

Highlights From the TIMSS 1999 Video Study of Eighth-Grade Science Teaching

The Third International Mathematics and Science Study (TIMSS) 1999 Video Study is a follow-up and expansion of the TIMSS 1995 Video Study of mathematics teaching. Larger and more ambitious than the first, the 1999 study investigated eighth-grade science teaching as well as mathematics teaching, expanded the number of countries, and included more countries with relatively high achievement on TIMSS assessments in comparison to the United States. The results of the mathematics portion of the study are presented elsewhere (Hiebert et al. 2003). Discussion of the results from the 1995 Video Study can be found in Stigler et al. (1999) and Stigler and Hiebert (1999). This document highlights key findings from the science lessons and is based on the full report, *Teaching Science in Five Countries: Results From the TIMSS 1999 Video Study* (Roth et al. 2006).

Who Participated in the Study and How Were Lessons Selected?

The TIMSS student assessments of mathematics and science were conducted in 1994-95, in 1998-99, and again in 2003. The countries participating in the science portion of the TIMSS 1999 Video Study included Australia, the Czech Republic, Japan, the Netherlands, and the United States. The countries were selected based on their performance in mathematics in 1995. At that time, the other four countries outperformed the United States (on average) in science as well as in mathematics. In 2003, U.S. students' average score in science was not measurably different from the average score in Australia and the Netherlands, but remained significantly below the average score of Japanese students. The Czech Republic did not participate in TIMSS 2003. The TIMSS 1995, 1999, and 2003 average science scores for these countries are displayed in table 1.¹

¹ Rescaled TIMSS 1995 science scores are reported here (Gonzales et al. 2000). The average for Australia in 2003 cannot be compared to the averages in 1995 and 1999 due to national level changes in the starting age/date for school. The 1995 and 1999 averages are those reported in Gonzales et al. 2000. The 2003 average is the one reported in Gonzales et al. 2004. Since the TIMSS 1999 Video Study sample selection of countries is based on the 1995 averages, and the target population for Australia in both 1995 and in 1999 was a mix of eighth and ninth grades, table 1 presents the averages for that population.

TABLE 1. Average science scale scores of eighth-grade students, by country: 1995, 1999, and 2003

Country	1995		1999		2003	
	Average	Standard error	Average	Standard error	Average	Standard error
Australia ¹	527	4.0	540	4.4	527	3.8
Czech Republic	555	4.5	539	4.2	—	—
Japan	554	1.8	550	2.2	552	1.7
Netherlands ¹	541	6.0	545	6.9	536	3.1
United States ²	513	5.6	515	4.6	527	3.1

—Not available. The Czech Republic did not participate in the 2003 assessment.

¹Nation did not meet international sampling and/or other guidelines in 1995. See Beaton et al. (1996) for details.

²Nation did not meet international sampling and/or other guidelines in 2003. See Gonzales et al. (2004) for details.

NOTE: Rescaled TIMSS 1995 science scores are reported here (Gonzales et al. 2000). The average for Australia in 2003 cannot be compared to the averages in 1995 and 1999 due to national level changes in the starting age/date for school. The 1995 and 1999 averages are those reported in Gonzales et al. 2000. The 2003 average is the one reported in Gonzales et al. 2004.

SOURCE: Gonzales, P., Calsyn, C., Jocelyn, L., Mak, K., Kastberg, D., Arafah, S., Williams, T., and Tsen, W. (2000). *Pursuing Excellence: Comparisons of International Eighth-Grade Mathematics and Science Achievement from a U.S. Perspective, 1995 and 1999* (NCES 2001-028). Washington, DC: Government Printing Office. Gonzales, P., Guzman, J.C., Partelow, L., Pahlke, E., Jocelyn, L., Kastberg, D., et al. (2004). *Highlights from the Trends in International Mathematics and Science Study (TIMSS) 2003*. Washington, DC: Government Printing Office.

