various kinds of interruption occurred at least once are displayed in Figure 3.11.

More Year 8 science lessons in Australia and the United States included at least one outside interruption compared with lessons in the Czech Republic and the Netherlands, with too few cases in Japan to be reported. At least one science organisation segment occurred in more Australian, Dutch and United States lessons than in Czech lessons. Three or more interruptions per lesson were also found to occur in more Australian, Dutch and United States lessons (58, 51 and 69 per cent, respectively) than in Czech and Japanese lessons (23 and 27 per cent, respectively) (data not shown).

Interruptions for science organisation, while often related to practical activities, did not correspond exactly with these. When science organisation *time* was compared for lessons in which students carried out independent practical activities and lessons in which they carried out independent seatwork activities, the average percentage of science organisation time was not significantly different within Japan and the Netherlands. Within the Czech Republic and the United States, smaller percentages of time were used for science organisation in lessons involving the students working on independent hands-on practical activities than on independent seatwork activities. Conversely, in Australia a larger average percentage of time was used for science organisation pertaining to students’ working independently on hands-on practical activities. This issue is discussed further in Chapter 5, where the nature of practical activities is described in detail.

**Figure 3.11 Percentages of Year 8 science lessons with any instance of outside interruptions, non-science segments and science organisation segments**



‡ Fewer than three cases reported (country excluded from the relevant analysis)

Outside interruptions: AU, US>CZ, NL

Non-science segments: NL>AU, JP, US

Science organisation segments: AU, NL, US>CZ; US>JP

More than 40 per cent of Australian lessons with outside interruptions may seem like a large number. However, outside interruptions were classified as non-science segments and, as reported earlier in the chapter, only 2 per cent of lesson time on average in Australia was categorised as non-science. Hence, although there is no available direct measure of their length, outside interruptions on average did not take much lesson time. Often they consisted of only a short announcement made over the intercom, or one comment made by the teacher (for example, to a late student or a messenger from another class). While such interruptions do not take up much time, they do tend to disrupt lesson flow and students' concentration and preferably should be kept to a minimum.

### Classroom Talk

Another aspect of pedagogy, one that has received a great deal of attention in the research literature, is the role of classroom talk. In this report, classroom talk is analysed and described in Chapter 6.

### The Role of Homework

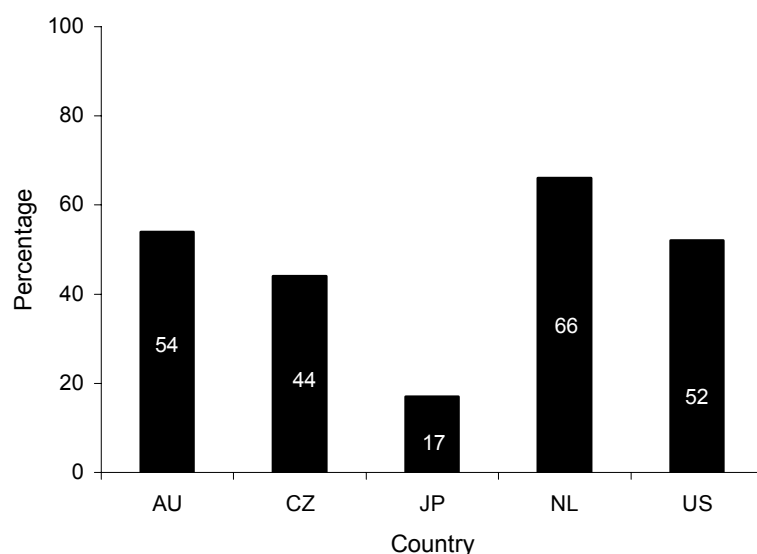
The decision to incorporate aspects of homework within a lesson can have a direct impact on how that lesson is organised. That is, teachers can review work that students completed prior to the lesson, allow students to begin homework assigned for a future lesson, or both. How often were Australian students expected to complete homework assignments for science lessons?

- *Homework was assigned in 54 per cent of Australian Year 8 science lessons, roughly the same as in the other countries with the exception of Japan, where homework was assigned in only 17 per cent of lessons.*

### Working on homework

Figure 3.12 displays the percentage of lessons per country where homework was assigned during the videotaped lesson. Homework was assigned for future lessons in fewer Japanese lessons than in lessons in all the other countries, and in more Dutch lessons than Czech lessons. Thus, assignment of homework was a more typical occurrence in Dutch lessons and less typical in Japanese lessons.

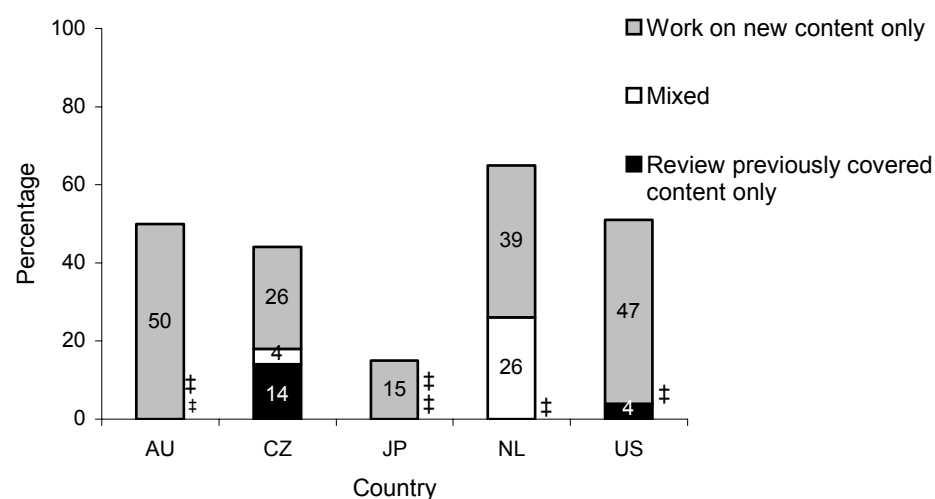
**Figure 3.12 Percentages of Year 8 science lessons in which the teacher assigned homework for future lessons**



Note: AU, CZ, NL, US > JP; NL > CZ

There were also cross-country differences in the nature of tasks assigned as homework for future lessons, as shown in Figure 3.13.

**Figure 3.13 Percentages of Year 8 science lessons in which the homework assignment focused on new content, review or both**



‡ Fewer than three cases reported (country excluded from the relevant analysis)

Work on new content only: AU > CZ, JP; NL, US > JP

Mixed: NL > CZ

Review previously covered content only: CZ > US

As shown in the figure, the Czech Republic was the only country where students were required to do science homework focusing only on review of previous lesson content to any noticeable degree. Dutch students were also expected to attend to previous content, but in combination with working on new content. Homework requiring review of previous content only occurred in 14 per cent of Czech lessons, 4 per cent of United States lessons, and too infrequently in the other countries to calculate reliable estimates. Homework requiring review of previously covered content combined with work on new content was set in a further 4 per cent of Czech lessons.

From Australia's perspective, the most interesting feature of the observations on homework is that, in the 54 per cent of lessons where homework was assigned, it almost always required the students to work only on new content. The same was observed in Japan, but pertaining to a significantly smaller percentage of lessons (15%). This finding for Australia is particularly interesting in comparison with results from the TIMSS 1999 Mathematics Video Study, where Australian teachers focused more extensively on review activities for students' homework than did teachers from several other countries (Hiebert et al., 2003).

Some examples of Australian students working on new content in advance of their next lesson can be inferred from two of the public release lessons. In *AU PRL 1* the teacher commented:

Students were expected to read up about the practical activity for homework the night before. They should have come to class with a general idea of what the class was about. This also means that less class time is wasted while the students read up about the activity. I expect all practical classes to be read up by students the night before. (*AU PRL 1, Teacher's Comments, 00:00:42*)

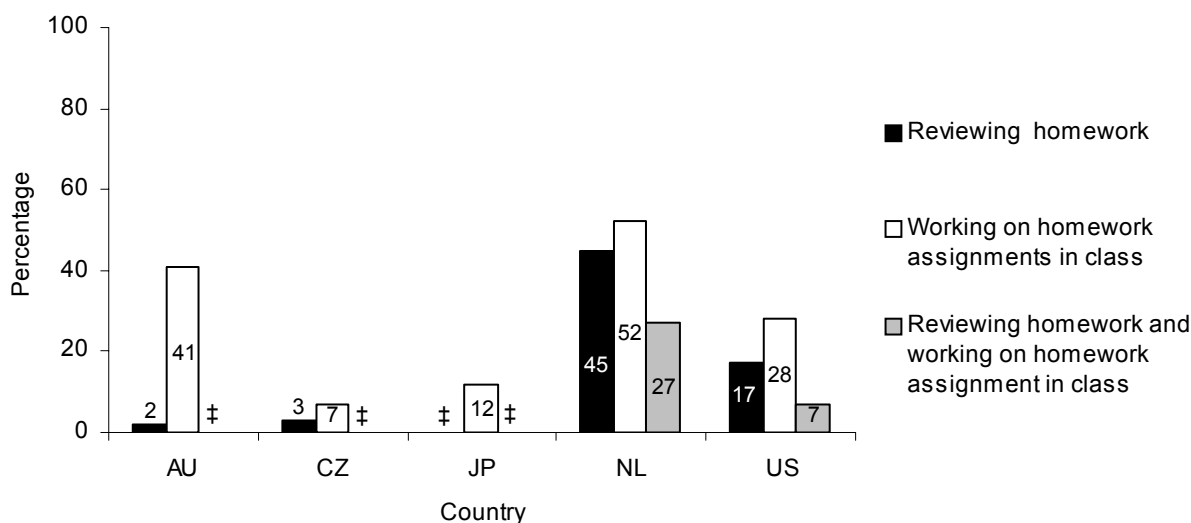
In *AU PRL 3* students dissected kidneys and studied names for the parts. The teacher noted:

For homework students had to make a model of the kidneys. I had given them an instruction sheet to follow. The aim of this activity was to improve their skills in following instructions and to enable students to visualise the structure of the kidney. (*AU PRL 3, Teacher's Comments, 00:02:01*)

There are also instances of homework sheets being given out containing exercises for students to do that related to the new content they had studied that day (for example *AU PRL 4, Teacher's Comments, 01:13:07*).

The importance of homework assignments in the Year 8 science lessons can also be assessed by examining the role that homework played during the lessons. Students sometimes had opportunities to review completed homework as a class or group activity (see Table 3.1), though this consumed only a few minutes of lesson time on average except in the Netherlands. In some cases, also, they were able to start work on homework assignments during the lesson. An example of homework started during an Australian class can be found in *AU PRL 3, 00:27:12*. The teacher's intention with this activity was that students would finish it in class, but there was not enough time for that. Hence he assigned the task to be completed at home.

The percentage of Year 8 science lessons per country in which activities connected with homework played a part are shown in Figure 3.14. The predominance of homework activities in the Netherlands compared with the other four countries shows clearly in this chart. In terms of opportunities to work on homework assignments in class, however, students in Australian lessons were similar to the students in Dutch lessons. Students in more Australian and Dutch Year 8 science lessons were allowed to start working on their homework assignments in class compared with students in Czech and Japanese lessons. Both the practices of working on homework in class and being assigned homework related to future lessons were relatively infrequent in Japan (12 per cent of lessons, shown in Figure 3.14, and 17 per cent of lessons, shown in Figure 3.12, respectively).

**Figure 3.14 Percentages of Year 8 science lessons that included reviewing homework and working on homework assignments in class**

† Fewer than three cases reported (country excluded from the relevant analysis)

Reviewing homework: NL>AU, CZ, US; US>AU

Working on homework assignments in class: AU, NL>CZ, JP; US>CZ

Reviewing homework and working on homework assignments in class: NL>US

## 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; NRC, 2000; Stigler et al., 1999), and the ways these features fit together.

In this chapter, results were presented on pedagogical elements of the videotaped Year 8 science 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 five countries made similar pedagogical choices. They used many of the same basic ingredients. Virtually all of the Year 8 science lessons developed new content, worked on for two-thirds or more of the lesson time (Table 3.1). Lessons devoted entirely to review of previous content were rare and review of previous content without at the same time referring to newly developed content was also rare across countries (Figure 3.4). Time was allocated to practical activities in 70 per cent or more of the lessons in all countries. Work was accomplished through two primary social structures: working together as a whole class and working independently of the teacher (Figure 3.6). In all countries computers were used in relatively few lessons.

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 those of 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 science instruction and other activities pertaining to science.

- Ninety per cent of the Australian Year 8 lessons were conducted in science laboratories, more than in any of the other countries except Japan (Figure 3.1).
- In keeping with their location, 90 per cent of the Australian lessons contained at least one segment of practical activities. Practical activities were also prevalent in the other countries, ranging from 72 per cent of the Dutch lessons to 83 per cent of the Japanese lessons.
- Textbooks or workbooks were used relatively rarely by students in the Australian science lessons; comparatively, students in three times as many Dutch lessons and in twice as many Czech and Japanese lessons used these resources (Figure 3.3).
- Eighty-five per cent of the lesson time on average in the Australian Year 8 science lessons was devoted to developing new content, with only 8 per cent spent on reviewing previously introduced content and 7 per cent on other purposes (Table 3.1).
- Sixty per cent of the Australian lessons were devoted entirely to the development of new content. As mentioned above, lessons devoted entirely to review of previously introduced content were very rare in all countries (Figure 3.4). This finding for Australian science lessons contrasts with the result for mathematics lessons from the TIMSS 1999 Mathematics Video Study, where Australia and the United States jointly had the highest percentage of lessons (28%) that were entirely review (Hiebert et al., 2003).
- Australia, together with Japan, had the highest percentage of science instruction time (42%) devoted to practical activities among the participating countries. Although practical activities occurred in more than 80 per cent of the Czech lessons, they were usually short activities and occupied on average only 14 per cent of the lesson time (Figure 3.5).
- The vast majority of lessons in all countries contained at least one segment of whole-class work directed by the teacher and at least one segment where students worked independently of the teacher.
- Australia, Japan, the Netherlands and the United States each allocated about half the instruction time to whole-class work and to independent student work. The Czech Republic, where more than 80 per cent of the time was allocated to whole-class work, was very different in this respect (Figure 3.6).
- Practical activities were undertaken during both whole-class and independent work time in all countries. They occurred about equally during whole-class and independent work time in Australia and Japan, but more commonly in whole-class work time in the other three countries (Table 3.2).
- In terms of duration, practical activities with students working independently of the teacher occupied more time than such activities undertaken as part of whole-class work at Year 8, except in the Czech Republic where the reverse occurred (Figure 3.7).
- Independent practical activities were rarely done by students working individually. In Australia, students working on independent practical activities worked in small groups for all but 2 per cent of the science instruction time (Figure 3.9).
- Goal statements were used by teachers in 95 per cent of the Year 8 Australian science lessons, but summary statements were made in only 24 per cent of the Australian lessons (Figure 3.10).
- Forty-two per cent of the Australian lessons experienced interruptions to the lesson flow from outside sources. Interruptions such as these occurred to the same extent in the United States, but were rare in the Czech Republic and Japan and less frequent in the Netherlands (Figure 3.11).
- In Australia, homework was assigned in 54 per cent of the Year 8 science lessons (Figure 3.12), almost always focusing on new content (Figure 3.13), and was worked on for at least one lesson segment in 41 per cent of the lessons (Figure 3.14). However very little science lesson time was devoted to discussing or working on homework (Table 3.1).

## Chapter 4

### SCIENTIFIC CONTENT

Chapter 3 presented information on the ways in which Year 8 science 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 science is, of course, its scientific content. Chapter 4 describes the scientific content of the videotaped lessons, and the ways in which that content was developed.

Lesson content is described according to:

- disciplines (that is, earth science, life science, physics, chemistry and other areas)
- topics within the disciplines; and
- the types of scientific knowledge that were addressed in the lessons.

The ways in which the content was developed are described in terms of:

- its source
- the amount of scientific content in the lessons and the activities through which it was presented
- its coherence
- its level of complexity and challenge; and
- types of evidence used to support it.

#### **Nature of the Lesson Content**

##### ***Definition***

Scientific content is defined in this report using the broadest definition found in any of the participating countries' standards or curriculum documents. According to the United States' *National Science Education Standards*: 'The content of school science is broadly defined to include specific capacities, understandings, and abilities in science' (NRC, 1996, p. 22). Thus, scientific content includes:

- understandings about the facts, definitions, terms, concepts and processes constituting scientific knowledge that is increasingly referred to in the literature as 'canonical' (for example, names of the organs in the excretory system, the idea that plants make their own food in the form of glucose and how the particulate theory of matter explains the water cycle);
- understandings about the nature of science and technology (for example, how scientists use evidence to support claims, science as a human endeavour, scientific values, how science works and history of science and technology);
- understandings about science in relation to personal and societal issues (for example, personal health, environmental issues, natural hazards, risks and benefits and the impact of science and technology on society); and
- skills to carry out procedures in science and technology (for example, how to use tools such as balances or microscopes and how to use experimental methods such as litmus tests or density calculations).

Both the research literature and the countries' standards and curriculum documents have different ways of thinking about content in the science curriculum, as briefly discussed below.

##### ***Research background***

The history of science education is characterised by debates about what scientific content should be learned in school science classes (e.g., Bybee & Ben-Zvi, 1998; DeBoer, 1991; Wallace & Loudon, 1998; White, 1994). Since the late 1980s, the call for a goal of scientific literacy for all

students has raised anew the question of what scientific content all students should learn (e.g., American Association for the Advancement of Science (AAAS), 1990; Bybee & Ben-Zvi, 1998; Fensham, 1987, 1988, 2000; NRC, 1996; Osborne, 2002).

Current debates in the field focus on the appropriate mix of different types of knowledge in the science curriculum. Among the many issues raised during these debates are:

- the extent to which students should focus on mastering the facts, definitions and concepts of science versus developing scientific inquiry abilities;
- the extent to which students should learn the language and discourse of science;
- the extent to which the curriculum in science should be centred on science-related societal or technological issues linked to real-world problems; and
- the extent to which curricula should focus on student understanding of major themes about the nature of science and overarching ideas that cut across the traditional disciplines versus learning science compartmentalised according to the traditional disciplines of biology, chemistry, physics and so on.<sup>28</sup>

In some countries, science teaching has been characterised as emphasising science as a body of canonical knowledge; that is, in these countries science teaching and textbooks continue to emphasise the facts, concepts, theories, and ideas that are produced by the scientific community and pay little attention to the nature and history of science and the importance of science to society (e.g., Bybee & DeBoer, 1994; DeBoer, 1991; Kesidou & Roseman, 2002). In other countries, science education reforms and observations of science teaching suggest more emphasis on knowledge about the connections between canonical knowledge and societal applications, scientific inquiry processes, and the nature of scientific knowledge (e.g., Andersson, 2000; AEC, 1994; Board of Studies, 1995; DeVos & Reiding, 1999; Goto, 2001; Millar & Osborne, 1998; NRC, 1996; OECD/PISA, 1999; Science Research Council of Canada, 1984). In other words, understanding science involves not only learning its basic concepts and ideas but also how these ideas relate to other events, why they are important, and the kind of world view that allows scientific knowledge to be generated (Osborne, 2001).<sup>29</sup>

### ***Country perspectives***

As reported in Roth et al. (2006), standards and curriculum documents from the countries in this study differ in the degree to which they emphasise different types of scientific knowledge. The Czech Republic's national curriculum guidelines emphasise canonical knowledge (that is, scientific facts, ideas, concepts or theories) as what the students are expected to learn about science (Kolavova, 1998). While the Czech Republic's curriculum guidelines mention real-life issues only briefly, documents in Australia, Japan, the Netherlands and the United States suggest an approach which, in addition to canonical knowledge, also emphasise knowledge about scientific processes in relation to real-life issues (AEC, 1994; Board of Studies, 1995; NRC, 1996; Dutch Ministry of Education, Culture, and Science, 1998; Ministry of Education, Science, and Culture [*Monbusho*], 1999). To reinforce this emphasis, Year 10 students in the Netherlands are required to take an entire course that focuses on public issues in science education (DeVos & Reiding, 1999).

Current reform movements in Japan also call for increased emphasis on connecting science to real-life issues to make science more meaningful and interesting for students (Goto, 2001). This content emphasis is reinforced by previous TIMSS results demonstrating low percentages of Japanese students who reported an interest in science or saw science as important to their daily lives (Beaton et al., 1996; Goto, 2001). Knowledge about safety is specifically mentioned in standards and curriculum documents in all of the five countries. Australian and United States documents also emphasise understanding the nature of science, which includes understanding its history as an ongoing and changing enterprise, understanding the scientific values and habits of

<sup>28</sup> References to and some discussion of these debates are provided in Roth et al., 2006.

<sup>29</sup> Definitions of the types of scientific knowledge described in the five countries' curriculum documents are given later in the chapter.



mind that underlie the doing of science, and understanding the role that science has played in the development of various cultures (AEC, 1994; NRC, 1996). Knowledge about the nature of science is not explicitly represented in curriculum documents in the other countries.

### ***Disciplines and topics addressed in the lessons***

The topics in the lessons were identified using the TIMSS *Guidebook to Examine School Curricula* (McNeely, 1997), which provided a common, international frame of reference for talking about scientific content. Although the guidebook identified frameworks for curriculum analysis other than disciplines and topics (i.e., performance expectations and perspectives), analysis for this video study focused only on the scientific content disciplines and topics. The content of each lesson is described at two levels: a content discipline category and a content topic subcategory. What were the main content foci of the Australian lessons?

- *Australia and the Netherlands were very similar to each other in the overall content of their science lessons, despite structuring science teaching in different ways (as an integrated subject in Australia and as separate disciplines in the Netherlands). In both countries, physics and life science together made up three-quarters or more of the lessons and almost half of the lessons were devoted to physics. However, coverage of topics within the major areas was varied.*

### **Disciplines**

The major disciplines of science in McNeely (1997) include earth science, life science, physics, chemistry, and other.<sup>30</sup> Year 8 students in the Czech Republic and the Netherlands are taught some of these disciplines in separate courses (biology, chemistry and physics), while in Australia, Japan and the United States science is taught as an integration of the disciplines or as general science. An 'other' category was used to describe disciplinary areas in science that were taught in only small percentages of Year 8 science lessons. These include: science, technology, and mathematics; history of science and technology; environmental and resource issues related to science; nature of science; and science and other disciplines.

No statistical comparisons are reported for curricular differences across countries because the video lessons were not sampled for specific disciplines. Therefore, only within-country comparisons of the disciplines covered were made. However, it is reasonable to presume each country's sample is somewhat representative of the disciplines covered in Year 8, to the extent that the videotapes of lessons were collected across the school year.

The percentage distribution of Year 8 science lessons that addressed earth science, life science, physics, chemistry and other areas is shown for each country in Figure 4.1. In Australia and the Netherlands, at least 47 per cent of the lessons addressed physics topics, while in the Czech Republic, 36 per cent of the lessons addressed life science topics. In Japan, chemistry and physics were addressed about equally, each in a little over a third of the lessons. Within Australia and Japan, more lessons addressed life sciences, physics, and chemistry than earth science, and physics than life sciences. More Australian lessons also addressed physics than chemistry whereas more Japanese lessons addressed chemistry than life sciences.

The percentage of physics lessons in Australia is higher than would be expected from knowledge of Year 8 curricula as a whole. It is probably an artefact of sampling in that, for several reasons, filming was not able to be done uniformly throughout the year. The majority of the lessons were filmed in third and fourth terms, when it seems from the data that teachers were more likely to be focusing on physics than on other areas of science.

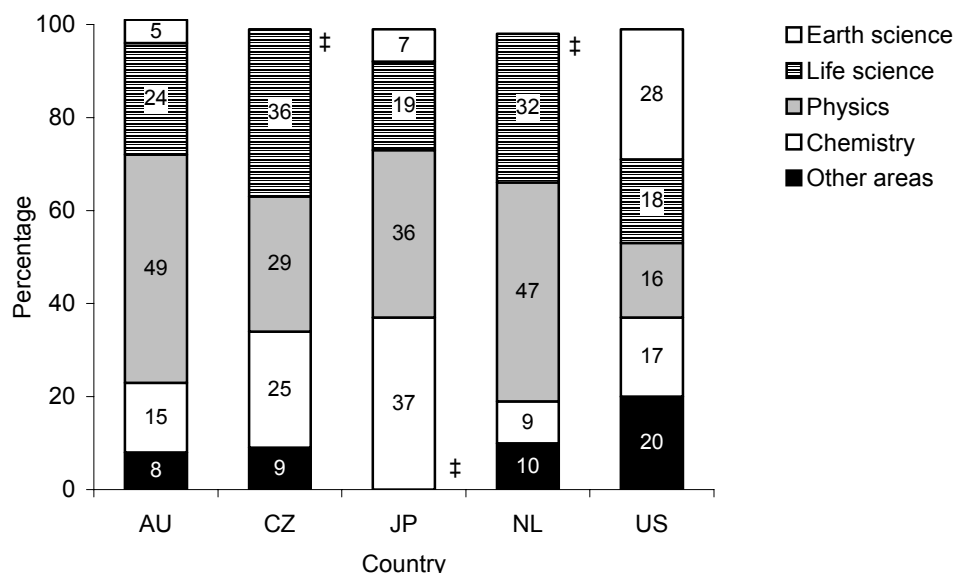
Within the Netherlands, more lessons addressed life science and physics than chemistry. Within the United States, the percentages of Year 8 science lessons that addressed each of the five

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<sup>30</sup> Since physical science is taught as separate courses for physics and chemistry in two of the five participating countries (the Czech Republic and the Netherlands), the original content category from the TIMSS *Guidebook to Examine School Curricula* (McNeely, 1997) was modified in this study to identify physics and chemistry as separate content disciplines.

categories of science ranged from the 16 per cent of lessons focusing on physics to the 28 per cent of lessons focusing on earth science, with no measurable difference found for any comparison between the disciplines.

**Figure 4.1** Percentage distributions of Year 8 science lessons devoted to earth science, life science, physics, chemistry and other areas



† Fewer than three cases reported (country excluded from the relevant analysis)

Note: Total may not sum to 100 because of rounding. Other areas include: interactions of science, technology, and society; nature of scientific knowledge; and science and mathematics.

The relative prominence of earth science in the United States and lack of focus on earth science in the Czech Republic and the Netherlands are interesting and probably point to differing views of what qualifies as science and what qualifies as earth science. Educators in the Czech Republic and the Netherlands do not regard geology, meteorology, and other subject areas as constituting earth science as a separate science (Dutch Ministry of Education, Culture, and Science, 1998; Kolavova, 1998). Instead, these earth science topics are often included as part of physics or, more commonly, as geography which is considered a social science in other countries and is, therefore, not sampled in this study. In the United States, earth science was defined only recently as a separate subject area in school science (Bybee & DeBoer, 1994). Prior to this, school science was typically defined as biology, physics and chemistry, with secondary ties to other disciplines.

### Topics

The content subcategories specify topics at the level typically used by the classroom teachers in describing the content of their videotaped lessons in their responses to the questionnaire (for example, rocks and soil, organs and tissues, electricity, chemical changes). Although several topics may have been included in one science lesson, only the primary science topic for each lesson was identified. The primary topic was defined as the topic that was addressed for the longest amount of science instruction time. Given the differential prominence of the science disciplines in the various countries' lessons, emphases on topics would also be expected to differ in a related way. This is clearly shown in Table 4.1, where the percentages of lessons devoted to various topics are presented by country.

The percentages in Table 4.1 are provided for information only. No statistical comparisons are reported for content differences across countries because the video lessons were not sampled for specific topics. However, as with the disciplines, it is reasonable to presume that each country's

sample is somewhat representative of the topics covered in Year 8 because as far as possible the videotapes of lessons were collected across the school year.

**Table 4.1 Percentage distributions of Year 8 science lessons devoted to topics within disciplines**

		Country				
		AU	CZ	JP	NL	US
Discipline	Topic area	Percentage of lessons				
Earth science	Building and breaking of Earth’s surface	-	-	-	-	2
	Planets in the solar system	-	-	-	-	4
	Rocks and soil	-	-	-	-	7
	Weather and climate	-	-	7	-	5
Life science	Animals	-	-	3	-	-
	Disease	-	-	-	-	6
	Evolution, speciation and diversity	-	-	-	-	3
	Organs and tissues	5	19	13	16	-
	Plants and fungi	5	-	-	-	-
	Reproduction	3	-	-	3	-
	Sensing and responding	-	-	3	3	-
	Variation and inheritance	-	-	-	-	3
Physics	Electricity	10	8	28	3	3
	Energy types, sources and conversions	10	-	-	-	-
	Fluid behaviour	3	3	-	-	-
	Heat and temperature	-	4	-	9	-
	Light	6	-	-	10	-
	Magnetism	-	-	4	-	-
	Physical properties and changes	-	6	-	-	3
	Sound and vibration	-	-	-	14	-
	Types of forces	8	-	-	4	-
Chemistry	Atoms, ions and molecules	-	3	-	-	5
	Chemical changes	3	4	33	5	-
	Chemical properties	8	5	-	4	2
	Classification of matter	-	11	-	-	4
Other		3	9	-	2	10

*Note 1:* Topics that did not occur or occurred very rarely within a country are shown with a dash (-).

*Note 2:* Totals do not sum to 100 because percentages are not shown for topics that occurred too infrequently for reliable estimates to be determined.

A commonly taught life science topic was 'organs and tissues', which was the focus of 19 per cent of Czech lessons, 13 per cent of Japanese lessons, 16 per cent of Dutch lessons, and 5 per cent of Australian lessons. In physics, 'electricity' was taught in all five countries, ranging from 3 per cent of lessons in the Netherlands and the United States to 28 per cent of the lessons in Japan. In Japan, only two topics – 'chemical changes' and 'electricity' – accounted for over 60 per cent of the lessons. Fourteen different topics (two within the 'other' category) were identified within the United States, none of them accounting for more than 7 per cent of the lessons. This latter finding is possibly a further illustration of the result reported from the TIMSS 1995 achievement study,

when United States curricula were characterised as ‘a mile wide and an inch deep’ (Schmidt, Raizen, Britton, Bianchi & Wolfe, 1997).

### *Types of knowledge in science*

During a science lesson many different types of knowledge can be addressed. For example, students may learn about scientific facts and theories, experimental procedures, or how science relates to their everyday lives. The choice of the extent to which these types of science-related knowledge are emphasised can present different images of science to students (e.g., Desautels & Larochelle, 1998; Driver, Leach, Millar & Scott, 1996; Millar, 1989; NRC, 1996; Russell & Munby, 1989).

Descriptions of the types of knowledge addressed during classroom interactions within lessons tell an important story about how science is represented and what kinds of opportunities students have to learn science. To identify and also measure the amount of time during which the students had an opportunity to learn about different types of knowledge, the ‘public talk’ parts of the Year 8 science lessons were segmented into the following six types of knowledge:<sup>31</sup>

- **‘Canonical’ knowledge:** Time in the lesson when the teacher or students publicly talk about or examine information about scientific facts, concepts, ideas, processes or theories. Canonical knowledge is the ‘what’ and ‘why’ of science, or the knowledge that science produces. Traditionally, science textbooks have commonly featured this type of knowledge. It can usually be characterised as one or more of the following types:
  - scientific conventions, labels or identifications;
  - concepts or processes in science;
  - science-related patterns, trends or laws; or
  - science-related explanations, theories, models or interpretations.

Examples include: names of different bones; the process of photosynthesis; global warming patterns; explanations for season changes; evolutionary theory; and atomic models.

- **‘Real-life’ issues:** Time in the lesson when the teacher and students publicly talk about or examine information about how scientific knowledge is used, applied, or related to societal issues or to students’ personal lives. This type of knowledge includes any talk about real-life issues that is topically related to the content of the science lesson. This talk may or may not be closely linked to the development of content ideas, and includes:
  - talk about the relationship of personal experiences to issues and ideas in science;
  - the uses of scientific knowledge in everyday life;
  - practical or motivational reasons to learn about science; and
  - everyday examples or illustrations of scientific ideas.

Examples and the role of this type of knowledge are explored further in Chapter 6.

- **‘Procedural and experimental’ knowledge:** Time in the lesson when the teacher or students publicly talk about or examine together information about how to do science-related practices such as manipulating materials and performing experimental procedures (e.g., how to connect a circuit, how to use litmus paper to tell if a substance is an acid or a base) (See *AU PRL 2*, 00:07:30 – 00:08:03 and *AU PRL 5*, 00:34:15 – 00:36:20 for examples.). However, also included are teachers’ directions about how to manipulate formulae (e.g., how to balance a

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<sup>31</sup> The knowledge categories were applied to all the lessons but restricted to those sections of the lesson when the intended audience of the speaker (the teacher or students) was the whole class. These sections of the lesson are identified as ‘public talk’ segments. Such segments usually occurred during whole-class interactions, but there were occasions when the teacher spoke briefly to the whole class while they were working on an independent activity. Public talk during an independent activity is included in these analyses. Limitations of the video methodology, together with the nature of independent work (when different students can be working on different things) prevented the categorisation of knowledge in non-public lesson segments. More details on public and non-public talk are included in Chapter 6.

chemical equation) and how to carry out scientific thinking practices in the lesson (e.g., ‘When you do this experiment, be sure to think about what evidence you are gathering that either supports or challenges your hypothesis’).

- **‘Classroom safety’ knowledge:** Time in the lesson when the teacher or students publicly talk about science-related safety issues in the classroom environment. Examples of this type of knowledge include identifying dangerous materials and discussing how to handle materials safely (e.g., what to do if hydrochloric acid spills). (AU PRL 4, 00:20:26 – 00:22:38)
- **‘Nature of science’ knowledge:** Time in the lesson when the teacher or students publicly and explicitly refer to issues about how science is conducted. This knowledge category includes values of science and science-related dispositions (e.g., open-mindedness, scepticism, objectivity), scientific methods, the scientific enterprise, how scientists work and communicate, the sociology of science, ethics in science, politics of science, history and philosophy of science. For example, the teacher may state: ‘In science, you must always support your explanations with evidence, and certain kinds of evidence are more permissible than others.’ This would be considered ‘nature of science’ because it makes explicit a view of science in general that goes beyond the particular activity or content being discussed. AU PRL 5 provides instances of this kind of knowledge – a discussion of historical aspects of science (00:02:15 – 00:03:24) and of issues in measurement accuracy (00:24:50 – 00:25:20).
- **‘Metacognitive’ knowledge:** Time in the lesson when the teacher or students publicly discuss or present information about strategies for learning (learning how to learn) or the importance of reflecting on one’s knowledge and learning as part of the learning process. An example of this type of knowledge involves the teacher modelling thinking (e.g., the teacher shows students how to work through a difficult problem or students reflect on how or why their thinking has changed). This type of knowledge is not featured in the publicly released Australian lessons.

### Canonical knowledge

Helping students learn about canonical knowledge (scientific facts, ideas, concepts, or theories) is central to the teaching of science. Canonical knowledge is included in all five participating countries’ curriculum or standards documents, and in some of these documents it is the most-represented knowledge type (e.g., Czech Ministry of Education, 1996; Ministry of Education, Science, and Culture [Monbusho], 1999). How frequently did Australian lessons address canonical knowledge publicly, and how much public interaction time was spent on this type of knowledge?

- *Development of canonical knowledge was a very important component of Australian lessons, as in all countries. Ninety-seven per cent of the Australian lessons contained at least one segment devoted to canonical knowledge development, although this type of knowledge occupied only about a third of the public talk time.*

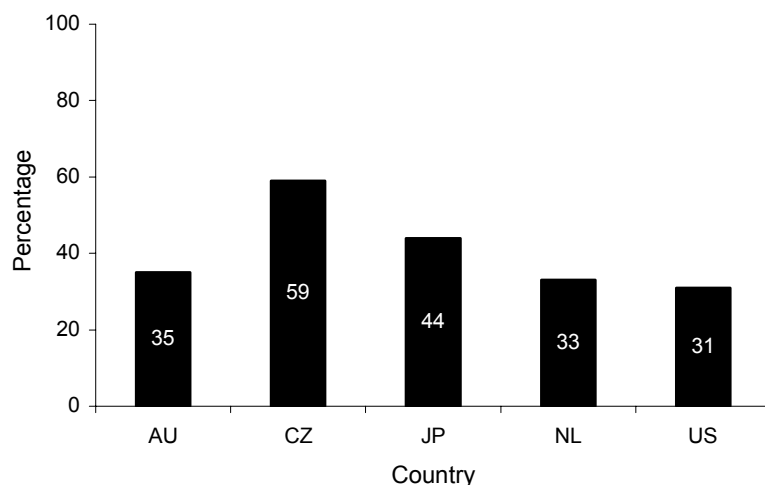
### *Incidence*

In each of the countries, canonical knowledge was addressed during public talk segments in the large majority of lessons, ranging from 84 per cent of lessons in the United States and 85 per cent in the Netherlands to 97 per cent in Australia, 99 per cent in Japan and 100 per cent in the Czech Republic (data not shown).

### *Percentage of public talk time*

When the lessons were examined in terms of time spent discussing or focusing on canonical knowledge, the average percentage of public talk time devoted to development of this type of knowledge ranged from 31 per cent in the United States to 59 per cent in the Czech Republic (35 per cent in Australia). Year 8 science lessons in the Czech Republic devoted a larger average proportion of public talk time to canonical knowledge than did lessons in the other four countries, on average. In addition, lessons in Japan devoted a larger proportion of public talk time, on average, to canonical knowledge compared with lessons in the United States. The average percentages of public talk time devoted to canonical knowledge development are shown in Figure 4.2.

**Figure 4.2 Average percentages of public talk time in Year 8 science lessons devoted to development of canonical knowledge**



*Note: CZ>AU, JP, NL, US; JP>US; analysis is limited to public talk time. Non-public time was not considered for these analyses because students typically worked independently on a variety of tasks that could have involved different types of knowledge.*

#### Real-life issues

As noted above, the ways in which real-life issues were used during the sampled science lessons are described in Chapter 6. They featured in more than 60 per cent of the lessons in every country and in almost 80 per cent of the Australian lessons.

#### Procedural and experimental knowledge

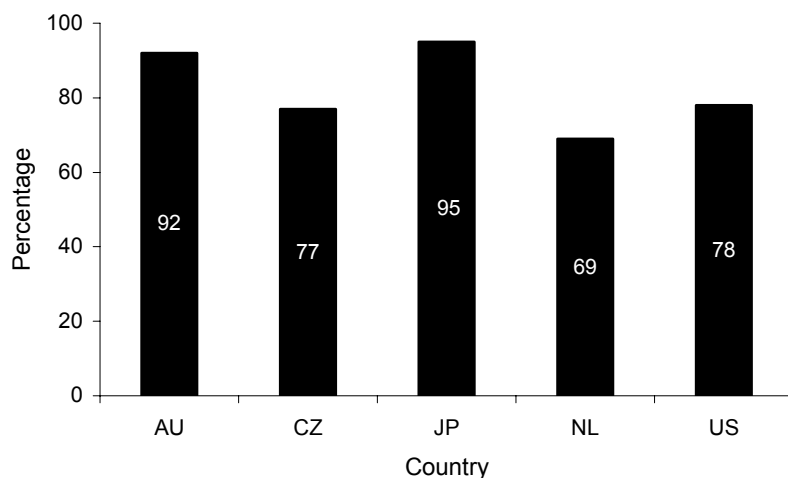
As described earlier, procedural and experimental knowledge includes practical skills (e.g., how to manipulate materials for an experiment), science-related procedures done as seatwork (e.g., how to balance a chemical equation, how to compose and draw a graph), and directions for engaging in scientific thinking practices (e.g., directing students to make a hypothesis, discussing how to infer patterns from data). While canonical knowledge can be thought of as the products of scientific inquiry, procedural and experimental knowledge can be thought of as the knowledge used to arrive at these products. This type of knowledge does not include information such as the reasons why scientists make hypotheses, organise data or draw graphs, which are considered to be aspects of the nature of science. How often did Australian lessons include procedural and experimental knowledge during public talk time, and how much time was spent on this type of knowledge?

