February 2006

ACER

Highlights from the TIMSS 1999 Video Study of Year 8 Science Teaching

TIMSS 1999 Video Study

Following on from a pilot video study carried out in 1995, the Third International Mathematics and Science Study (TIMSS) 1999 Video Study was undertaken to investigate and describe Year 8 mathematics and science teaching practices in a variety of countries. The countries involved in these studies were:

- 1995: Germany, Japan and the United States;
- 1999: Australia, the Czech Republic, Hong Kong SAR[1], Japan, the Netherlands, Switzerland and the United States.

The 1995 study focused on mathematics lessons only. In 1999, however, both mathematics and science lessons were included. All seven countries took part in the mathematics part of the study, while Hong Kong SAR and Switzerland chose not to participate in the science part.[2]

This *Highlights* document presents brief background information followed by key findings from the science part of the 1999 study. Australian and international reports of the video studies, together with details of how to obtain the reports, are listed at the end.

What gave rise to the video studies?

Results from the initial TIMSS pen-and-paper assessment of students' mathematics and science achievement in over 40 countries, which took place in 1995, led to interest in documenting and analysing what occurs during classroom instruction in these subjects. On average, students from the United States performed at significantly lower levels in both mathematics and science than students from the other countries that are represented in the 1999 video study. The same was found in the 1999 repeat of the written assessment.

Researchers and education policy makers, particularly in the United States, wondered: Could teaching practices be identified that were characteristic of instruction in each of mathematics and science in the higher achieving countries, that perhaps were not typical of United States classrooms? Findings from the 1995 pilot video study, which demonstrated very noticeable differences in mathematics teaching methods at Year 8 between Japan (a very high achiever on the written assessment) and the other two countries, provided encouragement for the more extensive 1999 video study to be undertaken.

HIGHLIGHTS FOR AUSTRALIA

In the national random sample of Australian Year 8 science lessons videotaped between June 1999 and May 2000, Australian science teaching at this level was found in many respects to resemble a model of ideal science teaching derived from research and Australian curriculum documents.

- The teachers were mostly well-qualified to teach science, which they had been teaching for an average of 14 years. Most said they were familiar with current ideas in science teaching and learning.
- Ninety per cent of the lessons took place in science laboratories. The teachers said they had sufficient resources except for computers and Internet access.*
- On average, all but 2 per cent of the lesson time was devoted to science instruction or organising students to undertake science-related tasks.
- New content was introduced and discussed in 97 per cent of the lessons, occupying 85 per cent of the lesson time on average.
- The lessons were well-structured. Australia and Japan were the only countries found to have strong conceptual links in the material presented in the majority of content-focused lessons.
- The science instruction predominantly featured an inquiry, inductive approach. Practical activities were featured in 90 per cent of the lessons and students worked on hands-on practical activities in pairs or small groups in three-quarters of the lessons.
- Real-life issues and first-hand data were used to support the development of ideas in the majority of lessons, which tended to feature multiple activities likely to engage the students' interest.

Despite the generally positive findings relating to the Australian lessons, students would benefit from more opportunities to learn and practise higher-order inquiry skills such as designing their own investigations and taking part in class discussions of their results.

* By now this situation would be expected to be much improved, as all education systems have devoted funds to supplying computer resources to schools in the intervening years.

What can be learned from a video survey of teaching across cultures?

Classroom teaching everywhere has the aim of helping students to learn. But comparative studies have usually found differences in performance, on average, between students from different countries and have demonstrated that some of these differences in achievement can be attributed to factors associated with what happens in the students' classrooms.

Compared with data obtained from teachers answering questionnaires about their teaching practices, much richer information about teaching can be gathered if lessons are videotaped to record, for later analysis, classroom events and activities as these actually take place. Videotapes allow the complexities of class lessons to be analysed in detail, many times over, from different points of view and by people with different kinds of expertise.

Comparing teaching across cultures allows teachers to look at their own teaching from fresh perspectives, providing them with food for thought about what they are doing well and possible improvements they might try. 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 adopting in one's own repertoire of teaching practices.

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

Did Australia have any special objectives for participating in the TIMSS 1999 Science Video Study?