The science portion of the TIMSS 1999 Video Study included 439 eighth-grade science lessons collected from the five participating countries. In each country, the lessons were randomly selected to be representative of eighth-grade science lessons overall. Each country was required to sample 100 schools. The response rates of the final sample of schools participating in the study ranged from 81 percent (weighted) in the Netherlands and the United States, to 100 percent in the Czech Republic.² From the schools that agreed to participate, one eighth-grade science class was randomly chosen from a list of all science courses in the school in which eighth-graders were enrolled. The randomly selected science class was videotaped for one complete period or lesson. No substitutions of schools or science classes were permitted. In each country, videotapes were collected across the school year to try to capture the range of topics and activities that can take place throughout an entire school year. In addition, teachers and students were asked to complete a questionnaire regarding the videotaped lesson.

How Should Science Teaching Across Countries Be Described?

Conceptual Framework

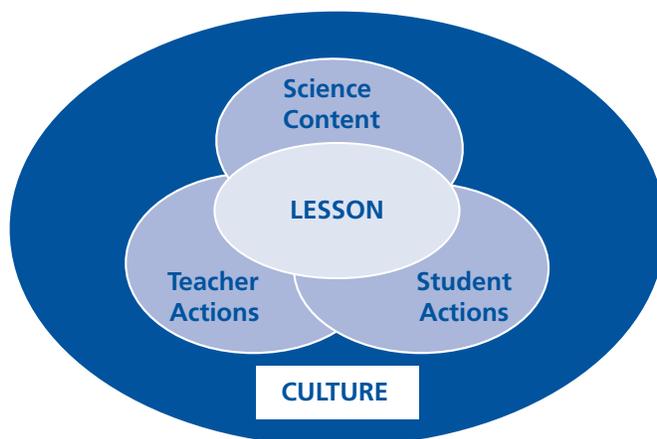
Multiple approaches were taken to organize and prioritize study goals, research questions, and coding dimensions. First, analysis of field test lesson videos by an international team of researchers (the Science Code Development Team) led to hypotheses about important features of science teaching in each of the participating countries. Next, an extensive literature review, including analyses of research studies as well as standards and curriculum documents from each of the participating countries

²Twelve of the lessons selected from the initial sample of 100 schools in the Czech Republic included only economic and political geography content and were excluded from the sample of eligible science lessons. See table A.1 in appendix A of the full report by Roth et al. 2006.

(American Association for the Advancement of Science (AAAS) 1990, 1993; Australian Education Council 1994; Czech Ministry of Education 1996; Dutch Ministry of Education, Culture, and Science 1998; Kolavova 1998; Ministry of Education, Science, and Culture [Monbusho] 1999; National Research Council (NRC) 1996; Nelesovska and Spalcilova 1998) provided an exhaustive list of features of science teaching that might be investigated in the study.³ Five U.S. science educators serving as advisors on a steering committee to the project and a national research coordinator from each of the five participating countries then reviewed and prioritized the nominated research questions and coding dimensions. Finally, the Science Code Development Team, which included representatives from each of the participating countries, compared the important features of science teaching emerging from the literature review, the advisors' recommendations of high priority lesson features to examine, and their own review of lessons from the data set to develop an overarching conceptual framework and a set of research questions that guided decisions about coding priorities as well as the organization of the presentation of the results in this report.

Figure 1 presents the conceptual framework for the TIMSS 1999 Video Study analysis of science lessons. The TIMSS conceptual framework emphasizes the centrality of the lesson as the unit of analysis in this study and emphasizes the importance of capturing aspects of all of Schwab's four commonplaces of teaching—the teacher, the learners, the subject matter, and the social milieu (Schwab 1969, 1971, 1973). There was strong consensus among the study's advisors and national research coordinators that the study not be limited to identifying teacher actions; there must also be an examination of the science content and the students' actions and opportunities for learning. Thus, teaching is more than the teacher's actions—it is an interaction among the teacher's actions, the