- *In Australia, as in Japan, more than 90 per cent of the lessons contained public talk segments devoted to procedural and experimental knowledge, but more lesson time was used on this type of knowledge in Japan (25 per cent of public talk time) than in the other four countries (17 per cent in Australia).*

#### *Incidence*

At least 69 per cent of the Year 8 science lessons across the five participating countries (with over 90 per cent in Australia and Japan), publicly addressed procedural and experimental knowledge, as shown in Figure 4.3. This type of knowledge was addressed in a larger percentage of Australian lessons in comparison with Dutch lessons, and in a larger percentage of Japanese lessons in comparison with both Czech and Dutch lessons.

**Figure 4.3 Percentages of Year 8 science lessons that addressed procedural and experimental knowledge during public talk**

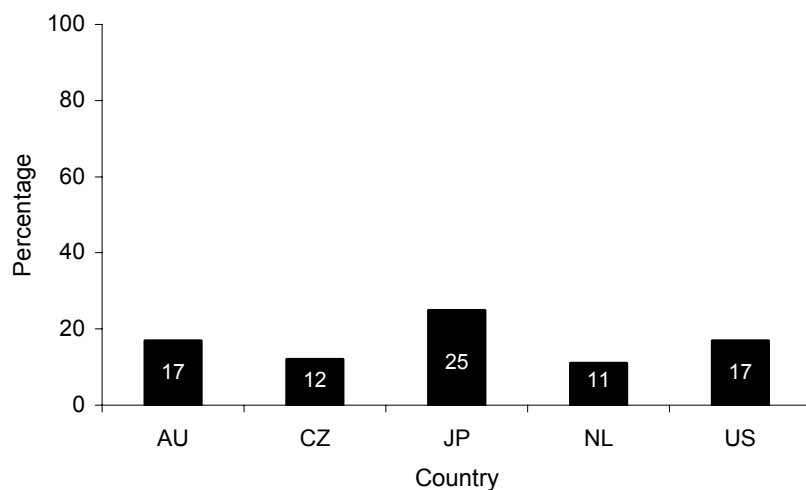


*Note:* AU>NL; JP>CZ, NL ; analysis limited to public talk time

*Percentage of public talk time*

Figure 4.4 displays the average percentages of public talk time devoted to discussion of procedural and experimental knowledge in Year 8 science lessons.

**Figure 4.4 Average percentages of public talk time in Year 8 science lessons devoted to discussion of procedural and experimental knowledge**



*Note:* JP>AU, CZ, NL, US; analysis limited to public talk time

Figure 4.4 shows that, when examining all the Year 8 science lessons, even though two-thirds or more of them contained segments dealing with procedural and experimental knowledge (Figure 4.3), the average proportion of public talk time devoted to this type of knowledge was relatively small, ranging from 11 per cent in the Netherlands to 25 per cent in Japan. Japanese lessons, on average, devoted a larger proportion of public talk time to procedural and experimental knowledge compared with lessons in Australia, the Czech Republic, the Netherlands, and the United States. Thus, although Australian and Japanese lessons did not differ measurably in the amount of time spent on independent practical activities (see Figure 3.6 in Chapter 3), they differed in the amount of time allocated for public talk about procedures and experimental knowledge.

An example of an Australian lesson devoting a considerable proportion of time to procedural knowledge is *AU PRL 1*, where the students were instructed in procedures for making finger prints. The teacher explained:

The focus of this unit was essentially one of process – technique, organisation of data, and problem solving. (*AU PRL 1, Teacher's Comments, 00:00:00*)

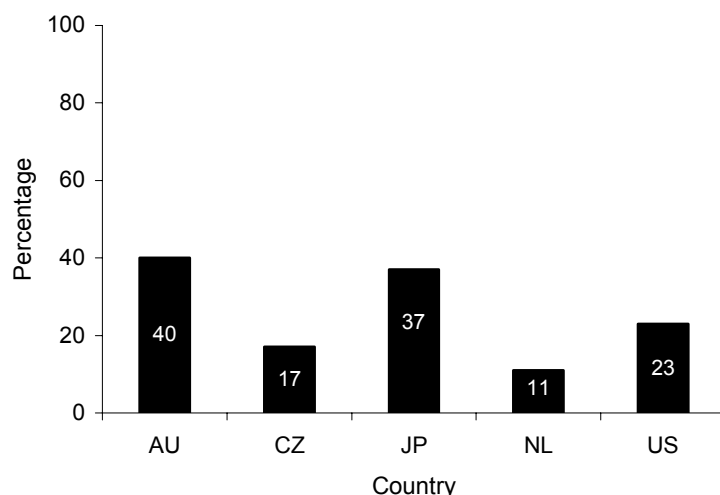
#### Classroom safety knowledge

Standards and curriculum documents call for practical work that may involve the use of materials that could be dangerous or harmful if misused. In science classrooms, therefore, safety is an important issue. Safety is specifically mentioned in standards and curriculum documents in each of the countries.

#### *Incidence*

In keeping with the larger proportions of lesson time devoted to practical activities in Australia and Japan than in the other countries (see Figure 3.5 in Chapter 3), similar variations in the incidence of lessons in which safety issues were discussed were found, as shown in Figure 4.5.

**Figure 4.5 Percentages of Year 8 science lessons containing discussion of classroom safety knowledge during public talk**



Note: AU>CZ, NL; JP>NL

#### *Percentage of public talk time*

Across all of the countries, the average proportion of public talk time devoted to safety information was no more than 2 per cent, suggesting that when teachers addressed safety knowledge, the discussion was brief (data not shown).



✎ *AU PRL 2* provides an additional example of public talk time devoted to safety issues. The researchers noted:

At this point the teacher introduces the materials. He warns students to be careful when burning the magnesium ribbon, as the bright light can be harmful to the eyes. He makes other statements about classroom safety knowledge on five other occasions in the lesson. (*AU PRL 2, Researchers' Comments, 00:08:01*)

### 'Nature of science' knowledge

Public talk about issues such as the values and dispositions of science (e.g., open-mindedness, scepticism, objectivity), science and society, historical aspects of science and the nature of scientific knowledge (evidence-based, tentative) is one strategy for providing students with opportunities to learn about what it means to do science. Documents in the United States and Australia place specific emphasis on nature of science issues (AEC, 1994; NRC, 1996). Despite this emphasis, nature of science issues was dealt with publicly in only 4 per cent of the Australian lessons and 6 per cent of the United States lessons. The percentages of lessons were about the same in Japan (7%) and the Netherlands (3%), while the Czech Republic had too few cases to be reported (data not shown). In all five countries no more than 1 per cent of public talk time was spent in discussing the nature of science (data not shown).

### Metacognitive knowledge

Metacognitive knowledge refers to information about strategies for learning (learning how to learn) or the importance of reflecting on one's knowledge and learning as part of the learning process. Metacognitive knowledge includes monitoring one's own understanding, evaluating progress towards completing a task, and reflecting on how thinking and understandings have changed over time. Research evidence in various school subject matter areas supports the theoretical stance that teaching students to reflect on their thinking processes helps them develop the skills needed to monitor and adjust their own learning and problem solving strategies, and hence promotes learning (e.g., Anderson & Roth, 1989; Bielaczyc, Pirolli & Brown, 1995; Novak & Gowin, 1984; Pressley & Levin, 1983; White & Frederickson, 1998).

About a fifth of the Year 8 science lessons in all countries contained public talk about metacognitive strategies, ranging from 17 per cent in Japan to 24 per cent in the United States (19 per cent in Australia) (data not shown). On average, no more than 1 per cent of public talk time was allocated to the discussion of these strategies (data not shown).

## **Developing the Lesson Content**

Science education research and reform documents as well as standards and curriculum documents from the participating countries present different views about how many content ideas are reasonable to include in a science lesson, about how best to organise content so that it is coherent and understandable to students, and about which content ideas are appropriate for Year 8 students to understand. Decisions about the content of science lessons are influenced by a variety of sources, including research knowledge about how science is learned, knowledge from the science community about what content is important for all students to learn and the goals and purposes of science education as defined at the country, state or local level. All of these factors typically contribute to the content of science curriculum guides and textbooks.

A common theme in recent science education and reform literature is the tension between including a large amount of content in the curriculum or covering fewer ideas but in more depth (e.g., AAAS, 1990; DeBoer, 1991; Fratt, 2002; NRC, 1996; Schmidt et al., 1997). In this section, the issue of depth versus breadth of content coverage is discussed not only by looking at how many ideas are addressed in a lesson but also through an examination of the organisation and coherence of that content and the level of challenge of the content in terms of its difficulty for Year 8 students, particularly in terms of its abstractness and theoretical emphasis.

Both the research literature and the countries' standards and curriculum documents advocate different ways of developing content in the science curriculum, as briefly discussed in the following section.

### **Research background**<sup>32</sup>

Providing opportunities for students to develop connected, evidence-based scientific understandings that the students can apply to make sense of a variety of phenomena is a key idea coming out of international research on science teaching and learning (e.g., Gunstone & White, 1992; Minstrell, 1989; Monk & Osborne, 2000; Resnick, 1987b; Roth, 1990; West & Pines, 1985; Wiske, 1997). Some studies document that even when students are able to memorise scientific information successfully, they often fail to develop the kinds of connected, conceptual understandings that enable them to use this knowledge to solve new problems or to explain phenomena in their everyday experience (e.g., Anderson & Roth, 1989; Anderson & Smith, 1987; Driver, Guesne & Tiberghien, 1985; West & Pines, 1985). Other studies have found that students often fail to make the intended connections between their learning of scientific content and their work on practical, or laboratory, activities (Hodson, 1993; Millar, 1989; Watson, 2000; White, 1996). In addition, research on human learning suggests that unrelated ideas hold less meaning than those that are richly interrelated (e.g., Chi, Glaser & Rees, 1982; NRC, 2000; Resnick, 1987b).

One result of this research has been the widespread call, particularly in the United States, for ‘less is more’ in the science curriculum – covering less content in more depth and with more coherence so that students receive the support they need to develop meaningful understandings of the content. However, critics have challenged that, in practice, ‘less is less’ – covering less content leads to a watered-down version of the science curriculum, in which students learn less science (e.g., Olson, 1998). Some scientists and science educators in the United States, for example, argue that the *National Science Education Standards*’ (NRC, 1996) emphasis on student-driven inquiry and minimal use of specialised vocabulary guarantee ‘misconceptions, fragmentation, and fog rather than clarity and comprehension’ (Shea, 1998, p. 118). They argue that depth of understanding requires knowledge about basic science concepts and specialised terminology, and that inquiry activities void of such knowledge are promoting misconceptions about the nature of science (e.g. Cromer, 1998).

What perspectives do the countries participating in this study have on these issues? A brief discussion of the countries’ views follows.

### **Country perspectives**

Standards or curriculum documents as well as reform documents from the countries in this study differ in the degree to which they emphasise content coverage versus in-depth study of selected key concepts (AEC, 1994; Czech Ministry of Education, 1996; Dutch Ministry of Education, Culture and Science, 1998; Martin, Gregory & Stemler, 2000; Schmidt et al., 1997). Curriculum guides in the Czech Republic, for example, emphasise canonical knowledge and contain more content specifications than standards or curriculum guides in the other countries. By contrast, a national-level curriculum document in Australia emphasises focusing science teaching on a few key scientific ideas. For example, one of the key principles for science curriculum developers in *A Statement on Science for Australian Schools* is that ‘students should explore a selection of ideas in science in depth rather than cover superficially a wide range of content’ (AEC, 1994, p. 10).

Recent standards and reform documents in the United States also emphasise covering less content in greater depth (AAAS, 1990, 1993; NRC, 1996). This focus is consistent with critics’ comments following the TIMSS 1995 achievement study that United States curricula were ‘a mile wide and an inch deep’ – trying to teach too much information and consequently lacking in depth (Schmidt et al., 1997) – as well as being filled with activities having little or no meaningful connections to rich scientific content (Kesidou & Roseman, 2002; Moscovici & Nelson, 1998).

The countries also differ in the role of a national science curriculum and textbooks. The Czech Republic, Japan and the Netherlands each have a national curriculum. However, as explained in Chapter 1, national curriculum guides or standards statements in Australia and the United States serve only as guidelines or suggestions and state- or local-level guides have more authority. With

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<sup>32</sup> Further references relevant to this section are included in Roth et al. (2006).

regard to textbooks, the TIMSS 1995 achievement study established that countries differ greatly in the number of textbooks used in Year 8 science, with some having a single mandated textbook and others where teachers have a large number of textbooks to choose from (for example, over 40 different books were named by the 160 or so Australian science teachers, although only 73 per cent of the teachers said they used a textbook in class) (Lokan et al., 1996). The TIMSS 1995 study of curricular visions and aims showed variations in the scientific content highlighted in both the curriculum guides and textbooks in the participating countries (Schmidt et al., 1997). These variations are likely to have influenced the types and amount of scientific content observed in the videotaped lessons, as well as the organisation of that content.

### ***Sources of lesson content and its organisation***

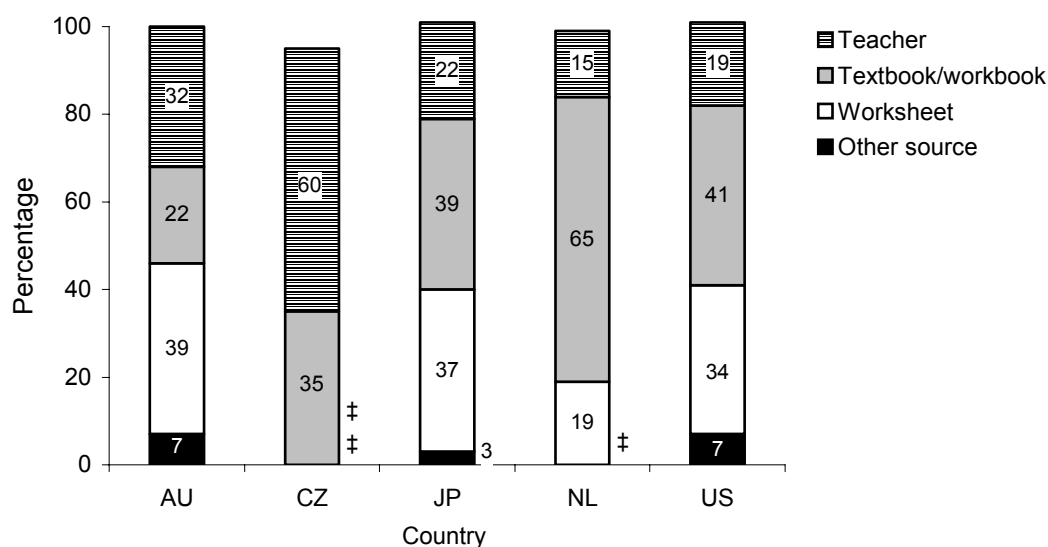
As discussed above, several factors can influence the content in a science lesson. The amount and the coherence, organisation and level of challenge of the content developed in the Year 8 science lessons may have been largely influenced by national or state curriculum guides or the textbooks or other curriculum materials being used. Alternatively, the teacher may have designed the content organisation of the lesson. Although the content organisation could be influenced by more than one factor, the intent of this variable was to identify the *main source* used during each of the videotaped lessons. Based on observations of the lessons, including analysis of the extent to which lesson content followed the outline of content in textbooks and worksheet pages used in the lessons, the main sources were defined as follows:

- **Teacher:** The source of the content organisation is largely determined by the teacher. The organisation of the content observed in the lesson is different from that presented in the textbook, workbook or worksheet, or there is no textbook, workbook or worksheet used.
- **Textbook or workbook:** The content organisation of the lesson is substantially influenced by a commercially prepared textbook or a workbook. The class closely follows the material contained in the textbook or workbook for a large portion of the lesson, working either together as a whole class or working independently.
- **Worksheet:** The content organisation of the lesson is substantially influenced by a worksheet (for example, a handout with a set of questions for students to answer or a laboratory sheet with directions for how to carry out a practical activity). The class closely follows the information contained in the worksheet for a large portion of the class period. The worksheet may have been designed commercially or by the teacher.
- **Other source:** The content organisation comes from some other source such as the students (for example, student presentations, students design their own experiments, or students conduct independent library research) or a video.

The percentage distributions of Year 8 science lessons in which the organisation of the content of the lesson was influenced by the teacher, the textbook or workbook, a worksheet or another source are presented in Figure 4.6.

Based on observations of the videotaped lessons, the teacher influenced the content of more Czech Year 8 science lessons (60%) than lessons in all the other countries, which ranged from 15 per cent in the Netherlands to 32 per cent in Australia, as shown in the figure. This does not mean that teachers created lessons completely on their own. For example, Czech lessons were taught by teachers who indicated on the questionnaires that their content decisions were influenced by curriculum guidelines (93 per cent of lessons), the textbook (67 per cent of lessons), their own interests and knowledge (47 per cent of lessons) and their assessment of their students' needs and interests (39 per cent of lessons) (see Chapter 2, Table 2.9). Rather, this may suggest that Czech science lessons are more likely to be taught by a teacher who relies less on prepared materials for instructional purposes. This supposition is reinforced by the lack of observed use of worksheets during the Czech lessons, whereas worksheets featured as sources of content in a third or more of the lessons in Australia, Japan and the United States.

**Figure 4.6** Percentage distributions of observed sources of content in Year 8 science lessons



† Fewer than three cases reported (country excluded from the relevant analysis)

Teacher: CZ>AU, JP, NL, US

Textbook or workbook: NL>AU, CZ, JP

Note: Totals may not sum to 100 because of rounding and data not reported. Lessons devoted entirely to review (a very small number) are not included in the analysis.

The content of more Dutch lessons (65%) was influenced by the textbook or workbook than lessons in Australia, the Czech Republic and Japan (only 22 per cent in Australia), suggesting that Dutch science lessons are more likely to be taught by a teacher who uses published prepared materials for instructional purposes.

### ***Amount of scientific content in the lessons***

From this point onwards the results presented in this chapter relate to segments of the science lessons in which teachers developed new content, went over homework, or went over assessments (as defined in Chapter 3). Segments focused on reviewing previously learned knowledge were excluded because these activities typically covered a large amount of content quickly, without any particular organisation that would make the content coherent. The relatively few science lessons in which the entire time was devoted to review only were also not included in the analyses presented in the rest of this chapter, for the same reason (see Chapter 3, Table 3.1 and Figure 3.4).

### **Opportunity to learn scientific content**

Science lessons vary in terms of how much content is addressed. Lessons with fewer ideas may provide the opportunity for students to study a few ideas in depth and to develop conceptual understandings (rather than simply memorising facts). On the other hand, lessons with more ideas may provide a strong base of vocabulary and factual knowledge that can be used to develop conceptual understanding. The scientific terminology used during a science lesson also provides opportunities for students to learn scientific content.

A first question to consider regarding the amount of scientific content in the lesson is whether the teacher directed students' attention to learning content knowledge at all (see the first part of this chapter for definitions of the knowledge types). Some lessons were largely devoid of scientific content and focused students instead on carrying out activities or procedures. Students' opportunity to learn scientific content in the videotaped Year 8 lessons was determined using indicators of whether or not students had opportunity to learn scientific content, whether few or

many canonical ideas were publicly presented or discussed, and whether few or many scientific terms were used during public talk time. The indicators were defined in the following ways:

- Learning scientific content: With or without the use of independent student activities, the teacher provides students with the opportunity to learn scientific content knowledge. The lesson may focus mainly on whole-class presentation or discussion of content knowledge. Alternatively, a content-focused lesson may devote a substantial amount of time to independent activities such as student work on experiments. In either case, the teacher or the text explicitly directs students to use the experiment to develop or support conceptual understanding or knowledge of science related to the activity (e.g. *AU PRL 2*, for example). If students were provided with at least some opportunity to learn scientific content, the lesson was coded in this category. Examples of content-focused lessons include the following:
  - The teacher leads students through a series of simulation activities to demonstrate the relationship between population density and food supply (canonical content).
  - Students work independently on a set of questions and problems about force throughout the entire lesson (canonical content).
  - Students examine the pros and cons of becoming an organ donor (content concerning societal issues).
  - Students learn about fair tests and control groups, and use this knowledge to design and carry out investigations (content about the nature of science).
- Undertaking activities without the opportunity to learn scientific content: The teacher provides opportunities for students to carry out scientific activities or procedures but does not direct or focus students' attention to learning content ideas. The activities occupy a large majority of the lesson time and engage students in following directions or practising procedures without explicitly linking the activities to scientific content knowledge in ways obvious to an observer. Content may be briefly mentioned in the lesson at the topic level or as an isolated piece of information, or a few students may develop some understanding of the content in the process of carrying out an activity, but the teacher or instructional materials do not explicitly guide students to this understanding (See e.g. *AU PRL 1*, 00:00:00 to 00:01:37.) Examples of lessons focused on doing activities include the following:
  - Students spend the class period building rockets, following procedures supplied by the teacher.
  - Students take their pulse before and after running, record their data and graph the class results, but they are not directed to use this information to develop or support knowledge about blood circulation, about the effect of exercise, about graphical representations, or about the nature of scientific inquiry.
  - Students are asked to go outside and take weather measurements, without any discussion about how these activities relate to scientific content knowledge.

Sometimes even a few brief statements could qualify the lesson as content-focused rather than activity-focused if the statements clearly framed activities with a content learning goal. For example, the teacher may have introduced an activity that took up most of the class time by explaining the ways in which the students would demonstrate their knowledge of scientific method by carrying out an experiment.

Using these definitions, a large majority of lessons in all the countries, from 73 to 100 per cent, were found to focus on developing content ideas. None of the lessons in the Czech Republic was observed to be predominantly activity-focused. In the other countries no more than 12 per cent of lessons (Australia) were activity-focused except in the United States, where 27 per cent of lessons focused primarily on activities with little or no explicit linkage to content (data not shown).

### Density of publicly-presented canonical ideas

The categorisation of a lesson as providing opportunity to learn scientific content takes no account of how much scientific content is dealt with. The quantity of ideas presented in the lesson provides one indication of the potential coherence, as well as the challenge and depth, of content coverage. Lessons with many ideas may provide content that is challenging for students in its complexity and level of detail, whereas lessons with fewer ideas may provide time for in-depth, challenging treatment of each idea. A lesson that moves quickly from one fact or idea to another may have less coherence and be more difficult for students to understand than a lesson that focuses on few ideas, although it is also possible that a lesson with few ideas could lack coherence and focus only on superficial coverage of the content.

For this analysis, a ‘public canonical idea’ was defined as:

- a publicly-presented statement that describes a scientific fact, concept, pattern in data, natural process, scientific model or law, or theoretical explanation (e.g. AU PRL 4, 00:04:21 – 00:05:50 and 00:09:24 – 00:11:45 are examples, where canonical ideas about energy transfer and transformations are discussed – and are also linked to real-life situations). The knowledge is canonical in the sense that it is an understanding that is generally shared by members of the scientific community. For example, a teacher draws a series circuit on the board and describes it. This public statement represents a canonical idea about the path of electron flow travelling through a series circuit. A public canonical idea can come from the teacher, the text, a video, from data collected in an experiment, from the students during discussion, and so on.

The number, or ‘density’, of public canonical ideas that are presented in a lesson provides an indication of the degree to which the lesson developed content by focusing on a few key ideas or on many ideas. A lesson with 20 ideas, for example, is denser than a lesson with one idea. For the purposes of this analysis, ‘high density’ lessons were defined as follows:

- High density lesson: A lesson that contains 15 or more distinct publicly-presented canonical ideas. For example, in addressing the big idea of how the digestive, respiratory, and circulatory systems work together to help all cells in the body get the energy they need, the lesson might include the names and functions of many different parts of the body as well as a description of the processes of digestion, circulation, and cellular respiration.

Only canonical ideas that were publicly-presented in the Year 8 science lessons were examined for this analysis. Identifying canonical ideas that were not publicly-presented would have required prohibitively extensive analyses of textbooks and additional materials used in the lessons but not available through classroom observations.

Using this definition, the incidence of high density lessons was found to be about 10 per cent in Australia and Japan, a little under 20 per cent in the Netherlands and the United States, and 26 per cent in the Czech Republic. The only difference that was significant was that between the Czech Republic and Japan (data not shown).

### Use of scientific terminology

Another way of looking at the amount of scientific content in a lesson is to examine the number and nature of scientific terms used by the teacher or students. Scientific terms were defined as follows:

- Scientific term: A scientific term is defined as a one- to three-word expression (e.g., energy, photosynthesis, aneroid barometer and relative molecular mass) with a specific meaning in science. A count of unrepeatable scientific terms in a lesson describes how many different terms are used in that lesson.

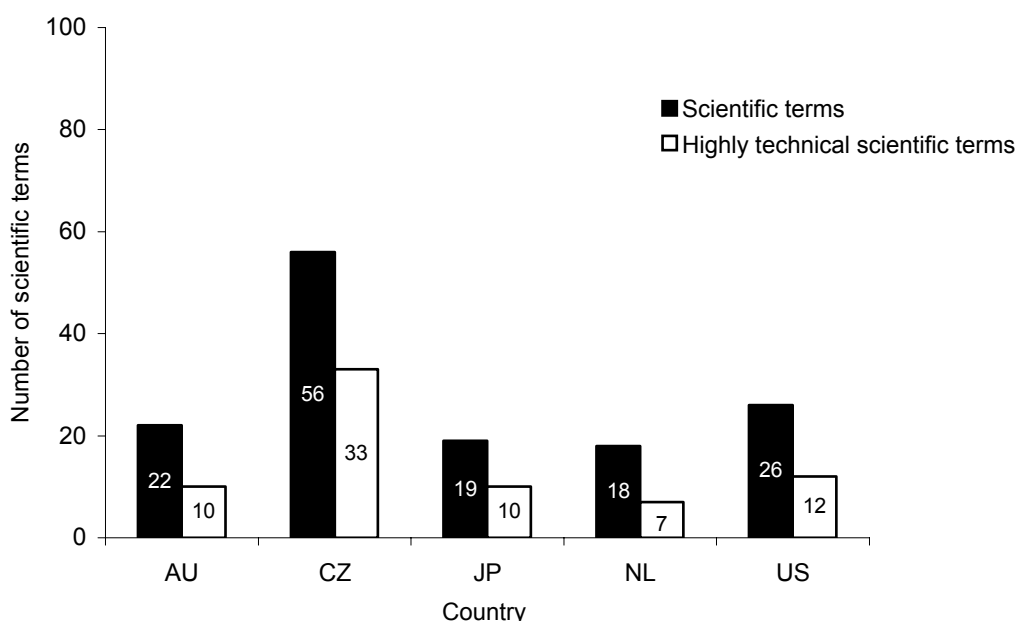
The use of highly technical scientific terms is another indicator of the density of content in the Year 8 science lessons. Scientific terms were identified by a team of six scientists who reviewed and categorised the words generated by the computer-assisted analysis that is described in more detail in Chapter 6. Scientific terms can range from terms commonly used outside the classroom (e.g., energy, force, kidney) to highly technical terms that students would not be likely to

encounter in everyday talk (e.g., photosynthesis, magma and ions). Highly technical terms, which are a subset of scientific terms, were defined as follows:

- **Highly technical scientific term:** A one- to three-word expression with a specific scientific meaning that is likely to be used to support science learning in the classroom, and is not likely to be encountered by students in everyday talk. A count of unrepeated highly technical scientific terms in a lesson describes how many different highly technical terms are used in that lesson.

Figure 4.7 displays the numbers of scientific terms and highly technical scientific terms that were spoken during the Year 8 science lessons in the five countries, on average.

**Figure 4.7 Average numbers of different scientific terms and highly technical scientific terms per Year 8 science lesson spoken during public talk**



Scientific terms: CZ>AU, JP, NL, US; US>NL

Highly technical scientific terms: CZ>AU, JP, NL, US; US>NL

*Note:* Analyses based on English language transcripts. The tests for significance take into account the standard error for the reported differences. Thus, a difference between averages of two countries may be significant while a similar apparent difference between two other countries may not be significant.

As would probably be expected from the dominant content focus of their Year 8 science lessons, students in the Czech Republic were more likely to be exposed to a higher density of scientific terms than students in the other countries. Czech lessons also contained more highly technical scientific terms, on average, than lessons in all the other countries (Figure 4.7). In addition, United States lessons contained more scientific terms and more highly technical scientific terms, on average, than Dutch lessons. *AU PRL 3, 00:02:29 – 00:05:51*, where students are labelling parts of the kidney on a diagram, is an example.

### **Lesson coherence**

Lesson coherence can be assessed in several ways. While a lesson with many ideas and scientific terms, as discussed in the previous section, might be organised in a coherent way, it seems reasonable to suggest that a lesson focusing on one or two main ideas would be more likely to provide the time necessary to develop a connected and coherent lesson. There are other indicators of coherence that may support this suggestion, or may tell a different story. In this section, countries are compared on three aspects of coherence that were observed in the Year 8 science lessons: 1) whether the pattern of content development focused on making connections versus

acquiring facts, definitions and algorithms; 2) whether strong conceptual links were made among ideas in the lesson; and 3) ways in which goal and summary statements were used to clarify the organisation of the lesson content. How coherent were the Australian Year 8 science lessons?

- *In almost 60 per cent of the Australian lessons, content was developed through making connections. The connections were made primarily through content-focused inquiry, with strong conceptual links between pieces of content and between information and activities. Australia and Japan were similar to each other in these respects, and mostly different from the other three countries.*

#### Patterns of content development

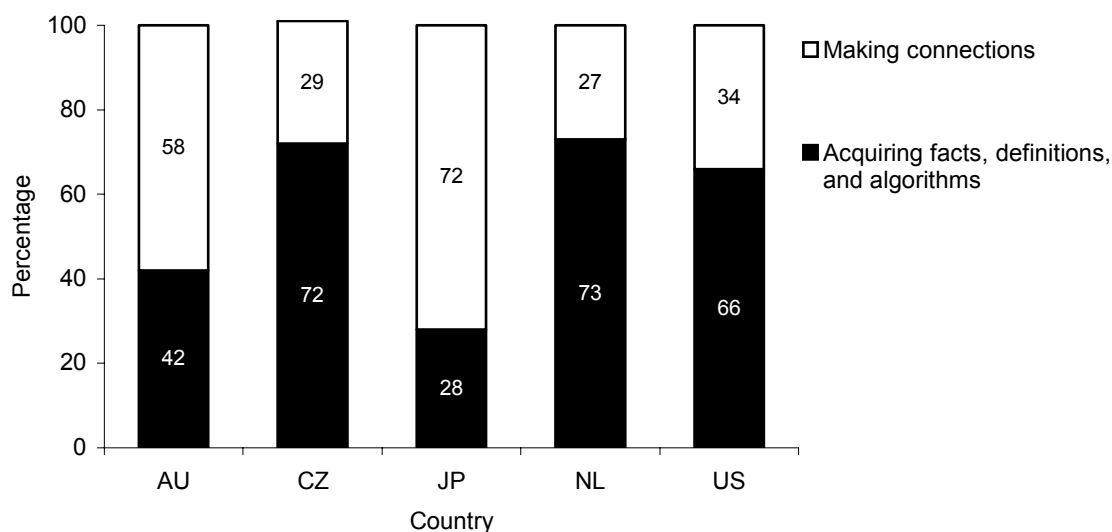
Students' opportunities to learn science are shaped by how teachers organise the way content is developed in their lessons as well as the nature of the content. The participating countries were compared on observations of two primary ways teachers developed scientific content within the lesson: 1) making connections among experiences, ideas, patterns in data and explanations through pattern-based reasoning; and 2) acquiring facts, definitions and algorithms through memorisation and practice. These two ways were defined as:

- Making connections: The primary approach in the lesson is to support students in making connections among experiences, ideas, patterns and explanations. Teachers and/or students are engaged in pattern-based reasoning – that is, recognising, explaining and using patterns in data by working on such tasks as building a case or an argument to explain patterns observed in data, predicting patterns in data from scientific laws or theories, or collecting data to verify the predicted patterns. (AU PRL 5 is a lesson where most of the scientific ideas are related to patterns in observations and experiences and AU PRL 2, 00:20:14 – 00:21:40 is a specific instance.)
- Acquiring facts, definitions and algorithms: The primary approach in the lesson is to teach students a set of facts, definitions or problem solving procedures that they will acquire primarily through memorisation and practice. Problem solving is limited to following linear, step-by-step procedures. The information is presented as distinct pieces that are not organised within a larger conceptual framework linking experiences, data and explanations. (AU PRL 3 is a lesson where most of the scientific ideas are concerned with facts and definitions.)

Figure 4.8 displays the percentages of Year 8 science lessons in which the scientific content was developed primarily by making connections or primarily by acquiring facts, definitions and algorithms. Although some lessons contained both approaches for developing content, the lessons were categorised based on the predominance of one approach or the other. As the figure shows, students in Japan were more likely to be in science lessons in which the content was developed primarily by making connections than by acquiring facts, definitions and algorithms. On the other hand, students in the Czech Republic, the Netherlands and the United States were more likely to be in science lessons in which the content was developed by acquiring facts, definitions and algorithms than by making connections. That content was developed primarily through making connections in almost 60 per cent of the Australian science lessons is particularly interesting in light of the lack of emphasis on making connections observed for Australia in the mathematics video study (Hiebert et al., 2003).<sup>33</sup>

<sup>33</sup> The codes used in the mathematics component of the TIMSS 1999 Video Study were developed by a different coding team from the codes in the science component. Nevertheless, similar ideas were used for many of the variables coded, including 'making connections', as the science code developers were able to draw on the mathematics code developers' experience.



**Figure 4.8** Percentage distributions of Year 8 science lessons according to the main method of scientific content development

Making connections: AU, JP>CZ, NL; JP>US

Acquiring facts, definitions, and algorithms: CZ, NL>AU, JP; US>JP

Note: Totals may not sum to 100 because of rounding.

It is possible that country variations in how scientific content was developed – that is, by making connections or by acquiring facts, definitions and algorithms – may be explained by differences in the distribution of science disciplines among countries rather than differences in approaches to developing content. For example, the content of physics lessons might more often be developed by making connections while biology content may more frequently be developed by acquiring facts, definitions and algorithms. In such a case, a country represented by a sample with more physics lessons would also be identified as having more lessons in which the content was developed through making connections.

To determine whether there was a relationship between the topic area of the lesson and the approach taken, the percentages of Year 8 science lessons that used the two approaches for developing content were compared for each of the four main disciplines of science identified at the beginning of the chapter (see Figure 4.1). The results showed very few significant differences and no clear relationship between the science discipline and the pattern of content development.<sup>34</sup>

#### Ways of making connections

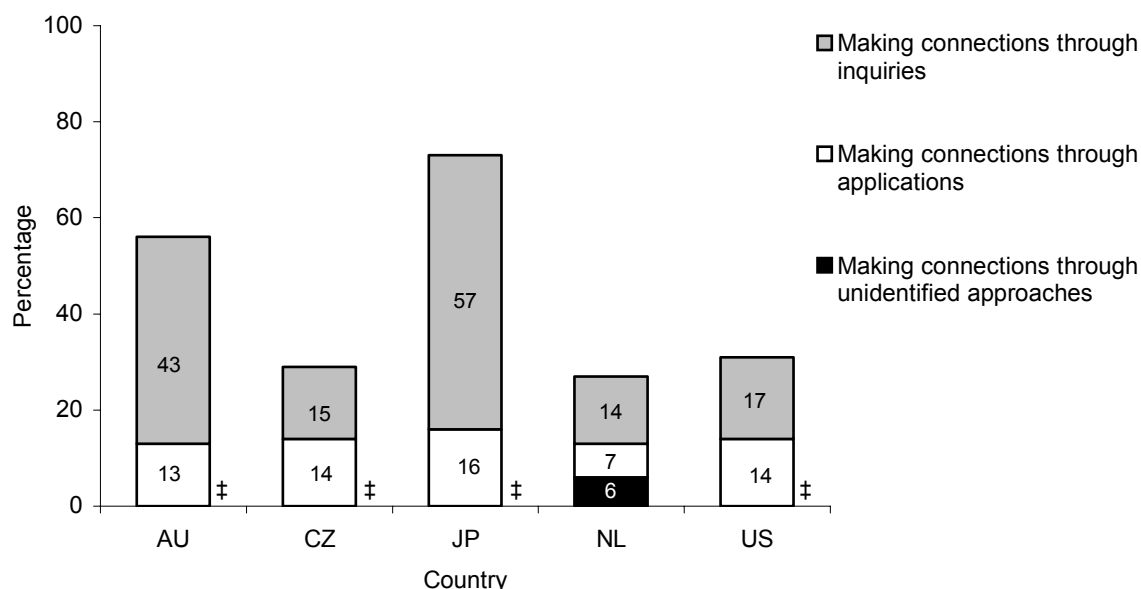
The primary way in which connections were made between experiences, ideas, patterns in data and explanations was identified in each of the science lessons based on the following definitions:

- **Inquiries:** Inductive approaches are used to construct explanations from patterns in data or experiences. The development of the scientific content involves posing a question, generating data, identifying patterns in the data and constructing explanations for these patterns.
- **Applications:** Deductive approaches are used to apply scientific ideas or theories to describe, explain or predict patterns in data or in experiences. Students first learn about the scientific content and then use or verify these ideas through analyses of data and experiences.
- **Unidentified approaches:** The teacher helps students make connections in a way that is not defined as primarily making connections through inquiries or applications.

<sup>34</sup> The results are reported in Table E.6 in the international report (Roth et al., 2006).

Figure 4.9 displays the percentages of lessons according to the way that connections were made in developing the scientific content – primarily through an inquiry or inductive approach or through an applications or deductive approach, or an unidentified approach. The data relate to the overall percentages of lessons categorised as making connections only (see Figure 4.8).

**Figure 4.9 Percentages of Year 8 science lessons that primarily developed scientific content through various approaches for making connections**



† Fewer than three cases reported (country excluded from the relevant analysis)

Making connections through inquiries: AU, JP>CZ, NL, US

*Note:* Only those lessons identified as developing scientific content primarily by making connections are included in the analysis (see Figure 4.8). The unequal distribution of developing content by making connections among the five countries means that different ways of making connections will be unequally distributed among the countries as well. The analyses that follow highlight the relative emphasis of different ways of making connections within each country.