As well as the more general objectives outlined in the boxed text above, Australia's goals for participating in the study emphasised:

- obtaining an authentic, rich and representative picture of science teaching in lower secondary classes across the country;
- ascertaining the extent to which Australian science teaching in 1999 reflected emphases in curriculum and other 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; and
- assembling an information base of classroom practice for professional development purposes.

What was the scope of the study, and how were lessons selected?

The TIMSS 1999 Science Video Study included a total of 439 Year 8 lessons collected from the five participating countries. The designed sample size 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.[3]

The Australian sample was 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 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 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.

The study was managed internationally by LessonLab Inc. in Los Angeles, California. The Australian component was managed by the Australian Council for Educational Research (ACER).

How were the results processed and how are they reported?

Processing of the videotapes was a long, complex and labour-intensive undertaking. Several specialist teams were needed to decide what data 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 in Los Angeles, the international headquarters of the project. Two Australian researchers, including one from ACER, were based at LessonLab for most of the duration of this work, together with colleagues in a similar role from the other countries.

Most of the data are reported in the form of tables or charts, which clearly show comparisons both within and across countries. Comparisons reported in this *Highlights* document have been tested for statistical significance at the .05 level. Differences between averages or percentages that are statistically significant are discussed using comparative terms such as 'higher' or 'lower'. These differences are noted using the 'greater than' symbol (>) in footnotes to each table or figure. Country percentages that appear different may not be statistically so because their standard errors differ. Small percentage values need to be interpreted very cautiously because they may have relatively large standard errors.

Comparisons that did not yield statistically significant differences are not shown in the footnotes. Failure to find a significant difference does not mean that country estimates are necessarily the same or similar; rather, failure to find a significant difference may be due to measurement or sampling errors, particularly given the relatively small samples of classes examined in this study.

The main national and international reports of the study are accompanied by illustrative videos of representative lessons collected during the study, released publicly to enrich the report findings and also to act as a resource for teacher professional development programs.

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 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 there, as described later in this summary.

Common features of Year 8 science teaching across countries

Common features observed across all the participating countries are presented here in four categories, to assist in reporting the summary of results. Some are features that appeared in most lessons in all of the countries while others are features that were observed with low frequencies in all of the countries.

Contextual commonalities

- Teachers in all countries were qualified to teach, and most were well qualified to teach science at Year 8 level.

Commonalities in instructional organisation

- 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 the 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 (when the teacher or a student was addressing the whole class) and private, individual or small group work.

Commonalities in scientific content

- A high percentage of lessons included public, whole-class attention to 'canonical knowledge' of science – that is, the generally accepted scientific 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.

Commonalities in teacher and student actions

- 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, which occurred relatively rarely.
- 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 in the document 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. Data on annual science instruction time collected for the TIMSS 1999 written assessment showed that countries where science was taught as several separate subjects at Year 8 generally spent more school hours per year on science (150 to 200 or more) than countries where it was taught as a single integrated subject (90 to 150 hours). The estimated average annual times for the science video study countries follow this pattern (Table 1).

Regardless of whether science is taught as separate subjects or as an integrated subject, many distinctive features were found in Year 8 science teaching between the countries. These involved time used for practical activities, the topics covered, the ways new content was introduced, the level of challenge of the subject matter and the extent of emphasis on review of previous content. 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. Key findings for Australia on these and other variables are presented below.

Table 1 Average annual in-school time spent on Year 8 science instruction[1]

Country[2]	Estimated average instructional time per year (hours)
Australia (AU)	129
Czech Republic (CZ)	236
Japan (JP)	94
Netherlands (NL)	181
United States (US)	144

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

2 Various options are available in these countries for students to obtain additional instruction related to school subjects, particularly in Japan.

What were the major Australian findings?

The Australian findings are summarised here in four categories similar to those used in the previous section. The contextual information was derived from responses to a Teacher Questionnaire while results in the other categories were based on observational data from 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, all of whom had been teaching for more than 30 years, 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 the 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. The United States, where almost negligible percentages of the teachers had studied physics or chemistry at university level, was at one extreme, with Japan, where more of the teachers had majored in physics and/or chemistry than in life sciences, at the other.
- On average, the Australian teachers had been teaching science for 14 years and most considered themselves to be effective teachers.
- Three-quarters said that they were familiar with current ideas in science teaching and learning.