FIGURE 1. TIMSS 1999 Video Study: Science conceptual framework



³Of the five participating countries, three have national curricula (the Czech Republic, Japan, and the Netherlands). Australia and the United States do not have national curricula; rather, decisions regarding curricula are taken at the state, provincial, or local level. Reference is made throughout this report to standards, curricular guidelines and reform documents from each of the countries. In the case of the Czech Republic, Japan, and the Netherlands, these are the official documents that guide classroom teaching and learning decisions. In Australia and the United States, these documents are produced by large national professional and scientific organizations that promote standards and improvement for science teaching and learning. However, these documents should not be construed as official or definitive statements of national, state, provincial or local governments in these two countries. Rather, they represent the most widely referenced and distributed curricular and standards documents available in these two countries

students' actions, and the science content. In this study, cultural differences were not directly observed but may be reflected in unique country patterns that emerged from observations of the teachers, students, and science content in the lessons

Guiding Research Questions

The main research question guiding the conceptual framework was: What opportunities did the lesson provide for students to learn science? This main research question was supported by three guiding questions to examine students' opportunities to learn in each of the three areas represented in the conceptual framework—teacher actions, science content, and student actions:

- How did the teacher organize the lesson to support students' opportunities to learn science?
- How was science represented to students in the lesson?
- What opportunities did students have to participate in science learning activities?

Each guiding question was then explored through a set of four to fifteen more specific questions. Although this is a study of classroom teaching, the focus of analysis was placed on students and the ways in which teaching actions 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 key stimuli for the study—the differences in student achievement as evidenced on TIMSS 1995 and 1999 assessments (Martin et al. 2000).

How Were the Videotaped Lessons Analyzed?

Three teams were assembled to develop and apply codes that would capture teaching activities and behaviors observed in the videotaped lessons. The Science Code Development Team (mentioned previously) included science specialists, researchers, and representatives from each of the participating countries who identified and developed codes, trained coders and established reliability, organized quality control measures, and managed the analyses and reporting of the data. The Science Code Development Team worked closely with two advisory groups consisting of national research coordinators representing each of the countries in the study and a steering committee of five U.S. science education researchers. The International Video Coding Team represented all of the participating countries and applied the developed codes to each of the videotaped lessons. The Science Content Coding Team included U.S. representatives with expertise in science content who developed and applied codes to all of the scientific content of the videotaped lessons.

Extensive training was conducted for the International Video Coding Team and the Science Content Coding Team. Reliability was established for codes that identified an activity or behavior and measured how long the activity or behavior took place. For

certain codes, the members of the Science Content Coding Team each established reliability through consensus coding.

Finally, to obtain reliable comparisons among the participating nations, the data were appropriately weighted to account for sampling design.

Comparisons made in this 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.” Moreover, these differences are noted using the greater than symbol (>) in the footnotes of each table or figure included in this document. Differences that are not statistically significant are either not discussed or referred to as “no measurable differences found” or “not statistically significant.” Failure to find a statistically significant difference should not be interpreted to mean that the estimates are the same or similar; rather, failure to find a difference may also be due to measurement or sampling error.

The purpose of this report is to introduce new NCES survey data through the presentation of selected descriptive information. Readers are cautioned not to draw 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 the report is intended to make the information available to the public and encourage more in-depth analysis of the data.

Limitations in an international video study of this type are related to the intensive and extensive nature of the data collection and coding processes. For example, a limited number of countries, and classrooms within the countries, were included in the TIMSS 1999 Video Study. As a result, the sample of four relatively higher-achieving countries in this study may not be representative of all the countries with students performing well on international assessments of science. In addition, the TIMSS 1999 Video Study cannot address differences in topic-specific teaching approaches because a wide range of topics were covered; not enough lessons covering any single topic were observed to allow within-topic analyses or comparisons across topics. Because the focus of the TIMSS 1999 Video Study is on recording and interpreting a complex set of teaching practices, it does not address students’ classroom behaviors and other characteristics of students. Finally, the reader is cautioned that direct inferences about links between classroom teaching and student achievement cannot be drawn from a study of this type.

What Can Be Learned From a Video Study of Teaching Across Cultures?