Countries varied in the percentages of Year 8 science lessons that primarily developed content by making connections in an inquiry or inductive mode, as shown in the above figure. Teachers in more Australian and Japanese science lessons used an inquiry or inductive approach to make connections among ideas, data and experiences (43 per cent in Australia) than did teachers in Czech, Dutch, and United States lessons. The countries did not differ on making connections in an applications or deductive mode. Within Australia and Japan, content in science lessons was more often developed by making connections primarily through an inquiry or inductive mode than primarily through an application or deductive mode; no measurable difference was detected within any of the other three countries.

#### Ways of acquiring facts, definitions and algorithms

The primary way in which facts, definitions, and algorithms were used to develop scientific content was also identified for each lesson. The different approaches to acquiring facts, definitions, and algorithms included: a focus on algorithms and techniques; a focus on sequences of events; a focus on discrete bits of information; and other approaches. Variations appeared within the Czech Republic and the Netherlands, where teachers of more lessons developed scientific content by helping students acquire facts by focusing on discrete bits of information than on algorithms and techniques or sequences of events. In the United States, lessons were equally likely to focus on acquiring algorithms and techniques as on acquiring discrete bits of information. Lessons in Australia and Japan relied on presentation of discrete bits of information less than did lessons in

the Czech Republic and the Netherlands. A focus on sequences of events occurred only in the Czech Republic.<sup>35</sup>

### Conceptual links

Whether or not conceptual links were made was identified as a second indicator of content coherence. To assess the overall coherence of the content development in the Year 8 science lessons, all parts of a lesson in which content was developed were considered (excluding the segments of the lesson that focused on review, formal assessment and ‘other’ functions as defined in Chapter 3). The lessons were reviewed for the presence of statements or activities that organised ideas together in a conceptual framework (such as goal and summary statements, concept maps, highlighting statements and outlines). The linking statements could be made by the teacher, or supplied by the textbook or worksheet, the students or some other source. The focus of each lesson was then categorised using the following definitions:

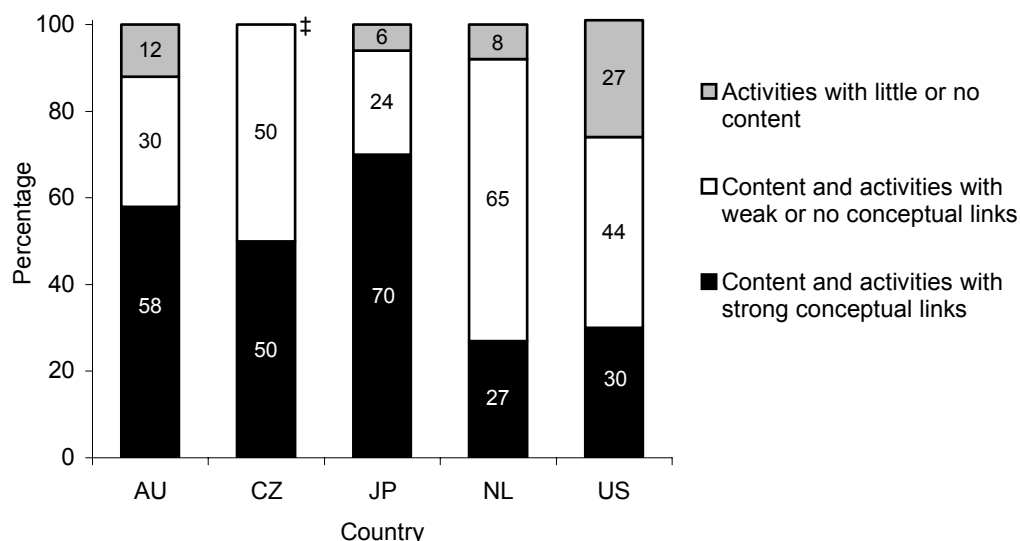
- Undertaking activities with no conceptual links: The teacher focuses students’ attention primarily on carrying out an activity or a procedure rather than learning a content idea. Students may encounter some scientific content in the process of carrying out an activity, but the information is presented as isolated bits of information without being linked to a larger concept (see the definitions presented earlier in the chapter in the section ‘Opportunity to learn scientific content’).
- Learning content with weak or no conceptual links: The lesson contains at least some content but there are only weak or no obvious conceptual links that integrate the information and activities. The information and tasks presented are connected only by a shared topic or by one or two concepts that tie together some of the ideas or activities but do not connect all the information together. An example of such content-focused lessons includes the following:
  - Information about the different parts of the heart and the different kinds of blood vessels and blood cells is presented. The teacher then briefly states that the heart, blood vessels and blood cells are all part of the circulatory system and then engages students in an activity about pulse rate. The conceptual idea about the circulatory system is only briefly mentioned and is never connected to the pulse rate activity, developed further or used by the students, nor is it used as an organising framework to tie together the ideas and activities of the lesson.
- Learning content with strong conceptual links: The lesson focuses on content with conceptual links that strongly connect and integrate the information and activities. The information presented consists primarily of interlocking ideas, with one idea building on another as strong conceptual links are made. The lesson contains a strong conceptual thread that weaves the entire lesson into an organised whole. An example of a content-focused lesson with strong conceptual links follows (see *AU PRL 2*):
  - The lesson begins with the teacher pointing to metals and non-metals on the Periodic Table and saying: ‘Today we will explore the chemical differences between metals and non-metals, and you will learn how all these metals here and these non-metals here behave chemically in similar ways.’ After demonstrating the differences in how sulfur (a non-metal) burns compared with magnesium (a metal), the teacher instructs the students to carry out independently a series of reactions with metals and non-metals to find patterns and common features across the different reactions. The teacher then helps students link these activities to concepts about metals and non-metals through a discussion and interpretation of the results. At the end of the lesson, the teacher asks students to write their own conclusions and then ends the lesson with a discussion and summary about the differences between metals and non-metals.

Figure 4.10 presents the percentage distributions of lessons according to the nature of their main focus and the presence or absence and nature of conceptual links within the lessons. More Australian and Japanese Year 8 science lessons were judged to focus on learning with strong

<sup>35</sup> The results are reported in Figure E.1 in the international report (Roth et al., 2006).

conceptual links (58 per cent in Australia) compared with Dutch and United States lessons and more Czech lessons were judged to focus on learning with strong conceptual links compared with Dutch lessons. In addition, more Dutch than Australian or Japanese lessons, and more Czech than Japanese lessons, were content-focused with weak or no conceptual links.

**Figure 4.10 Percentage distributions of Year 8 science lessons by focus and strength of conceptual links**



† Fewer than three cases reported (country excluded from the relevant analysis)

Activities with little or no content: US>JP, NL

Content and activities with weak or no conceptual links: CZ>JP; NL>AU, JP

Content and activities with strong conceptual links: AU, JP>NL, US; CZ>NL

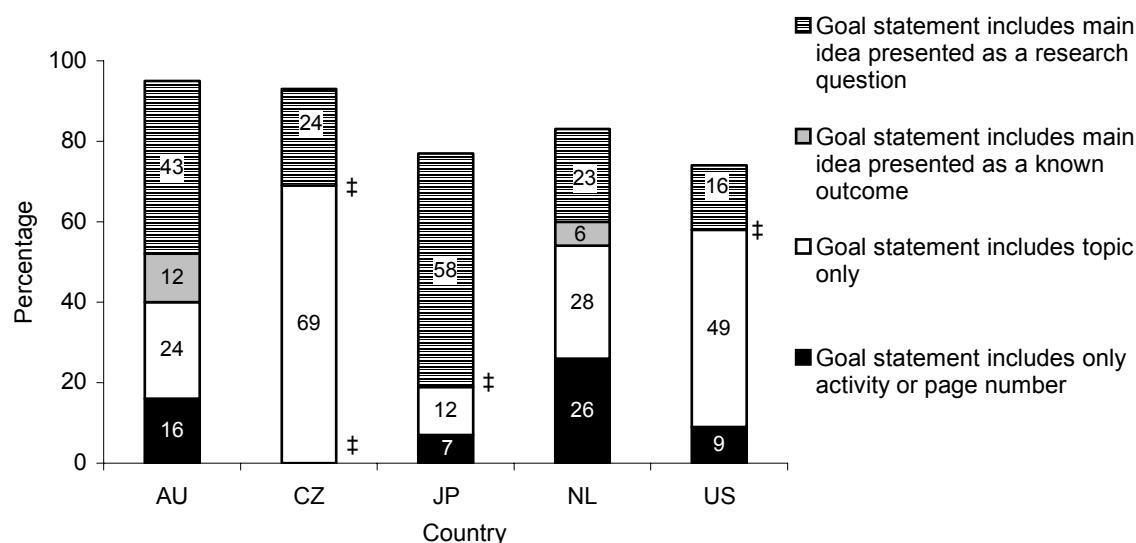
Note: Totals may not sum to 100 because of rounding and data not reported.

Within all of the countries except the United States, more lessons were judged to involve learning content (with weak or strong conceptual links) than merely undertaking activities, as mentioned earlier in the chapter. As well, more of the lessons involving learning content within Australia and Japan were judged to contain strong conceptual links than weak or no conceptual links, whereas more of the lessons involving learning content within the Netherlands contained only weak conceptual links. No measurable difference was found within the United States between the three types of approach shown in Figure 4.10.

In each of Australia, Japan, the Netherlands and the United States, the percentage of lessons with strong conceptual links is the same, or about the same, as the percentage of lessons classified as primarily 'making connections' shown in Figure 4.8. In these countries, the lessons classified as primarily 'acquiring facts, definitions or algorithms' were clearly a mixture of activities with weak or no conceptual links, or had minimal scientific content. In the Czech Republic the percentage of lessons classified as primarily 'acquiring facts, definitions and algorithms' (Figure 4.8) is about 20 per cent greater than the percentage for 'content and activities with strong conceptual links' (Figure 4.10), implying that some of the lessons focusing on acquisition of facts and algorithms did so in a conceptually linked way.

#### Goal and summary statements

Goal and summary statements placed at strategic times during a lesson can help to make the lesson more coherent and therefore easier for students to follow. The incidence of use of goal and summary statements across countries is discussed in Chapter 3 and illustrated in Figure 3.10. In the present chapter information is given about the range of ways that goal statements were made, as displayed in Figure 4.11.

**Figure 4.11** Percentage distributions of Year 8 science lessons with various types of goal statement

‡ Fewer than three cases reported (country excluded from the relevant analysis)

Main idea presented as a research question: AU>US; JP>CZ, NL, US

Topic only: CZ>AU, JP, NL, US; US>AU, JP

Activity or page number only: NL>JP

Note: Totals may not sum to 100 because of rounding and data not reported. Lessons without goal statements are not included in the analyses (see Figure 3.10 in Chapter 3).

Goal statements may be especially helpful for students when they go beyond simply naming the topic or activity for the day and instead identify the key ideas or questions of the lesson (Kesidou & Roseman, 2002). Some goal statements simply name the topic of study ('Today we will learn about the kidneys'), the activity ('Today we are going to do a lab experiment'), or the pages to be covered ('In today's lesson we will finish Chapter 3'). Providing students with descriptions of the main idea of the lesson presented as a known outcome ('In today's lesson you will be able to explore firsthand what we learned yesterday about sound travelling at different speeds depending on the medium') or the central research question for the lesson ('Today we will find out how the medium affects the travel of sound') can increase the coherence of a lesson by providing students with a conceptual framework.

The data shown in Figure 4.11 both support and elaborate on the data presented in Figure 4.10. In both Australia and Japan, more than half the goal statements were of the kinds that can increase the coherence of the lesson, whereas teachers in the Czech Republic (69%) tended to mention only the topic of the lesson (in other countries this ranged from 12 per cent in Japan to 49 per cent in the United States). Teachers in the Netherlands were more likely than teachers in Japan to mention an activity or page number only.

The teacher of *AU PRL 2*, a lesson judged to be very coherent, had particularly useful ways of providing goal and summary statements, as he explained:

I tend to use flow charts as a lesson introduction – a type of mind map to tie together past class work, this lesson, and concepts that will be developed in future lessons. (*AU PRL 2, Teacher's Comments, 00:00:00*), and

I try always to use previous knowledge to develop new knowledge, to go from the known to the unknown using student-guided summaries of the lesson's main points. (*AU PRL 2, Teacher's Comments, 00:15:20*)

### **Level of challenge of the scientific content**

Curricular choices regarding the level of challenge of the scientific content and the types of canonical ideas that teachers present to students can vary, thus exposing students to different levels

of complexity of scientific knowledge. 'Level of challenge' can be examined in various ways. For example, content may be judged as challenging if a lesson is dense with many canonical ideas. Using this measure, Czech lessons would appear to be more challenging than Japanese lessons, for example, as discussed earlier in the chapter. But the level of challenge of the content can also be assessed in terms of the quality of the content, rather than the quantity. In this section, the challenge of the content is examined in terms of its complexity for Year 8 students. Two indicators were used: 1) the difficulty and complexity of the ideas; and 2) the inclusion of more abstract, theoretical knowledge.

How challenging was the scientific content of the Australian lessons?

- *In 57 per cent of the Australian lessons, the scientific content was judged to be at basic level only. The Czech Republic, where only 18 per cent of the lessons were judged to be at a basic level of challenge, differed from the other four countries in this respect. Only 9 per cent of the Australian lessons involved content that was judged to be highly challenging.*

### Challenging and basic content

National standards or curriculum documents on science describe content that some experts in their countries believe is appropriate for Year 8 students to learn (AAAS, 1993; AEC, 1994; Czech Ministry of Education, 1996; Dutch Ministry of Education, Culture, and Science, 1998; NRC, 1996). Based on the definitions in these documents, the concepts and/or procedures used to teach science in the Year 8 science lessons were rated for their complexity and challenge to the students.

For these analyses, a Science Content Coding Team was assembled to evaluate each lesson. Because the lessons varied in terms of the disciplinary areas covered (for example, biology, chemistry, geology or physics), team members coded lessons within their own disciplinary expertise for the level of challenge. When disagreements were encountered among the coding team, differences were resolved through discussion. Training and reliability checks assured consistent judgments based on the inherent complexity of the content being taught and the level of challenge of the information for Year 8 students according to a review of the curricular and standards documents from the five countries.<sup>36</sup>

To code the lessons, the Science Content Coding Team used the following definitions:

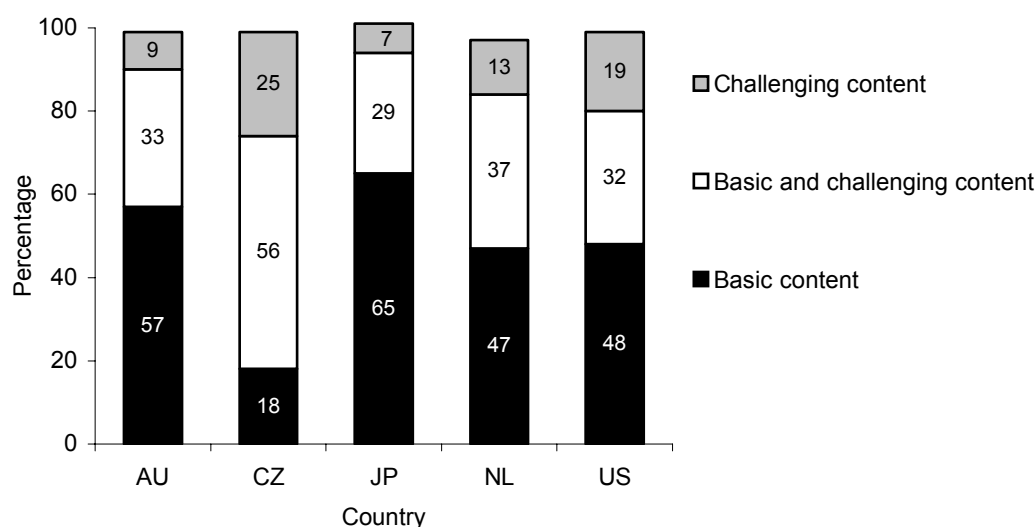
- Challenging content: The scientific information includes a substantial amount of difficult and/or complex ideas for Year 8 students, relative to the overall information presented in the lesson. Ideas were judged as difficult if they were represented as standards or curriculum goals for students in grades or at ages above those participating in the study in the five countries. Ideas were considered complex if they involved multiple steps or interrelated parts, if they required putting different pieces of information together or required higher level thinking in order to be understood. Examples of challenging content for Year 8 include: discussions of nuclear reactions; the role of adenosine triphosphate (ATP) in cell respiration; differences between organic and inorganic materials; oxidation/reduction reactions; balancing chemical equations; radioactivity; electromagnetic forces within atoms; heat and energy patterns inside the earth; wave theory; mathematical calculations about sound travel; and mathematical representations of Archimedes Law.
- Basic and challenging content: The scientific information includes mostly simple and basic ideas in the overall lesson, but there are also some challenging or complex ideas for Year 8 science. For example, a lesson on electricity may focus on presenting students with basic definitions and examples of parallel and series circuits, but also include some attention to the more challenging concept of Ohm's law. (AU PRL 2 is an example of a lesson containing a mix of basic and challenging content.)

<sup>36</sup> A level of at least 98 per cent agreement within and across pairs during the monitoring of coding reliability was achieved by this team. The team members are listed in Roth et al. (2006).

- **Basic content:** The scientific information includes predominantly simple and basic ideas in the overall lesson, which are likely to be easily understood by most Year 8 students. In a lesson containing predominantly basic scientific content and procedures, the teacher may discuss the physical characteristics of acids and bases (for example, acids taste sour and corrode metal; bases taste bitter and feel slippery), instruct students on how to use litmus paper and require students to test several household liquids to determine whether they are acids or bases.

Figure 4.12 displays the percentage distributions of Year 8 science lessons according to the Science Content Coding Team's judgments of the level of challenge of the lesson content.

**Figure 4.12 Percentage distributions of Year 8 science lessons according to experts' judgments of the level of challenge of their scientific content**



Challenging content: CZ>JP

Basic and challenging content: CZ>AU, JP, US

Basic content: AU, JP, NL, US>CZ

Note: Totals may not sum to 100 because of rounding.

According to the coding team's judgment ratings, students were presented with predominantly basic content in 47 to 65 per cent of the Year 8 science lessons in all the countries except the Czech Republic (57 per cent in Australia). More Czech lessons presented students with a mix of basic and some challenging content compared with Australian, Japanese and United States lessons, and more Czech lessons presented students with predominantly challenging content compared with Japanese lessons. Australian and Japanese lessons were more likely to present basic content to students than more challenging content or a mix of basic and more challenging content, whereas Czech lessons were more likely to present a mix or more challenging content than basic content.

Variations in the challenge of the scientific content could be related to the specific discipline presented in a lesson. In checking for such a relationship, comparisons within the countries identified few significant differences and no detectable overall pattern indicating that the content of one discipline was more challenging than another (excluding earth science for which reliable estimates could only be calculated for the United States).<sup>37</sup>

#### Scientific laws and theories

A review of research on learning highlights the progression in learning from the concrete to the abstract. Students learn most easily about things that are tangible and within their own experience and have most difficulty with more abstract concepts and generalisations such as theories (AAAS,

<sup>37</sup> The results of this analysis are included in Table E.7 in the international report (Roth et al., 2006).

1990). Therefore, another way of assessing the level of challenge of the scientific content in the lessons is to examine the abstractness of the content. Of interest is whether the lessons provided students with opportunities to learn about explanations, processes and patterns that they could not directly observe in the classroom. As an indicator of the level of abstractness, the public talk parts of the lessons were examined for the presentation of generalisable scientific laws and theories (limitations of the video technology made it difficult to determine whether students were focusing on or using theoretical knowledge during independent work).

Scientific laws and theories were defined as follows:

- **Scientific laws and theories:** Publicly-presented generalised explanations of patterns of data and events in the real world that have been established and more or less verified to account for known facts and phenomena. Laws and theories predict across a large range of phenomena and/or contexts that students cannot directly observe. Examples include: Newton's First Law of Motion; the conservation of mass; and Archimedes' Law. Theoretical ideas include, for example: explanations of sound behaviour based on the particulate theory of matter; plate tectonics and the relationship to earthquakes; and evolution. (e.g. AU PRL 5, 00:07:05 – 00:09:55, where the teacher publicly develops theory associated with gravity, is an example.)

Scientific laws and theories were publicly-presented in no more than 49 per cent of the Year 8 science lessons across all of the participating countries (29 per cent in Australia). They were observed being publicly presented in more Czech science lessons (49%) than in Japanese or Dutch lessons (15 and 19 per cent, respectively) and in more United States lessons (40%) than Japanese lessons (data not shown).

### **Uses of Evidence in Developing the Scientific Content of Lessons**

This section focuses on the types of evidence used to develop the scientific content in the Year 8 science lessons. A central practice of the scientific community is supporting knowledge claims with various forms of evidence such as data, natural phenomena and visual representations of data and phenomena (Kelly & Chen, 1999; Lemke, 1990). As reviewed in Roth et al. (2006), scientific concepts are not simply propositional knowledge, but rather whole systems of linked practices that include ways of talking, ways of collecting data by observing and measuring, ways of representing data and ideas and ways of seeing and interpreting. Based on substantial research evidence, science education and reform literature often argue that educators need to provide students with opportunities to experience and appropriate the full range of these scientific practices.

Some researchers claim that, to learn science effectively, students need to be exposed to and understand several different representations of scientific concepts (for example, graphs, figures, formulae and three-dimensional models). The contention is that this will support students in making sense of key ideas and in coordinating ideas, phenomena, experiences and data in meaningful ways. Investigating the extent to which scientific knowledge in the lessons is supported by various kinds of evidence, as done in this study, provides an important picture of how science is represented in the classroom.

### **Country perspectives**

The stated goals of science education in each of the participating countries provide rationales for investigating the extent to which ideas are supported by evidence in the Year 8 science lessons. The observations on uses of evidence to support content development inform the science education and research communities about the extent to which the countries' stated goals are currently being implemented.

In Australia, one stated goal is for students to use scientific language appropriately to create visual representations such as drawings and graphs. In addition, practical work in which students generate data is emphasised for its value in enabling students to 'work back-and-forth between theoretical ideas and direct experience' (AEC, 1994, p. 6). Czech teaching goals emphasise the importance of balance between theoretical knowledge and empirical knowledge developed through demonstrations and independent practical work (Nelesovska & Spalcilova, 1998). In Japan, current





secondary school reforms emphasise scientific ways of thinking, which include drawing on direct experience and observation to construct analytical and integrated points of view (Goto, 2001).

A goal of science education in the Netherlands is to enable students to describe and interpret phenomena from a scientific point of view. This goal includes acquiring abilities such as observing, data collecting and relating scientific concepts and skills to phenomena observable in daily life (Dutch Ministry of Education, Culture, and Science, 1998). United States documents emphasise the need for students to engage in scientific inquiries in which they actively collect data and represent data in different forms in order to detect patterns and communicate findings to others. Teachers are encouraged to focus these inquiries on real phenomena and to use these phenomena to support conceptual understandings. They are also encouraged to make use of multiple representations, phenomena and data sets to give students opportunities to apply new ideas in multiple contexts (AAAS, 1990; 1993).

It was of interest in this study to find out what types of evidence were used in the videotaped lessons and also whether main ideas were supported with multiple sets and types of evidence.

### *Types of evidence used*

This section describes the kinds of evidence that teachers use to support the development of the scientific content, either publicly or privately, in Year 8 science lessons. Three distinct types of evidence were used to develop and illustrate the different types of scientific knowledge defined and described early in this chapter: first-hand data; phenomena; and visual representations. These types of evidence were defined as follows:

- First-hand data: Observations or measurements of specific change events (phenomena) or real-world objects observed by students in the classroom. Examples include phenomena such as: the sound that a tuning fork produces during a teacher demonstration on the property of sound; the brightness of a light globe observed by students while building circuits to learn about electric current; or the air temperature in sunny and shady locations of the playground. They also include real-world objects such as: a jar of vinegar displayed by the teacher as an example of a common acidic substance; and a rock passed around and described by the teacher as a sedimentary rock.  All of the released Australian lessons contain examples of first-hand data, though mostly the data are associated with observations of phenomena (see below).
- Phenomena: Change events of scientific interest that students have the opportunity to observe and/or experience. For example, the teacher may melt ice in a glass so that students can see condensation appear on the sides of the glass, or students may observe a pea plant at different stages of development to learn about plant growth. Phenomena are commonly produced by the teacher or students through first-hand observations, but they may occur through simulated experiences as well. As an example,  AU PRL 2, 00:07:30 – 00:11:55 shows the teacher publicly setting up an independent activity where the students will burn magnesium ribbon and place the remains in a universal indicator solution to see if the solution changes colour (this segment also refers to two aspects of safety knowledge).

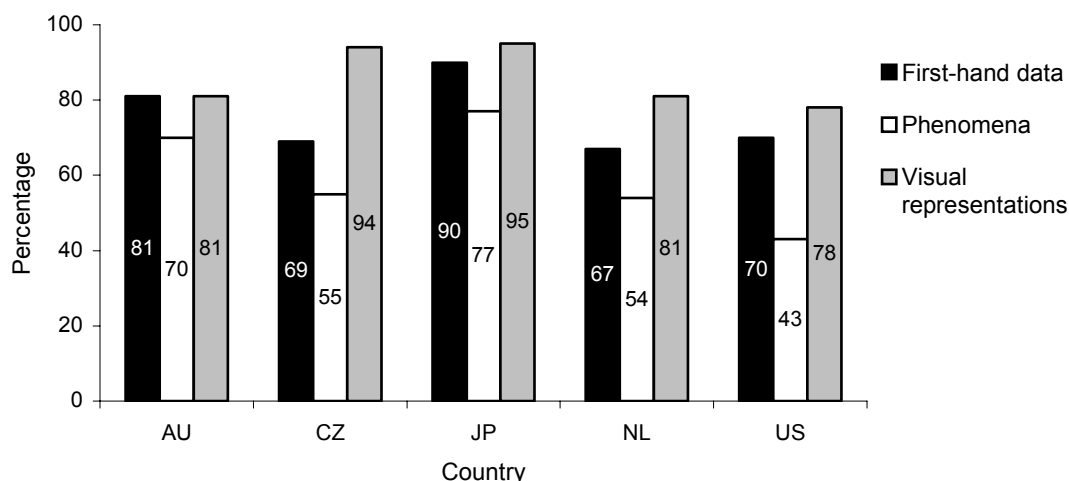
Phenomena are a subcategory of first-hand data. Except for simulated phenomena, phenomena always generate first-hand data, whereas first-hand data can be produced without the occurrence of observable phenomena in the classroom. For example, observing examples of different kinds of rocks is considered an experience with first-hand data, but is not considered as a phenomenon (in the sense of events undergoing some change) that students can observe during the lesson. Therefore, as a special subset of first-hand data, phenomena are examined separately.

- Visual representations: Visual images that provide compact descriptions or drawings to illustrate real objects, data, processes or procedures. Visual representations often include words along with some kind of organising framework to help students imagine or better understand the real object, process or procedure. For example, students observe a diagram, a three-dimensional model or a photograph of a human heart, rather than an actual heart. The diagram can include arrows and words that help students visualise the process of blood flow. Thus, the visual representation may highlight concepts and processes as well as the object or data. The

lesson segment where students are using a model, drawn on paper, to label parts of the kidney illustrates the use of a visual representation (AU PRL 3, 00:01:54 – 00:05:51).

Figure 4.13 presents the percentages of Year 8 science lessons that incorporated first-hand data, phenomena and visual representations.

**Figure 4.13 Percentages of Year 8 science lessons that incorporated at least one instance of various types of evidence**



First-hand data: JP>CZ, NL

Phenomena: AU>US; JP>CZ, NL, US

Visual representations: JP>AU

*Note:* The tests for significance take into account the standard error for the reported differences. Thus, a difference between averages of two countries may be significant while a similar apparent difference between two other countries may not be significant.

Use of first-hand data to support the development of scientific concepts occurred in at least two-thirds of the Year 8 science lessons and observations of phenomena were made in at least 43 per cent of the lessons across the countries, as shown in Figure 4.13. Japanese science lessons were more likely to include first-hand data in support of ideas being developed than Czech and Dutch lessons. Japanese lessons also incorporated observations of phenomena in a higher proportion of lessons than all the other countries except Australia. Except in the United States, it is clear from comparison of the black columns with the white columns in the graph that most of the first-hand data was generated from observations of phenomena. The United States lessons were less likely to include observations of phenomena than lessons in either Australia or Japan.

Visual representations were used in at least three-quarters of the lessons, ranging from 78 per cent in the United States to 95 per cent in Japan. Visual representations were used more often than phenomena within all the countries except Australia.

### ***Types of visual representation***

Five distinct types of visual representation were observed in the Year 8 science lessons: diagrams, three-dimensional models, graphic representations, diagrams, formulae and 'other'.

Although diagrams were used in all countries in more than half of the lessons (57 per cent in Australia), the use of diagrams occurred more in Japan (80 per cent of lessons) than in all the other countries except the Czech Republic (78 per cent of lessons). Formulae were used more often in Czech lessons (39%) than in the lessons of the other four countries (5 per cent in Australia to 17 per cent in Japan). Three-dimensional models were used more often in Czech lessons (31%) than

in Japanese (5%) and United States lessons (6%). The countries did not differ in the use of graphic representations, which occurred in 36 per cent of the Dutch lessons to 53 per cent of the Australian lessons (data not shown).<sup>38</sup>

### ***Multiple types of visual representation***

Figure 4.13 also illustrates the fact that more than three-quarters of the science lessons per country used at least one type of visual representation. Additional analyses showed that teachers in the Czech Republic were more likely to utilise multiple distinct types of visual representation in their Year 8 science lessons than teachers in the other four countries. Seventy-three per cent of the Czech lessons incorporated at least two types of visual representation and 36 per cent included at least three types of visual representation (data not shown).

### ***Support of main ideas with multiple sets and types of evidence***

This section of the chapter describes the extent to which the scientific content of the lessons was supported with multiple instances of evidence in the form of first-hand data, phenomena or visual representations. As briefly mentioned earlier, research indicates that the use of multiple examples, phenomena and representations of ideas may be linked to increased understanding of ideas in science and the ability to transfer learning to new situations (e.g., Ainsworth, 1999; Brenner, Mayer, Moseley, Brar, Durán, Reed & Webb, 1997; Lehrer & Schauble, 2000; Minstrell, 1989; Roth, 1990-91; Stenning, 1998). In addition, students will likely vary in terms of which representations, data or phenomena are most meaningful to them.

#### Main ideas

To portray accurately how teachers develop and support content in science with multiple instances of evidence, it is of most interest to identify all the evidence used to support the same idea. To achieve this, the evidence used to develop and support each individual main idea pertaining to scientific knowledge was identified in each lesson. Main ideas were defined as follows:

- **Main idea:** A set of related information that includes ideas, procedures, activities and/or other types of knowledge that are explicitly interconnected by the teacher, a textbook or other instructional materials. A main idea explicitly combines smaller, related ideas and activities that are developed by the teacher or worked on by the students at some length. A main idea can be developed during public or private interactions, and it can address any type of scientific knowledge as described earlier in the chapter (canonical, procedural and experimental, societal issues, safety, and nature of science).

In a lesson with one main idea, all of the ideas and activities in the lesson are explicitly related to each other. In a lesson with two or more main ideas, there are no explicit connections made between the main ideas.

The results presented in this section describe the extent to which Year 8 science lessons supported all of the main ideas with more than one piece of evidence. Results are presented first for use of more than one instance of each type of evidence within a lesson. These are followed by results for use of all three types of evidence within a lesson. The focus is on supporting all main ideas, rather than just some, in order to examine how consistently students encountered ideas that were supported by multiple sources of evidence.

#### Multiple sets of the same type of evidence

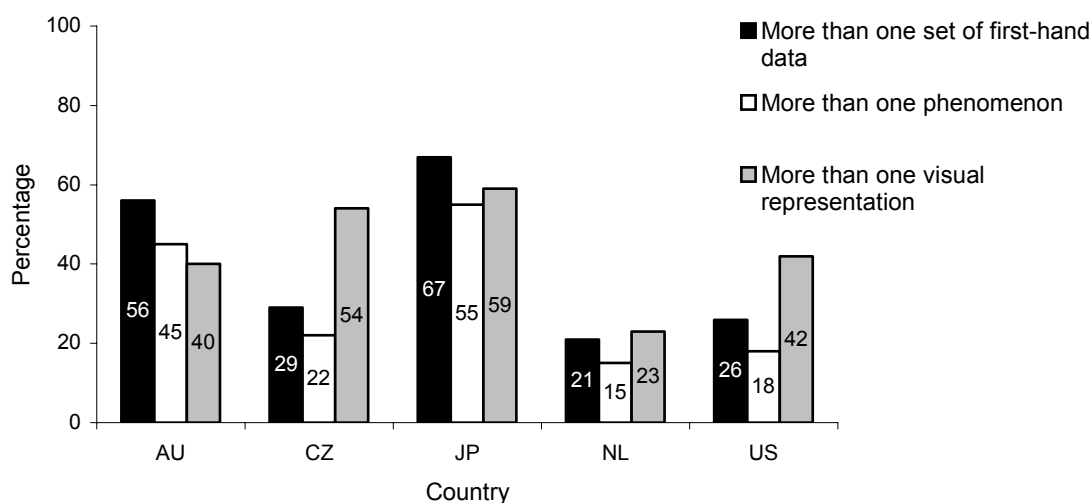
Countries were compared on the percentages of lessons in which teachers developed all main ideas with more than one set of first-hand data, or with more than one phenomenon, and/or with more than one visual representation, as shown in Figure 4.14. For example, a lesson focused on the main idea that condensation can be explained by the behaviour of water molecules may have engaged students in observing multiple phenomena related to this idea: water droplets forming on the outside of a can of soft drink; a 'mini cloud' forming in a 2-litre soft drink bottle; 'fog' forming on a mirror when breathed on; and dew on the morning grass in the school yard.

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<sup>38</sup> The results of this analysis are included in Figure E.2 in the international report (Roth et al., 2006).

Figure 4.14 shows that Australian and Japanese Year 8 science lessons were more likely than the three other countries' lessons to support all of the main ideas with multiple sets of first-hand data (shown by the black columns on the graph) and were also more likely to support all of the main ideas with multiple phenomena (shown by the white columns). For example, in comparison with Australian and Japanese lessons (56 and 67 per cent, respectively), science lessons in the other three countries incorporated multiple sets of first-hand data in only about a fifth of the lessons. More Czech and Japanese lessons supported all main ideas with multiple visual representations compared with lessons in the Netherlands (shown by the grey columns).

**Figure 4.14 Percentages of Year 8 science lessons that supported all main ideas with more than one set of various types of evidence**



More than one set of first-hand data: AU, JP>CZ, NL, US

More than one phenomenon: AU, JP>CZ, NL, US

More than one visual representation: CZ, JP>NL

Within all the participating countries, sets of first-hand data were used to support all of the main ideas in more lessons than were sets of phenomena. Within the Czech Republic and the United States, visual representations were used more often than first-hand data or phenomena to support all of the main ideas.

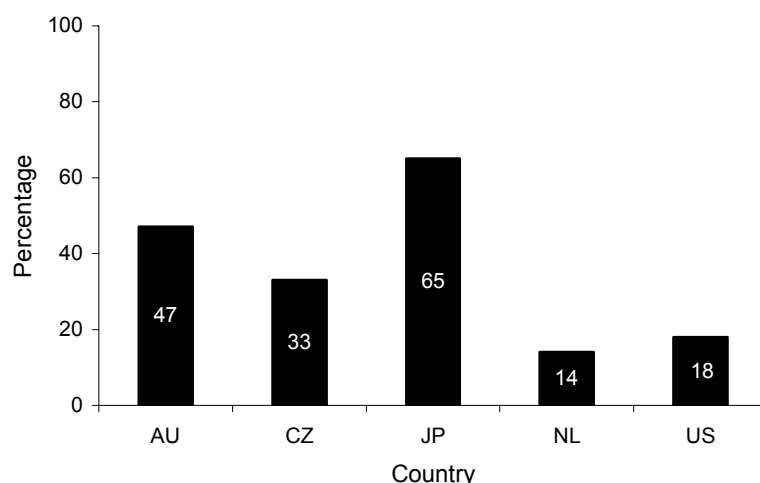
#### Multiple types of evidence

Students may also be presented with multiple yet *different* types of evidence for a given main idea. For example, they may observe a chemical reaction (a phenomenon) and then examine the same reaction in terms of a formula, a diagram or a 3-dimensional model showing how the atoms and molecules behaved during the reaction (a visual representation). Multiple types of evidence provide different ways of examining the main idea. First-hand data and phenomena, on the one hand, may provide a motivating, meaningful context for exploring a main idea, or they may challenge student thinking by providing an unexpected result (a discrepant event, for example). Visual representations, on the other hand, may give students a different, more conceptual or theoretical, way to visualise what is happening with the phenomenon. A visual representation can add an extra dimension to the information presented (a time dimension, for example) or highlight certain features that cannot be revealed with first-hand observations during the lesson.

Figure 4.15 displays the percentages of Year 8 science lessons in which all of the main scientific ideas were supported with at least one of each of three distinct types of evidence: first-hand data;

phenomena; and visual representations. In other words, teachers supported each main idea by providing at least one example of each type of evidence.

**Figure 4.15 Percentages of Year 8 science lessons in which all main ideas were supported with all three of first-hand data, phenomena and visual representations**



*Note:* AU>NL, US; CZ>NL; JP>AU, CZ, NL, US

Countries varied in how often main ideas in a lesson were supported with all three types of evidence, ranging from 14 per cent of the Year 8 science lessons in the Netherlands to 65 per cent of the lessons in Japan. The Japanese science lessons stand out as supporting all main ideas with multiple types of evidence more often than occurred in the lessons in the other four countries. Multiple types of evidence to support all main ideas were used in more Australian lessons than Dutch or United States lessons, and more Czech lessons used multiple types of evidence to support all main ideas compared with Dutch lessons.

### Summary

In this chapter, results were presented on the scientific disciplines and topics covered during the 439 Year 8 science lessons that were videotaped in five countries for this study. Different types of scientific knowledge and a variety of ways in which the lesson content was developed were noted. All of these would have contributed to the students' opportunities to learn science and helped to shape the images of science that the students would take with them into Year 9.

In terms of disciplines, substantial differences across countries were observed in the discipline most commonly taught. At least 47 per cent of Australian and Dutch Year 8 science lessons focused on physics, 36 per cent of Czech lessons focused on life science, 37 per cent of Japanese lessons focused on chemistry and 36 per cent on physics, and 28 per cent of United States lessons focused on earth science (Figure 4.1). There was some similarity across countries in topics addressed within the disciplines, but also much variation. 'Organs and tissues' was the focus of 19 per cent of Czech lessons, 13 per cent of Japanese lessons, 16 per cent of Dutch lessons and 5 per cent of Australian lessons. 'Electricity' was taught in all five countries, ranging from 3 per cent of lessons in the Netherlands and the United States to 28 per cent in Japan (Table 4.1). In Japan, only two topics, chemical changes and electricity, accounted for over 60 per cent of the lessons, while in the United States, 14 different topics were addressed, with no more than 7 per cent of lessons focusing on any given topic (Table 4.1 – note that there were two topics within 'other').