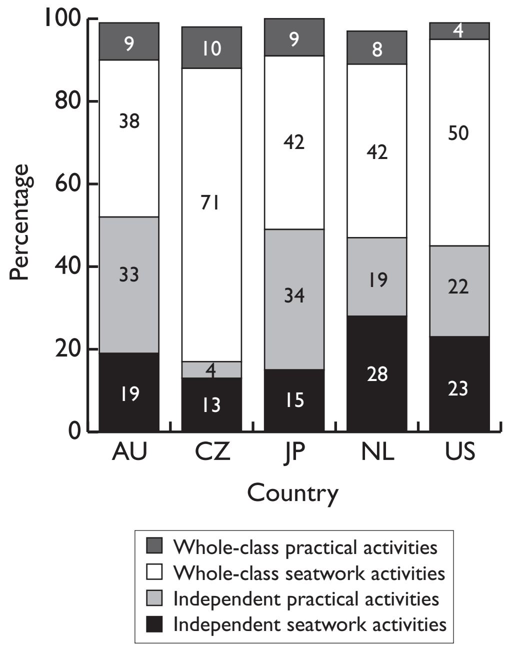
- Over 80 per cent agreed that their videotaped lesson was typical or very typical of their teaching methods and 95 per cent agreed that their students' behaviour was about the same as or better than usual (27 per cent replied 'better than usual'). About three-quarters said the presence of the camera 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 (in 1999–2000) only a quarter were satisfied with their access to computers, software and Internet connections. Other countries reported shortages of laboratory equipment, particularly the Netherlands and the United States, while almost 90 per cent of the Japanese teachers said they had insufficient access to reference materials.
- Ninety per cent of the Australian lessons took place in science laboratories, significantly more than in any of the other countries except Japan (76%).

Observations from the videotapes

Differences in instructional organisation

- *Instructional 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 (Australia, 85%; Japan, 93%). Other types of activity varied, including review of previous content, going over homework in class and assessing student learning, all of which occurred rarely in Australia, Japan and the United States. The Czech Republic stood out in its emphasis on review and the Netherlands stood out in its emphasis on going over homework (data not shown).
- *Whole-class and independent activities:* The partition of lesson time into whole class versus independent activities was approximately equal in Australia, as it was in all countries except the Czech Republic, where 80 per cent of the time, on average, was spent on whole class work (Figure 1).
- *Practical work and other activities:* Australia and Japan had the closest to equal divisions of lesson time devoted to practical activities and seatwork activities such as making notes, completing written exercises and reading textbooks (just over 40 per cent for practical activities). In the other countries, 70 per cent or more of the lesson time was spent on seatwork, done either by the class as a whole or by students working independently (Figure 1).
- *Seatwork done independently:* Independent seatwork, such as reading or writing, used more science instruction time in the Netherlands than in the Czech Republic and Japan (Figure 1).

Figure 1 Percentage distributions of science instruction time in Year 8 science lessons devoted to each combination of activity and lesson organisation type, on average



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.