Across cultures, classroom teaching is a complex process aimed at helping students learn. The TIMSS 1999 Video Study is based on the premise that the more educators and researchers can learn about teaching as it is actually practiced across cultures, the more effectively educators can identify factors that might enhance student learning

opportunities and, by extension, student achievement. The detailed portraits of what actually happens in mathematics and science classrooms that emerged from the video study can contribute to further research into features of teaching that may influence students' learning.

Comparing teaching across cultures has additional advantages:

- Comparing teaching across cultures allows educators to examine and reflect on their own teaching practices from a fresh perspective.
- Comparing teaching across cultures can reveal alternative pedagogical approaches and stimulate discussion about the choices being made within a country. Observations of teaching across cultures can stimulate debate about the best approaches for achieving the learning goals defined within a country.

Using national video surveys to study teaching has special advantages:

- Video enables the detailed examination of complex activities from different points of view, while preserving classroom activity. Videos can be slowed down and viewed multiple times by many people with different kinds of expertise.
- Collecting a random national sample provides information about students' actual experiences across a range of conditions. The ability to generalize nationally can elevate policy discussions beyond the anecdotal.

What Are the Major Findings From the TIMSS 1999 Video Study of Eighth-Grade Science Teaching?

Eighth-grade science teaching shares some common general features across all five of the participating countries, including countries that have historically achieved at a variety of levels.

Although the study highlights differences across the countries, all five countries shared some general features of teaching eighth-grade science. Features common in all the countries were observed in three major domains that are used to organize the reporting of these results:

- instructional organization,
- science content, and
- student actions.

Some of these commonalities 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.



Commonalities Regarding Instructional Organization

- Whole-class seatwork (i.e., presentation and discussion periods) occurred in at least 98 percent of eighth-grade science lessons in all the countries, and at least some time was spent developing new science content in 95 percent or more of the lessons (data not shown).
- Some form of practical activity (e.g., showing objects to the whole class or students working independently on experiments or model-building activities) occurred in at least 72 percent of lessons across the countries, although there were differences in the amount of time spent on these activities.

Commonalities Regarding Science Content

- Across all of the countries, 84 percent or more of the eighth-grade science lessons included at least some public attention to science canonical knowledge—the generally accepted facts, ideas, concepts, and theories shared within the scientific community.
- Knowledge about the nature of science (i.e., its values, dispositions, processes, politics, or history), meta-cognitive strategies (i.e., learning strategies or reflecting on the learning process), and safety accounted for no more than a combined total of 2 percent of public talk time (sections of the lesson when the intended audience of the teacher or student speaking was the whole class) in any of the countries. Science canonical knowledge was more prominent in the science lessons of all five countries than any other type of science knowledge investigated.

Commonalities Regarding Student Actions

- During whole-class interactions, students participated in some form of discussion in at least 81 percent of the lessons in each of the countries.
- Although the percentages of science lessons and instruction time allocated for student independent work on practical activities varied across the participating countries, students in all the countries were more likely to observe phenomena during independent practical activities rather than to design and make models, to carry out dissections or classification activities, or to conduct controlled experiments.
- Students wrote a paragraph or more of text during independent practical activities in no more than 11 percent of lessons in the countries where there were enough observations for reliable estimates (Australia, the Netherlands, and the United States).
- Students generated their own research questions and designed procedures for practical investigations in no more than 10 percent of lessons in countries with sufficient observations to calculate reliable estimates (Australia, Japan, and the United States).

Though the five countries share some commonalities in the teaching of science, they also implement distinct approaches.

Each of the countries has a distinct approach to science teaching, although the pattern in the United States is different from the other countries in its use of a variety of teaching approaches rather than one consistent, core instructional approach. The different approaches to eighth-grade science teaching taken in each of the countries provide students with different ways to learn science.

The ways the lessons varied in their instructional organization, science content, and the students' actions are described below. Following these presentations, a summary of the science teaching pattern for each country is presented.