In terms of types of scientific knowledge, 84 per cent or more of the lessons in all countries had segments devoted to 'canonical' knowledge (information about scientific facts, concepts, ideas, processes or theories), occupying on average between 31 and 59 per cent of the lesson time (Figure 4.2). Sixty-nine per cent or more had segments devoted to 'procedural and experimental'

knowledge (information on how to carry out scientific procedures) (Figure 4.3), occupying on average between 11 and 25 per cent of the time (Figure 4.4). Other types of knowledge, although referred to in all or most curriculum guides – knowledge of safety issues, for example – were less commonly addressed across countries.

In terms of the amount of scientific content and ways in which this was developed, lessons were categorised as either primarily offering opportunities for students to learn content knowledge or primarily emphasising activities when students' attentions were focused on carrying out tasks or procedures with no explicit reference to content. Using these definitions, a large majority of lessons in all countries, from 73 per cent in the United States to 100 per cent in the Czech Republic, emphasised the development of content knowledge. Two ways in which the content might be developed were defined: a focus on acquiring facts, definitions and algorithms, and a focus on making connections among experiences, ideas and pattern-based reasoning. All countries had lesson segments featuring each of these methods, but the mix between the methods within countries varied. At one extreme, over 70 per cent of the Czech and Dutch lessons focused on acquiring facts, definitions and algorithms, while at the other extreme, over 70 per cent of the Japanese lessons focused on making connections (Figure 4.8).

Key results for Australia reported in the chapter include the following:<sup>39</sup>

- Half of the Australian lessons focused on physics. Next most common were the quarter of the lessons focused on life science, followed by the 15 per cent focused on chemistry (Figure 4.1).
- Australia, the Czech Republic and the Netherlands were similar in the variety of topics covered, though not in the topics themselves. In Australia, eleven topics were featured in the sampled lessons. 'Electricity' and 'energy types, sources and conversions' were each featured in 10 per cent of the Australian lessons, and 'types of forces' and 'chemical properties' were each featured in 8 per cent. Seven other topics were covered in from 3 to 6 per cent of the remaining lessons (Table 4.1).
- Ninety-seven per cent of the Australian lessons contained segments in which 'canonical' knowledge (scientific facts, concepts, ideas, processes and theories) was covered, though development of this type of knowledge used only about a third of the 'public talk' time (time when the audience was the whole class) (Figure 4.2).
- 'Procedural and experimental' knowledge was developed in over 90 per cent of the Australian lessons, but occupied only 17 per cent of the public talk time (Figures 4.3 and 4.4).
- Despite the emphasis in Australian science curriculum documents on issues related to the nature of science, discussions on this topic were observed in only 4 per cent of the lessons.
- Textbooks or pre-printed workbooks were used as the source of lesson content in only about 20 per cent of the Australian lessons, numerically the lowest of any country (here, the Netherlands was very different from the other countries). The most common sources of content in Australia were worksheets or a handout with procedures to follow in an experiment (almost 40 per cent of lessons), followed by the teacher in lessons where no textbook or worksheet was used (32 per cent of lessons) (Figure 4.6).
- When lessons were categorised as primarily emphasising learning content versus primarily emphasising carrying out activities with no explicit connection to content, 88 per cent of the Australian lessons were deemed to be in the former category. The United States, with 27 per cent of the lessons in the latter category, differed from the other countries on this aspect.
- An average of 22 scientific terms, 10 of which were classified as 'highly technical', were spoken during public talk time in the Australian lessons (Figure 4.7). About three times as many terms in each of these categories were observed in the Czech lessons.

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<sup>39</sup> Note that, in the aspects cited, Australia, Japan, the Netherlands and the United States were often similar to each other. The Czech Republic stood out as being different from the other countries on most of the aspects.

- When the time spent on developing scientific content was categorised as based on ‘making connections’ (as an indicator of lesson coherence) versus ‘acquiring facts, definitions and algorithms’, Japan had the highest percentage of lessons (72%) in the former category. Australia followed, with 58 per cent of the lessons based primarily on making connections (Figure 4.8). Most of the connections were made through inquiries rather than through applications or other methods (Figure 4.9).
- Lesson coherence was also assessed through the use of conceptual links in the development of content during the content-focused lessons. Almost two-thirds of the Australian content-focused lessons featured conceptual links that were judged to be strong (Figure 4.10).
- While the majority of Australian lessons fared well on the coherence criteria, few (9%) were judged to focus primarily on content that was challenging for Year 8 students. This result is not surprising, given that streaming students for science instruction is rare in Australia at this grade level. A third were observed to contain a mixture of basic and challenging content while the content of 57 per cent of the lessons was judged to be at a basic level only (Figure 4.12). Scientific laws and theories were publicly-presented in only 29 per cent of the Australian lessons.
- As appropriate for instruction in science, it was expected that teachers would support the development of content with various kinds of evidence. Incidences of use of visual representations, first-hand data and observations of phenomena were coded. In Australia, visual representations and first-hand data were used in 81 per cent of the lessons and were also commonly used in the other countries. Japan had the highest use of observations of phenomena (77 per cent of lessons) followed by Australia (70 per cent of lessons) (Figure 4.13).
- When lessons were analysed according to use of more than one set of the various types of evidence in support of all the main ideas covered in the lesson, Australia and Japan were found to feature more than one set of first-hand data and more than one phenomenon each in about half or more of the lessons, significantly more than the other countries (Figure 4.14). All three types of evidence were used in more Japanese lessons (65%) than lessons in the other four countries. Australia followed, with all three types of evidence used in 47 per cent of the lessons, more than in the Netherlands and the United States (Figure 4.15).

In a nutshell, the videotaped Australian lessons can be characterised as being primarily content-focused and coherently-structured, generally providing connected, richly supported material as the content is developed. The content itself, however, is typically only at a basic level for Year 8.

The role of scientific inquiry in content development has been mentioned only briefly in this chapter. The next chapter focuses on the important role of practical activities in Year 8 science learning.





## Chapter 5

# SCIENTIFIC INQUIRY THROUGH PRACTICAL ACTIVITIES

Practical activities provide students with the opportunity to observe and/or interact first-hand with objects and related phenomena. They include both traditional laboratory experiments and other hands-on interactions with objects such as producing and observing phenomena, building models, designing and testing technological solutions to problems, classifying materials and drawing observations of objects. Chapter 3 defined practical activities as opportunities for students to observe and/or manipulate science-related objects, reported the amount of time spent on such activities and described the range of contexts in which the activities were undertaken. As discussed, practical activities can be carried out independently by students working in small groups or individually. They can also occur during whole-class interactions, typically when the teacher performs a demonstration for the entire class to view and discuss together. Chapter 5 explores the nature of the practical activities featured in the sampled Year 8 science lessons and examines the ways in which students in those lessons were engaged in science through the use of various inquiry practices.

Inquiry practices describe actions that students are asked to do as they carry out their practical work. The facets of the scientific inquiry process included in this analysis focus on students' work with first-hand data and phenomena:

- asking questions to investigate;
- designing procedures for investigation;
- making predictions;
- gathering qualitative or quantitative data;
- making observations and recording data;
- manipulating data into graphs or charts; and
- interpreting data and linking predictions to results.

### Research Background

Practical activities often are justified as important because they reflect the nature of work in the larger science community, where heavy reliance on the use of empirical evidence supports the building of knowledge (e.g., Jenkins, 1999; Ntombela, 1999; Watson, 2000). However, there are other reasons given for including practical activities in science lessons. Many research and reform documents recommend that students have the opportunity to engage in scientific inquiry actions in science lessons which, if appropriately structured, will enhance students' understanding of science and scientific inquiry processes (e.g., Carey, Evans, Honda, Jay & Unger, 1989; Garnett, Garnett & Hackling, 1995; Hackling & Fairbrother, 1996; Harmon, Smith & Martin, 1997; Hart, Mulhall, Berry, Loughran & Gunstone, 2000; Klopfer, 1990; Lazarowitz & Tamir, 1994; Metz, 1998; White, 1994).

In particular, some assert that first-hand data and observations of phenomena help students to build and understand scientific ideas by making the ideas more concrete or by challenging students' experience-based but scientifically naïve conceptions (e.g., Hodson, 1993; Lazarowitz & Tamir, 1994; Watson, 2000). Others believe that practical activities stimulate and maintain student interest and engagement (e.g., Ben-Zvi, Hofstein, Samuel & Kempa, 1977; Henry, 1975) or provide students with opportunities to practise using particular scientific skills, tools or processes (e.g., Hegarty-Hazel, 1990; Klopfer, 1990; Woolnough & Allsop, 1985). Still others advocate that practical work is useful in helping students learn to cooperate and to understand the collaborative nature of science (e.g., Beatty & Woolnough, 1982; Watson, 2000).

Despite the widespread inclusion of practical activities in the science curriculum in many countries, critiques of practical work in science teaching abound. School science tends to involve students most often in following a prescribed set of steps to arrive at the one correct answer as prescribed by the textbook (Watson, 2000). Critics argue that this does not challenge students to think like scientists and presents a misleading picture of what is involved in doing science (e.g., Hodson, 1991; Millar, LeMarechal & Tiberghien, 1999; Tobin, 1986). Others criticise the teaching of scientific process skills, such as observation skills, in isolation of idea development (Millar & Driver, 1987). This strategy presents science as a set of processes or skills rather than as a way of thinking and arguing from evidence to build ideas (Driver et al., 1996).

Many of the critiques of practical work point to the mixed research evidence that student participation in practical activities leads to improved learning. Reviews of the literature by Hodson (1993) and White (1996) reveal that there is little evidence that practical work improves student understanding of concepts in science and even suggest that there is evidence to support that it is sometimes less effective than other methods (Watson, Prieto & Dillon, 1995). Nevertheless, following his review, White (1996) suggests some ideas for effective laboratories, and argues that:

The acquisition of knowledge of science can be justified as illumination of phenomena, the construction of a coherent system of explanations of natural events, and the appreciation of a lengthy and intensive human enterprise to make sense of the universe. That justification implies that knowledge will involve understanding and valuing of the facts and explanations of science, and commitment to them. The core purpose of laboratories is to assist the learning with deep understanding of those facts and explanations. (p. 763)

Several qualitative studies have shown that, without carefully structured guidance in which teachers selectively and gradually assist students, students sometimes use first-hand data to develop ideas unintended by the curriculum (e.g., Leach & Scott, 2000; McRobbie, Roth & Lucas, 1997; Roth, 1990-91; Watson et al., 1995). Some studies have also raised doubts about the effectiveness of practical activities in helping students develop positive attitudes towards science (e.g., Head, 1982; Lynch & Ndyetabura, 1984) or in improving students' skills in carrying out practical tasks (Assessment Performance Unit, 1982, 1985; Gott & Duggan, 1995).

In spite of these critiques, some science educators continue to study the ways in which practical activities may be structured to achieve more success with student learning, such as involving students in first-hand inquiry activities that increase their interest and improve student understanding of the nature of science (e.g., NRC, 1996; Schauble, Glaser, Duschl, Schulz & Johnson, 1995; White, 1993) or increasing student responsibility for their science learning by having them ask their own questions and design their own investigations (e.g., Jenkins, 1999; Roth, W-M., 1995; Roth & Bowen, 1995). Researchers are also examining the ways in which project-based, 'authentic' inquiries, such as a study of a local stream, may better support student learning (e.g., Krajcik, 2001; Woolnough, 2000). In connection with hands-on scientific work, many researchers support increased attention to 'minds-on' work in science in which students predict, analyse, represent and interpret first-hand data to build scientific arguments and to support scientific concepts (e.g., Driver, Asoko, Leach, Mortimer & Scott, 1994; Kesidou & Roseman, 2002; Lehrer & Schauble, 2002; Roth, 2002).

## Country Perspectives

Engaging students in practical work in the science classroom is addressed in all of the curricula and standards documents of the five countries participating in this study. The documents in all five countries specify that during such practical work students should learn to use scientific inquiry practices (AAAS, 1993; AEC, 1994; Czech Ministry of Education, 1996; Dutch Ministry of Education, Culture and Science, 1998; Ministry of Education, Science, and Culture [*Monbusho*], 1999; NRC, 1996). As well as carrying out investigations, predicting outcomes, giving reasons for predictions and learning how to make connections between these predictions and the results of independent practical activities are important parts of scientific inquiry that are specifically named in all of the country curriculum and standards documents referenced here.

In Australia, Japan and the United States, the curriculum and standards documents emphasise the importance of students' involvement in generating questions to explore and in designing procedures for investigating these questions. The *National Science Education Standards* (NRC, 1996) in the United States also emphasises the importance of students taking active roles in implementing their investigations and in preparing and presenting their work to their peers. The emphasis on involving students in investigations is also evident in Australian and Japanese documents. The 1994 Australian curriculum profile identifies 'working scientifically' as a major strand in the science curriculum, emphasising students' roles in planning and conducting investigations (AEC, 1994). The Japanese Course of Study (Ministry of Education, Science, and Culture [Monbusho], 1999) prioritises experimentation and scientific observation, with the overall objective of enabling students to 'develop the capacity to undertake investigations in a scientific manner' (Goto, 2001, p. 32).

Similarly, the Dutch attainment goals include 'designing tests to investigate simple problems as a goal within the physics and chemistry strand' (Dutch Ministry of Education, Culture and Science, 1998, p. 64). The Czech documents however put more emphasis on content learning goals, but students are also expected to learn how to conduct simple experiments designed by others and to develop skills such as observing and using scientific tools (the microscope, for example) (Czech Ministry of Education, 1996).

Data from the TIMSS 1999 achievement study indicate that the goals described in these documents are reflected in the intended Year 8 science curriculum in both Japan and the United States. These curricula placed a major emphasis on three aspects of practical work – involving students in performing science experiments, using laboratory equipment, and designing and conducting scientific investigations (see Table 5.1, which provides data from Martin et al., 2000).

**Table 5.1 Relative emphases given in intended Year 8 science curricula to students using laboratory equipment, performing experiments and designing and conducting scientific investigations**

Function	Country				
	AU	CZ	JP	NL	US
Using laboratory equipment	Moderate	Minor/ None	Major	Moderate	Major
Performing science experiments	Moderate	Minor/ None	Major	Moderate	Major
Designing and conducting scientific investigations	Moderate	Minor/ None	Major	Moderate	Major

*Note:* Data were provided by the TIMSS National Research Coordinator for each country.

SOURCE: Martin et al. (2000). *TIMSS 1999 International Science Report: Findings from IEA's Repeat of the Third International Mathematics and Science Study at the Eighth Grade*, Exhibit 5.8. Chestnut Hill, MA: Boston College.

These three facets of practical work were reported to receive a moderate emphasis in Australia and the Netherlands, and minor or no emphasis in the Czech Republic. The companion TIMSS 1999 Video Study generally concurs, showing that in four of the five participating countries, there was some degree of emphasis on students doing practical work independently, especially in Australia and Japan, while in the Czech Republic there was less emphasis on students doing such work (see Chapter 3, Figure 3.7). As also shown in Figure 3.7, with the exception of the Czech Republic, the Year 8 science lessons within all the countries allocated more instructional time for students to work on independent practical activities than on whole-class practical activities. Therefore, the primary focus of this chapter is to examine various aspects of students' independent work on practical activities (that is, activities undertaken by students working in small groups or individually, largely independent of the teacher).

The chapter focuses on the following main questions:

- What are the features of independent practical activities?
- What scientific inquiry actions do students practise during independent and whole-class work?

Before presenting the results, it is important to note that, although the students worked independently of the teacher on their practical activities, it was possible to capture these inquiry practices on videotape through the teachers' public instructions to the class about the independent work (for example, generate their own research questions, design their procedures and make predictions). The video also recorded students working on their own and talking to the teacher as the teacher privately interacted with the students during their independent work. Furthermore, any text or worksheets used during independent practical activities were captured on videotape and provided information about which inquiry practices the students were expected to carry out.

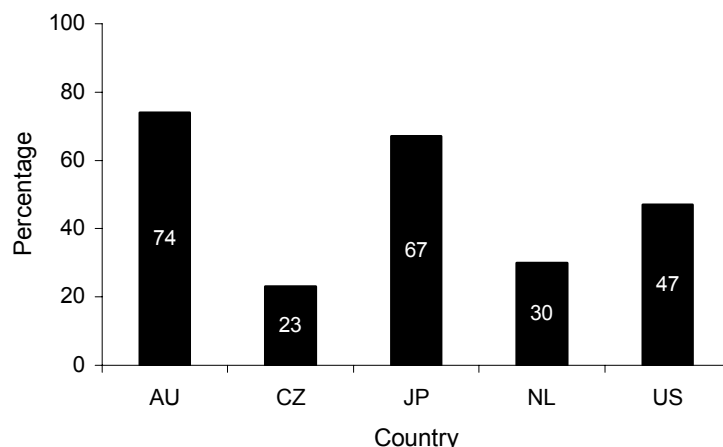
How much did the Australian teachers involve their students in independent practical activities during the sampled Year 8 science lessons?

- *As shown in Chapter 3 and below, Australia and Japan had the highest percentages of lessons containing independent practical activities (74 and 67 per cent, respectively).*

### Features of Independent Practical Activities

Figure 5.1 shows that independent practical activities occurred in fewer Year 8 science lessons in the Czech Republic and the Netherlands compared with Australia and Japan, and in fewer Czech lessons than United States lessons.

**Figure 5.1 Percentages of Year 8 science lessons that contained at least one segment of student independent practical activity**



Note: AU, JP>CZ, NL; AU>US; US>CZ

In addition, independent practical activities occurred in more Australian Year 8 science lessons than in United States lessons.<sup>40</sup> This unequal distribution of independent practical activities among

<sup>40</sup> The proportions of instructional time spent on a single segment of an independent practical activity also varied substantially within countries, ranging from 6 to 100 per cent in Australia (2-49 minutes), 1 to 68 per cent in the Czech Republic (1-30 minutes), 3 to 95 per cent in Japan (1-46 minutes), 16 to 99 per cent in the Netherlands (5-42 minutes) and 3 to 95 per cent in the United States (1-67 minutes).

the five countries, which occurred in from 23 to 74 per cent of lessons, means that lesson features related to practical activities (for example, conducting experiments, posing research questions, interpreting results) are very likely to be unequally distributed among the countries as well. In order to keep the overall analysis on independent practical activities in perspective, the analyses that follow are presented to highlight the relative emphasis of particular features of practical activities *within* each country.

### ***Types of independent practical activity***

During the Year 8 science lessons filmed for this study, students were observed engaging in the following types of independent practical activity:

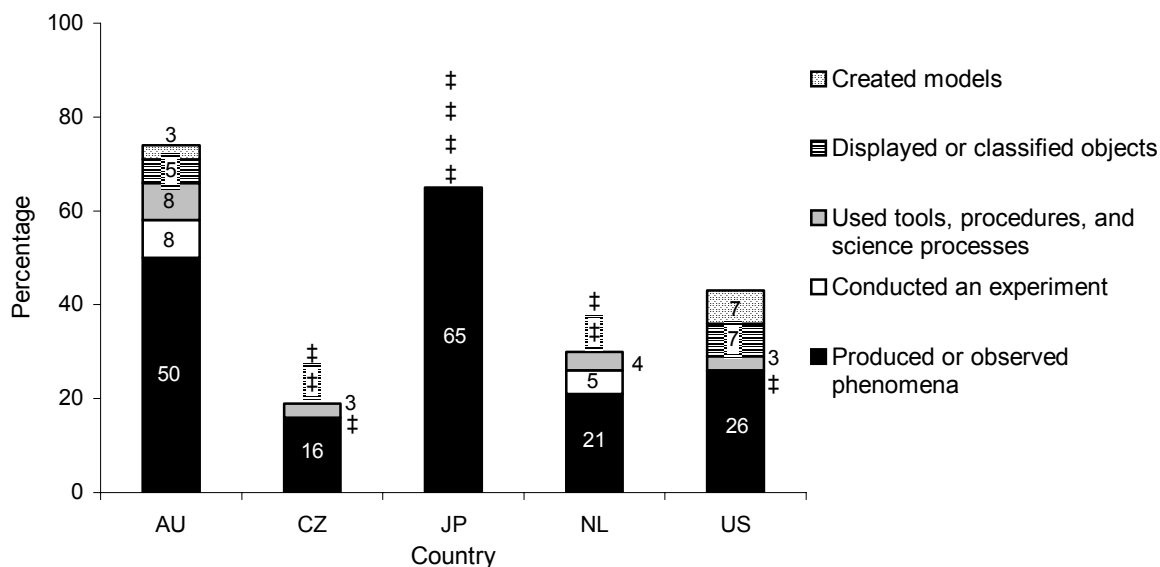
- **Creating models:** The activity requires students to design and make models or prototypes for the purpose of illustrating scientific principles. For example, students may be asked to use materials to build a model of a cell, or they may be asked to use materials to demonstrate one of Newton's Laws. Alternatively, models or prototypes may be built for the purpose of testing a design to see if it will work better than another design. For example, students may design and build hovercrafts and then race them to see which design is fastest.
- **Displaying or classifying objects:** The activity requires students to learn how to present an object, or set of objects, to display certain features clearly. For example, students may carry out a dissection to show the parts of the circulatory system in a frog or organise a set of rocks into categories. (AU PRL 3, 00:10:35 – 00:12:43 provides a clear explanation of steps that students are expected to undertake in a dissection in the next part of the lesson, as well as labelling and displaying features.)
- **Using tools, scientific procedures and processes:** The activity requires students to practise using a scientific instrument or to master a scientific procedure. The main focus is on learning the procedure or process skill rather than on generating data to be used to support development of a concept. For example, students may learn how to use a microscope or how to carry out a filtration procedure.
- **Conducting an experiment:** The activity is a traditional controlled scientific experiment or 'fair test' that involves making comparisons of control and test cases. An independent variable is manipulated to have an effect on a dependent variable, while controlling all other relevant variables. For example, students may conduct an experiment to determine if the temperature of water rises faster when heating a) water alone, b) water with copper in it, or c) water with gold in it. Observations of phenomena are a key part of a controlled experiment.
- **Producing or observing phenomena:** The activity requires students to produce or observe phenomena that are not part of a controlled experiment. For example, students may observe a series of chemical reactions and, for each one, describe evidence that a chemical reaction has taken place. Or students may use batteries, globes and wires to build a circuit that will enable a globe to light. (AU PRL 2, from 00:08:41 – 00:11:35, shows activities of this nature.

What was the most common activity in Australia?

- *'Producing or observing phenomena' was clearly the dominant independent practical activity in the Australian lessons. This was also the case in all countries except the United States.*

Figure 5.2 presents the percentages of Year 8 science lessons by the incidence of the different types of independent practical activities described above. Within all the participating countries for which reliable estimates could be calculated, the type of independent practical activity that was most often observed involved producing or observing phenomena. This activity occurred in almost 100 per cent of such lessons in Japan, down to about 55 per cent of such lessons in the United States (68 per cent in Australia – that is, about two-thirds of the 74 per cent of lessons in this category).

**Figure 5.2 Percentages of Year 8 science lessons in which the students performed various types of independent practical activities**



‡ Fewer than three cases reported (country excluded from the relevant analysis)

Produced or observed phenomena: AU, JP>CZ, NL, US

Note: Totals may not sum to the percentage of lessons with independent practical activities (shown in Figure 5.1) because of rounding and data not reported.

Not only was producing or observing phenomena during one continuous segment of science instruction time the most common type of independent practical activity observed within the participating countries, it was at least twice as common as the other four types of activity combined, except in the United States. The relatively small percentages of lessons in which students conducted experiments are notable – the only countries where there were enough of these lessons for estimates to be determined were Australia and the Netherlands.

When students were engaged in independent practical work, this tended to be as a continuous activity rather than as multiple activities linked in some way. Three-quarters or more of the lessons with practical work segments were characterised as having one continuous activity (four-fifths of such lessons in Australia – although both *AU PRL 2* and *AU PRL 4* are examples of conceptually linked multiple activities) (data not shown).

### ***Setting up independent practical activities***

#### ***Set-up talk***

To help students undertake practical activities independently, teachers may set up the activities with discussions about how an activity will proceed, or what its purpose is, for example. When teachers include such discussions, students may be asked to generate hypotheses, be provided with theoretical background information, or be given instructions for completing the activity. In order to understand how science teachers prepared students for the independent practical activities, each lesson was examined for the following characteristics:

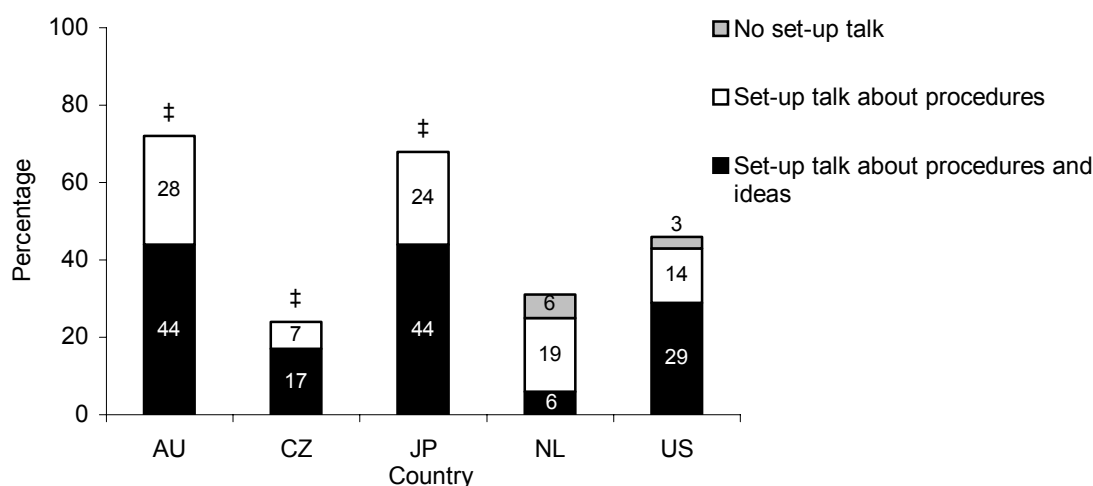
- **No set-up talk:** The teacher provides no explicit discussion of the nature or purpose of the practical activity prior to its commencement. For example, the teacher gives students a set of written procedures and immediately sends them off to work independently.
- **Primarily procedures:** The teacher primarily discusses with students the procedures to be followed during the practical activity. Ideas are mentioned at the topic level only or are focused only on how to use tools or how procedures and equipment work.

- **Mix of procedures and ideas:** The teacher discusses both procedures and the idea(s) that relate to the main purpose of the independent practical activity. Discussion of ideas goes beyond simply naming the topic or stating the goal of the activity. For example, prior to a practical activity in which students will investigate whether saliva plays a chemical or a physical role in digestion, the teacher leads a discussion about differences in starch and sugar molecules and reviews the differences between physical and chemical changes (e.g., *AU PRL 4*, 00:18:58 – 00:19:55 and *AU PRL 3*, 00:08:52 – 00:09:15 both describe procedures, but the procedures are only an adjunct to the main purpose of the independent practical activity).

Figure 5.3 shows the percentages of the total samples of Year 8 science lessons in which teachers set up the independent practical activities in each of these three ways. Preparation for the independent practical activities in the Year 8 science lessons involved discussion of procedures in all five countries. Lessons with no such discussion were observed, but were relatively rare.

Japanese and Australian Year 8 science lessons were observed to include discussions of both procedures and the ideas of an independent practical activity more often than Czech and Dutch lessons and more Australian than Czech lessons included discussions mainly of procedures. Within countries, however, more Dutch lessons set up independent practical activities through discussions mainly of procedures than discussions of both procedures and ideas, whereas more Japanese lessons set up independent practical activities through discussion of both ideas and procedures.

**Figure 5.3 Percentages of Year 8 science lessons in which the teacher explicitly set up an independent practical activity**



‡ Fewer than three cases reported (country excluded from the relevant analysis)

Set-up talk about procedures: AU>CZ

Set-up talk about procedures and ideas: AU, JP>CZ, NL; US>NL

Note: Totals may not sum to the percentages of lessons with independent practical activities (shown in Figure 5.1) because of rounding and data not reported.

Sometimes teachers had students do some of the preparation work on their own. *AU PRL 3* is an example of a lesson where the teacher had students make a cut-out model for homework, to help them with the practical activity they would be doing the next day. Other times students were asked to read independently about the procedures they would use, as was done in *AU PRL 1*, or to form small groups to design procedures or to suggest hypotheses for the anticipated practical activity. Although two of the Australian public release tapes happen to include this type of student work, it occurred in only 9 per cent of the Australian lessons. Japanese students performed these kinds of preparatory activities in 21 per cent of their filmed science lessons (data not shown).

### Purpose of the practical activity

Other ways teachers prepared students for independent practical activities were through explanations of the activities' purposes or learning goals. Three different ways were defined:

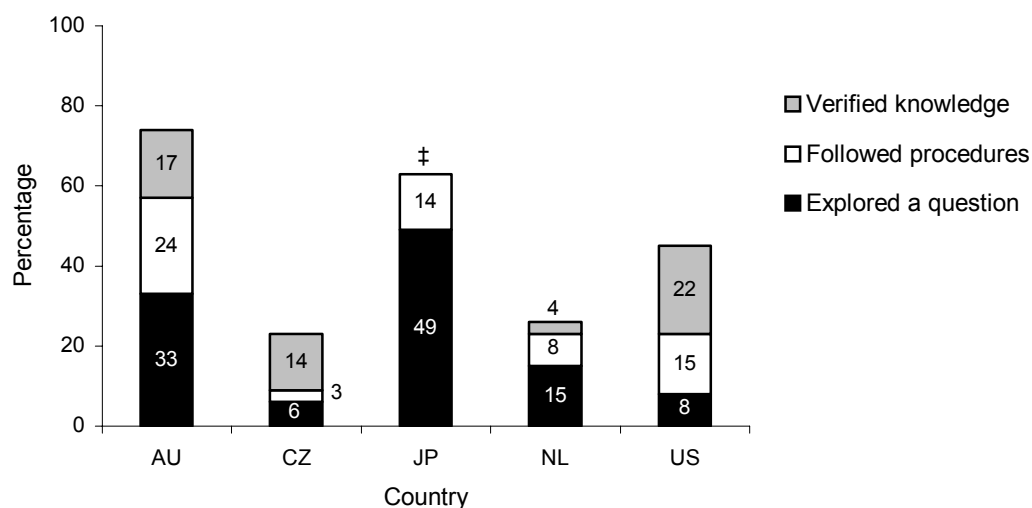
- **Verifying knowledge:** The teacher, text, or worksheet communicates the scientific knowledge, fact, or idea that will be demonstrated through the practical activity. For example, a teacher may review the formula for density and then have students practise calculating the densities of various objects by collecting data about their mass and volume. (e.g., AU PRL 3, in which there is prior discussion and demonstration of the parts students need to find in a kidney dissection, is partly an example of this purpose.)
- **Following procedures:** The teacher, text, or worksheet identifies an observation, measurement or procedure that will be conducted through the practical activity but does not state why students will be making these observations or measurements. For example, a teacher may tell students only that they will 'measure the current in a series circuit' or 'observe different kinds of rocks'. While procedures are important in all of the Australian public release lessons, none of the five lessons is primarily about following procedures for procedures' sake.
- **Exploring a question:** The teacher, text, or worksheet poses a main question or idea that students will explore through the practical activity (the intended learning outcome is unknown to students). For example, a teacher may explain to students that in the practical activity they 'will measure current to determine if there are differences between series and parallel circuits' (e.g., AU PRL 2 explores the question of differences between metals and non-metals).

What was the most common purpose of independent practical activities in Australian lessons?

- *Most commonly, the purpose of independent practical activities in Australian science lessons was 'exploring a question' rather than 'verifying knowledge'. A third of the Australian lessons with practical activities had 'following procedures' as their focus.*

Figure 5.4 presents the percentages of the total samples of Year 8 science lessons in which the teacher, text or worksheet oriented students to the purpose of a practical activity.

**Figure 5.4 Percentages of main purposes of Year 8 practical activities, as indicated in instructions from the teacher, a textbook or a worksheet**



† Fewer than three cases reported (country excluded from the relevant analysis)

Verified knowledge: AU, CZ, US>NL

Followed procedures: AU>CZ, NL

Explored a question: AU, JP>CZ, US; JP>NL

*Note:* Totals may not sum to the percentages of lessons with independent practical activities (shown in Figure 5.1) because of rounding and data not reported. Lessons with no known outcome are not included in the analyses.



Among the five countries, instructions for practical work were more likely to raise a question to be explored in Japanese and Australian lessons than in Czech and United States lessons, and in Japanese than in Dutch lessons. Knowledge outcomes to be verified as the purpose of practical activities were most often observed in Australian, Czech and United States science lessons. Students in the Australian Year 8 science lessons were more likely to know a question to be explored than a knowledge outcome to be verified, while the opposite was true for students in the United States science lessons.

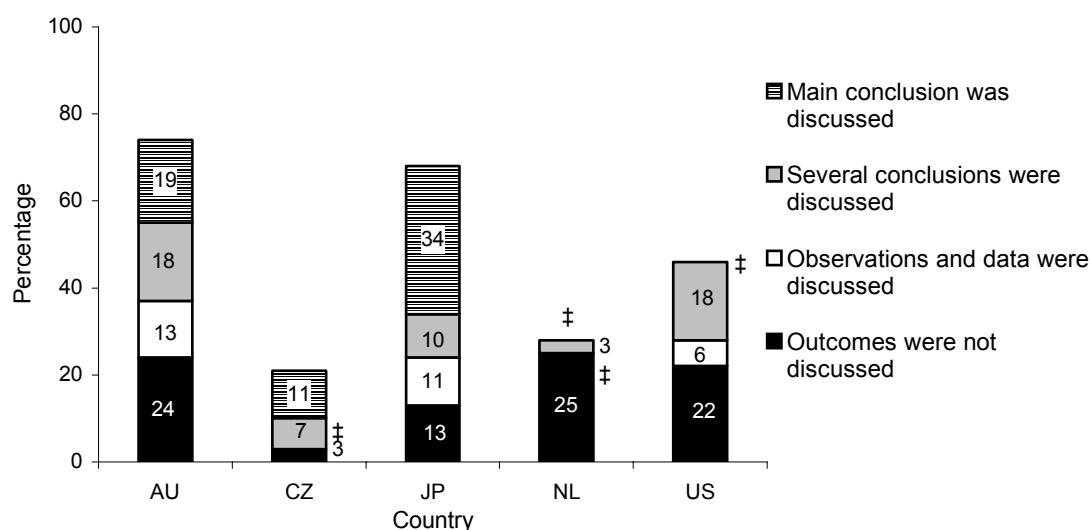
### Following up independent practical activities

#### Discussion of results

As may be expected, teachers sometimes were observed discussing or asking students to discuss or present the observations, data, results or conclusions of the independent practical activities to the whole class. In some cases these discussions focused only on the data and observations, without discussing a possible conclusion or conceptual idea based on the outcomes of the activity (e.g., *AU PRL 5, 00:59:34 to the end*, though it is clear that the teacher intends to return to the discussion in the next lesson). In other cases the aim of the discussion was to make interpretations and draw conclusions. Typically, if more than one conclusion was mentioned, no attempt was made to link them together to draw a larger, overarching conclusion. In the most coherent lessons, class discussions occurred about how the outcomes of the practical activity or activities were connected to and supported a single main conclusion or scientific idea (e.g., *AU PRL 4, 01:10:10 – 01:13:00*). There were also lessons in which nothing about the outcomes or results of the independent practical activity was discussed publicly.

The percentages of these various kinds of class discussion of the results of independent practical activities immediately after the activity are shown in Figure 5.5.

**Figure 5.5 Percentages of Year 8 science lessons in which outcomes of independent practical activities were discussed publicly**



‡ Fewer than three cases reported (country excluded from the relevant analysis)

Main conclusion was discussed: JP>CZ

Several conclusions were discussed: AU>NL

Outcomes were not discussed: AU, NL, US>CZ

*Note:* Totals may not sum to percentage of lessons with independent practical activities (shown in Figure 5.1) because of rounding and data not reported.

What occurred in the Australian lessons?

- *Students in Year 8 science lessons in Australia, as well as in Japan, were more likely than students in the other three countries to be involved in discussion of the outcomes of their independent practical work. However, a third of the Australian lessons with practical activities, compared with a fifth in Japan, had no discussion of outcomes of the activities.*

Up to one quarter of Year 8 science lessons across the five countries included no discussion of the outcomes of the practical activities conducted during the lessons (24 per cent in Australia, which is about a third of the lessons containing independent practical activities, and 22 per cent in the United States, which is more than half of the lessons containing such activities). Overall, Year 8 students in Australia and Japan were more likely than their counterparts in the other three countries to be in science lessons in which there was some discussion of the outcomes of the independent practical activities. Year 8 students in Dutch science lessons engaged in some kind of discussion after a practical activity less often than students in all the other countries except the Czech Republic. They were also more likely not to engage than to engage in discussions of practical activities, whereas their counterparts in lessons in all the other countries except the United States were more likely to engage than not to engage in discussions of the practical activities they had worked on. When engaged in discussions of practical activities, students in Japanese Year 8 science lessons were more likely to discuss the main conclusions of the activities than several conclusions or only their observations. Students in the Netherlands and the United States were observed to discuss the main conclusion arising from independent practical activities in too few cases for estimates to be determined.

#### Critique methods and raise new questions

Standards and curriculum documents in both the United States and Australia expect Year 8 students to learn about the nature of science, including the importance of scepticism in scientific inquiry, the need to scrutinise methods used in investigations, and the provisional and incomplete status of scientific knowledge (AAAS, 1993; AEC, 1994; NRC, 1996). In science lessons, teachers can help students learn about the nature of scientific knowledge and thinking in many ways. For example, the class may discuss why a certain procedure was used and consider the limits and possible inaccuracies of the data provided by the procedure (see [AU PRL 5, 00:27:38 – 00:27:57](#)). Alternatively, the teacher may help students raise new questions to be asked, demonstrating that scientific knowledge is always tentative, incomplete and subject to further exploration. They may also engage students in evaluating or critiquing the procedures and methodological limitations of the practical activities the students have carried out.

The percentages of lessons in which the methods of the independent practical activities were evaluated or critiqued and in which new questions to investigate were discussed were relatively low in all countries. Independent practical activities were critiqued in 4 to 17 per cent of the Year 8 science lessons across countries (17 per cent and 5 per cent in Australia and the United States – the two countries where students are expected to learn these skills – respectively). By the end of the lesson, students developed new questions to be investigated, derived from their practical activities, in 18 per cent of the Japanese and 8 per cent of the Australian science lessons. There were too few lessons in which students discussed new questions to be investigated to calculate reliable estimates in the other three countries (data not shown).

#### **Scientific Inquiry Actions Practised During Independent Work**

Teachers sometimes provide opportunities for students to engage in different types of inquiry practices before, during, and after their independent practical activities. For example, before engaging in independent practical work, students may be expected to generate research questions, design procedures to investigate a research question and make predictions about the outcomes. During the independent practical work, students may collect and record data. After the investigation, students may be expected to manipulate the data collected or interpret the data.