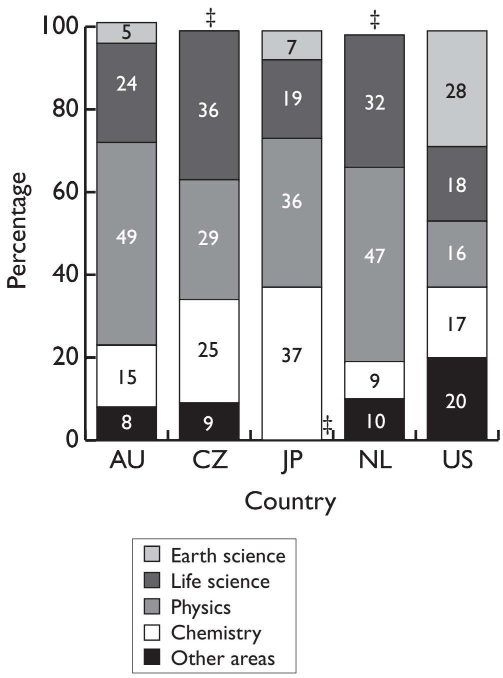
Differences in scientific content

- *Types of scientific knowledge:* Different types of knowledge were addressed in the science lessons. Considering 'public talk' time (time when the whole class was the intended audience of a teacher or student), Czech lessons allocated a larger percentage of time (59%) to presenting and discussing 'canonical' knowledge (generally-accepted scientific facts, ideas, concepts or theories) than the other countries' lessons (Australia: 35%). More public talk time was spent on procedural and experimental knowledge during Year 8 science lessons in Japan (25%) than in any of the other four countries (Australia: 17%). However, Japanese lessons allocated less time for public talk about science-related real-life issues (6%) than lessons in the other countries, except for Australia (12%; other countries, 14 to 17%) (data not shown).
- *Topics:* 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 knowledge of Australian Year 8 curricula, and probably occurred because more than half of the Australian lessons were filmed during the third and fourth terms. Physics and chemistry topics were featured in more Japanese lessons than earth science or life science. The United States' pattern differed from the other countries' patterns in that earth science, life science, physics, chemistry and other topics were addressed about equally (Figure 2).
- *Challenge and density of scientific content:* The majority of Australian and Japanese lessons were judged to contain content at basic level only. The country distributions were similar except for the Czech Republic, where 81 per cent of the lessons were judged to be more advanced (Figure 3).

  Other evidence of the higher level of challenge of scientific content in the Czech lessons arises from the extent of use of scientific terms and highly technical scientific terms. On average, 56 unrepeated scientific terms were observed per Czech science lesson, 33 of which were judged to be highly technical, compared with about 20 and 10 terms, respectively, in the other countries (data not shown).

  Classes were streamed in the Czech Republic through being in schools which catered for students at different academic levels. Streaming also occurred in the Netherlands, either at school level or at class level within schools. In Australia and Japan, streaming of students for Year 8 science instruction rarely occurred, and hence it would have been surprising to see many lessons in these countries classified as containing only highly challenging material.

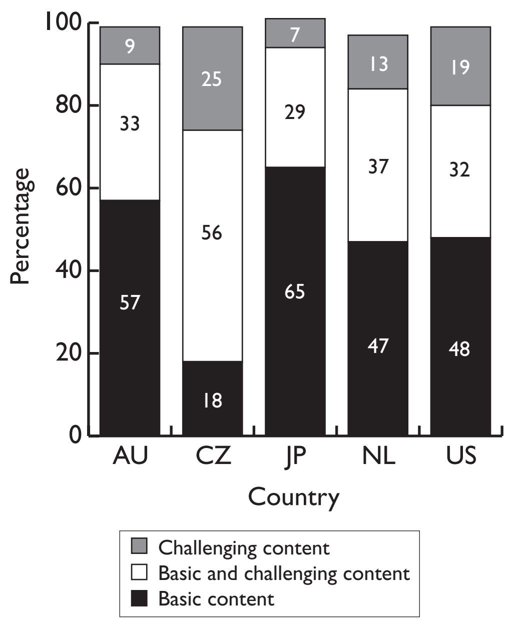
Figure 2 Percentage distributions of Year 8 science lessons devoted to earth science, life science, physics, chemistry and other areas



‡ 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.

Figure 3 Percentage distributions of Year 8 science lessons according to experts' judgments of the level of challenge of their publicly-presented scientific content