Differences in Instructional Organization

- Instructional purposes:** In each country except the Czech Republic, at least three-quarters of lesson time was devoted to developing new content (table 2). However, when this activity is compared to other lesson purposes, country-specific differences emerge. For example, teachers in Japan allocated more lesson time (93 percent) to developing new content than did teachers in three other countries. Czech science lessons included more time for review (19 percent) and assessment (9 percent) than did lessons in three other countries. Students in Dutch science lessons spent relatively more time going over homework (12 percent) than did students in three other countries. Czech and Japanese science lessons allocated a smaller average percentage of lesson time for “other” purposes, such as administrative tasks, compared to the other three countries.

TABLE 2. Average percentage distribution of eighth-grade science lesson time devoted to different types of lesson purposes, by country: 1999

Purpose	Australia (AUS)	Czech Republic (CZE)	Japan (JPN)	Netherlands (NLD)	United States (USA)
Developing new content ¹	85	67	93	78	79
Reviewing previous content ²	8	19	3	1!	8
Going over homework ³	#	1!	‡	12	3
Assessing student learning ⁴	‡	9	1	2	3
Other purposes ⁵	7	4	3	7	8

Rounds to zero.

! Interpret data with caution. Estimate is unstable.

‡ Reporting standards not met. Too few cases to be reported.

¹ Developing new content: AUS, JPN, USA>CZE; JPN>NLD, USA.

² Reviewing previous content: CZE>AUS, JPN, NLD, USA; USA>JPN, NLD.

³ Going over homework: NLD>AUS, CZE, USA.

⁴ Assessing student learning: CZE>JPN, NLD, USA; NLD>JPN.

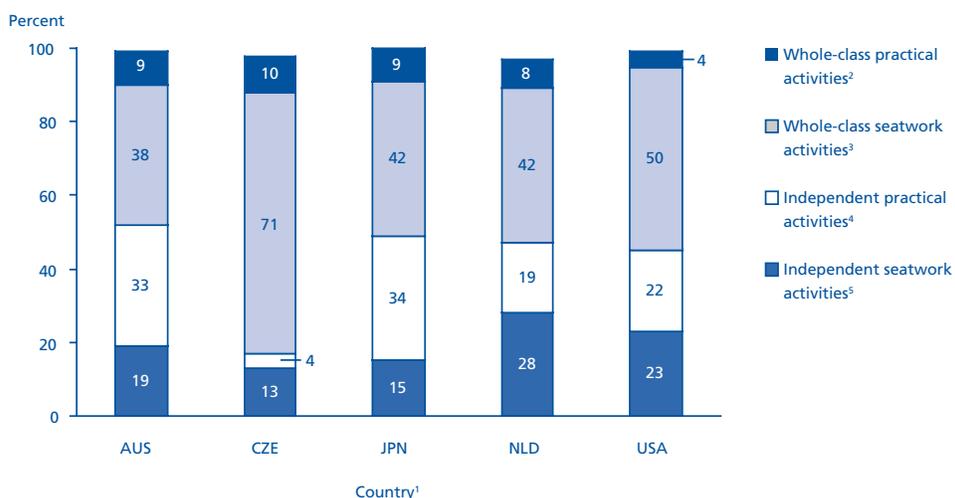
⁵ Other purposes: AUS, NLD, USA>CZE, JPN.

NOTE: Detail may not sum to 100 because of rounding and missing data. 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 the same difference between two other countries may not be significant.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Third International Mathematics and Science Study (TIMSS), Video Study, 1999*.

- **Social organization:** Lessons also were organized differently in terms of whole-class and independent work and in terms of the opportunity for students to engage in practical work (hands-on, laboratory) versus seatwork (reading, writing, and discussing) activities.
- Independent practical activities occurred in fewer Czech and Dutch science lessons than in Australian and Japanese science lessons. In the United States, fewer lessons than Australia and more lessons than the Czech Republic provided students with independent practical activities (data not shown).
- A similar pattern emerges when use of instructional time is examined. Australian and Japanese science lessons allocated more time for independent practical activities than Czech and Dutch lessons. Four percent of instructional time was spent on independent practical activities in Czech science lessons, less than in the science lessons of the other countries (figure 2).
- Dutch science lessons allocated more time for independent seatwork activities than Czech and Japanese science lessons (figure 2).
- In contrast with the other four countries, practical activities within Czech science lessons occurred more often as a whole-class activity than an independent activity (figure 2).