As noted at the beginning of the chapter, the curriculum and standards documents from all of the participating countries in this study specifically mention some or all of the inquiry actions described in this section. That being said, some researchers caution that engaging students in such inquiry actions in isolation of the development of conceptual knowledge may lead to important misconceptions about the nature of science. Millar and Driver (1987) suggest that activities such as classification exercises with no explicit underlying link misrepresent science and teach children that science is about observing and classifying but that these activities have nothing to do with developing new ideas. Roth (1990–91) encountered evidence of such misconceptions when she interviewed students who had grown, measured, and graphed plants grown in the light and in the dark during a six-week inquiry-focused science unit. One student explained her frustration with the activities: ‘I don’t know why we kept measuring those plants. I mean it was fun for awhile, but I already know that plants need light, and now I know it again’ (p. 20).

The types of inquiry actions that were observed in relation to independent practical work and in which students engaged before, during and after the independent practical work were defined as follows:

- Students generate the research question: Students generate the research questions related to a practical activity, either with complete freedom or with several options provided by the teacher.
- Students design procedures for investigation: Students design procedures for their own investigation related to a practical activity, either with complete freedom or with several options provided by the teacher.
- Students make predictions: Students predict the outcome of a practical activity and may also provide the reason(s) for the prediction. (AU PRL 5, 00:21:10 – 00:24:40)
- Students interpret data or phenomena: Students use first-hand data or phenomena from the independent practical activity as evidence to explain patterns, draw conclusions, make generalisations and/or link the first-hand data or phenomena to predictions or hypotheses made before beginning the activity. Students may work independently on generating interpretations of their first-hand data or phenomena (either individually or in pairs or small groups), or the teacher may guide students in making interpretations during public, whole-class discussions. (AU PRL 2: 00:31:26 – 00:32:42)
- Students collect and record data: Students are involved in collecting and recording first-hand data or observations of phenomena during independent practical activities. (AU PRL 5, 00:39:15 – 00:41:05)
- Students organise or manipulate collected data without assistance from the teacher: Students independently organise or manipulate first-hand data or observations into tables, graphs or charts. They design the structure or form of the table, graph or chart themselves.
- Students organise or manipulate collected data as directed by the teacher or the textbook: First-hand data or observations are organised or manipulated into tables, graphs or charts under the direction of the teacher, textbook or workbook. In many cases, the teacher, textbook or workbook provides the table, graph or chart templates, and students fill in the data. In other cases, the teacher uses student-generated data and demonstrates on the board or overhead how to organise the data into a graph or chart. (AU PRL 5, 00:33:00 – 00:34:10)

What scientific inquiry actions were commonly practised by the Australian students during their independent practical work?

- *Students in Australia both collected and recorded data during their independent practical work as well as interpreted the collected data in more than half of the videotaped Year 8 science lessons. They organised data, with guidance, in more than a quarter of the lessons but designed procedures, made predictions and organised or manipulated data on their own in only about 10 per cent of the lessons. The latter three inquiry actions were uncommon in all countries except for students making predictions in Japan, which occurred in about a quarter of the lessons.*

### ***Generating research questions and designing procedures for investigations***

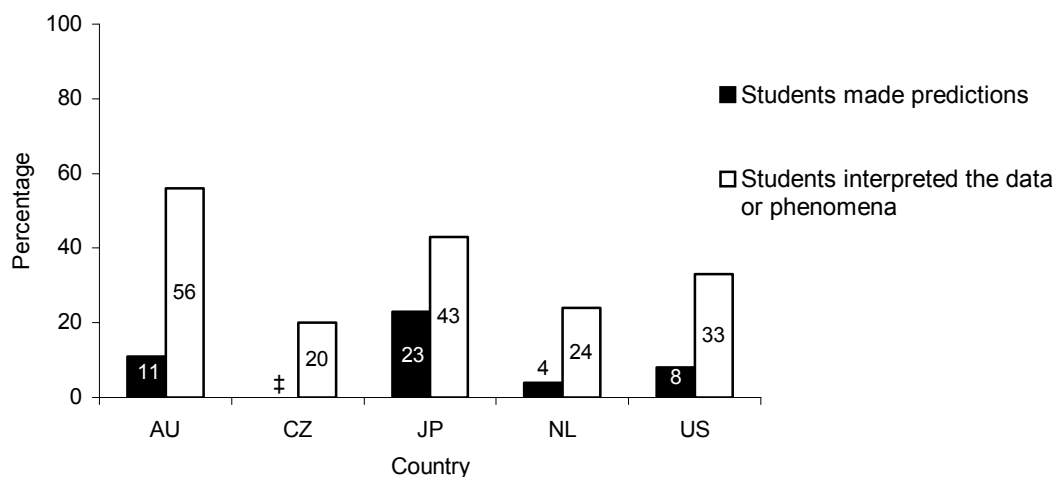
Independent practical activities in the Year 8 science lessons seldom involved students in generating their research questions or designing their investigations, despite the emphasis on these skills in the curriculum and standards documents in Australia, Japan and the United States, as discussed above. Australia was the only country where there were sufficient occurrences of students generating research questions for an estimate to be made, but even so there were only 3 per cent of lessons in which this action was observed. Students designed procedures for their independent work in 10 per cent of Australian lessons and 5 per cent of Japanese and United States lessons, and in too few Czech and Dutch lessons to calculate reliable estimates (data not shown).

### ***Making predictions and interpreting first-hand data or phenomena***

The percentages of lessons in which students made predictions or interpreted the data or phenomena related to their independent practical activities are shown in Figure 5.6. Making predictions or hypotheses before beginning the independent practical activities occurred relatively rarely, except in Japan. Further analyses revealed that students were expected to give reasons for their predictions in 6 per cent of the Australian lessons and 8 per cent of the Japanese lessons. In the three other countries there were too few occurrences to determine estimates of how often students were expected to give reasons for their predictions (data not shown).

Figure 5.6 also shows that students were more often observed interpreting results upon completion of their independent practical activities than they were observed generating predictions before beginning these activities within all of the countries with sufficient data available. More Australian Year 8 science lessons provided opportunities for students to interpret their first-hand data or phenomena than Czech or Dutch lessons. More Japanese lessons also provided these opportunities for their students than did Czech lessons. In all countries the percentages of lessons in which students interpreted their results represent substantial proportions of the overall percentages of lessons that included independent practical activities (see Figure 5.1).

**Figure 5.6 Percentages of Year 8 science lessons in which students made predictions and interpreted data or phenomena related to independent practical activities**



† Fewer than three cases reported (country excluded from the relevant analysis)

Students made predictions: JP>NL

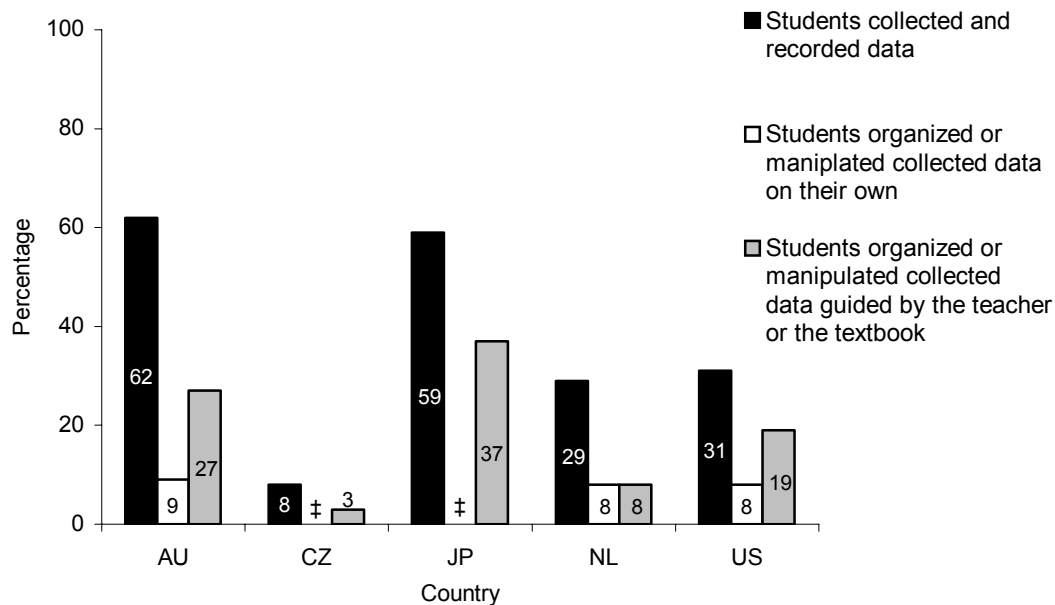
Students interpreted the data or phenomena: AU>CZ, NL; JP>CZ

Note: The overall percentages of lessons with independent practical activities are shown in Figure 5.1.

### Organising and manipulating collected data

Figure 5.7 presents the percentages of lessons in which students collected and recorded first-hand data or observations of phenomena and organised or manipulated collected data as part of their independent practical work.

**Figure 5.7 Percentages of Year 8 science lessons in which data from independent practical activities were recorded and manipulated by students**



‡ Fewer than three cases reported (country excluded from the relevant analysis)

Collected and recorded data: AU, JP, NL, US>CZ; AU, JP>NL, US

Organised or manipulated collected data guided by the teacher or the textbook: AU, JP>CZ, NL; US>CZ

Note: The overall percentages of lessons with independent practical activities are shown in Figure 5.1.

As the figure indicates, Year 8 students were given the opportunity during independent practical activities to collect and record first-hand data or observations of phenomena in from 8 to 62 per cent of the science lessons across the countries. This also represents a substantial proportion of the lessons in which students conducted independent practical activities (see Figure 5.1). Students collected and recorded first-hand data in more Australian and Japanese lessons than in Dutch and United States lessons. Also, students were more likely to collect and record first-hand data in Year 8 science lessons in all of the other countries compared with students in the Czech Republic, where this activity occurred in only 8 per cent of the lessons. This difference however may be largely due to the relatively low overall percentage of Czech lessons that included independent practical activities (see Figure 5.1). The teacher of *AU PRL 1* explains some advantages of having students collect and record data:

Students are still working well and on task. Their interest in the work is quite pleasing and their questions demonstrate a solid understanding and an enthusiasm for the practical work (*AU PRL 1, Teacher's Comments, 00:29:58*); and

Students are still working well and organising their observations. The background sound level suggests a productive working noise and that students are still reasonably well focused (*AU PRL 1, Teacher's Comments, 00:39:56*)

The teacher of *AU PRL 3* further endorses the belief that it is a positive experience for students to deal with first-hand data:

Hands-on experiences allow students opportunities to discover new things. This student-centred approach inevitably leads students to ask questions: "Why?" "How?" "What does this do?" I also find that this experience is more memorable for students, making it easier for them to retain what they have learnt. (*AU PRL 3, Teacher's Comments, 00:18:49*)

It was relatively rare for students to be required to design their own strategy or form for organising or manipulating their first-hand data collected during their independent practical work, which occurred in no more than 9 per cent of the Year 8 science lessons in any of the participating countries. Students organising or manipulating their collected data with guidance from their teacher or a textbook occurred more often in Australian and Japanese lessons than in Czech and Dutch lessons. Although it is possible that students could organise or manipulate the first-hand data related to the independent practical activities both independently and guided by the teacher during a lesson, these two practices were never both observed to occur within the same lesson. This may have been due to relatively short lesson lengths and the need or desire to cover material. It is also possible that teachers mostly introduce students to these more sophisticated inquiry skills beyond Year 8. The few teachers whose students organised and manipulated data on their own in the sampled lessons seem to have believed in the process sufficiently that they did not interfere with it.

### ***Further patterns of scientific inquiry actions during independent practical activities***

Additional within-country analyses of Year 8 science students' use of the various scientific inquiry actions during their independent practical work reveal different patterns of opportunities for students to engage in such actions (data not shown):

- Czech students were less likely than others to collect and record first-hand data or observations of phenomena than to make predictions or to organise or manipulate collected data.
- In Dutch and Japanese lessons, the students were more likely to collect and record data than to predict outcomes, manipulate data or interpret the results of their independent practical work.
- When Australian students manipulated their first-hand data, they were more likely to be guided by the teacher or a pre-designed textbook or workbook page than to design the procedure by themselves. They were also more likely to interpret the results of their independent practical activities than to organise or manipulate collected data.
- Czech students were more likely to interpret the results of their independent practical activities than to collect and record first-hand data.

### **Scientific Inquiry Actions Practised During Whole-class Work**

Teachers can also encourage students to engage in scientific inquiry practices during whole-class practical activities such as demonstrations, although the range of possible inquiry practices can be more limited. In the videotaped lessons, students were asked to generate predictions, to interpret first-hand data or phenomena and to organise and manipulate first-hand data into tables, graphs or charts during whole-class practical activities. However, since a whole-class practical activity usually involves the students watching someone else (typically the teacher) generating and collecting the data, students in the videotaped lessons were mostly not observed designing their own questions to be investigated, designing procedures to investigate their questions, or collecting their own first-hand data from observations of phenomena during whole-class practical activities.

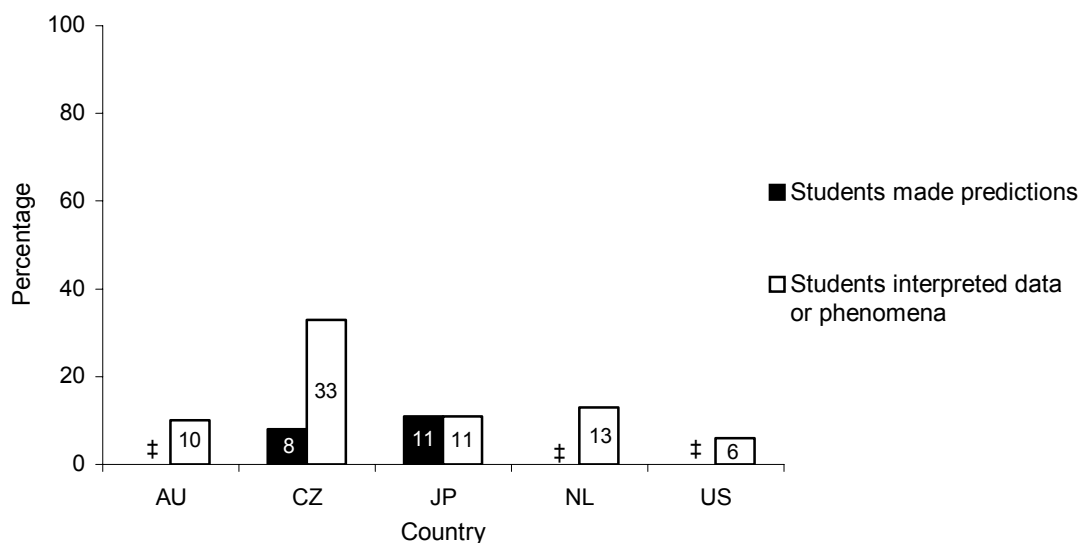
Students participated in whole-class practical activities in a large percentage of the Year 8 science lessons in all the participating countries, ranging from 62 per cent in the Netherlands to 81 per cent in Australia (data from Table 3.2 in Chapter 3). In contrast with the percentages of lessons containing independent practical activities, which varied across countries as shown both in Table 3.2 and Figure 5.1, countries were not found to vary significantly on the distribution of lessons with whole-class practical activities. However, as also described in Chapter 3 (Figure 3.7), it is important to keep in mind that, even though whole-class practical activities occurred in a large proportion of the science lessons, only a small average proportion of science instruction time (from 4 to 10 per cent) was devoted to these activities.

### ***Students make predictions and interpret first-hand data or phenomena***

The main scientific inquiry actions carried out by students during whole-class practical activities were interpreting data or observing phenomena and, to a much lesser extent, making predictions about outcomes, as shown in Figure 5.8.

Predictions can be derived from previously-known scientific knowledge, such as theories or laws of science, with the expectation that students will be able to generate an accurate prediction. Alternatively, teachers can ask students to make predictions in situations where the students do not have enough information or prior knowledge to ensure that they will make a correct prediction. In these situations, the teacher may expect a wider array of student responses. Students can also be expected to interpret the results of the whole-class practical activities by explaining patterns, drawing conclusions, making generalisations, and/or linking the data or phenomena to predictions they made before the activities occurred (e.g., *AU PRL 2, 00:12:58 – 00:18:30*).

**Figure 5.8 Percentages of Year 8 science lessons in which students made predictions and interpreted data or phenomena related to whole-class practical activities**



‡ Fewer than three cases reported (country excluded from the relevant analysis)

Students interpreted the first-hand data or phenomena: CZ > AU, JP, NL, US

Note: The overall percentages of lessons with whole-class practical activities are shown in Table 3.2 in Chapter 3.

No more than 11 per cent of the Year 8 science lessons in any of the five countries provided opportunities for students to make predictions related to whole-class practical activities. Within the Czech Republic students were provided with more opportunities for interpreting the results of these activities than making predictions about what the results would be. Students were more likely to interpret the first-hand data or phenomena related to their whole-class practical activities in Czech lessons than in lessons in the other four countries.

It is interesting to compare these percentages for whole-class practical work with the percentages for the same activities in the context of independent practical work, as shown in Figure 5.6. Except in the Czech Republic, students were involved much more in interpreting their data or observations about phenomena when they were ‘active learners’ who carried out the practical activities themselves, than they were when they were passively watching the teacher perform a demonstration. The reverse was observed in the Czech Republic, again possibly because of the smaller incidence of lessons involving independent practical activities. Except for independent work in Japan, it was uncommon in both whole-class and independent practical work for students to make predictions about outcomes of an investigation.

## Summary

This chapter explored the nature of practical activities that were undertaken by the Year 8 science students in the videotaped lessons. These activities provided students with different patterns of learning opportunities to conduct science independently and as a whole class, which are also described in the chapter.

An underlying factor that needs to be kept in mind when reading the chapter is the overall percentage of lessons per country that contained at least one segment of whole-class practical work versus the percentage with at least one segment of independent practical work. Many classes contained both these types of practical activity, particularly when a teacher demonstrated something to the whole class in order to help explain what the students were expected to do independently.

There was no difference among countries in the percentages of Year 8 science lessons containing at least one segment of whole-class practical activity (shown in Table 3.2 in Chapter 3). The percentages for occurrence of whole-class practical work ranged from 62 per cent of science lessons in the Netherlands to 81 per cent in Australia. In contrast, countries differed significantly in the percentages of lessons during which the students undertook independent practical activities. More than three-quarters of the Czech lessons and more than two-thirds of the Dutch lessons proceeded without the students being involved in any independent practical work. The reverse occurred in Australia and Japan, where three-quarters and two-thirds of the lessons, respectively, included opportunities for students to undertake practical activities independently (Figure 5.1).

Despite the differences in overall percentages of lessons containing independent practical activities, some commonalities were identified. For example, producing or observing phenomena during one continuous segment of science instruction time was the most common type of independent practical activity observed in all five countries (Figure 5.2), and preparation for the independent practical activities involved teacher and student discussions of procedures in all five countries (Figure 5.3). Students were rarely required to conduct a formal experiment in any of the countries (also Figure 5.2).

In many of the results presented in this chapter, the Czech Republic, and sometimes the Netherlands, emerged as different from the other countries participating in the study. On several results, Australia and Japan emerged as similar to each other. Key results concerning Australia reported in the chapter include the following:

- Australian and Japanese Year 8 science lessons (both 44%) more often included discussions of both procedures and the ideas of an independent practical activity than did Czech and Dutch lessons (17 and 6 per cent, respectively) (Figure 5.3).
- Teachers of Australian and Japanese Year 8 science lessons were more likely to explore a question than teachers of Czech and United States lessons (33 and 49 per cent compared with 6 and 8 per cent, respectively) (Figure 5.4).
- In the Year 8 science lessons containing independent practical activities, Australian, Japanese and Czech students discussed outcomes of the activities (conclusions and/or observations) in proportionally many more lessons than lessons in which outcomes were not discussed. In absolute terms, Australian and Japanese lessons were more likely than lessons in the other participating countries to include some discussion of the outcomes of the independent practical activities (Figure 5.5).
- Although generating research questions and designing procedures are stated as aims for Year 8 science in *A Statement on Science for Australian Schools* (AEC, 1994), Australian students generated research questions related to their independent practical activities in only 3 per cent of the videotaped lessons and designed procedures for an investigation in only 10 per cent of the lessons. These aspects rarely occurred in the other countries as well (data not shown).
- The Australian students were asked to make advance predictions about the outcomes of an investigation in only about 10 per cent of the lessons involving independent practical work (Figure 5.6).



- Australia had numerically the highest percentage of lessons of any country (56%) in which data or phenomena were interpreted as part of an independent investigation, followed by Japan (43%) (Figure 5.6).
- In 9 per cent of lessons, Australian students were asked to design their own data manipulation processes for their independent practical work. This practice was uncommon in all countries (Figure 5.7).
- Australia and Japan together had the highest percentages of lessons (62 and 59 per cent, respectively) in which data were collected and recorded during independent practical work. They also had the highest percentages of lessons in which the collected data or observations were organised or manipulated with guidance from the teacher or a textbook (27 and 37 per cent, respectively) (Figure 5.7).
- Australian students interpreted data or made predictions about outcomes in many fewer lessons during whole-class practical work than during practical work carried out independently (Figures 5.6 and 5.8).
- Looking within the countries, interpreting results was a more prominent type of student inquiry practice than organising or manipulating collected data in Australian lessons, and than collecting and recording data in Czech lessons (Figures 5.6 and 5.7).

In a nutshell, the Australian Year 8 science lessons overall can be characterised as providing many opportunities for students to practise several of the important scientific inquiry skills. Collection and interpretation of scientific evidence are prominent and generally take place in meaningful contexts, not merely as exercises in procedures.

The opportunities for Year 8 science students to participate in inquiry activities were described and compared across the participating countries in this chapter. Looking within the classrooms at the scientific activities the students undertook, as well as observing how teachers developed the lesson content as discussed in the previous chapter, add to our picture of the students' learning environments. Some other relevant aspects, such as use of grouping structures and how much time was taken for various activities rather than merely observing that a segment occurred at least once, are discussed in Chapter 3. One important aspect of students' practical work not discussed in this chapter is the opportunities students have to communicate with each other and with the teacher about their activities, ideas, discoveries and conclusions. The next chapter describes students' opportunities to communicate during both practical and seatwork activities, as well as several other aspects about their involvement in their science lessons.



## Chapter 6

# INVOLVING AND ENGAGING STUDENTS

Student involvement and engagement have complex links to learning. Engagement can refer to participation in schoolwork-related activities, identification with school or personal investment of effort in learning that results in a person pursuing an issue with the intention of mastering an idea or concept (Fredericks, Blumenfeld, & Paris, 2004). Chapter 5 presented information on the ways in which students in Year 8 science lessons were engaged in science through participation in practical activities. This chapter presents information on other types of activities and strategies used by teachers to actively involve and engage students in their science learning.

Activities and strategies specifically directed at engaging students' interest and active involvement are examined in the chapter. These include:

- The use of relevant issues and real-life objects during science instruction;
- The use of motivating activities in science lessons; and
- The use of different strategies within a lesson to engage students.

In addition, other strategies associated with engaging and involving students are examined. These include:

- Opportunities for students to communicate science; and
- Student responsibility for science learning.

### **Real-life Issues, Motivating Activities, and Different Strategies Within a Lesson**

#### ***Research background***

##### Real-life issues

Research on science teaching provides at least two reasons that support the inclusion of real-life issues in science teaching.

First, real-life applications of science have been found to play a role in helping students to reconcile their experience-based prior knowledge about the world with scientific explanations. Studies of science learning as a process of conceptual change, as well as studies of knowledge transfer, suggest that students need to use ideas and concepts in multiple real-world contexts in order to understand their meaning (e.g., Driver et al., 1985; Hewson, Beeth & Thorley, 1998; NRC, 2000; Posner, Strike, Hewson & Gertzog, 1982; Roth, 1995; Wandersee, Mintzes & Novak, 1994; West & Pines, 1985).

Second, research suggests that real-life applications may be a way to engage students' interest in learning science (e.g., Simon, 2000). From a learning theory perspective, it is hypothesised that students become more engaged in their learning when they can see the wide usefulness of the knowledge they are studying (McCombs, 1996; Pintrich & Schunk, 1996; Posner et al., 1982). Analyses of videotapes of science lessons from another study have illustrated that there is wide variability in the way students engage with real-life issues and that these forms of engagement may differ from those intended by their teachers, however (Ainley, 2001). Many studies report the lack of connection between students' in-school learning about science and their out-of-school experiences with natural phenomena, and advocate making in-school learning more authentic and centred around real-world problems and situations (e.g., Krajcik, Blumenfeld, Marx, Bass, Fredricks & Soloway, 1998; Resnick, 1987a). Studies have provided evidence supporting the idea that student interest is enhanced by involvement in real-world science projects and investigations such as studying water quality in a local lake (e.g., Barron, Schwartz, Vye, Moore, Petrosino, Zech & Bransford, 1998; Edelson, 2001; Roth & Roychoudhury, 1994; Williams, 1992). However, these studies fall short of linking students' engagement and interest to improved student learning.

### Hands-on practical activities

As reported in Chapter 5, another way teachers may try to interest and engage students in science is through hands-on practical activities (Fraser, 1980; Freedman, 1997). Although studies suggest that many students lose interest in science lessons after age 11 and find school science boring (e.g., Ebenezer & Zoller, 1993; Hadden & Johnstone, 1983; Simon, 2000; Simpson & Oliver, 1985; Yager & Penick, 1986), the aspect of science that students consistently report as most appealing is hands-on laboratory work (e.g., Millar et al., 1999; Molyneux-Hodgson, Sutherland & Butterfield, 1999; Myers & Fouts, 1992; Woolnough, 1994).

### Motivating activities

Beyond real-life issues and practical activities, teachers also employ other types of motivating activity that may help capture students' interest (e.g. Palmer, 2004). For example, teachers may use jokes and humour, games, role plays, artistic projects, dramatic events, physical activity, prizes or rewards or outdoor excursions. In addition, telling anecdotal stories has been shown to be related to changes in students' attitudes (Shrigley & Koballa, 1992). Studies of attitudes towards science suggest that science lessons that use a variety of teaching strategies and unusual or novel learning activities positively influence student attitudes (e.g., Corno & Rohrkemper, 1985; HM Inspectors of Schools, 1994; Myers & Fouts, 1992; Piburn & Baker, 1993). However, as yet little research literature addresses either the learning advantages or disadvantages of these approaches.

### Alternative viewpoints

That being said, the research literature points to the potential limitations of making science engaging for students through the use of real-life applications, hands-on independent practical activities, and motivating activities. Approaches to teaching that claim to incorporate these strategies have been criticised for being light on science and for lacking strong evidence of positive impact on student learning. For example, United States teachers have been criticised as conducting lessons filled with activities that may be fun or engaging, but that have little or no meaningful connections to rich scientific content (e.g., Kesidou & Roseman, 2002; Moscovici & Nelson, 1998; Roth, 1984).

Reviews of research on the relationship between students' hands-on, practical work and learning outcomes report that there is little evidence that practical work improves student understanding of concepts in science (e.g., Hodson, 1993; White, 1996), but it should be noted that practical work often has other intended learning outcomes related to developing investigative skills and an appreciation of the nature of science. Some studies have suggested that students often use first-hand data to develop ideas unintended by the curriculum (e.g., Leach & Scott, 2000; McRobbie et al. 1997; Roth, 1990-91; Watson et al., 1995). Project-based science teaching, in which students investigate real-life problems in their community, has been criticised because it often embeds student learning of a rich, interdisciplinary set of ideas in only one learning context that is unlikely to support students' transfer of knowledge to other contexts (e.g., Cognition and Technology Group at Vanderbilt, 1997).

Finally, there is debate about what it means for science to be engaging to students. Are hands-on, practical activities engaging simply because they involve physical activity, and are motivating activities engaging simply because they are entertaining? Or can students be engaged by intellectual stimulation with scientific ideas? In the science education community, there has been a clear call for 'minds-on' science. Researchers are concerned with examining ways in which students can be engaged with the ideas of science, rather than simply being entertained or carrying out activities.<sup>41</sup>

### ***Country perspectives***

Results from the TIMSS 1999 student questionnaires show that Year 8 students in three countries – Australia, Japan, and the Netherlands – held relatively less positive attitudes towards science than many of their international counterparts (Martin et al., 2000). The importance of making

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<sup>41</sup> References to and some discussion of this research are provided in Roth et al., 2006.

science enjoyable and relevant to students' lives is codified in the curriculum and standards documents of each of the five countries participating in this study.

In Australia, for example, one of the seven 'principles for effective learning experiences in science' is 'engaging in relevant and useful activities' (AEC, 1994, p. 7). In the Czech Republic, curriculum guidelines stress the importance of practical applications of scientific knowledge so that students can use and apply knowledge and experiences from life outside school (Czech Ministry of Education, 1996). The Japanese course of study promotes inquiry goals as the core features of the learning program for science at the lower secondary level. However, in part as a response to students' less positive attitudes towards science, recent reforms in Japan emphasise the importance of applications of science to everyday life (Goto, 2001). In the Netherlands, four of the six general objectives for physics, chemistry, and biology include applications to daily life (Dutch Ministry of Education, Culture, and Science 1998) and reform efforts recommend that lessons emphasise linking science to daily life contexts and to a variety of vocations (Eijkelhof & Voogt, 2001).

In the United States, standards documents emphasise the importance of 'science literacy' for all students (AAAS, 1990, 1993; NRC, 1996). In these documents, 'science literacy', or 'scientific literacy' as it is known in many countries, includes the ability to adapt scientific knowledge and processes to personal decision making and to civic and cultural affairs. For example, these documents define scientifically literate citizens as able to understand articles about science in the popular press, to see scientific issues involved in national and local political decisions, and to evaluate the quality of scientific information in light of its source. Drawing on research such as the studies described above, the standards documents also emphasise the importance of making the curriculum responsive to students' 'interests, knowledge, understanding, abilities, and experiences' (NRC, 1996, p. 30).

As noted in 'Nature of the Lesson Content' early in Chapter 4, the curriculum and standards documents in each of the countries participating in this study include an emphasis on connecting science to real-life issues.

### ***Relevant issues for students***

To what extent did teachers actually engage students in thinking about real-life issues during instruction in the Australian science lessons?

- *Some attention was given to real-life issues in at least 62 per cent of the Year 8 lessons in all countries. In Australia, real-life issues were raised in 79 per cent of the lessons.*

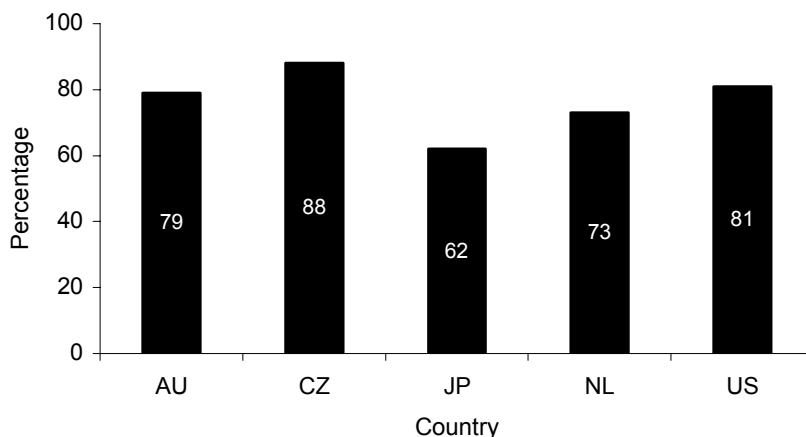
Based on the videotaped lessons, real-life issues were defined as follows:

- **Real-life issues:** Information about how scientific knowledge is used, applied, or related to societal issues or students' personal experiences. Real-life issues include attention to students' personal experiences, the uses of science-related knowledge in everyday life, science-related societal issues, and everyday examples or illustrations of scientific ideas. Examples include:
  - a whole-class public discussion comparing a bicycle ride on pavement and on gravel to support an idea about friction;
  - a small group discussion among students about whether or not to be an organ donor;
  - preparing lists of what people need to have available in case of a bushfire;
  - a practical activity in which students weigh the rubbish collected in their homes across a 3-day period; and
  - a presentation about the kinds of careers that use knowledge about electricity.

### **Incidence**

Figure 6.1 shows the percentages of sampled science lessons in which at least one real-life issue was raised during instruction. Comparing results among the countries, more Czech science lessons addressed real-life issues than did Japanese lessons.

**Figure 6.1 Percentages of Year 8 science lessons in which at least one real-life issue was raised during science instruction**



Note: CZ > JP

#### Percentage of lesson time

When the percentage of instruction time spent addressing real-life issues was calculated, teachers were found to devote between 9 and 23 per cent of instruction time per lesson, on average, to such issues (12 per cent in Australia). Among the countries, no measurable difference was found in the average percentage of time spent on real-life issues during science lessons (data not shown).

✎ *AU PRL 1* provides an example of a real-life issue presented in a lesson. As the teacher explained:

This lesson is part of a unit on forensic science. (...) We consider it important in Australia to teach science as being relevant so that our students see science as being applicable to the real world. (*AU PRL 1, Teacher's Comments, 00:00:00*)

#### ***Role of real-life issues in the lessons***

The importance of helping students understand the connections between scientific ideas and real-life issues has already been noted. However, real-life issues are not always presented in science lessons in ways that provide obvious opportunities for students to make these connections. Instead, real-life issues are sometimes presented as interesting topic-related sidebars, that is, brief examples or stories that are mentioned in relation to the general topic area of the lesson but not used to develop students' understanding of a specific main scientific idea.

The real-life issues addressed in the Year 8 science lessons were examined to assess their use in developing canonical ideas in science or as topic-related sidebars. How were real-life issues used in the Australian science lessons?

- *In Australian and Czech Year 8 lessons, real-life issues were more likely to be used for the development of ideas in science (Australia, 69 per cent; Czech Republic, 83 per cent) than presented as topic-related sidebars (Australia, 52 per cent; Czech Republic, 66 per cent). No measurable differences were found within the three other countries.*

The following definitions were used to determine whether or not real-life issues were used to develop scientific ideas in the Year 8 science lessons or as sidebars:

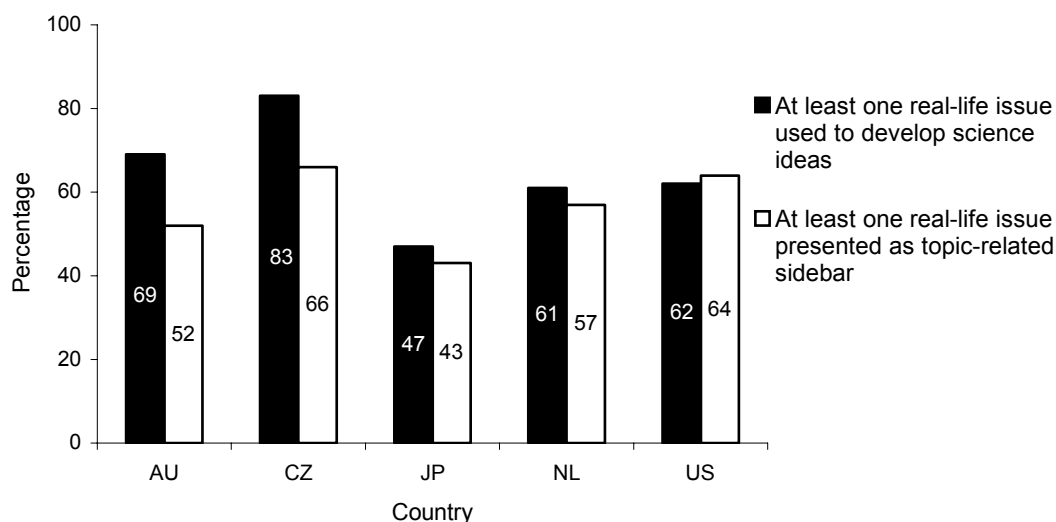
- Real-life issues used to develop scientific ideas: Real-life issues are used to develop, clarify, and/or support ideas in science beyond a simple topic connection. The teacher can tell students about how the real-life issues support the ideas or engage students in making the links themselves (e.g., through class discussions or independent activities). Examples include:

- showing the students a torch from home and explaining how the batteries, globe, and wires in the torch form a simple series circuit;
  - examining a compost bin that the class has constructed to consider how matter is being changed (chemical and physical changes); and
  - providing an everyday example to support the idea that fat floats on water: e.g., fat floating on soup.
- Real-life issues mentioned as topic-related sidebars: Real-life issues are not used to develop, clarify, and/or support scientific ideas in the lesson. Instead, the real-life issues are mentioned as interesting ‘asides’ related to the topic. For example, the students or the teacher talk about personal experiences related to the topic, information is presented about topic-related science careers, examples related to the topic in students’ everyday life are named or shown, or topic-related news stories are discussed but are not used to develop specific ideas in science. Examples include:
    - having students recount personal experiences of rapid weather changes as an introduction to a unit on weather; and
    - recounting a personal hiking experience in a gorge during a lesson about the changing surface and layers of the earth.

### Incidence


Figure 6.2 compares the percentages of Year 8 science lessons in which at least one real-life issue was used to develop scientific ideas and lessons in which at least one real-life issue was mentioned as a topic-related sidebar only.

**Figure 6.2 Percentages of Year 8 lessons that contained at least one real-life issue used to develop scientific ideas and as a topic-related sidebar only**



Real-life issue used to develop ideas in science: AU>JP; CZ>JP, NL, US  
Real-life issue mentioned as topic-related sidebar: CZ>JP

At least one real-life issue was used to develop scientific ideas in more Czech Year 8 science lessons than in all the other countries except Australia. More Australian lessons used at least one real-life issue to develop scientific ideas than Japanese lessons.

The use of real-life issues to develop ideas in science can be viewed in  AU PRL 4. The teacher commented:

I began with this example as it is something that is familiar to all the students, something that they all would have experienced. I believe that if students can relate science concepts back to a familiar experience of their own, then they can better understand that concept and remember it. (AU PRL 4, Teacher's Comments, 00:04:34)

And later the researchers noted:


During discussions such as this, the teacher links canonical knowledge with real-life issues when she asks the students to compare the energy transformation of lighting a match with the energy transfer of a warm foot to a cold bathroom floor. (AU PRL 4, Researchers' Comments, 00:11:15)

#### Percentage of lesson time

Despite the moderately high incidence of lessons in which reference was made to one or more real-life issues or examples, discussion of these issues and examples occupied relatively low percentages of lesson time. Average percentages of science instruction time when real-life issues were used to support concept development ranged from 3 to 10 per cent, in Japan and the Czech Republic, respectively, while average percentages of time in which real-life issues were mentioned as interesting sidebars only ranged from 4 to 17 per cent, in the Czech Republic and the United States, respectively. The differences between these extreme values were significant in both cases.

In the Australian lessons, 12 per cent of Year 8 science instruction time was spent equally on using real-life issues to develop scientific ideas and on using them as topic-related sidebars only. Within the United States, more time was spent presenting real-life issues as topic-related sidebars than using real-life issues to develop scientific ideas, whereas the opposite was observed within the Czech Republic. No measurable difference was found within the other three countries (data not shown).