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

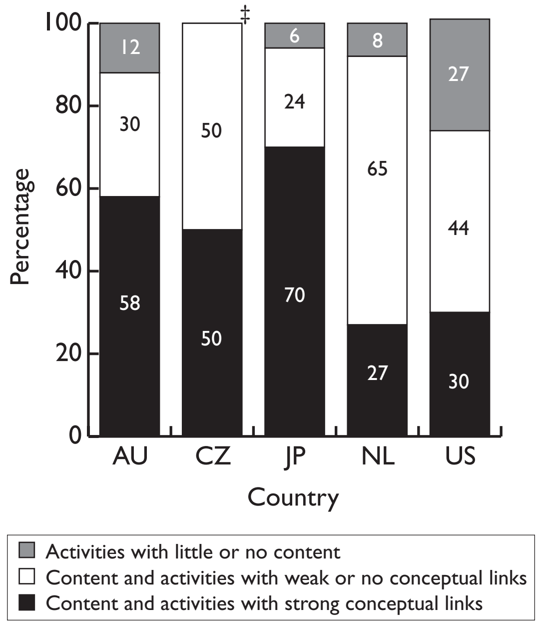
Note: Totals may not sum to 100 because of rounding and a few lessons with no publicly-presented content.

- *Lesson coherence:* Australia fared relatively well on aspects of lesson coherence such as use of goal statements, which occurred in 95 per cent of the videotaped lessons. However, summary statements were used in only about a quarter of the lessons, midway between Japan (41%) and the Netherlands (6%) (data not shown).

  Science instructional practices were found to vary in how closely content ideas and activities were woven together to form a coherent, strongly linked lesson. Australia and Japan were the only countries found to have strong conceptual links in the material presented in the majority of content-focused lessons. Although lesson content was generally more challenging in the Czech Republic than in the other countries, in half of the Czech lessons conceptual links between content segments were either weak or not made at all. Only 12 per cent of Australian lessons and 6 per cent of Japanese lessons were activity-focused with no conceptual links, compared with 27 per cent in this category in the United States. The mix of strong and weak or no conceptual links from country to country is shown in Figure 4.

- *Content supported by evidence:* All countries used first-hand data, observations of phenomena and visual representations to support the development of scientific concepts to some extent. Australian and Japanese science lessons involved more use of multiple sets of first-hand data and multiple phenomena to support the scientific content being presented or developed than science lessons in the other three countries. In the Czech Republic and Japan, multiple visual representations were used to support all the main ideas in science lessons more often than in the Netherlands (Figure 5).

Figure 4 Percentage distributions of Year 8 science lessons by focus and strength of conceptual links

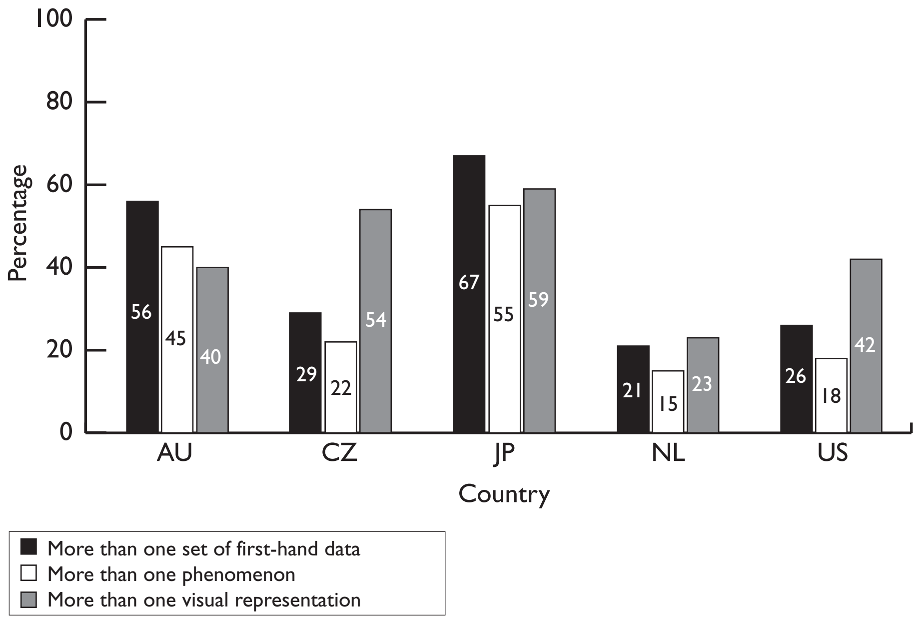


Activities with little or no content: US>JP, NL
Content and activities with weak or no conceptual links:
CZ>JP; NL>AU, JP
Content and activities with strong conceptual links:
AU, JP>NL, US; CZ>NL