FIGURE 2. Average percentage distribution of science instruction time in eighth-grade science lessons devoted to each combination of social organization type and science activity, by country: 1999



¹AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

²Whole-class practical activities: AUS, CZE, JPN>USA.

³Whole-class seatwork activities: CZE>AUS, JPN, NLD, USA; USA>AUS.

⁴Independent practical activities: AUS, JPN, NLD, USA>CZE; AUS, JPN>NLD.

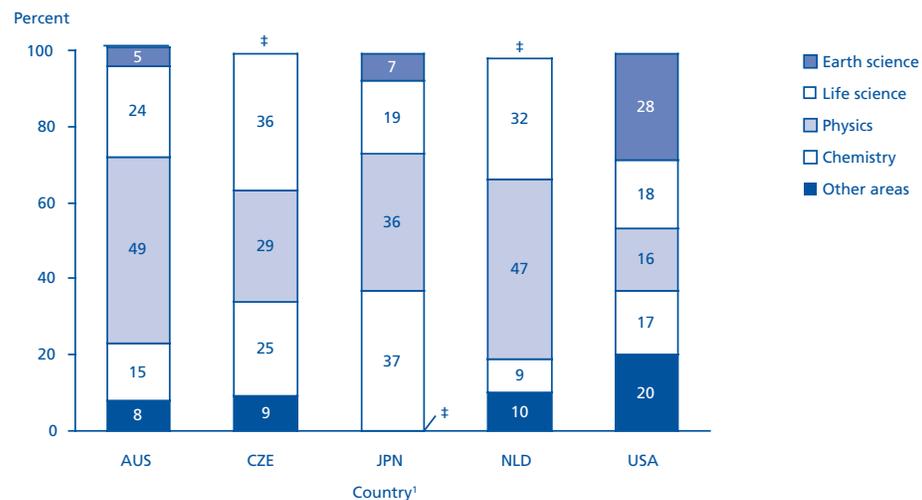
⁵Independent seatwork activities: NLD>CZE, JPN; USA>CZE.

NOTE: Detail may not sum to 100 because of rounding and data not presented for "divided class work." Analysis is limited to those portions of lessons focused on science instruction. See table 3.2 and figure 3.2 in the full report (Roth et al. 2006). SOURCE: U.S. Department of Education, National Center for Education Statistics, *Third International Mathematics and Science Study (TIMSS), Video Study, 1999*.

Differences in Science Content

- Topics:** Within the United States, no differences were found between the percentages of eighth-grade science lessons that addressed topics in earth science, life science, physics, chemistry, or other areas (nature of science, technology, environment and resource issues, science and other disciplines) (figure 3). In contrast, physics and chemistry topics were addressed in more Japanese science lessons than earth science and life science. Within Australia, more lessons focused on physics topics than earth science, life science, and chemistry topics. Life science and physics topics were addressed in more Dutch lessons than chemistry, with too few earth science lessons for reliable estimates.

FIGURE 3. Percentage distribution of eighth-grade science lessons devoted to life science, earth science, physics, chemistry, and other areas, by country: 1999



†Reporting standards not met. Too few cases to be reported.

¹AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

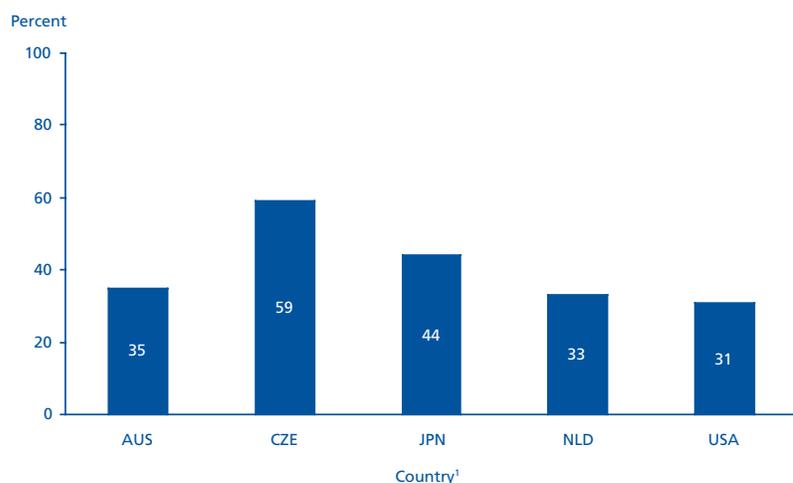
NOTE: Detail may not sum to 100 because of rounding. Other areas include: interactions of science, technology, and society, nature of scientific knowledge, and science and mathematics.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Third International Mathematics and Science Study (TIMSS), Video Study, 1999*.