#### ***Real-life objects***

In addition to print and visual aids, science teachers sometimes use 3-dimensional objects to support their science teaching. Many of these objects may be unfamiliar to students in their experiences outside of the science classroom, such as microscopes, beakers, flasks, ammeters and graduated cylinders. However, teachers may also use everyday objects that are familiar to students. These were defined as objects likely to be familiar to students from their experiences outside of school and that are used during science instruction to illustrate and/or develop concepts in science. The objects may be shown by the teacher in front of the whole class or used by the students during independent practical activities. (See  AU PRL 5, 00:22:46 – 00:23:15, for example.) The percentages of lessons per country that used at least one real-life object to develop scientific ideas ranged from 11 per cent in Japan to 25 per cent in Australia, with no measurable difference found between countries (data not shown).

#### ***Hands-on practical work***

In Chapter 3, independent practical activities were presented in comparison with other types of lesson activities and in Chapter 5 the nature of practical work was described. Because practical activities are often mentioned by students as interesting (e.g., Millar et al., 1999; Molyneux-Hodgson et al., 1999; Myers & Fouts, 1992), they are mentioned briefly again here from the perspective that teachers may have used them to engage students' interest and involvement in learning science. How often did Australian teachers engage students in hands-on practical work?

- *Seventy-four per cent of Australian Year 8 science lessons contained at least one independent practical activity, and, on average, 33 per cent of instruction time in Australian lessons was allocated to independent practical activities.*

Czech and Dutch Year 8 science lessons were less likely to include independent practical activities than lessons in Australia and Japan (see Figure 5.1). In addition, Czech lessons were less likely to include independent practical activities than lessons in the United States, which in turn were less likely than lessons in Australia to include such activities. Furthermore, Czech lessons allocated a



smaller average percentage of instructional time to independent practical activities than the other four participating countries (see Figure 3.7). Dutch lessons allocated a smaller percentage of time to independent practical activities compared with lessons in Australia and Japan.

### ***Motivating activities***

Teachers in the Year 8 science lessons used activities with the potential to motivate their students to engage in science learning, though the actual effects of the activities could not be determined. How often did Australian teachers use this type of activity in their science instruction?

- *At least one motivating activity was used in 37 per cent of Australian science lessons. On average, these activities consumed 11 per cent of the instruction time.*

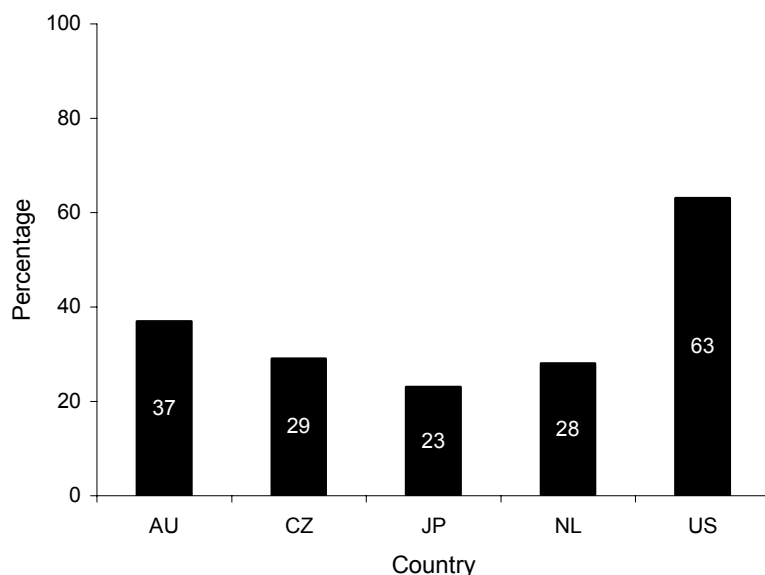
Motivating activities were defined as activities that include at least one of the following elements:

- surprising, exciting, and/or dramatic phenomena or demonstrations;
- dramatic presentations or stories such as personal experience stories and role plays;
- unusual, creative, or competitive student activities such as creating a travel brochure to a planet, making a battery out of citrus fruits or racing model cars, or simulation or scenario activities (e.g. a crime lab), competitions, games or puzzles;
- presentation and/or use of materials or objects that appeal to students' fascination such as novel gadgets or mysterious substances such as 'slime'; and
- activities that require going outside of the classroom to do things such as collect rocks, observe clouds, shoot off rockets, or run up and down the stairs to get timed for speed.

### **Incidence**

The percentages of Year 8 science lessons that contained at least one potentially motivating activity are presented in Figure 6.3.

**Figure 6.3 Percentages of Year 8 science lessons that had at least one motivating activity**



*Note: US > CZ, JP, NL*

More Year 8 science lessons in the United States contained at least one potentially motivating activity compared with lessons in the Czech Republic, Japan and the Netherlands. Thirty-seven per cent of Australian lessons had at least one potentially motivating activity.

#### Percentage of lesson time

In keeping with the incidence of lessons in which potentially motivating activities were featured, a larger average proportion of instructional time was spent on such activities in United States lessons (23%) compared with lessons in the Czech Republic, Japan and the Netherlands (3% to 5%). In Australian Year 8 science lessons 11 per cent of science instruction time was allocated to motivating activities (data not shown).

✎ *AU PRL 3* provides an example of an activity aimed at motivating student interest. As the teacher explained:

I am trying to quiz them in different ways to keep things interesting. (...) Students often call out answers and this can sometimes be difficult to manage. But often students, like in this situation here, do so out of enthusiasm. (*AU PRL 3, Teacher's Comments, 00:11:11*)

#### ***The use of different strategies to engage students***

Variations were found within the countries in the percentages of lessons in which the teachers used different types of activities for engaging students. Within all the participating countries, teachers used one or more real-life issues to engage students' interest in more of the Year 8 science lessons than they used motivating activities. Within the Czech Republic, the Netherlands, and the United States, teachers also used one or more real-life issues in more lessons than they involved students in carrying out hands-on independent practical activities (see Figure 6.1 and Figure 5.1). Within Australia and Japan, however, teachers used both real-life issues and independent practical activities in more lessons than they used motivating activities.

#### Multiple activities

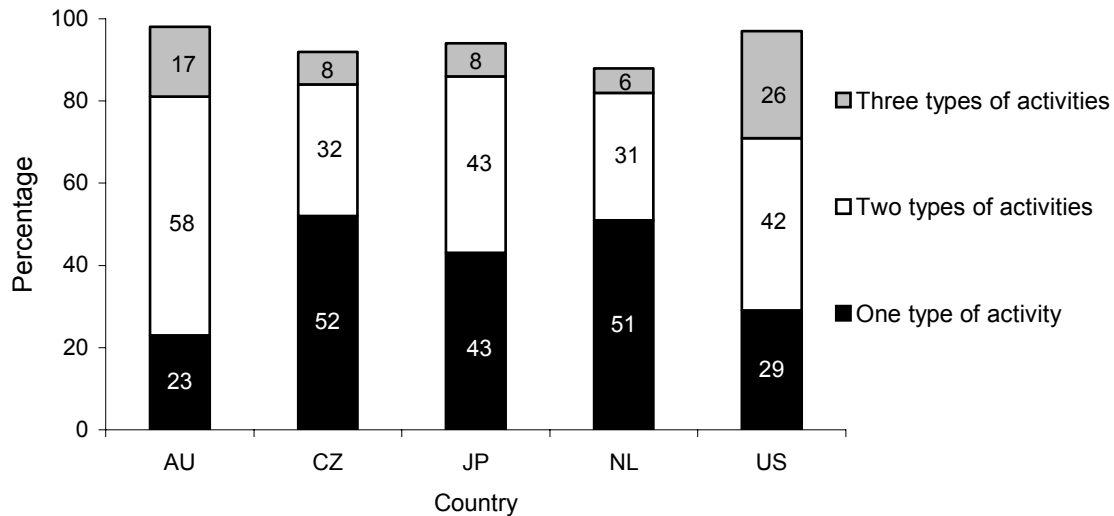
Teachers can use more than one instructional strategy to increase students' interest and motivation in science. This practice is consistent with the research, cited at the beginning of the chapter, which suggests an association between students' positive attitudes towards science and a variety of teaching strategies and unusual learning activities. How often did Australian teachers use more than one instructional strategy to increase students' interest and engagement?

- *Australian teachers made use of more than one type of activity to engage students' interest in 75 per cent of the Year 8 science lessons.*

Figure 6.4 presents the percentage distributions of Year 8 science lessons that involved use of one or more of the three types of activities that can potentially engage students in science (real-life issues, motivating activities, and independent practical activities – see Chapter 5 for discussion of the latter).

Teachers in at least 88 per cent of the science lessons in each of the participating countries used at least one of the three activity types to make science engaging to students. Countries varied from each other on the average number of strategies that teachers employed to try to engage students. Year 8 science teachers in more United States lessons used all three types of activity to try to engage students compared with science teachers compared with the Czech Republic and Japan. Two types of strategy were used in more Australian lessons than in Czech or Dutch lessons, which tended to use only one type of strategy per lesson to engage students.

**Figure 6.4** Percentage distributions of Year 8 science lessons in which teachers used three, two and one type of activity to engage students' interest



Three types of activities: US>CZ, JP, NL

Two types of activities: AU>CZ, NL

One type of activity: CZ>AU, US; NL>AU

## Opportunities for Communicating Science

### *Research background*

In their review of the research literature, Roth et al. (2006) suggest four main reasons why communication in science teaching and learning is important:

- Communication is an essential feature of science, the scientific inquiry process and the ways in which the scientific community works;
- The language of science can be both important and difficult for students to learn;
- Communication plays a critical role in supporting the science learning process; and
- To prepare students to become scientifically literate adults, science teaching needs to support students in learning how to become critical listeners and readers who can communicate their ideas and responses clearly.<sup>42</sup>

With respect to student involvement, Roth et al. highlight the importance of students playing an active role in communicating about science:

Research on learning conducted in a variety of fields and from differing methodological approaches and theoretical perspectives points to the need for the learner to play an active role in the sense-making process, interacting with experts (whether this is a teacher or text) to develop new understandings (Brown & Campione, 1994; Collins, Brown & Newman, 1989; Gee, 1999; Halliday & Martin, 1993; Lemke, 1990; NRC, 2000; Posner et al., 1982; Rosebery, Warren & Conant, 1992; Saul, 2003; Schoenfeld, 2002; Vygotsky, 1978). Consistent with these theoretical perspectives and findings, research on science teaching and learning suggests that students could benefit from being active learners rather than passive recipients of knowledge. (...) That is, students might benefit from speaking, listening, reading, and writing about science while interacting with others who can challenge and shape their thinking. In support of this, a number of studies provide evidence that the writing tasks that require active processing and sense-making are effective in supporting students' science learning (Eggleston et al., 1976; Keys et al., 1999; Roth, 1992). (Roth et al., 2006, beginning of Chapter 9)

<sup>42</sup> References to and some discussion of this research are provided in Roth et al., 2006.

### ***Country perspectives***

Communication is of interest in this study because curriculum and standards documents in most of the participating countries indicate that learning to communicate about science is a goal of science education. An important objective is that students should be 'scientifically literate' and students' development in this regard is facilitated through communicating about science in various ways (Norris & Phillips, 2003).

In Australia, a national document on science for Australian schools (AEC, 1994) specified two of nine goals for science education related to communication: 1) to learn to communicate scientific understanding to different audiences for a range of purposes, and 2) to use scientific language to communicate effectively and to further one's understanding of science. One of seven principles for effective learning experiences in science specified in the Australian document emphasises the importance of helping students use scientific language appropriately:

The language students use, whether speaking, writing, or drawing, is a critical part of their learning as they try to express their ideas, grasp the ideas of others, and extend their understanding. (...) The use of technical language should not be an end in itself, however, but should be regarded as a means of developing a greater understanding of and more precise ways of communicating about science. (p. 8)

In the United States, the American Association for the Advancement of Science (AAAS) benchmarks document highlights communication skills as one of the five habits of mind that students should develop, and the *National Science Education Standards* encourages teachers to require students to record their work and to use different forms of communication (spoken, written, pictorial, graphic, mathematical, and electronic) (NRC, 2000).

In the Czech Republic and the Netherlands, communication goals are identified as important general attainment goals or basic targets for education in all subject areas (Czech Ministry of Education, 1996; Dutch Ministry of Education, Culture, and Science, 1998). The Czech standards call for students to be able to clearly articulate, listen, read with understanding, and interpret what is read. Students should be able to work independently with the textbook, to look for information, to organise it, and to make notes. In the Netherlands, one of the six general attainment target areas across subject areas is learning to communicate. In another general attainment category—learning to do, goals focus on comprehending written and spoken Dutch and English as well as speaking and writing correct Dutch. These communication goals are expected to contribute to the goals for physics, chemistry and biology education.

Thus, each of the countries emphasises students' abilities to speak, read and write intelligently about science. The countries also emphasise students' abilities to understand and use specific and precise scientific terms. Details related to the use of specific scientific language in the videotaped lessons were presented in Chapter 4.

What different kinds of opportunities did students in the Year 8 science lessons have to be actively involved in communicating science? How often, and in what ways did they talk about science, write about science, and read about science?

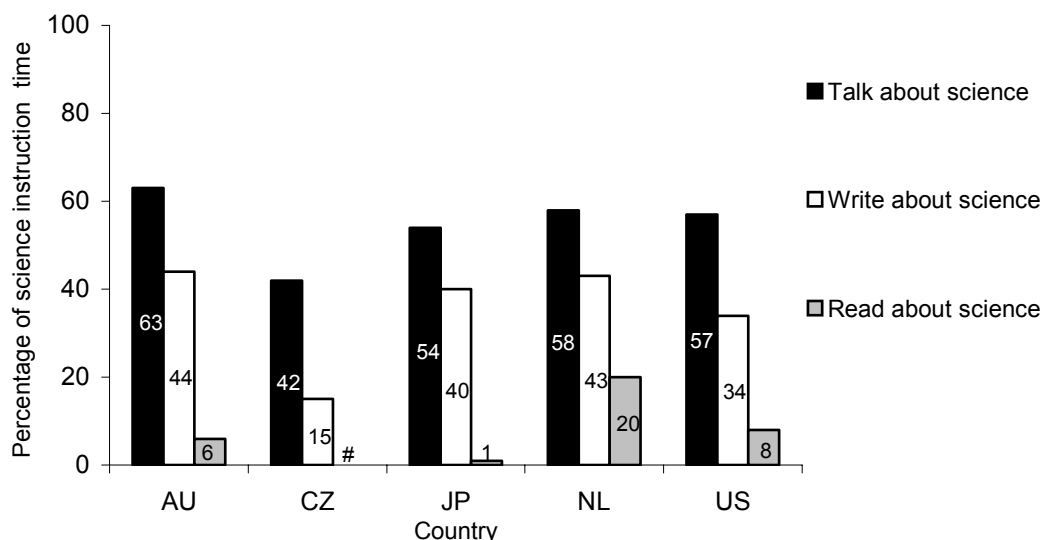
### ***Different kinds of opportunities to communicate about science***

Teachers can provide a variety of opportunities for students to communicate about science through talking, writing and reading activities. What do the patterns of opportunities for students to communicate in these three different communication modes look like in Australia and across the participating countries?

- *In Australia, as in all the countries, more instructional time, on average, was provided for students to talk about science than to write about science, and more time was provided to write about science than to read about science.*

Figure 6.5 presents the average percentages of science instruction time students were observed talking with their teacher and/or peers, writing or reading about science during whole-class work, private teacher–student talk or independent work in the Year 8 science lessons.

**Figure 6.5** Average percentages of science instruction time in Year 8 science lessons when students had opportunities to talk, write or read about science



# Rounds to zero

Talk about science: AU, JP, NL, US>CZ

Write about science: AU, JP, NL, US>CZ

Read about science: NL>AU, CZ, JP; AU, US>CZ

Note: Percentages may add to more than 100 because some activities could occur together (e.g., talking and writing).

The time during which students have the opportunity to talk with the teacher and their peers includes whole-class discussion time, private student–teacher talk time, and time during pair/group and individual work time when students have the opportunity to talk with each other. Students’ opportunities to write include time spent on taking notes, selecting answers and generating text. Students’ opportunities to read include time spent in reading text aloud together and time spent reading silently. The more specific opportunities to communicate will be presented in more detail in the following sections of this chapter.

Within all the participating countries, more instruction time, on average, was provided for students to talk about science with their teacher and peers during discussions, private teacher–student talk, and independent work than to write or read about science. Also, more time was allocated for students to write about science during the lessons than to read about science.

The countries varied from each other, however, in how much instruction time was allocated for these different kinds of opportunities to communicate science. Compared with all of the other countries, lessons in the Czech Republic provided less instruction time, on average, for students to talk with their teacher and/or peers about science and to write about science. Dutch Year 8 science lessons mostly provided a larger average proportion of instruction time for students to read about science than other countries’ lessons. Australian and United States lessons also provided more time for students to read about science than Czech lessons, which provided almost no time for this activity.

#### Opportunities to communicate about science during seatwork activities

Further analyses examined differences between students’ opportunities to communicate during practical and during seatwork activities. Of particular interest are the Dutch patterns that emerged for seatwork activities. During such activities, Dutch science lessons provided more opportunities

for students to communicate through talking, writing and reading than in some other countries. Dutch lessons allocated more instruction time, on average, for students to discuss science with their teacher and peers (39%) than Australian and Japanese lessons (29 and 20 per cent, respectively); more instruction time per lesson for students to write about science (25%) than the Czech Republic and Japan (12 and 13 per cent, respectively); and more time to read about science (16%) than Australia (4%) and Japan (1%) (data not shown).

### ***Opportunities for students to talk about science***

The role of classroom talk has received a great deal of attention in the research literature. Although most studies show that teachers talk the majority of the time while their students are listeners (e.g., Goodlad, 1984; Hiebert et al., 2003), there is disagreement over the effect of this pattern on learning. Some argue that student learning is best fostered by explicit or direct teaching, where teachers necessarily have substantially more talk opportunities than students (e.g., Gage, 1978; Walberg, 1986). Advocates of student talk suggest that student interaction increases opportunities for students to elaborate, clarify and reorganise their own thinking and that some teacher–student interaction strategies can support students’ opportunities to make sense of new experiences (Bleicher, Tobin & McRobbie, 2003). A third view is that the optimum ratio of teacher to student talk is a function of the lesson content (Goldenberg, 1992/1993). Another area of debate concerns the use of technical terms in science teaching. Some argue for the use of common, everyday words instead of technical terms in the science classroom (e.g., Maskill, 1988). On the other hand, some research has provided evidence that learning the language and terms of science is fundamental to understanding science (e.g., Gee, 2002; Lemke, 1990; Wellington & Osborne, 2001; Yager, 1983). In summary, there is no broad consensus regarding the impact of student participation in classroom discourse.

In this section, findings with regard to students’ opportunities to talk during whole-class work and during independent work in the Year 8 science lessons are described first. These include the science instruction time available for different types of talk, and the ratios of words spoken by teachers and students. Then, the length of student utterances is presented in terms of the number of words spoken. 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 (e.g., 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.

#### Teacher–student talk during whole-class work

Public talk during whole-class work can be described in two ways: discussions between teachers and students, and presentations by teachers, students or other sources. The lessons were analysed for any type of whole-class discussion in order to identify students’ opportunities to interact verbally with, rather than simply listen to, the teacher. In contrast to presentations by teachers or other sources, discussions most often took the form of a series of teacher questions, student responses and evaluations of the responses by the teacher, known as the initiation–student response–teacher evaluation (IRE) pattern (e.g., Cazden, 1986; Sinclair & Coulthard, 1975). Discussions could involve both everyday forms of talk and scientific terms. Discussions where students played a more central role, such as those described elsewhere as ‘highly interactive discourse structures’ (Schoenfeld, 2002), ‘argumentation discourse’ (Kelly & Chen, 1999), ‘diagnostic teaching’ (Bell & Purdy, 1985) and ‘science talks’ (Gallas, 1995), were rarely observed.

How often were Australian students involved in public presentations and discussions in Year 8 science lessons?

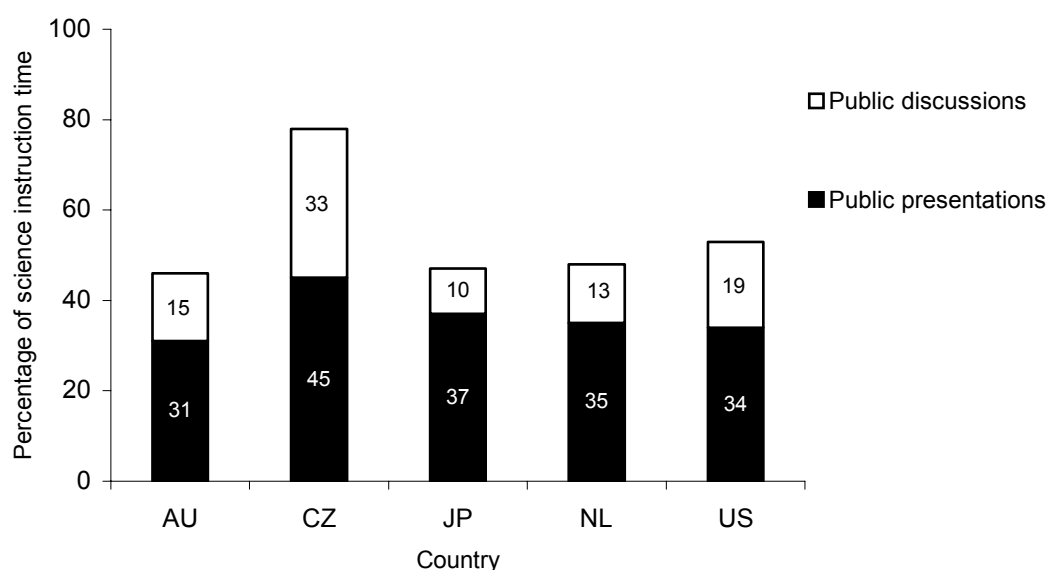
- *In Australian lessons, like lessons in all participating countries, whole-class talk was more likely to take the form of public presentations (31 per cent of science instruction time) than public discussion (15 per cent of science instruction time).*

The types of public talk during whole-class work are defined below.

- **Public presentations during whole-class work:** Time during whole-class work when the teacher or some other source (e.g., student, video, textbook read aloud or visiting speaker) gives information intended for the whole class to hear and there are no (or only very short) back-and-forth exchanges among class members. (AU PRL 2, 00:13:35 – 00:15:51)
- **Public discussions during whole-class work:** Time during whole-class work with public exchanges between the teacher and students or among different students. These segments are characterised by back-and-forth dialogue, where no one speaker keeps the floor continuously for more than 30 seconds. (Otherwise, this time would be coded as public presentations during whole-class work.) (AU PRL 4, 00:09:42 – 00:11:50)

Figure 6.6 presents the average percentage of science instruction time per country spent on public presentations and discussions during whole-class work. Within all the participating countries, whole-class talk was more likely to take the form of public presentations (usually by the teacher) than back and forth public discussion among students and teachers. Lessons in the Czech Republic devoted more time to public presentations and more time to public discussion than lessons in any of the other four countries. Although discussions accounted for only 10 to 33 per cent of the instruction time, they occurred in at least 80 per cent of the lessons in all five countries (data not shown).

**Figure 6.6 Average percentages of science instruction time per Year 8 science lesson devoted to public presentations and discussions during whole-class work**



Public discussions: CZ>AU, JP, NL, US; AU, US>JP

Public presentations: CZ>AU, JP, NL, US

Note: The percentage of science instruction time devoted to public talk during independent work is not reported.

#### Teacher–student talk and student–peer talk during independent work

While instruction time may be provided for private talk between the teacher and an individual student or between the teacher and a small group of students in the Year 8 science lessons, students also may have opportunities to talk among themselves as they work individually or in pairs or groups on independent activities. What kinds of opportunities did Australian students have to communicate during independent work?

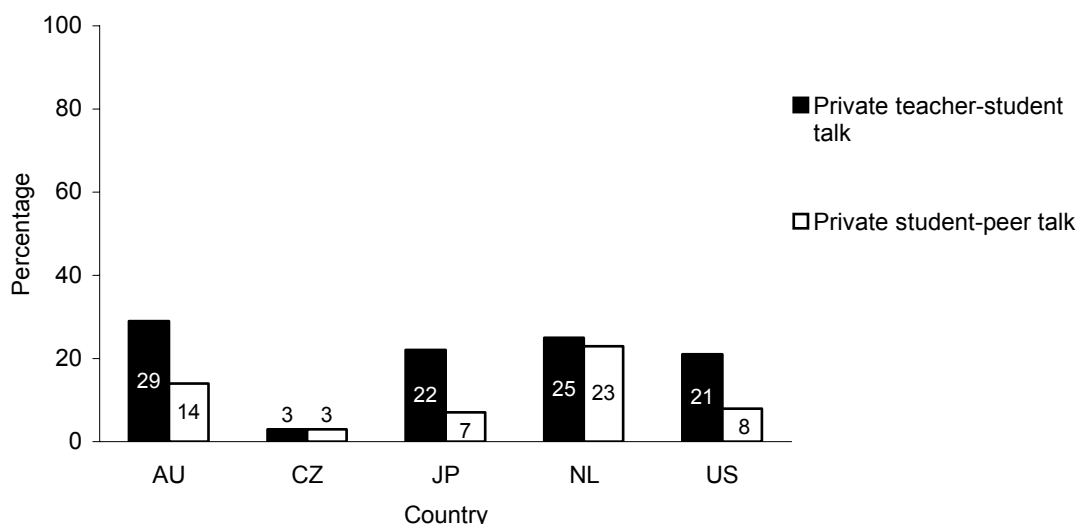
- *Australian students were able to communicate privately, either with their teacher or among themselves, for about half the instruction time in their Year 8 science lessons.*

Each lesson was examined for the amount of time students had for different opportunities to communicate during independent work using the following definitions.

- **Private teacher–student talk:** Time during independent work when the teacher provides guidance or instruction to an individual or group, but not to the whole class, or receives information from them. Either the teacher or a student may initiate the assistance. The content of the talk must be related to scientific ideas or tasks. (AU PRL 5, 00:36:40 – 00:37:45)
- **Private student–peer talk:** Time during independent work when students have opportunities to talk among themselves as they work individually or in groups. Although the talk among students may have been related to science, it was not possible to identify the content of the talk. (The intent of measuring private student–peer talk was to capture how much opportunity students had to talk about science with each other.)

Figure 6.7 presents the average percentage of science instruction time per country that students engaged in private talk with their teacher or talked among themselves.

**Figure 6.7 Average percentages of science instruction time in Year 8 science lessons with opportunity for private teacher–student talk and private student–peer talk during independent work**



Private teacher-student talk: AU, JP, NL, US > CZ

Private student-peer talk: AU, JP, NL, US > CZ

*Note:* Percentages of science instruction time devoted to copying notes, silent reading, divided class work, and whole class work are not reported.

During independent work, Year 8 students in all the countries except the Czech Republic used roughly a quarter of the time to communicate privately with their teacher. Students were observed talking privately with their teachers during an average of only 3 per cent of science instruction time in the Czech Republic. Although Czech lessons provided students with more instruction time for public discussions than all the other countries (Figure 6.6), Czech students were less likely to have opportunities to discuss science both privately with their teacher and with their peers than students in science lessons in all the other countries (Figure 6.7).

Different country patterns emerge when comparing opportunities within independent and whole-class work. While Czech science lessons provided the smallest average percentage of science instruction time (3%) for private teacher–student talk and for students to interact with their peers



compared with all the other countries, they provided more opportunities for students to communicate during whole-class work by allocating a larger average percentage of science instruction time to public discussions (Figure 6.6).

#### Ratios of teacher words to student words during whole-class and independent work


How much did teachers and students talk during whole-class and independent work in the Australian Year 8 science lessons?

- *In all the participating countries, including Australia, teachers spoke more words per lesson than students during both whole-class and independent work (ratios of at least 7:1 words in whole-class work and at least 3:1 in independent work). In Australian lessons, on average, teachers spoke 9 words to every one student word in whole-class work and 3 words to every one student word in independent work. In Australia, as elsewhere, students tended to speak in short utterances – only about 20 per cent of their utterances during whole-class work and about 30 per cent during independent work were of 5 words or more.*

Computer-assisted text analyses were applied to English transcripts of the lessons to quantify how often Year 8 students and teachers talked during science lessons. For the Czech Republic, Japan and the Netherlands, all lessons were translated from the respective native languages. Analyses based on same-language transcripts allow for comparisons of speech across countries, though not without potential bias. To minimise bias, translators were fluent in both English and the language of the countries they translated and a glossary was developed to standardise translation of special terms. All translations were checked for accuracy by a second translator as well as by a content expert.

Before presenting the results, it is important to note that student talk was recorded and transcribed from a microphone worn by the teacher as well as one mounted on each of the two video cameras. When several students spoke at once or made remarks out of range of the microphones, transcribers sometimes were able to detect that something was said without being able to make out the words. Since these student utterances were not transcribed, estimates of the amount of student talk are likely to be lower than actually occurred.

As would be expected, teachers spoke more words per lesson during whole-class work than did students, at a ratio of at least 7:1 (in the Netherlands). The Netherlands, the Czech Republic and the United States (both 8:1) and Australia (9:1) were similar to each other. Japanese Year 8 science teachers spoke significantly more words relative to their students (13:1) during whole-class work than did teachers in all of the other countries except Australia (data not shown).

An example of one Australian teacher's attempt to encourage student talk during whole-class work can be viewed early in  *AU PRL 5*. The teacher has the students come nearer to the front of the room into what he calls a 'huddle'. He explains:

This is designed to create an informal and somewhat more intimate situation where students will feel less intimidated than the formal seating arrangement. It encourages students to engage verbally in the lesson and to take some intellectual risks such as suggesting ideas that they might otherwise think are not worth mentioning. (*AU PRL 5, Teacher's Comments, 00:00:30*)

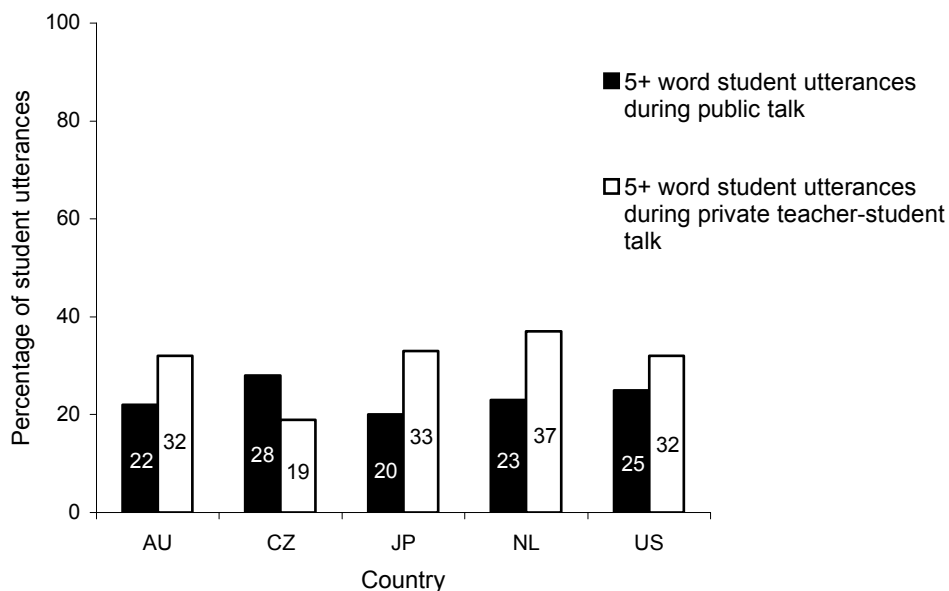
In four of the countries, as teachers walked around the classroom assisting with or monitoring students' work during independent activities, the ratios of teacher to student talk were much lower, at about 3:1, including in Japan. The country that was different in this respect was the Czech Republic, where teachers spoke seven words to every one student word during the relatively small portions of time devoted to independent work (see Figure 3.6).

#### Length of utterances

Another way to describe students' opportunities to talk is to examine the average length of student utterances. 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 this analysis it was assumed that an

utterance of five or more words is likely to constitute a meaningful thought constructed by the student. Country comparisons on the proportion of student utterances that included five or more words per utterance during the different types of talk are presented in Figure 6.8.

**Figure 6.8** Average percentage of student utterances of 5 or more words per Year 8 science lesson during public and private teacher–student talk



5+ words student utterances during public talk: CZ>AU, JP, NL

5+ words student utterances during private teacher-student talk: AU, JP, NL, US>CZ

Note: Analyses based on English language transcripts.

Longer utterances of five words or more constituted on average between 20 and 28 per cent of student utterances per lesson during whole-class work time (labelled as ‘public talk’) and between 19 and 37 per cent of student utterances per lesson during independent work time (labelled as ‘private talk’). In all countries, around 80 per cent of teacher utterances on average consisted of five or more words (data not shown). There were differences between countries in the incidence of longer student utterances, indicating that lessons in some countries provided different opportunities for students than lessons in other countries on this dimension.

When Czech students spoke publicly during whole-class work, they were more likely to use five or more words than students in Australian, Dutch and Japanese lessons. They were less likely to use utterances of five or more words than students in all the other participating countries during private teacher–student talk that transpired during independent work.

In broad terms, the Year 8 science lessons in all the countries revealed students taking many brief opportunities to talk during their lessons, and very few long opportunities. This is similar to the pattern often reported in the literature, including for the TIMSS 1999 Mathematics Video Study, in which teachers talk and students listen (e.g., Cazden, 1988; Goodlad, 1984; Hollingsworth et al., 2003).

### ***Opportunities for students to write about science***

In the scientific community, writing is an essential tool for communicating, sharing, and critiquing scientific investigations, claims, arguments and theories (Lemke, 1990; Locke, 1992), and standard forms are used for writing science and for formal procedures for peer review of scientific writing (AAAS, 1993). Writing in science classrooms, however, can take different forms and can serve different purposes than writing in the scientific community. Some educators emphasise the need

for students to learn scientific modes of writing, and to understand and reproduce the written language used by scientists (e.g., Hand, Alverman, Gee, Guzetti, Norris, Phillips, Prain & Yore, 2003; Prain, 2002). This emphasis is reflected in the widespread requirement for students to write formalised laboratory reports in science classrooms (Rudd, Hand & Greenbowe, 2002). Prain and Hand (1999) emphasise the usefulness of giving students 'writing tasks that require them to explore and consolidate understandings, and also to reflect on their own learning from writing' (p. 161).

Research by Newton, Driver and Osborne (1999) found that students spent a significant amount of time writing during their science lessons – 22 per cent of practical work time and 23 per cent of seatwork time. Wellington and Osborne, on the other hand, express concern that the call for increased focus on hands-on practical work and inquiry activities 'pushes writing into the background, denying children access to the genres of science that store information' (2001, p. 67).

There appears to be agreement, however, that writing in science lessons often involves copying notes, or low level writing tasks that focus on reproduction of knowledge (Davies, 1984; Eggleston, Galton & Jones, 1976; Newton et al., 1999; Wellington & Osborne, 2001). Writing that requires more active processing on the part of the learner occurs less frequently, but has been shown to be more effective in challenging and supporting student learning (Eggleston et al., 1976; Keys, Hand, Prain & Collins, 1999; Roth, 1992).

To what extent did Australian students in Year 8 science classrooms have the opportunity to communicate about science through writing? The following sections describe the types of writing tasks students were involved in during whole-class work and during independent work that involved letters or words only, and the opportunities students had to create representations other than words, including diagrams, graphs and mathematical calculations.

#### Types of writing

Writing that required students to put only letters or words on paper (versus diagrams, graphs, or mathematical representations) ranged from less cognitively demanding tasks, such as taking notes during whole-class work and selecting answers during independent work, to potentially more cognitively demanding tasks, such as preparing a laboratory report or writing an essay (e.g., *AU PRL 2, 00:32:25 – 00:32:45*, where a writing task based on practical work is assigned).

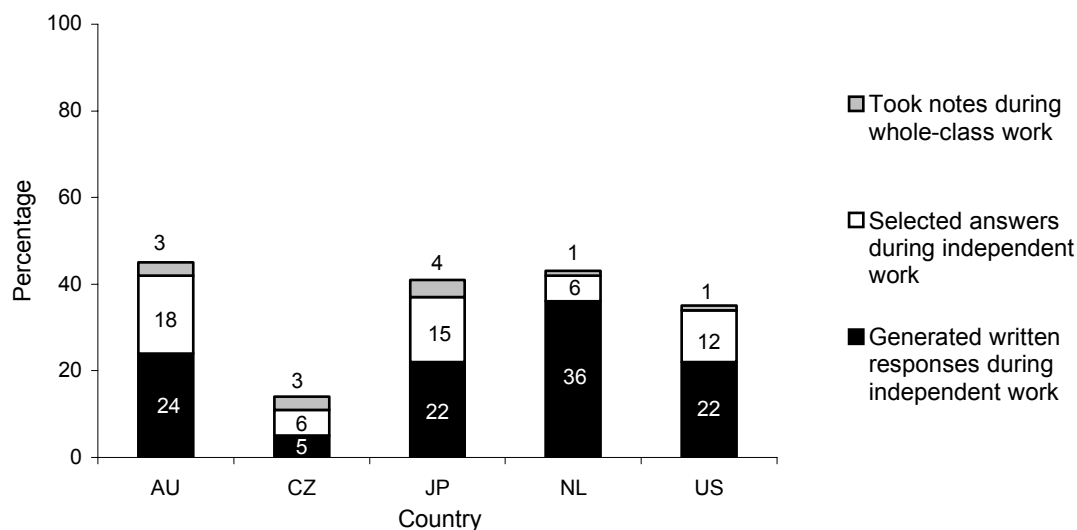
The videotaped lessons were examined for students' opportunities to engage in each of these types of writing. What kinds of opportunities did Australian students have to write in Year 8 science lessons?

- *In Australian science lessons, and in science lessons in most of the other countries, students generated written responses during independent work more often than they took notes during whole-class work.*

Figure 6.9 presents the average percentages of science instruction time per country in which students were expected to take notes during whole-class work, to select answers during independent work, and to generate written responses during independent work. Overall, students in the Year 8 science lessons in Australia, Japan, the Netherlands and the United States were provided with more total instruction time, on average, to write about science during independent and whole-class work combined than in Czech lessons.

More information on these differences is provided by looking separately at the types of writing tasks in which the students engaged. Specifically, compared with the Czech Republic, students independently generated written responses for larger percentages of instruction time, on average, in the other four countries. Students in Dutch lessons independently selected answers for a smaller proportion of instruction time than students in Australian lessons. Students in Czech lessons also spent less time on independently selecting answers than students in Australian and Japanese lessons. Within all the participating countries, more instruction time, on average, was provided for writing during independent work than for taking notes during whole-class work. Within the Netherlands and the United States, students generated written responses for longer average proportions of instruction time than they selected answers during independent work. No measurable difference was found within Australia, the Czech Republic, or Japan.