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

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

Figure 5 Percentages of Year 8 science lessons that supported all main ideas with more than one instance of various types of evidence

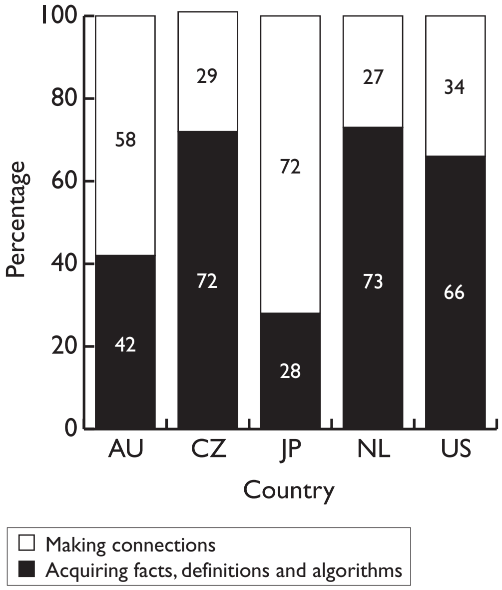


More than one set of first-hand data: AU, JP>CZ, NL, US
More than one phenomenon: AU, JP>CZ, NL, US
More than one visual representation: CZ, JP>NL

Overall, more Japanese science lessons (65%) supported every main idea with at least one set of first-hand data, at least one phenomenon and at least one visual representation than science lessons in the other countries. Australian lessons used all three types of evidence to support all the main ideas (47%) more than Dutch and United States lessons (14 and 18 per cent, respectively). In the Czech Republic, all three types of evidence were used in this way in a third of the lessons (data not shown).

- *Content developed through making connections or acquiring facts and definitions:* Scientific content was developed through making connections among ideas, experiences, patterns and explanations in more Japanese and Australian lessons than in Czech and Dutch lessons. More Japanese lessons focused primarily on making connections than lessons in all countries except Australia (Figure 6). In contrast, Czech, Dutch and United States lessons were more likely to develop content through focusing on facts, definitions and algorithms (Figure 6). Further analysis revealed that making connections in Australian and Japanese science lessons was most often accomplished through an inquiry or inductive approach wherein data were collected and then used to develop new ideas, which occurred in 43 and 57 per cent of the lessons, respectively (data not shown).

Figure 6 Percentage distributions of Year 8 science lessons according to the main method used to develop scientific content



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

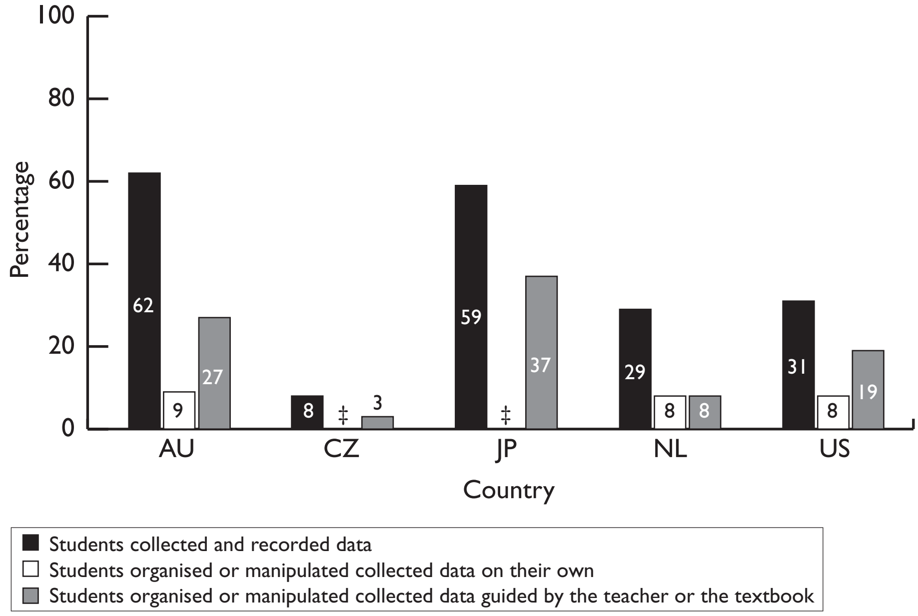
- *Content developed through real-life issues:* While discussion of real-life issues did not consume much time (see 'Types of scientific knowledge' above), such issues were used in many lessons to assist in the development of scientific concepts. They were used for this purpose in more Czech lessons (83%) than in the lessons of other countries except Australia (69%). Japanese lessons were lowest in this respect, with content developed through discussion of real-life issues in only 47 per cent of the lessons (data not shown).