- Types of science knowledge:** Different types of knowledge were addressed in the science lessons. Comparing across countries, Czech eighth-grade science lessons allocated a larger percentage of public talk time, on average, to address canonical science knowledge (generally accepted scientific facts, ideas, concepts, or theories) than the lessons of the other four countries (figure 4). Across-country differences also were evident in the percentage of public talk time devoted to procedural and experimental knowledge. Japanese science lessons addressed procedural and experimental knowledge (information about how to do science-related practices such as manipulating materials and performing experimental processes) for a larger average percentage of public talk time (25 percent) compared to the lessons

of the other countries (between 11 and 17 percent). Further, Japanese lessons allocated a smaller percentage of public talk time (6 percent) to science-related real-life issues (e.g., societal issues or students' personal experiences) than lessons in all of the other countries except Australia (14, 15, and 17 percent for the Czech Republic, Netherlands, and United States, respectively; 12 percent for Australia; data not shown).

FIGURE 4. Average percentage of public talk time in eighth-grade science lessons devoted to canonical knowledge, by country: 1999



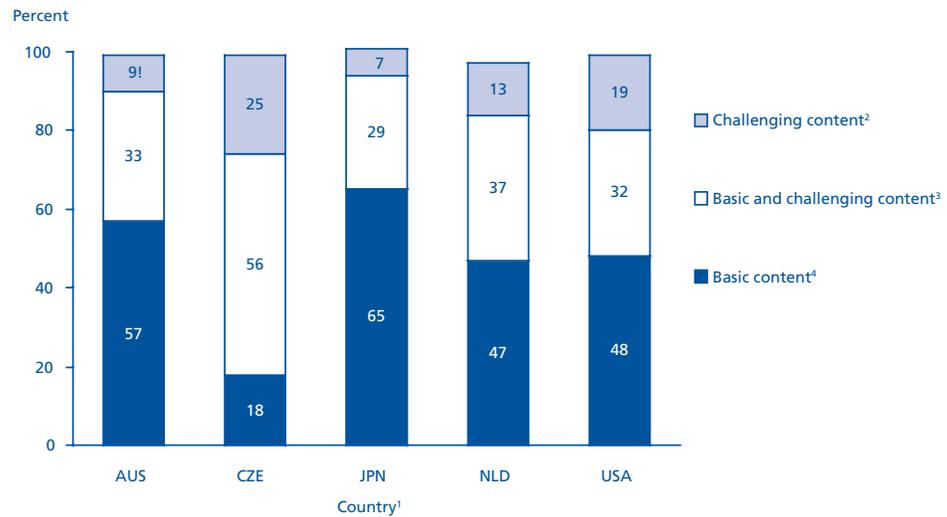
¹AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

NOTE: CZE>AUS, JPN, NLD, USA; JPN>USA. Analysis is limited to public talk time. The above category was not applied to non-public segments of the lesson because of the nature of independent work and the limitations of the video methodology. During non-public talk segments, students were typically working independently on a set of tasks that may involve different types of knowledge.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Third International Mathematics and Science Study (TIMSS), Video Study, 1999*.