**Figure 6.9** Average percentages of science instruction time in Year 8 science lessons during which students undertook various science-related writing activities



Took notes during whole-class work: CZ, JP>NL, US

Selected answers during independent work: AU>CZ, NL; JP>CZ

Generated responses during independent work: AU, JP, NL, US>CZ

Similar patterns of differences appeared when countries were compared on the percentages of Year 8 science lessons that provided any opportunity for students to engage in the different writing tasks. Again, compared with the Czech Republic, students independently generated written responses in more Australian, Dutch, and United States Year 8 science lessons (70, 72 and 56 per cent, respectively) (data not shown). Students in Dutch lessons also independently selected answers in fewer lessons (18%) than students in Australian, Czech, and Japanese lessons (54, 40 and 49 per cent, respectively). While writing activities occurred in 40 per cent or more of the lessons in some countries, the tasks typically involved providing only short answers or descriptions. Students in the Year 8 science lessons in all five countries were expected to write at least a paragraph related to independent practical or seatwork activities in no more than 11 per cent of the lessons (data not shown). Students took notes during whole-class work in more Czech and Japanese lessons (45 and 43 per cent, respectively) compared with students in Dutch and United States lessons (13 and 16 per cent, respectively).

#### Diagrams, graphs, and mathematical calculations

Students also independently worked on writing tasks that used representations other than words. These tasks required students to construct graphs and diagrams (including concept maps) and to carry out mathematical calculations using operations such as addition, subtraction, multiplication and division, or simplification of two or more numerical values (such as calculating density of objects, force, pressure). Activities such as simple counting, numbering, reading numerical values and comparisons of numbers that could be made without calculations are not included.

Tasks that involved graphs were observed in 3 to 12 per cent of the science lessons (3 per cent in Australia), with too few observations in the Czech Republic to calculate reliable estimates. Students were observed working independently on diagrams in 6 to 25 per cent of the science lessons (21 per cent in Australia), and working on mathematical calculations in 12 to 30 per cent of the science lessons (12 per cent in Australia). Students worked on diagrams during independent work in more Dutch Year 8 science lessons (25%) than Czech lessons (6%). No measurable difference among countries was found on the percentages of science lessons that included independent work on graphs or mathematical calculations (data not shown).

### ***Opportunities for student reading about science***

Reading is seen as another equally important part of scientific inquiry. Scientists take a critical stance towards written information: analysing it, evaluating it and assessing the soundness of its knowledge claims (AAAS, 1993; Goldman & Bisanz, 2002; Hand et al., 2003). For the general public, engaging in reading scientific texts can be challenging, but it is an essential skill for a scientifically literate citizenry (Goldman & Bisanz, 2002).

Studies show that reading receives scant attention in the science classroom (Davies, 1984; Lunzar & Gardner, 1979; Wellington & Osborne, 2001). Little time is spent on extended, planned reading in science classrooms, and textbooks are used primarily as a source of homework assignments or directions for practical activities rather than for reading (Wellington & Osborne, 2001). Scientific text can pose difficulties for some learners and may not be as engaging for some students as other types of literature (Driscoll, Moallem, Dick & Kirby, 1994; Garner, Alexander, Gillingham, Kulikowich & Brown, 1991; Wellington & Osborne, 2001). In addition, some contend that science textbooks can be dense with technical terms and organised in ways that are less likely to support student understanding (e.g., Ciborowski, 1992; Roseman, Kesidou, Stern & Caldwell, 1999).

To what extent did students in Australian Year 8 science lessons have opportunities to read about science? Did students in some countries have more opportunities to read than others? Discussed in this section are comparisons of students reading together during whole-class work, students reading independently and students using textbooks in their science lessons.

#### ***Reading aloud together and reading silently***

In the videotaped lessons, teachers provided students with opportunities to read about science silently on their own or aloud to the whole class. The text needed to be at least a paragraph in length and beyond merely reading questions to be answered.

##### ***Incidence***

Students read aloud together in 6 to 13 per cent of the videotaped lessons (6 per cent in Australia), with no measurable difference detected between countries. More Dutch and United States science lessons involved students in silent reading tasks (43 per cent and 25 per cent, respectively) than did lessons in the Czech Republic (3%) or Japan (8%). Students also were asked to read silently in more Australian lessons (23%) than in Czech lessons (data not shown).

##### ***Percentage of instruction time***


Teachers allocated between 6 and 20 per cent of science instruction time for reading about science in Australian, Dutch and United States lessons (6, 20 and 8 per cent, respectively, as shown in Figure 6.5). Most of this time was spent in reading silently rather than reading aloud together as a class, which occurred in no more than 1 per cent of science instruction time in any country (data not shown).

On the assumption that writing tasks are sometimes undertaken together with reading tasks, the pattern of country differences on students' opportunities to write about science, shown in Figure 6.9, could perhaps be partly explained by looking at the pattern of instruction time allocated to reading about science (see Figure 6.5). The main departure from this pattern occurred in Japan, where negligible instruction time was allocated to reading tasks but about the same percentage of instruction time as in Australia and the United States was spent by students on generating written responses during independent work.

#### ***Reading with textbooks***

Students in science lessons are sometimes required to use assigned textbooks and/or workbooks. As described in Chapter 3, textbooks are pre-printed materials that are designed to present science-related information. They may also provide exercises for students to do in their own notebooks. Workbooks are pre-printed materials that present information and also provide spaces for students to write notes, answer questions, record data and draw diagrams and/or graphs. How often did Australian students use textbooks and workbooks in the Year 8 science lessons?

- *Textbooks and workbooks were used in fewer Australian and United States science lessons than science lessons in the other countries (see Figure 3.3).*

An example of Australian students completing an independent reading task using a textbook can be seen in  *AU PRL 1*. As the researchers explained:

The teacher instructs the students to look at the textbook and independently read about the activities they will do. Students reading science is an example of independent seatwork. Independent seatwork activities occurred in 88% of the Australian lessons. (*AU PRL 1, Researchers' Comments, 00:06:47*)

### **Student Responsibility for Science Learning**

Provision of opportunities for students to take responsibility for their own learning is another element of science lessons that can contribute to student involvement and engagement in science learning. Both research findings and the curriculum and standards documents in each of the five countries participating in this study describe various aspects of helping students to become self-directed learners.

#### ***Research background***

Research in the areas of adult and lifelong learning, student self-direction and self-efficacy, and self-regulated learning provides insights about ways in which science teaching may be organised to support students in becoming independent learners.

The research literature suggests that instructional practices can influence students' self-efficacy – their beliefs about their ability to learn particular kinds of knowledge or to perform certain skills – and positive self-efficacy can influence motivation and achievement (e.g., Bandura, 1986, 1997; Schunk & Pajares, 2002). For example, the literature indicates that students might benefit from having specific attainable goals and from receiving prompt feedback about their progress in meeting these goals (Bandura, 1986; NRC, 2000). Moreover, students can become more self-directed learners if they are taught strategies that enable them to monitor their own progress towards goals (Schunk, 1995) and if they participate in setting their own goals (e.g., DeBacker & Nelson, 2000; Hom & Murphy, 1983; Pinkerton, 1994). Research also suggests that students need opportunities to make choices and decisions if they are going to develop skills of self-management and the ability to be self-directed learners (e.g., Goodlad, 1984; Jones, Valdez, Nowakowski & Rasmussen, 1995; Pajares, 1996; Schunk, 1995). These choices put students in the position of being responsible for directing and assessing their own learning and may contribute to more 'engaged learning' (Jones et al., 1995).

#### ***Country perspectives***

In Australian science curriculum and standards documents, independent learning is included as one of the stated goals. Students at early secondary level are expected 'to reflect on and evaluate their own understandings and purposes, using them for planning their own further learning' (AEC, 1994, p. 31). In addition, national curriculum standards documents emphasise the importance of students taking responsibility for generating questions and planning investigations. The Australian curriculum profile identifies 'working scientifically' as a major strand in the science curriculum, emphasising students' roles in planning and conducting investigations (AEC, 1994). Curriculum documents from the other participating countries also reveal specific intentions regarding students' responsibilities in the science learning process. In the Czech Republic and the Netherlands, the emphasis is on students becoming independent, self-directed learners as an overarching, cross-curricular goal. In Japan, the Netherlands, and the United States as well as Australia, students are expected to take responsibility for their own learning by generating their own questions and designing their own investigations.

Students can be observed taking responsibility for their own learning in many ways. What responsibilities did Australian students have during science lessons, and outside science lessons?

#### ***Student-initiated science questions***

Students often ask questions in science lessons, but many questions are simply procedural clarifications: When is this due? Where are the tongs? What do we do next? What mark did I get for the test? While these questions may indicate that students are taking responsibility for their

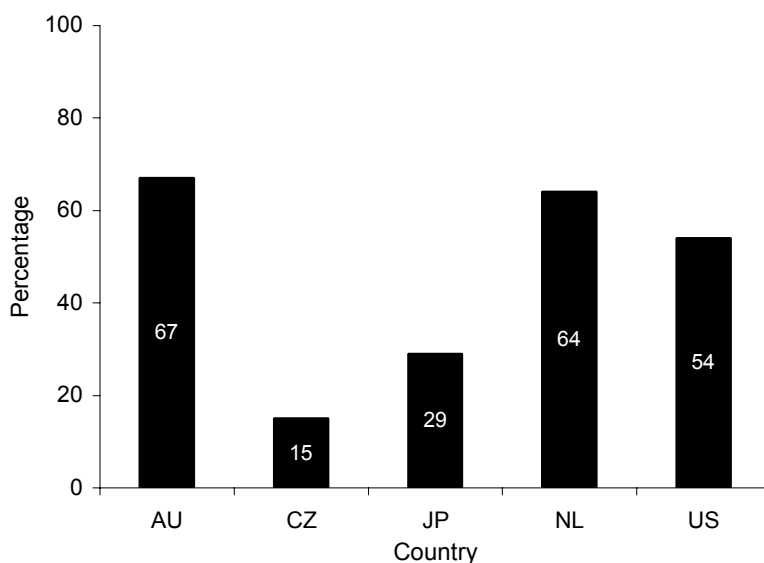
own learning at some level, they reflect a teacher-directed rather than student-directed style of teaching. Students can play a more active role in taking responsibility for their learning by monitoring their own understanding of the scientific content and raising questions to help them understand it better. How often did Australian students initiate such sense-making questions about the scientific content?

- *Australian students initiated science-related questions in 67 per cent of the lessons. On average, they initiated three science-related questions per lesson.*

The student-initiated questions of interest here were those directed by students to other students or the teacher, reflecting their efforts to make sense of the scientific content by asking for clarifications, elaborations, connections, examples and so on. The questions needed to be related to scientific content, for example, “Why do you have to put the ammeter there?”, “Is that why your veins look blue under your skin?” or “But I thought that heart attacks are caused by exercising too hard – is that correct?”. Questions such as these are taken as a positive indication of student engagement.

Figure 6.10 presents the percentage of Year 8 science lessons by country with at least one student-initiated science question. Australia and the Netherlands had higher percentages of Year 8 science lessons that included student-initiated science questions than the Czech Republic and Japan, and more Year 8 science lessons in the United States included student-initiated science questions than corresponding lessons in the Czech Republic.

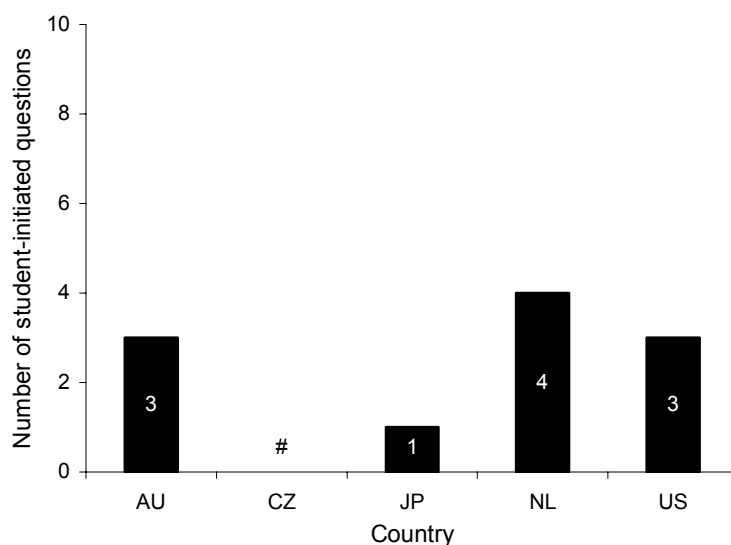
**Figure 6.10 Percentages of Year 8 science lessons that included at least one student-initiated science question**



Note: AU, NL > CZ, JP; US > CZ

Figure 6.11 displays the average number of student-initiated questions across all the science lessons per country. Students publicly initiated more science questions per lesson, on average, in Australia, the Netherlands and the United States than in the Czech Republic and Japan. Although Czech lessons included more instruction time for public talk and discussions than all the other countries (see Figure 6.6), Czech students were rarely observed to initiate science-related questions during these interactions. Although Japanese lessons did not provide a measurably different percentage of public talk time compared with Australian, Dutch and United States lessons (Figure 6.6), students in Japanese lessons initiated fewer questions in public talk time, on average, than students in these other countries.

**Figure 6.11** Average number of student-initiated science questions per Year 8 science lesson



# Rounds to zero.

Note: AU, NL, US > CZ, JP

### ***Research questions, procedures for investigations, and data collection***

Australian, Japanese, and United States standards and curriculum documents emphasise students taking responsibility for generating research questions to explore, designing procedures for investigating these questions, and collecting data during their investigations (AEC, 1994; Goto, 2001; NRC, 1996). These activities, among other aspects of practical work, were discussed in Chapter 5. They are reviewed here because they constitute important ways for students to take some responsibility for their own learning.

Analysis of the videotapes found that students generated their own research questions to investigate in only 3 per cent of Australian Year 8 science lessons. In all the other countries, this activity occurred too infrequently to calculate reliable estimates. For the three countries in which students were observed designing procedures to be used for investigations, 5 per cent of Japanese lessons, 5 per cent of United States lessons and 10 per cent of Australian lessons allowed students some options or complete freedom to design their own procedures. As shown in Figure 5.7, students independently collected data in more Australian and Japanese Year 8 science lessons (62 and 59 per cent, respectively) than in Czech and Dutch lessons (8 and 29 per cent, respectively). Thus, Australian teachers, followed by Japanese teachers, are providing students with at least some opportunities to take responsibility in these areas. However, given the emphases on these aspects of practical work in the 'working scientifically' strand of the Australian curriculum document (AEC, 1994), these opportunities appear to be fewer than might be expected for Australian students.

### ***Other ways students take responsibility for science learning***

Some other ways students might have taken responsibility for science learning are presented in this section.

#### ***Routine lesson openers***

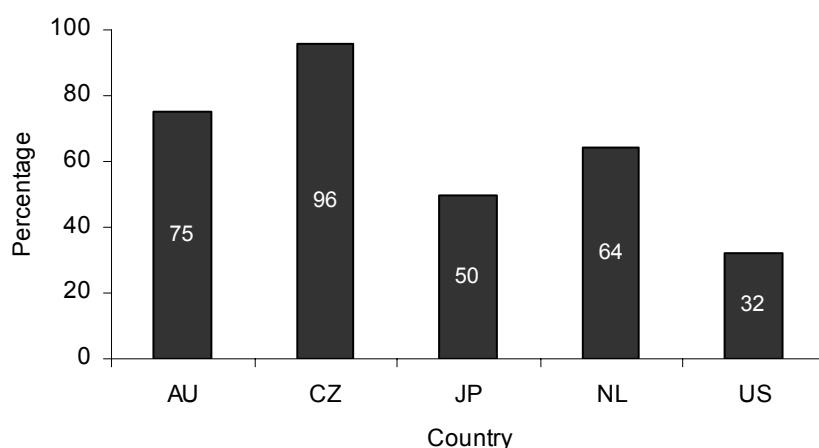
In some of the sampled lessons, as students entered the room they started to work, without any direction from the teacher, on a lesson opening task that was displayed on the board or an overhead projector. In these lessons it was clear that this was a familiar routine and the students understood that they should begin working independently. Although the tasks themselves were teacher-directed, the students recognised that they needed to take responsibility for identifying the tasks and starting to work on them. Routine lesson openers occurred rarely except in the United States (26 per cent of lessons) and Japan (5 per cent of lessons) (data not shown).



### Organised science notebooks

Students were sometimes observed organising their notes and other science work in special science notebooks. These notebooks gave a chronological record of their science class experiences. Figure 6.12 shows the percentages of Year 8 science lessons in which students were observed creating special science notebooks for organising notes and other work during their science lessons.

**Figure 6.12 Percentages of Year 8 science lessons in which students were creating organised science notebooks**



Note: CZ>AU, JP, NL, US; AU>JP, US; NL>US

Almost all science lessons in the Czech Republic included students creating organised science notebooks, which is a greater percentage of lessons than in the other four participating countries.

Although the incidence of organised science notebooks was not the highest in Australia, notebooks played a central role in Australian science lessons. In fact, they were often the main vehicle for presenting and recording information. *AU PRL 1* provides an example of Australian students using their own science notebooks. As the researchers explained:

Students in Australian schools tend to construct their own “textbook” by keeping an organized notebook. Seventy-five per cent of Australian science lessons showed students keeping organized notes. (*AU PRL 1, Researchers’ Comments, 00:35:56*)

Some of the teachers of the Australian public release lessons elaborated further. In *AU PRL 1*, the teacher noted:

I am also pleased with the level of organisation of the students; they appear to be giving due regard to getting their results down and into their workbooks (*AU PRL 1, 00:21:36*);

As the lesson heads towards the end, there are many more students now approaching me about their results and how they should enter it into their book. They are keen to have something good and a nicely finished product in their workbook (*AU PRL 1, 00:34:22*); and

I tend to count the quality of their notebooks as part of their final grade in science (*AU PRL 1, 00:41:19*).


The teacher of *AU PRL 2* explained that the students’ notebooks had the status of a textbook:

I like to have students develop a summary that they can then use to make their own set of notes about the experiment and to draw appropriate conclusions. I regularly check the validity of student notes. These notes along with those from past and future lessons, as well as

assignment work, make up a student class-work text. This personal text, their textbook, and the set of defined lesson outcomes for each unit of work is used for study purposes. The personal text is also used as a component of the assessment process. (*AU PRL 2, 00:28:12*)

### Public grading, assessment and students' work

Students' work was sometimes put up for public scrutiny and grading, a practice that may motivate students to take responsibility for studying and preparing for their lessons. Sometimes teachers would return tests and comment on individual student marks publicly, enabling students to hear the marks of other students. Other times, a student would be called to the front of the class for an oral quiz while the rest of the class watched or worked on a different assignment. Students occasionally were responsible for doing science work publicly, in front of the rest of the class. In these cases, the teacher may call students to the front to present results from an assignment, or to help with a practical demonstration, or to work on a task such as balancing a chemical equation on the blackboard or identifying the parts of a skeletal model. In all of these cases, students were expected to be prepared to work on these tasks and to carry them out in front of their classmates.

Czech students were more likely to work publicly in front of the class, which occurred in three-quarters of the lessons, than students in the other participating countries. In 19 per cent of Czech lessons students were assessed publicly; this practice occurred too infrequently in the other countries to produce reliable estimates (data not shown). An example of public grading in an Australian lesson can be seen in  *AU PRL 3*. The National Research Coordinator commented:

In assigning marks publicly, the teacher is careful to be encouraging to those who didn't score as well as the others. (*AU PRL 3, National Research Coordinator's Comments, 00:32:00*)

### Student presentations

During classroom lessons, teachers sometimes challenge students to take responsibility for their own learning by sharing their thinking, knowledge, and problem-solving strategies publicly with the teacher and their peers (NRC 1996). This can be done in the form of students describing their work to the class using the blackboard/overhead or students demonstrating and explaining phenomena to the class, among other ways. The expectation that students will share their work or have to think publicly places responsibility on them to prepare for such events, by attending during the lesson and by preparing outside the lesson. Formal student presentations of this nature to their peers and/or their teacher occurred within a small percentage of Year 8 science lessons across all of the countries (ranging from 4 per cent in Japan to 9 per cent in the Czech republic, with 5 per cent in Australia) (data not shown). No measurable difference was detected among countries.

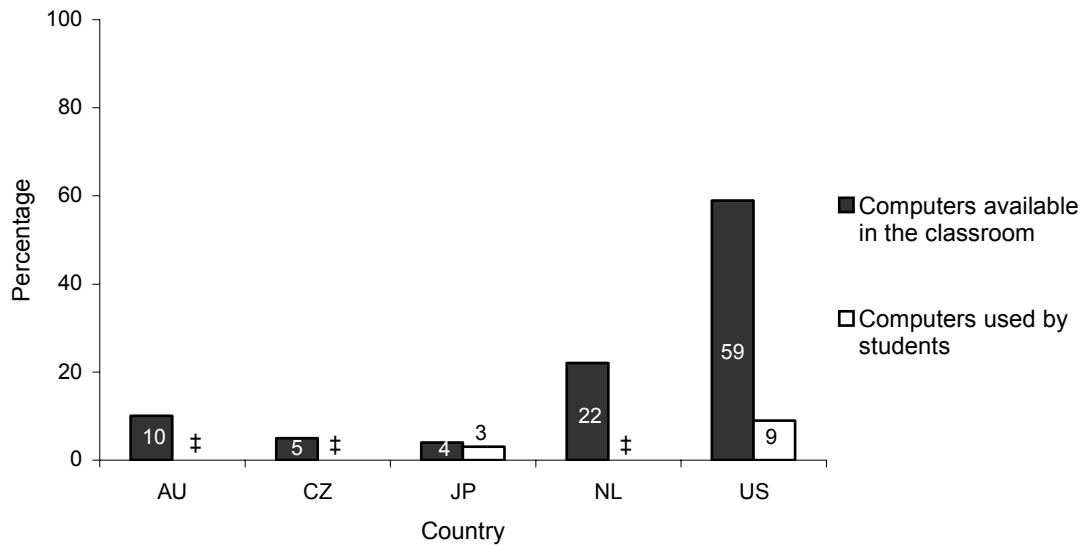
### Use of computers

In a technology-rich world, students need to learn the skills that will enable them to take responsibility for their own learning. There are many ways that students could use computers to assist their own learning, such as looking for information, organising that information, making notes, and working with databases. Although official support for this strategy has resulted in more computers in classrooms, evidence collected in other studies at the time of the present study indicated that computers remained underutilised by students (e.g., Cuban 2001).

Observations of the filmed science lessons in the TIMSS 1999 Video Study showed that students were occasionally expected to use computers during lessons to support their own learning in the ways mentioned above. The percentage of Year 8 science lessons per country in which students were observed to use a computer to support their own learning is presented in Figure 6.13, together with data on availability of computers in the classroom.

Computers were available for students to use in more Year 8 science lessons in the United States than in corresponding lessons in any of the other four countries that participated in the study. However students were observed using computers in only 9 per cent of United States lessons, indicating that, although computers were available, they were mostly not used. The incidence of computer use by students was small to negligible, as can be seen in Figure 6.13, with no measurable difference between countries, thus echoing Cuban's (2001) findings.

**Figure 6.13 Percentages of Year 8 science lessons in which computers were available in the classroom and used by students during the lesson**



† Fewer than three cases reported (country excluded from the relevant analysis)

Computers available in the classroom: US>AU, CZ, JP, NL; NL>CZ, JP

Computers used by students: No measurable difference detected

### Homework

The frequency and nature of assigned homework may be indicators of student responsibility for their own learning outside of the classroom. Results related to the assignment and nature of homework were reported in Chapter 3 (see Figures 3.12 and 3.13). Almost all the homework set for Australian students required them to work on new content only, in a higher percentage of lessons than in the Czech Republic and Japan. Their homework assignments appeared to provide Australian students with good opportunities to engage in new science learning.

### Self-pacing long term assignments

Sometimes students are given assignments with multiple parts and several days or weeks to complete, in which they must monitor their own pace across time. Year 8 students worked at their own pace on assignments in more Dutch lessons (52%) compared with Australian lessons (19%) (data not shown). Thirty-five per cent of United States lessons included long-term student assignments. In the Czech Republic and Japan there were too few cases to be reported.

### Summary

Engaging students' interest and active involvement in their science learning is a priority for most science teachers, and for many members of the wider science education community.

In this chapter, results were presented on the types of activities that teachers used to engage and involve students in the videotaped Year 8 science lessons. In some respects, it appears that teachers in the five countries provided similar kinds of activities and opportunities to engage and involve students. All countries raised real-life issues in a majority of lessons (Figure 6.1). Teachers in most lessons across all countries used at least one activity to make science engaging to students (Figure 6.4). In all countries, teachers provided more instructional time, on average, for students to talk about science than to write about science, and more time to write than to read about science (Figure 6.5). In all countries, whole-class talk was more likely to take the form of a presentation than a discussion (Figure 6.6). Teachers spoke more than students in all countries, and in all countries students tended to speak in short phrases of four or fewer words (Figure 6.8). In most countries, students wrote independently more than they took notes during whole-class work

(Figure 6.9). And computers, although available in at least some classrooms in each country, were used infrequently (Figure 6.13).

A closer look reveals, however, that there are also differences among countries in the kinds of activities and opportunities that might engage and involve students in their science learning. What were the features and emphases of activities that could engage and involve students evident in Australian lessons, and how were they similar to or different from the other countries?

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

- In Australian Year 8 science lessons, like those in most countries, real-life issues were raised in a high percentage of lessons (79%) (Figure 6.1).
- In Australian and Czech Year 8 lessons, real-life issues were more likely to be used for the development of scientific ideas than presented as interesting asides to the topic. No measurable differences on these two aspects were found within the other countries (Figure 6.2).
- At least one motivating activity was used in 37 per cent of Australian Year 8 science lessons (Figure 6.3), occupying 11 per cent of instruction time.
- Australian teachers made use of more than one type of activity to engage students' interest in 75 per cent of Year 8 science lessons (Figure 6.4).
- In Australia, as in all the countries, more instructional time, on average, was provided for students to talk about science than to write about science, and more time to write about science than to read about science (Figure 6.5).
- In Australian lessons, like lessons in all participating countries, whole-class talk was more likely to take the form of public presentations than public discussions (Figure 6.6).
- Australian students were able to communicate privately, either with the teacher or among themselves, for 43 per cent of science instruction time in their Year 8 science lessons (Figure 6.7).
- In Australia, and in all participating countries, teachers spoke more than students during both whole-class and independent work (ratios of at least 7:1 words in whole-class work and at least 3:1 in independent work).
- In Australia, as elsewhere, students tended to speak in short phrases – only about 20 per cent of their utterances during whole-class work and about 30 per cent during independent work were of 5 words or more (Figure 6.8).
- In Australian science lessons, and in science lessons in most other countries, students wrote independently more often than they took notes during whole-class work (Figure 6.9).
- Australian students were observed reading silently for 6 per cent of instruction time. Silent reading was relatively rare in most countries but occupied 19 per cent of instruction time in the Netherlands (data not shown).
- The percentage of Year 8 lessons that included at least one student-initiated science question was numerically highest in Australia and the Netherlands (Figure 6.10). Three science-related questions were initiated by Australian students on average in each lesson.
- Students generated their own research questions to investigate in 3 per cent of Australian Year 8 science lessons (data not shown). In all of the other countries, this activity occurred too infrequently to calculate reliable estimates.
- Australian students used organised science notebooks in three quarters of the videotaped Year 8 science lessons (Figure 6.12). Their notebooks tended to have the status of personal textbooks, especially in the many classes where textbooks were not used (see Figure 3.3 in Chapter 3).
- Computers were available in 10 per cent of the Australian science classrooms, but they were used in too few cases to be reported (Figure 6.13).

## Chapter 7

### COMPARING THE ACTUAL LESSONS WITH AN IDEAL

The stated purposes and goals for science education in Australian schools contained in seminal Australian research and professional documents allow an ideal picture of science education to be constructed. This chapter provides a commentary on the Australian science video lessons and interprets the data in terms of a theoretical framework based on those documents and the ideal picture that is implicit in them. The chapter comprises five sections. The first describes the purpose and goals that have been specified for science education in Australia over the past 15 years. The second section constructs an ideal picture of science education for Australian schools and the third provides an overview of the Australian science video lessons. Section four analyses the video data in terms of the ideal picture and the final section identifies implications for research and science teacher professional learning.

#### **Purpose and Goals for Science Education in Australian Schools**

In 1989, the Australian State, Territory and Commonwealth Ministers of Education endorsed 10 national goals for schooling, and in 1991 agreed that the curriculum would comprise eight learning areas and that a national statement and profile would be developed for each learning area. The statements would guide curriculum development and the profiles would provide a framework to guide assessment and reporting of achievement. The statements and profiles were developed under the direction of the Australian Education Council (AEC), the national council of Ministers of Education.<sup>43</sup> The statement on science was published in 1994 (AEC, 1994) and, although some states developed their own science curriculum frameworks between 1994 and 1999 when the video study was conducted (e.g., WA Curriculum Council, 1998), each of these new documents was based on the 1994 national statement on science.

The national statement on science specified several goals for the science curriculum (AEC, 1994). The science curriculum was expected to develop students' ability to:

- Uphold attitudes and values such as openness to new ideas, intellectual honesty, commitment to scientific reasoning and to striving for objectivity, respect for evidence and for the tenacious pursuit of evidence to confirm or challenge current interpretations.
- Use the skills of scientific investigation, reflection and analysis to generate or refine knowledge, find solutions and pose more questions.
- Apply scientific knowledge and understanding of some of the key scientific theories, principles, concepts, models and ideas to explain and predict events in their everyday endeavours and in the physical and biological world.
- Communicate scientific understanding to different audiences for a range of purposes.
- Use scientific language to communicate effectively and to further their own understandings.
- Apply and evaluate scientific knowledge and understanding across a range of contexts and to construct and modify their understanding of the natural and technological world.
- Understand and appreciate the evolutionary nature of scientific knowledge and the nature of science as a human endeavour, its history, its relationship with other human endeavours and its contribution to society.

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<sup>43</sup> This body subsequently became the Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA). In 1999 the Ministers, as MCEETYA, endorsed a new set of National Goals for Schooling in the Twenty-First Century. The 1989 national goals and the 1994 statement on science were operative over several years immediately preceding the TIMSS 1999 Video Study and also during the time the study was taking place.

- Appreciate the role of science in society as an activity that can be carried out by all people as a part of their everyday lives in ways that contribute to their personal, social, environmental, cultural and economic wellbeing.
- Make decisions that include ethical consideration of the impact on people and the environment of the processes and likely products of science. (p. 5)

These goals encompass a wide range of learning outcomes including scientific attitudes and habits of mind, skills of investigation, an understanding of the nature of science and its role in society, the capacity to use the literacies of science in learning and communicating about science, and the ability to apply understandings of science for decision making in their everyday lives taking account of the likely impact of those decisions on others and the environment.

The review of the status and quality of teaching and learning of science in Australian schools (Goodrum, Hackling & Rennie, 2001) conducted in 1999-2000 recommended to the Australian government that the primary purpose of science education in the compulsory years of schooling is to develop scientific literacy, a view consistent with major British and North American curriculum documents and reviews (Millar & Osborne, 1998; NRC, 1996).

Scientific literacy is a high priority for all citizens, helping them:

- to be interested in, and understand the world around them,
  - to engage in the discourses of and about science,
  - to be sceptical and questioning of claims made by others about scientific matters,
  - to be able to identify questions, investigate and draw evidence-based conclusions, and
  - to make informed decisions about the environment and their own health and well-being.
- (Hackling, Goodrum & Rennie, 2001, p. 7).

Scientific literacy therefore encompasses a range of science learning outcomes that enable individuals to navigate their way through life, rather than focusing on preparing them for further studies of science in the post-compulsory years.

### **An Ideal Picture of Australian Science Education**

The ideal picture of science education in Australian schools constructed in this section is based on three literature sources: the national review as cited above, the professional standards for accomplished teachers of science, and the components of effective science teaching developed in the Victorian Science in Schools (SiS) project.

The national review of the status and quality of science teaching and learning in Australian schools (Goodrum et al., 2001) developed ideal and actual pictures of science education. The ideal picture was developed from the research literature, curriculum documents and from focus group meetings with teachers and curriculum experts. The ideal picture was described in nine themes:

1. The science curriculum is relevant to the needs, concerns and personal experiences of students.
2. Teaching and learning of science is centred on inquiry. Students investigate, construct and test ideas and explanations about the natural world.
3. Assessment serves the purpose of learning and is consistent with and complementary to good teaching.
4. The teaching-learning environment is characterised by enjoyment, fulfilment, ownership of and engagement in learning, and mutual respect between the teacher and students.
5. Teachers are life-long learners who are supported, nurtured and resourced to build the understandings and competencies required of contemporary best practice.
6. Teachers of science have a recognised career path based on sound professional standards endorsed by the profession.
7. Excellent facilities, equipment and resources support teaching and learning.
8. Class sizes make it possible to employ a range of teaching strategies and provide opportunities for the teacher to get to know each child as a learner and give feedback to individuals.

9. Science and science education are valued by the community, have high priority in the school curriculum, and science teaching is perceived as exciting and valuable, contributing significantly to the development of persons and to the economic and social well-being of the nation. (p. vii)

The national professional standards for highly accomplished teachers of science (Australian Science Teachers Association & Monash University, 2002) describe the professional knowledge, practice and attributes of highly accomplished teachers. The standards specify that teachers need rich knowledge of science, curriculum, teaching, learning and assessment, and of their students. Further, they are able to transform these components of knowledge into the pedagogical content knowledge that allows them to make subject knowledge comprehensible to their students (Gess-Newsome, 1999). The standards relating to professional practice for highly accomplished teachers include that:

1. They design coherent learning programs appropriate for their students' needs and interests.
2. They create and maintain intellectually challenging, emotionally supportive and physically safe learning environments.
3. They engage students in generating, constructing and testing scientific knowledge by collecting, analysing and evaluating evidence.
4. They continually look for and implement ways to extend students' understanding of the major ideas of science.
5. They develop in students the confidence and ability to use scientific knowledge and processes to make informed decisions.
6. They use a wide variety of strategies, coherent with learning goals, to monitor and assess students' learning and provide effective feedback. (p. 3)

The components of effective science teaching developed in the Science in Schools (SiS) project (Tytler, 2002) describe the pedagogical practices that effectively support student learning and engagement in science:

1. Students are encouraged to actively engage with ideas and evidence.
2. Students are challenged to develop meaningful understandings.
3. Science is linked with students' lives and interests.
4. Students' individual learning needs and preferences are catered for.
5. Assessment is embedded in the science learning strategy.
6. The nature of science is represented in its different aspects.
7. The classroom is linked with the broader community.
8. Learning technologies are exploited for their learning potentialities. (p. 9)

When these three documents are analysed, they reveal strong convergence around six characteristics of effective science teaching:

1. Students experience a curriculum that is relevant to their lives and interests within an emotionally supportive and physically safe learning environment.
2. Classroom science is linked with the broader community.
3. Students are actively engaged with inquiry, ideas and evidence.
4. Students are challenged to develop and extend meaningful conceptual understandings.
5. Assessment facilitates learning and focusing on outcomes that contribute to scientific literacy.
6. Information and communication technologies are exploited to enhance learning of science.

Science education in the compulsory years of schooling is therefore expected to support the development of scientific literacy (Hackling et al., 2001) through achieving the curriculum goals outlined in the national statement (AEC, 1994) using the effective science teaching practices described in the national review (Goodrum et al., 2001), professional standards (Australian

Science Teachers Association & Monash University, 2002) and components of effective science teaching developed in the SiS project (Tytler, 2002).

All of these documents take a social constructivist perspective to teaching and learning (Driver, Asoko, Leach, Mortimer & Scott, 1994). This perspective is reflected in these six characteristics of effective science teaching, which highlight the role of learners using prior knowledge and experience to construct their own meaning within the socio-cultural context within which they find themselves, when challenged by teachers to extend and deepen their understandings. This synthesis of Australian science education literature provides an ideal picture with which actual science education, as captured by the video studies, can be compared.

### **Overview of Australian Year 8 Video Lessons**

The international report of the video studies (Roth et al., 2006) noted that each of the five participating countries had a characteristic pattern of science teaching and learning at the Year 8 level, which suggests that science teaching is a cultural activity (Stigler & Hiebert, 1999).<sup>44</sup>

Briefly, in the Czech Republic, students were expected to learn many ideas and technical terms relating to theoretical content and students were often required to display their mastery of this content publicly. Dutch students were expected to learn science content independently, being frequently asked to read the textbook and generate written answers to questions in the text. Year 8 science lessons in the United States were characterised by a diversity of learning approaches rather than a core instructional strategy, and the approaches used were not well connected to the development of scientific concepts. The Australian pattern of science teaching appears to be in many ways similar to the Japanese pattern, in that the central pedagogical approach involves gathering and analysing data through independent practical activity to develop ideas in an inquiry mode. The Australian lessons had the added emphasis of making connections between ideas and real-life experiences and issues (Roth et al., 2006).

The following summary of the Australian video lessons in relation to teacher characteristics and resources, instructional organisation of lessons, lesson content and student actions is derived from the present report, which, in most respects, is based on Roth et al. (2006).

#### ***Context: Teacher characteristics and resources***

All of the 87 Australian teachers were certified to teach and all but three of these were trained to teach in secondary schools. About 90 per cent of Australian Year 8 science lessons were taught by teachers who had a graduate or undergraduate major in a science field (Table 2.2). On average, they had been teaching for 15 years. More than 90 per cent of the Australian science classes were taught by teachers who had undertaken some kind of professional learning activity in the previous two years.

The Australian teachers reported that they were adequately resourced with laboratories, equipment and reference materials. Ninety per cent of the Australian lessons were taught in a science laboratory, which was a higher percentage than in all other countries. Teachers reported a shortage of computers, software and Internet connections; however, in 1999 this was common in other countries also (Table 2.1). The Australian teachers were therefore well qualified, experienced and had access to professional learning opportunities and generally adequate resources for teaching science.

#### ***Instructional organisation of lessons***

In contrast with lessons in both the Czech Republic and Japan, Australian Year 8 science lessons allocated less time for science instruction (91 per cent of lesson time) and more time for organisational work (7 per cent of lesson time). Forty-two per cent of lessons were observed to be interrupted by outside sources compared to 7 per cent in the Czech Republic and too few cases in

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<sup>44</sup> Extended summaries of each country's characteristic patterns of science teaching and learning, as derived from the video study findings, together with illustrative charts of each country's results, are included in the international report (Roth et al., 2006).



Japan to calculate reliable estimates. The Australian lessons focused primarily on developing new content during science instruction time (85 per cent) with less focus on review (8 per cent of instruction time) and other lesson purposes, such as assessment or going over homework (Table 3.1).

Australian students worked independently for 52 per cent of science instruction time and 47 per cent of the time as a whole class (Figure 3.6). Forty-two per cent of science instruction time was devoted to practical activities (Figure 3.5).

### ***Lesson content***

Thirty-five per cent of public talk time was devoted to the development of canonical knowledge (Figure 4.2). The main sources of content were worksheets, the teacher and the text or workbook (Figure 4.6). Fifty-seven per cent of the lessons were judged to address basic content and only 9 per cent of lessons involved content that was judged to be highly challenging. Evidence in the form of first-hand data and phenomena played an important role in the development of main ideas in Australian lessons. For example, 56 per cent of Australian lessons linked each main idea in the lesson to two or more instances of first-hand data, and 45 per cent of lessons supported each main idea with two or more phenomena (Figure 4.14). This practice occurred more frequently than in the lessons of other countries except Japan. Australian lessons used fewer visual representations than Japan.