Differences in patterns of teacher and student actions

- *Practical activities:* Ninety per cent of the 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 (data not shown).

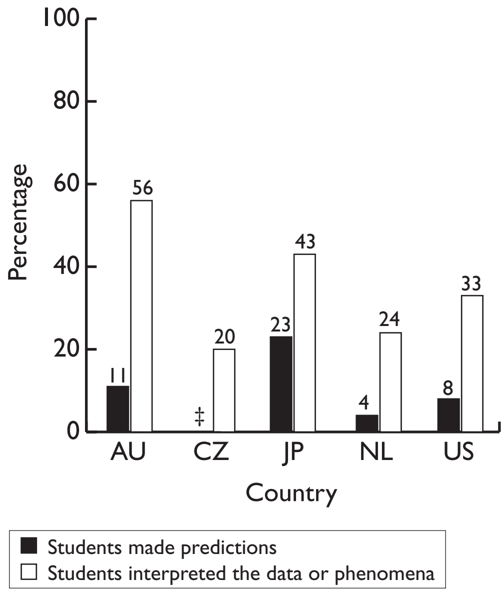
  The practical investigations performed by the students were usually directed or guided by the teacher or a worksheet. Students rarely formulated their own research questions, designed their own investigations or determined how they would organise or manipulate the data they collected. Australian and Japanese lessons were very similar in these respects (Figure 7).
- *Making predictions and interpreting data or phenomena:* Students rarely made predictions of the outcomes of their investigations, except in Japan. Australia was the only country where students interpreted data or phenomena in more than half of the lessons (Figure 8).

Figure 7 Percentages of Year 8 science lessons in which data from independent practical activities were recorded and manipulated by students



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

Figure 8 Percentages of Year 8 science lessons in which students made predictions and interpreted data or phenomena related to independent practical activities



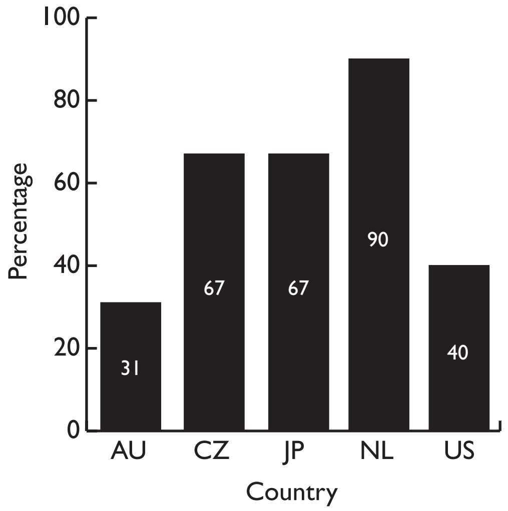
Students made predictions: JP>NL
Students interpreted the data or phenomena: AU>CZ, NL; JP>CZ

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

- *Discussion of outcomes of practical activities:* 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 (data not shown).
- *Homework activities:* Teachers assigned homework 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. In the Netherlands and Australia, students worked on homework during class time in 40 per cent or more of the lessons (although only for very short periods of time, on average, in Australia). 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 (data not shown).

- *Use of textbooks:* Textbooks or printed, structured workbooks were used in only 31 per cent of the Australian lessons, significantly fewer than in all countries except the United States. Textbooks were used most by students in the Netherlands (Figure 9).

Figure 9 Percentages of Year 8 science lessons in which students used textbooks and/or printed workbooks



Students used textbooks/workbooks:
NL>AU, CZ, JP, US; CZ, JP>AU, US

Following from this, Dutch students spent 20 per cent of science instructional time in reading, which occurred in no more than 8 per cent of science instructional time elsewhere (data not shown).

- *Motivating activities:* Teachers in all countries made use of motivating activities (e.g., games, puzzles, dramatic demonstrations, competitive activities, role plays) to stimulate students' interest. This occurred in about a third of the Australian lessons, though on average occupied only about 10 per cent of the science instruction time. The United States, where teachers used motivating activities in about two-thirds of the lessons, consuming on average almost a quarter of the science instruction time, stood out in this respect (data not shown).
- *Notebooks and note-taking:* In Australia and the Czech Republic most 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.

  Australian students were sometimes expected to copy or take down verbatim notes during lessons, but this was relatively rare. By contrast, Czech students frequently copied notes into their notebooks (data not shown).

How is science teaching approached in each country?

The study's results show that each of the five countries has an observable pattern of science teaching. Summaries of these patterns, as observed in 1999–2000, are presented here, with countries in alphabetical order except for Japan, which is placed after Australia because of the extent of similarities between these two countries' approaches. The summaries are followed by a discussion of commonalities observed in the four higher-achieving countries.

Australia: 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. 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 both 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.

Japan: 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 Republic: 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 acquiring 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.

Netherlands: 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 assignments 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.

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: Implementing a 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 variety in the topics covered as well, with lessons spread across the areas of earth science, life science, physics, chemistry and other topics such as the nature of science and interactions of science, technology and society. 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 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 did not develop scientific content ideas at all, focusing instead on carrying out activities.

Commonalities shared by the four relatively 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 within 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.

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), together with the national professional standards developed by the Australian Science Teachers Association (2002) and the components identified in the Victorian Science in Schools study (Tytler, 2002). 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 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 across 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. Typically, they followed teachers' instructions or a worksheet in carrying out their practical activities. 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

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 results of the TIMSS 1999 Science Video Study suggest different, sometimes country-specific patterns of Year 8 science teaching in each of the five participating countries and highlight the role of content and a core instructional approach in each of the four relatively higher-achieving countries (Australia, the Czech Republic, Japan and the Netherlands). However, no single approach was shared by the higher-achieving countries – lessons differed in their organisational features, content features and the ways in which students were involved in actively doing scientific work. The main difference in Year 8 science teaching between the four higher-achieving countries and the United States was that, although United States students were exposed to a variety of organisational structures, content and activities, these features were not typically used in ways that would offer students a clear and coherent picture of conceptual links that can be made between content ideas.

The video records of the representative sample of Australian Year 8 science lessons collected for the study provide strong endorsement for the quality of Australian science teaching both when these lessons are compared with lessons from other high-achieving countries and when they are judged against the picture of ideal science teaching outlined above. The extent and quality of inquiry-based learning and the strong connectedness of most of the Australian lessons provided the students with good opportunity for quality learning. It is interesting to note the extent of similarities with Japanese lessons, as reflected in the results and country summaries included above. Although lesson content was generally more challenging in the Czech Republic than in the other countries, in half the Czech lessons conceptual links between content segments were either weak or not made at all. The Australian and Japanese lessons tended to focus on developing smaller numbers of ideas in conceptually coherent, evidence-based ways.

From the pictures of science teaching portrayed in the videotaped lessons, opportunities for the development of scientific literacy were missed in all countries. 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, except in Japan, public discussion of conclusions occurred in a minority of the lessons in which students did practical work. These aspects of the lessons limited the opportunities for students to learn higher levels of inquiry skills. 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 more public discussion of the results and conclusions arising from the practical work to ensure that scientific concepts underlying investigations can be developed and consolidated.

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, including the United States, improved, in some cases substantially. Thus it appears that Australia has been standing still, while other countries have been moving forward.

Endnotes

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

2 In 1999 full funding for five of the countries was provided by the United States Department of Education, through its National Center for Education Statistics. Substantial funding (about two-thirds of the full participation costs), which was supplemented by their own governments, was provided from United States sources for Australia and Switzerland.

3 The weighted response rate reached the specified 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 of schools.

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