Australian lessons had several features that indicated coherent content development. Fifty-eight per cent of lessons developed science content primarily through making connections among data, patterns, and/or explanations; that is, evidence was used to build a case for a new idea (Figure 4.8). Connections were most often made through an inquiry/inductive approach (43 per cent of lessons, Figure 4.9). In addition, students' work on independent practical activities was linked to the development of ideas. Before starting to work, students knew the question or conceptual issue to be explored in 33 per cent of the lessons. After an independent practical activity, observations, results or conclusions were discussed in 50 per cent of the total pool of lessons, that is, in two-thirds of the lessons in which these activities were undertaken, though conclusions were discussed in only half of these lessons (Figure 5.5).

A high percentage of Australian lessons addressed at least one real-life issue (79 per cent). Rather than simply mentioning real-life issues as interesting stories or contexts related to the topic at hand, a larger percentage of Australian lessons (69 per cent) used at least one real-life example to develop scientific ideas compared to Japanese lessons (47 per cent) (Figure 6.2). Thus, using real-life issues was another way in which ideas were supported by evidence in Australian lessons.

As in the Japanese lessons, content in the Australian lessons focused on a few scientific concepts, emphasised making connections through inductive inquiry, and supported ideas with data and phenomena. The Australian lessons contrasted with the Japanese in giving more attention to supporting and developing ideas with the use of real-life issues and giving less attention to the use of visual representations to support ideas.

### ***Student actions***

Australian students were involved in carrying out independent practical activities in 74 per cent of lessons (Figure 5.1) usually generating data to support the development of scientific ideas. Students typically worked on these practical activities in small groups.

Students were asked to complete several inquiry actions in relation to the independent practical activities. They made predictions before carrying out their independent practical activities in 11 per cent of lessons (Figure 5.6), and they collected and recorded data in 62 per cent of lessons, which was a larger percentage of lessons than in all the other countries except Japan (Figure 5.7). Australian students manipulated data into graphs or charts in 36 per cent of the lessons (Figure 5.7) and interpreted data relevant to their independent practical work in 56 per cent of the science lessons (Figure 5.6).

Students in Australian science lessons spent 47 per cent of science instruction time participating in whole-class activities (Figure 3.6). Australian students appeared to be more actively involved during whole-class activities than Japanese students. For example, Australian students engaged in discussions led by the teacher for 15 per cent of instruction time compared to 10 per cent in Japanese lessons (Figure 6.6). Australian students were also more likely than Japanese students to raise content-related questions during whole-class discussions. In 67 per cent of the science lessons, Australian students raised content questions, asking three questions per lesson, on average (Figures 6.10 and 6.11).

Australian lessons differed from Japanese lessons in their inclusion of activities likely to engage students' interests. Already noted was the more frequent use of real-life issues to develop content in Australian science lessons (Figure 6.2). While potentially motivating activities occurred more frequently in American lessons (63 per cent) than in all the other countries, 37 per cent of the Australian lessons incorporated potentially motivating activities (Figure 6.3).

### **Analysis of Australian Video Lessons in Terms of the Ideal Picture**

The main influences on teachers' practice are their beliefs (Fang, 1996), knowledge (Gess-Newsome, 1999), curriculum and constraints imposed by limiting factors such as resources and class size. Given that the teachers were well qualified, had access to and had used professional learning opportunities, were experienced, adequately resourced except for IT facilities and had an average class size of 25.6 students, there were few constraints on their practice. One would therefore expect their practice to reflect the curriculum and their own beliefs about effective science teaching. The following paragraphs consider the Australian video data in relation to the characteristics of effective science teaching, which represent the ideal picture of science education in Australian schools.

To what extent does the actual picture as revealed by the video data match the ideal? To answer this question, the characteristics of effective science teaching synthesised in the second section of this chapter are considered in turn. The first pair of characteristics from the list above, which are closely related, are considered together, as are the fourth and fifth characteristics, for the same reason.

**1 *Students experience a curriculum that is relevant to their lives and interests within an emotionally supportive and physically safe learning environment;* and**

**2 *Classroom science is linked with the broader community.***

Many young Australian adolescents are alienated from schools (Cumming, 1996) and have poor attitudes towards science. Surveys of secondary students indicate that one-fifth are almost always bored in science lessons, only 20 per cent report that science lessons are relevant or useful to them and one-third indicate that science never deals with things they are concerned about (Goodrum et al., 2001). One way of enhancing relevance is to link school science to the community.

Data gathered from Australian secondary students in 1999 by questionnaire reveal that most commonly students' experience of science is limited to the classroom and has few links to the community. Thirty-five per cent of students reported they never learn about scientists and what they do, 43 per cent indicated they never do practical work outside the classroom, 76 per cent never visit the zoo, museum or science centre and 84 per cent reported they never have visiting speakers who talk to them about science (Goodrum et al., 2001).

To what extent do the Australian video lessons provide data about strategies used by the teachers to interest and engage learners in science and to enhance the relevance of the curriculum? Coding of the videos provided information about teachers' use of relevant issues, real-life objects and motivational activities. Some attention was given to real-life issues in at least 62 per cent of lessons in all countries and in 79 per cent of the Australian lessons, which occupied on average 12 per cent of instruction time. Real-life issues were used to develop scientific content and also as topic-related sidebars. The coding did not provide data about the incidence of science-related social issues that have the potential to be both engaging and strongly link science to the

community. The category of real-life issues was quite general and included everyday examples of the phenomenon of interest, students' personal experiences and use of scientific knowledge in daily activities in addition to science-related social issues. Teachers also used real-life objects to provide concrete exemplification of concepts and make links to the real-world; such objects were used by the Australian teachers in 25 per cent of lessons.

Relevance and engagement can be enhanced when teachers provide relevant contexts that make connections with students' lives outside of school and when learning tasks are authentic in the sense that they are like tasks members of the community need to engage in (Wiggins, 1998). In these circumstances students can find an authentic purpose for learning. Unfortunately the coding of the videos provides limited data about the purpose for learning in each lesson. Data in Figure 4.11 summarise information from the Teacher Questionnaire about lesson goal statements, but no information is provided about purpose for learning from a student's perspective.

One of the limitations of the video study is that teachers, planning lessons for the study in the knowledge that they were to be videotaped,<sup>45</sup> would be unlikely to consider lessons that involved visiting speakers and activities that involved students engaging in community-based activities.<sup>46</sup> Other research methods may therefore be more effective in gathering data about these important characteristics of effective science teaching.

### ***3 Students are actively engaged with inquiry, ideas and evidence.***

The characteristic of effective science teaching that provides for students to have opportunities for active engagement with inquiry, ideas and evidence is founded on constructivist learning theory (Driver et al., 1994). Curriculum goals regarding students' learning of inquiry and investigation skills, regarding the nature of science (AEC, 1994) and the development of scientifically literate citizens (Goodrum et al., 2001) are also relevant. Inquiry engages students in developing researchable questions and then planning and conducting investigations that generate data that students then interpret in terms of their existing ideas to generate explanations and answers to their questions. This active engagement of the learner in generating explanations from experience with natural phenomena using their prior knowledge is at the heart of constructivist theory (Osborne & Wittrock, 1983; Osborne & Freyberg, 1985).

If students are to develop scientific investigation skills and an understanding of the nature of science and of scientific evidence they need opportunities in the curriculum to conduct their own investigations of authentic science problems and generate evidence that can be used to test and extend their ideas. It is through having an authentic experience of science that students can appreciate the nature of science and how it generates evidence-based conclusions (Gott & Duggan, 1996). It is these understandings and skills that enable citizens to be sceptical and questioning of claims made about scientific matters.

Roth et al. (2006) reported that the central pedagogical approach of the Australian science video lessons involved gathering and analysing data through independent practical activity to develop ideas in an inquiry mode. Ninety per cent of the Australian lessons contained practical work, that averaged 42 per cent of lesson time. Whole-class practical activities such as teacher demonstrations occupied on average 9 per cent of lesson time and practical work conducted by students averaged 33 per cent of lesson time. Almost all of the student practical activity work was conducted by students working in pairs or small groups.

A significant amount of class time was devoted to student practical activity, but did the organisation of these activities provide opportunities for inquiry-based learning? The analysis of the lessons distinguished between: inquiry-based or inductive approaches where students

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<sup>45</sup> Teachers had between one and five days' advance notice that their class had been selected for videotaping. They were asked to do nothing special for the session and to conduct the lesson as they had planned (see the section entitled 'Videotaped lessons' in Appendix A).

<sup>46</sup> Given the teachers' assessment that their videotaped lessons were generally typical of their teaching methods (Figure 2.4), it may be that such lessons are still relatively rare.

investigated, collected data, identified patterns in the data and then developed conclusions and explanations from the data; and application or deductive approaches in which students were first taught the ideas and then experimented to verify the ideas. Forty-three per cent of Australian lessons developed content ideas through inquiry and 13 per cent developed content through application-based approaches (Figure 4.9).

A majority of student practical activity work in Australia was therefore inquiry-oriented. To develop inquiry skills students need opportunities to formulate their own questions, design their own investigations, analyse their data and develop conclusions. Analysis of the lessons revealed the types of activity work conducted by the students. The analysis distinguished between model making, displaying or classifying objects, practising science procedures or techniques, conducting experiments, and producing or observing phenomena. By far the most common type of practical activity conducted by students in all countries, including Australia, was producing or observing phenomena, for example, observing chemical reactions.

Only Australian and Dutch lessons included experiments in which students manipulated variables and conducted controlled experiments; 8 per cent of Australian lessons were of this type (Figure 5.2). To what extent were these lessons student directed or teacher directed? Was it the teacher or the students who developed questions and designed the experiments? Australian students generated their own questions in 3 per cent of lessons, made predictions in 11 per cent of lessons and designed their own procedures in 10 per cent of lessons. Students organised or manipulated their data on their own in 9 per cent of lessons. These opportunities for learning were even more scarce in lessons conducted in the other four countries.

In 24 per cent of the lessons, or about a third of the student practical activity lessons, none of the results or conclusions were discussed publicly, and in a further 13 per cent of the lessons (about a sixth of the practical activity lessons) only observations were discussed. That is, in half of the student practical lessons no conclusions were developed in whole-class discussions (Figure 5.5). If an inquiry approach is to be used effectively to develop scientific content, public whole-class discussion scaffolded by the teacher is needed to draw out the patterns in the data and relate these to scientific concepts to develop explanations for results and conclusions. Issues of time management may have resulted in some of these discussions being completed in the following lesson, as revealed in some of the released lessons, but a significant opportunity for learning is lost if this type of discussion is not conducted.

Significant learning about the limitations of experimental designs and sources of error can occur through evaluating investigations students have conducted (Hackling & Fairbrother, 1996). The percentage of lessons in which investigations were evaluated and new questions developed was very low in all countries, although it did occur in 17 per cent of Australian lessons.

Understanding the nature of science not only requires students to have authentic experiences of scientific investigation work, but also to have discussions about how their experiences exemplify the nature of science. There was little explicit public discussion of the nature of science in Australian lessons, being observed in only 4 per cent of lessons.

These data indicate that the Year 8 science lessons provided many opportunities for students to learn through inquiry-oriented independent practical work. However, little of the student practical work was effective in providing opportunities for students to learn the full range of skills of scientific investigation, nor were conclusions developed through public discussion in half of the lessons containing practical activities, thereby defeating much of the purpose of developing scientific content through inquiry.

**4 *Students are challenged to develop and extend meaningful conceptual understandings; and***

**5 *Assessment facilitates learning and focusing on outcomes that contribute to scientific literacy.***

If students are to develop deep, connected and meaningful understandings of phenomena in science, teachers need to plan appropriate sequences of learning experiences that facilitate the development of conceptual understandings and connections between them. Lessons need to challenge and extend students' thinking. Selection and sequencing of content and appropriate questioning that prompts deeper thinking and connection-making can facilitate this. Appropriate questioning arises from monitoring students' developing understandings and providing appropriate feedback.

Challenging and extending thinking are therefore strongly linked to formative assessment practices (Black & Wiliam, 1998). If students are to respond to feedback and extend their understandings, they need to be engaged metacognitively in their own learning (Sadler, 1989). The construction of meanings from experiences can also be facilitated and extended by students processing information and transforming it into different forms of representation (Prain & Hand, 1999). Extended writing and the construction of concept maps that represent the relationships between concepts can be powerful tools to extend conceptual understandings and make connections between related concepts. To what extent does the coding of the videos provide evidence about selection and sequencing of content, monitoring students' learning, questioning, feedback, metacognitive talk and opportunities for representing understandings through activities such as extended writing?

The analysis of the video lessons provides information about the types of lesson content. A surprisingly high percentage of the Australian Year 8 lessons developed content related to the discipline of physics (49 per cent), while life sciences (24 per cent), chemistry (15 per cent) and earth sciences (5 per cent) were the subject of fewer lessons. Most lessons were focused on developing content and often through activities, while only 12 per cent of lessons were focused on activities themselves. Video analysis also distinguished between lessons that were of high or low density of publicly discussed canonical knowledge. Ten per cent of Australian lessons were classified as being high-density lessons. The Australian lessons, on average, were shown to involve public mention of 22 scientific terms and 10 highly technical scientific terms, which was typical of four of the five countries involved in the study.

Density of canonical ideas and terminology only provide a measure of the amount of content in the lessons. The coding also discriminated between challenging and basic content. Fifty-seven per cent of Australian lessons focused on basic content which would have offered limited challenge for students, while 33 per cent of lessons provided a mix of basic and challenging content and a further 9 per cent focused on predominantly challenging content (Figure 4.12). The low percentage of lessons containing predominantly challenging content in Australia and Japan suggests a low level of intellectual challenge for more able students. This may be related to the lack of ability streaming in these countries. Where classes are of heterogeneous ability, teachers are likely to avoid lessons with predominantly challenging content.

Lessons containing some challenging content would provide opportunity for deep learning if students are engaged in making connections between ideas and experiences and have opportunities to represent their understandings using scientific terms in talk or writing. The video analysis distinguished between lessons that developed content by focusing on making connections and lessons that focused on acquiring facts, definitions or algorithms. Seventy-two per cent of Japanese lessons and 58 per cent of Australian lessons developed content through making connections, significantly more than in the other three countries (Figure 4.8). Another measure of development of conceptual coherence is the percentage of lessons with strong conceptual links. Fifty-eight per cent of Australian lessons were content-focused with strong conceptual links, and again a numerically higher percentage of Japanese lessons (70 per cent) were of this type (Figure 4.10). Again, the difference between the percentages in Australia and Japan was not large enough to be

significantly different according to the criterion used in the study, but the two differences of 12 per cent or more in the same direction may indicate a trend that might be substantiated in larger samples.

Students are engaged in making connections when they process information and transform it into new forms of representation through reading, talking and extended writing (Prain & Hand, 1999). Student talk occupied 63 per cent of Australian lesson time, writing occupied 44 per cent and reading only 6 per cent (sometimes these activities overlapped, and could yield percentages adding to more than 100). Much of the writing in science lessons is often copying or low-level short response writing. The video analysis revealed that, on average, 24 per cent of instruction time in Australian lessons was devoted to generating written responses during independent work that would have provided opportunity for students to make connections between ideas and represent their understandings using scientific terms.

To what extent did the Australian teachers monitor students' learning and provide feedback or probing questions to stimulate deeper thinking and engage students in metacognitive reflection on learning? The coding of the video lessons provides little data to answer this significant question. The coders looked for 30-second or longer segments of lessons in which teachers performed some form of assessment activity. There were too few instances of assessment behaviour in Australia to make a reliable estimate of its incidence (Table 3.1). The coding category focused on the more obvious forms of assessment behaviour and may well have missed important aspects of monitoring learning and providing feedback typical of formative assessment.<sup>47</sup>

Given that, of all teaching-learning strategies, monitoring learning and giving feedback have been demonstrated to have the greatest effect on student achievement (Black & Wiliam, 1998; Hattie, 2003), it is surprising that a more detailed analysis of assessment behaviours was not made. As Sadler (1989) has argued, students need to be metacognitively engaged to respond appropriately to a teacher's feedback. It was pleasing to note that 19 per cent of Australian lessons contained some talk about metacognitive strategies.

## ***6 Information and communication technologies are exploited to enhance learning of science.***

There is currently in Australia a much higher interest in using Information and Communication Technologies (ICTs) to enhance learning in science than was the case in 1999 when the video studies were conducted. The interest in ICTs relates to their capacity for engaging learners, simulating non-observable phenomena, providing resources for constructing multimodal representations and for communicating these to others (Bagui, 1998).

In 1999, no more than 27 per cent of the Australian teachers reported sufficient access to computers, computer software or computers with Internet connections and only 10 per cent of the classrooms and laboratories in which the Australian science lessons were taught contained at least one computer. In comparison, 40 per cent of Japanese teachers and 48 per cent of United States teachers reported sufficient access to computers, and computers were observed in 59 per cent of the United States classrooms.

When teachers were asked about the professional development activities in which they had participated during the two previous years, 79 per cent of the Australian teachers reported they had participated in professional development relating to use of technology. This was more than twice the response rate for any other professional development topic.

Computers were used in 9 per cent of the United States lessons; however, there were too few instances of computer use in Australian lessons to reliably estimate the frequency of use. Data collected in 1999 from secondary students throughout Australia by questionnaire revealed that two-thirds of students never used computers to do science work (Goodrum et al., 2001). The

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<sup>47</sup> It is also possible that teachers may have tended to avoid assessment episodes because of the proviso that a selected lesson would not be taped on a day when the full period was to be used for a test (see 'Videotaped lessons' in Appendix A).

reasons for the lack of computer use at that time may have included limited access to computers, software and Internet connections, teachers' lack of confidence in using computers for teaching science or lack of curriculum resources that integrated the use of ICTs into the learning programs. With recent Australian Government initiatives to develop large numbers of multimedia learning objects (DEST, 2001), state and territory government initiatives to supply laptop computers to teachers and improve networks in schools and Internet access, and the increasing availability of digital cameras, data projectors and data loggers in schools, one would expect that ICTs are now being more widely incorporated in the Year 8 science curriculum in Australian schools.

### **Limitations, Findings and Implications**

Within the limitations of the codes adopted for analysing the video lessons, the data provide rich insights into science teaching in the sample of Year 8 lessons. The Australian lessons were characterised by a core pedagogical approach that involved gathering and analysing data through independent practical activity to develop ideas in an inquiry mode. The Australian lessons also made connections between ideas and real-life experiences and issues. Given this core approach and that the science teachers were well trained and resourced, there was every opportunity for students to develop the then stated goals of the science curriculum and to develop aspects of scientific literacy.

The analysis of the data in terms of characteristics of effective science teaching revealed limitations in the available data, generated some interesting findings and raised some implications for further research and for teacher professional learning.

#### ***Limitations***

Despite the very extensive coding process and codes used to quantify the lesson events, there were limitations in the data regarding some important aspects of good science teaching. These include lack of details of links between science and the broader community; relating classroom science to science-related social issues; providing information regarding discussion of experimental results and conclusions in the following lesson; and teachers' use of questioning and formative assessment practices. Some of these limitations (e.g., links to the community) may require other research methods to provide the data while the existence of the videotapes means that there are opportunities to re-analyse the lessons using expanded coding schemes to gather information about other issues (e.g., formative assessment).

#### ***Interesting findings***

The data provide strong endorsement for the quality of science teaching as exemplified in the sample of Australian Year 8 science lessons when these lessons are compared with lessons from other high achieving countries. The extent and quality of inquiry-based learning and the strong connectedness of most Australian lessons provide opportunity for quality learning. The low provision of opportunity for students to formulate their own research questions, devise their own experimental procedures and analyse their own data because the independent practical work was largely teacher-directed, limited the opportunities for students to learn inquiry skills and aspects of scientific literacy in Australian and other countries' lessons. The fact that in half the Australian lessons in which students did practical work there was no public discussion of conclusions arising from the practical activities severely limited the opportunity for scientific content to be developed through inquiry. Except for Japan, this aspect was even more neglected in the other participating countries.

A particularly interesting finding relates to the many similarities between Australian and Japanese lessons, especially given that Japanese students have usually outperformed Australian students in international studies (see Table 1.1 for an example). Based on the video study, Australian and Japanese science teachers appear to use similar instructional strategies for their Year 8 students in important aspects such as focusing on a few scientific concepts in some depth, developing content in conceptually coherent ways and supporting ideas with collection and manipulation of data and interpretation of phenomena. The similarities in science teaching between Australia and Japan identified in the science component of the video study are even more remarkable in view of the

extensive differences in Year 8 mathematics teaching between these two countries observed in the mathematics component of the study (Hiebert et al., 2003).

The incidence of teachers' assessment practices was too low in Australia to make reliable estimates. This may have been an artefact of the videotaping procedures (see Appendix A) or the scope of the coding and may have been influenced by teachers' choice of lessons to be video recorded. However, given the research evidence about the effectiveness of integrating formative assessment into teaching and learning it is a concern that assessment was not more evident in the data from the lessons.

Given the current interest in incorporating ICTs into science teaching and learning it was interesting to note the very low incidence with which computers were used in the science lessons, even when, as in the United States, computers were available in the majority of classrooms .

### ***Implications***

An important implication for future research is to conduct complementary studies as well as further analysis of the lessons to fill gaps in the available data about some key aspects of science teaching practice (for example, follow-up studies of computer use, further analysis of assessment and questioning practices and analysis of references to science-related social issues).

There are also important implications for teacher professional learning. Given the centrality of inquiry-based learning in Australian science teaching, the commitment to developing scientific literacy and the large proportion of lesson time in the Year 8 science lessons devoted to independent practical activities, there is a need to enhance teachers' skills of managing inquiry lessons. Teachers need to allow more student-directed investigations and manage quality public discussions of the results and conclusions arising from the practical work to ensure that the scientific concepts underlying the investigations can be developed from the inquiry process.



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## Appendix A

### TECHNICAL INFORMATION

The Third International Mathematics and Science Study (TIMSS) 1999 Video Study was carried out to the same high methodological standards as the TIMSS 1995 and 1999 written assessments and other International Association for the Evaluation of Educational Achievement (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 methodological details are contained in the *TIMSS 1999 Video Study Technical Report, Volume 1: Mathematics* (Jacobs et al., 2003) and in the companion volume, *Volume 2: Science* (Lemmens et al., in press, 2006).

This appendix provides a summary for Australian readers of the technical details of the science portion of the study, which are similar to those for the mathematics portion. The summary is drawn largely from Appendix A of the international report, *Teaching Science in Five Countries* (Roth et al., 2006), but is supplemented with some relevant Australian data.

#### Sampling

The sampling objective was to obtain a representative sample of Year 8 science 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. The sampling of science classes was less rigid, for pragmatic reasons, in that timetables were used to select a Year 8 science class held on the same day as the selected mathematics class, or on the next day if there was no possible science class on the same day. It was not expected that this procedure for science would introduce much bias, if any, particularly in countries such as Australia where streaming for science classes at Year 8 is very uncommon.<sup>48</sup>

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 linked to the video database internationally and also within most countries. Switzerland and Australia both extended the mathematics video study by having the videotaped students complete the full TIMSS written mathematics test and part of the TIMSS written test, respectively.

#### Sample size

All of the TIMSS 1999 Video Study countries were required to include 100 schools in their initial selection of schools.<sup>49</sup> The final sample for the science component comprised 439 Year 8 science lessons, compared with 638 lessons for the mathematics component. Table A.1 indicates the sample size and participation rate for each country in the science component.

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<sup>48</sup> Seven countries, including Australia, participated in the mathematics component of the study. From the countries in the mathematics component, Switzerland and the Special Administrative Region of Hong Kong (Hong Kong SAR) did not participate in the science component.

<sup>49</sup> Some countries selected more than 100 schools for their own purposes in the mathematics component of the study.

**Table A.1 Sample size and participation rate for each country**

Country	Number of schools in initial sample	Number of schools that participated	Percentage of schools that participated, including replacements <sup>1</sup> – unweighted <sup>2</sup>	Percentage of schools that participated, including replacements <sup>1</sup> – weighted <sup>3</sup>
Australia	100	87	87	85
Czech Republic <sup>4</sup>	88	88	100	100
Japan	100	95	95	95
Netherlands	98	81	81	83
United States	108	88	82	81

<sup>1</sup> The participation rate including replacement schools is the percentage of all schools (i.e., original and replacements) that participated.

<sup>2</sup> Unweighted participation rates were computed using the actual numbers of schools and reflect success in terms of getting schools to take part.

<sup>3</sup> 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.

<sup>4</sup> All of the 100 schools in the initial Czech sample participated, but it was later decided to exclude the 12 schools in which the sampled lesson happened to be a geography lesson. In the Czech Republic 'geography' has a wider scope than 'earth science' has in other countries.

### ***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 science, separate samples were drawn for the video and assessment studies in all countries (though some different strategies were used in Hong Kong SAR and Switzerland for mathematics).

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, a statistical and research agency in Washington, so that Westat staff could appropriately weight the school samples.<sup>50</sup>

### ***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, 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 written 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

<sup>50</sup> In the United States, Westat selected the school sample and LessonLab selected the classroom sample. Complete details about the sampling process in each country can be found in the Technical Report (Garnier & Rust, in press, 2006).



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,<sup>51</sup> 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 <sup>1</sup>	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
<b>Total</b>	<b>258 003</b>	<b>100.0</b>	<b>100</b>

<sup>1</sup> 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.

**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.

<sup>51</sup> 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.

As is customary in Australia in such studies, schools were initially approached through their principal, once the Head Office of each jurisdiction had agreed that their schools could participate in the study. 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 and a Year 8 science 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.<sup>52</sup> 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 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.

### *Videotaped lessons*

As noted earlier, only one science class was 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 science 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) or guardian(s), agreeing to the student's participation in the filming, was strictly adhered to by the researchers.

Two cameras were used during each videotaping. One camera was placed at the back or side of the classroom, utilising the widest possible angle shot of the teacher and the class, to capture the overall proceedings of the lesson as it occurred. Information from this camera was used to verify student activities and the degree to which the entire class was focused on the same or similar activities, for example. The second camera was positioned so that it captured what an attentive student would see. For the most part, this camera focused on the teacher, especially during whole class presentations and to follow the teacher around as he or she helped individual students during independent work periods. Filming of laboratory lessons was particularly challenging, given the amount of student and teacher activity typical of these lessons. All videographers received

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<sup>52</sup> Disparities in representativeness of the achieved sample were compensated for in the analyses by statistical weighting.

extensive training and opportunities to practise filming lessons before filming of the sampled classes began. The training was undertaken in each country by LessonLab staff.

## Questionnaires

### *Teacher Questionnaire*

To help understand and interpret the videotaped science 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 science course of which the filmed lesson was a part, the context and goal of the filmed lesson, and the teacher's perceptions of the lesson's typicality. Teacher Questionnaire response rates are shown in Table A.4.

**Table A.4 Teacher Questionnaire response rates**

Country	Number of lessons filmed	Number of questionnaires received	Response rate (%)
Australia	87	87	100
Czech Republic	88	88	100
Japan	95	95	100
Netherlands	81	79	98
United States	88	84	95

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.<sup>53</sup>

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.<sup>53</sup> 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 Science 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.

<sup>53</sup> The Teacher Questionnaire is included in Lemmens et al. (in press, 2006) and the Student Questionnaire is included in the Technical Report of the mathematics component of the study (Jacobs et al., 2003).

## **Video Data Coding**

This section provides information about the teams involved in developing and applying codes to the video data. Group members are not identified here, but are listed in Appendix B of *Teaching Science in Five Countries*. Further details of the coding groups described below, and the codes they developed and applied as well as the processes they undertook, can be found in the Technical Report (Lemmens, Garnier & Roth, in press, 2006; Lemmens et al., in press, 2006).

The very first step was to prepare transcripts, in the language of instruction, of the teacher's and students' talk during the lessons. Special purpose software was then used to apply time codes progressively through each transcript. English translations from the Czech, Japanese and Dutch transcripts were then prepared. The transcribers and translators were fluent in both English and their native language, were educated at least to eighth grade in the country whose lessons they translated and had undertaken two weeks' training in the transcription/translation procedures designated for the study.

For validity and credibility of the study's findings, it is crucial that the 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. Discussion of the procedures used for and results obtained from reliability checks is included following the description of the coding teams.

### ***The Science Code Development Team***

An international team was assembled to develop codes to apply to the TIMSS 1999 Video Study science data. The team consisted of country associates (bilingual representatives from each country) and was directed by a science education researcher. The Science 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 Science Code Development 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 science education researchers.

### ***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 174 codes in 12 coding dimensions during many passes through each of the videotaped lessons.

### ***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 science or teaching. Therefore, two specialist coding teams with different areas of expertise were employed to create and apply special codes regarding the scientific nature of the content and the discourse in the science lessons.

#### **Science Content Coding Team**

Members of the Science Content Coding Team were individuals with expertise in science and science education. The nine members of the team developed and applied a series of codes to all of the scientific content in the videotaped lessons.

From textbooks and curriculum materials provided by countries, this specialist coding team began by constructing a comprehensive, detailed, and structured list of the predominant topics covered in eighth grade science in all participating countries. In addition to coding the nature of the topics, the team also coded the types of scientific knowledge, the level of difficulty of the content and the different ways in which the content was developed (see Chapter 4 for definitions of these aspects).

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.

#### Text Analysis Team

The Text Analysis Team used all parts of the lesson transcripts associated with periods designated as 'public interaction' to conduct various text analyses. The 14 members of this team used specially designed computer software for these quantitative analyses of classroom talk. Because of resource limitations, computer-assisted analyses were applied to the English translations of the lesson transcripts (see above, under 'Video data coding').

### **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 international report (and by extension, this Australian 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. It was not deemed appropriate to determine simply that the same codes were applied – it was crucial that the codes were applied to the same time point in the lesson as well.

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. What counted as an agreement or disagreement depended on the specific nature of each code, and is explained in detail in Lemmens, Garnier and Roth (in press, 2006). 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. Rationales for each code's margin of error are provided in Lemmens, Garnier and Roth (in press, 2006).

Reliability of coders was established at two points. *Initial reliability* was determined on all codes in a coding pass prior to their actual implementation. It was computed as agreement between coders and a 'master' document showing codes determined by consensus of the Science Code Development Team. To create the master document, the country associates who made up this team independently coded the same lesson and then met as a group to compare their coding and discuss disagreements until consensus was reached. 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*, which was assessed through inter-rater agreement between pairs of coders.

Further steps to check coding reliability were also implemented. The first two lessons coded by each coder were cross-checked by a code developer and inconsistencies discussed with the coder, while hard-to-code lessons were discussed with other coders and/or code developers. Reliability for the Science Content Coding Team was assessed through consensus coding of all the team members. The text analysis was done by computer and hence the quality of the resulting data depended on the quality of the software and the lesson transcriptions and translations. The software was thoroughly tested and the rigorous procedures for transcription and translation ensured the quality of the data as far as possible.

During the initial reliability checking, average reliability was 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. The minimum acceptable reliability score for each code (averaging across coders) was specified as 85 per cent. Exact agreement was required for codes that had a small number of categorical coding options. Codes were dropped from the study if these levels of reliability could not be achieved. Individual coders or coder pairs had to reach at least 80 per cent reliability on each code.<sup>54</sup>

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 50 variables for which illustrative results are included in the international report, the mean percentage agreement was just under 96 per cent for the initial measurement and close to 97 per cent for the midpoint measurement. Least reliable, at 86 per cent agreement for both occasions, were judgments of 'independent practical activities – writing'; most reliable, at 100 per cent, were variables such as 'use of textbooks' and 'presence of an adult teaching assistant'. The largest discrepancy, of seven percentage points, between initial and midpoint reliability was for judging the 'density of science ideas' and 'independent practical activities – drawing diagrams'. In both cases the midpoint reliability was higher than the initial reliability.

## Other Aspects of Data Reliability

### *Sampling errors*

Sampling errors occur when the discrepancy between a population characteristic and the sample estimate arises because not all members of the reference population are sampled for the survey. The size of the sample relative to the population and the variability of the population characteristics both influence the magnitude of sampling error. The sample of science classrooms from the relevant school year was just one of many possible samples that could have been chosen in each country. Estimates produced from the TIMSS 1999 Video Study sample would therefore be expected to differ from estimates that would have been produced from other samples. This type of variability is called *sampling error* because it arises from using a sample of science classrooms, rather than all science classrooms in the year in question.

The *standard error* is a measure of the variability due to sampling when estimating a statistic. Standard errors can be used as an indication of the precision expected from a particular sample. Standard errors for all of the estimates presented in this report, computed for each country using the jack-knife technique, are included in Appendix C of *Teaching Science in Five Countries*. These standard errors can be used to produce confidence intervals. There is a 95 per cent chance that the true average lies within the range of 1.96 times the standard errors above or below the estimated score. For example, it was estimated that 70 per cent of Australian science lessons incorporated at least one instance of observing phenomena, and this statistic had a standard error of 1.9. Therefore, it can be stated with 95 per cent confidence that the actual percentage of Australian science lessons for the total population in 1999–2000 was between 66.3 and 73.7 per cent ( $1.96 \times 1.9 = 3.72$ ; confidence interval (rounded) =  $70.0 \pm 3.7$ ). The standard errors, which are reported in Appendix C of Roth et al. (2006), ranged quite widely in magnitude, from 0 to over 6, as would be expected from the wide range of percentages reported as results on the many variables examined in the study. The median standard error for Australia was 3.3.

Sampling errors are minimised by ensuring representative coverage of all sections of the population and by drawing samples of adequate size. The video study sampling procedures ensured coverage of the population being studied, but the elaborate and expensive data collection methods necessitated a smaller than ideal sample size. A compromise designed sample of 100

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<sup>54</sup> 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.

classrooms per country was specified, which project teams could be expected to achieve within their available budgets and the desired timeline.

### ***Non-sampling errors***

Several other types of error typically occur with surveys. Examples are missing responses to questions, respondents not interpreting questions in the same way, and respondents not answering honestly because they feel that a true answer would reflect badly on them ('social desirability'). Efforts were made in the video study to minimise such sources of error through field trial and thorough review of questionnaire content and the study's implementation procedures. Respondents were assured that all answers would be treated in the strictest confidence.

Accuracy of data entry was regularly monitored by both random and systematic checks, during which any errors were noted and immediately corrected.

### **Statistical Analyses**

Most of the analyses presented in *Teaching Science in Five Countries* are comparisons of means or distributions across five countries for video data and questionnaire data. The TIMSS 1999 Video Study was designed to provide information about and compare science 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, as determined by the above procedures, pairwise comparisons were computed. For most variables ten comparisons were possible between pairs of countries (comparing each country with each other country). 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 on that variable.

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, there is no more than a 5 per cent chance that a difference would be identified as significant when, in fact, there was no difference in the corresponding true population values.

For each difference indicated in the pairwise comparisons, therefore, the probability that a particular difference will falsely be declared significant is low (5%). However, the probability of making such an error increases when pairwise comparisons between countries are considered as a set (usually referred to as *multiple comparisons*). For example, if six pairwise comparisons were made on a set of data, the probability that at least one would falsely be declared significant at the .05 level is just over one-quarter (0.26), while for 10 comparisons it is close to .4.

Fortunately it is possible to make an adjustment when determining the significance of multiple comparisons that reduces the probability that at least one comparison will falsely be declared significant to 0.05 (5%). 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 adjustment was made by applying the Bonferroni *t* tables published by Bailey (1977) to the Student's *t* values computed for continuous variables on each available pairwise contrast for each variable in turn. All tests were two-tailed. For categorical variables, the Bonferroni Chi-square tables published in Bailey (1977) were used. The degrees of freedom were based on the number of replicate weights (these weights were calculated by Westat specifically for the classrooms in the

TIMSS 1999 Video Study),<sup>55</sup> which was 50 for each country. Thus, in any comparison between two countries there were 100 replicate weights, which were used as the degrees of freedom.

Throughout the report, terms such as 'less', 'more', 'greater', 'higher' and 'lower', for example, are applied only to statistically significant comparisons. The text 'no measurable differences detected' is used in discussion of results where statistical significance was not established. In this latter case, failure to find a statistically significant difference may not mean that the population parameters on the variable are the same or similar. Rather, failure to find a difference may be due to sampling or measurement error. The small number of countries in the study made it quite likely that many apparent differences would not be statistically significant.

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<sup>55</sup> A full description of the weighting procedures is provided in Rust (in press, 2006).



## Appendix B

### TABLE AND FIGURE NUMBERS FROM THE NATIONAL AND INTERNATIONAL REPORTS

National	International
Table 1.1	Table 1.2
Table 1.2	Table 1.1
Table 2.1	*
Table 2.2	Table 2.1
Table 2.3	Table 2.2
Table 2.4	Tables 2.3 & 2.4
Table 2.5	Table 2.5
Table 2.6	[other source]
Table 2.7	Table 3.1
Table 2.8	Table 2.6
Table 2.9	Table 2.7
Figure 2.1	Figure 2.2
Figure 2.2	Figure 3.1
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Figure 2.4	Figure 2.4
Figure 2.5	*
Figure 2.6	Figure 2.5
Table 3.1	Table 3.4
Table 3.2	Table 3.5
Figure 3.1	*
Figure 3.2	*
Figure 3.3	Figure 11.2
Figure 3.4	Figure 3.4
Figure 3.5	Figure 3.5
Figure 3.6	Figure 3.6
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Figure 3.8	Figure 8.1
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Figure 3.12	Figure 11.7
Figure 3.13	Figure 11.8
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Table 4.1	Tables E.1 to E.5
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Figure 4.2	Figure 4.3

National	International
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Figure 4.4	Figure 4.7
Figure 4.5	Figure 4.8
Figure 4.6	Figure 5.1
Figure 4.7	Figure 5.4
Figure 4.8	Figure 5.5
Figure 4.9	Figure 5.6
Figure 4.10	Figure 5.7
Figure 4.11	Figure 5.9
Figure 4.12	Figure 5.11
Figure 4.13	Figure 6.1
Figure 4.14	Figure 6.2
Figure 4.15	Figure 6.3
Table 5.1	Table 7.1
Figure 5.1	From Table 3.5
Figure 5.2	From Table 7.2
Figure 5.3	Figure 7.1
Figure 5.4	Figure 7.2
Figure 5.5	Figure 7.3
Figure 5.6	From Table 7.3
Figure 5.7	From Table 7.3
Figure 5.8	Figure 7.5
Figure 6.1	Figure 10.1
Figure 6.2	Figure 10.3
Figure 6.3	Figure 10.5
Figure 6.4	Figure 10.7
Figure 6.5	Figure 9.8
Figure 6.6	Figure 9.1
Figure 6.7	Figure 9.2
Figure 6.8	Figure 9.4
Figure 6.9	Figure 9.5
Figure 6.10	Figure 11.5
Figure 6.11	Figure 11.6
Figure 6.12	Figure 11.1
Figure 6.13	Figure 11.3

\* This table/figure was prepared for *Teaching Science in Five Countries* (Roth et al., 2006), but was not included in the final version. It is used here with permission of the authors.