- Challenge and density of science content:** In general, Czech lessons contained more content ideas and more challenging ideas than lessons in the other countries with reliable estimates. Based on expert judgments, Czech teachers included a mix of basic and challenging content in 56 percent of the science lessons and mostly challenging content in 25 percent of lessons (figure 5). In contrast, 47 to 65 percent of the lessons in the other countries included only basic content. In addition, more eighth-grade science lessons in the Czech Republic contained a high density of 15 or more canonical ideas (26 percent) compared to lessons in Japan (7 percent) (data not shown). Other evidence of the higher level of challenge and density of science content in Czech lessons was the inclusion of more unrepeated science terms during public talk in a lesson (56 per lesson, on average), and more unrepeated highly technical science terms during public talk (33 per lesson, on average) compared to science lessons in the other four countries (data not shown). In addition, more Czech science lessons included theoretical ideas (49 percent) than lessons in Japan and the Netherlands (15 and 19 percent, respectively; data not shown).

FIGURE 5. Percentage distribution of eighth-grade science lessons that were judged to contain challenging content, basic and challenging content, and basic content, by country: 1999



! Interpret data with caution. Estimate is unstable.

¹ AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

² Challenging content: CZE>JPN.

³ Basic and challenging content: CZE>AUS, JPN, USA.

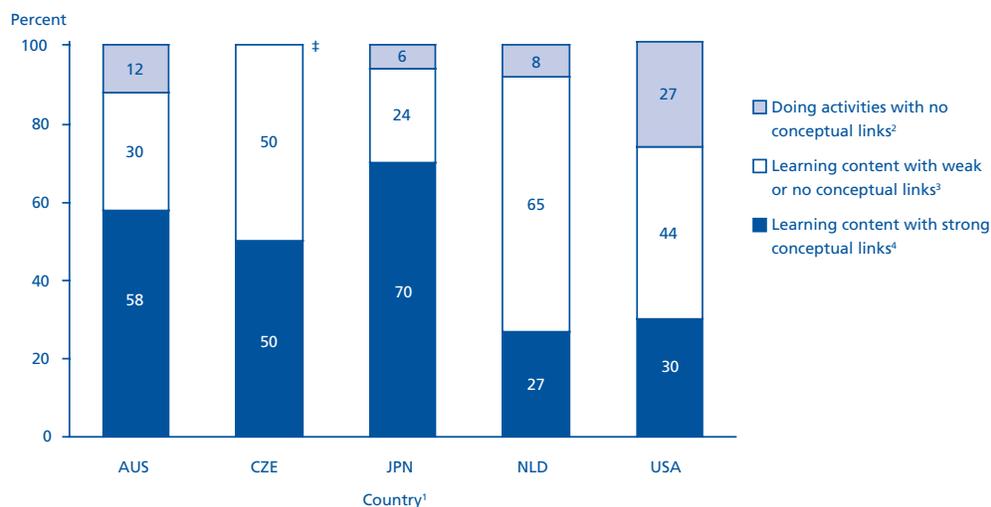
⁴ Basic content: AUS, JPN, NLD, USA>CZE.

NOTE: Totals may not sum to 100 due to rounding. The level of challenge in the science content could not be determined in 3 percent of Dutch lessons and 1 percent each of Australian, Czech, and U.S. lessons because these lessons did not include publicly-presented canonical ideas.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Third International Mathematics and Science Study (TIMSS), Video Study, 1999*.

- Content coherence:** The lessons varied in how closely content ideas and activities were woven together to form a coherent, strongly linked lesson. A higher percentage of Australian and Japanese science lessons focused on engaging students in learning content and doing activities with strong conceptual links (58 and 70 percent, respectively) compared to lessons in the Netherlands and the United States (27 and 30 percent, respectively; figure 6). Twenty-seven percent of U.S. science lessons focused on doing activities, with no attention to content or only brief mentions of science content terms or ideas and no conceptual links among them.

FIGURE 6. Percentage distribution of eighth-grade science lessons by focus and strength of conceptual links, by country: 1999



† Reporting standards not met. Too few cases to be reported.

¹ AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

² Doing activities with no conceptual links: USA>JPN, NLD.

³ Learning content with weak or no conceptual links: CZE>JPN; NLD>AUS, JPN.

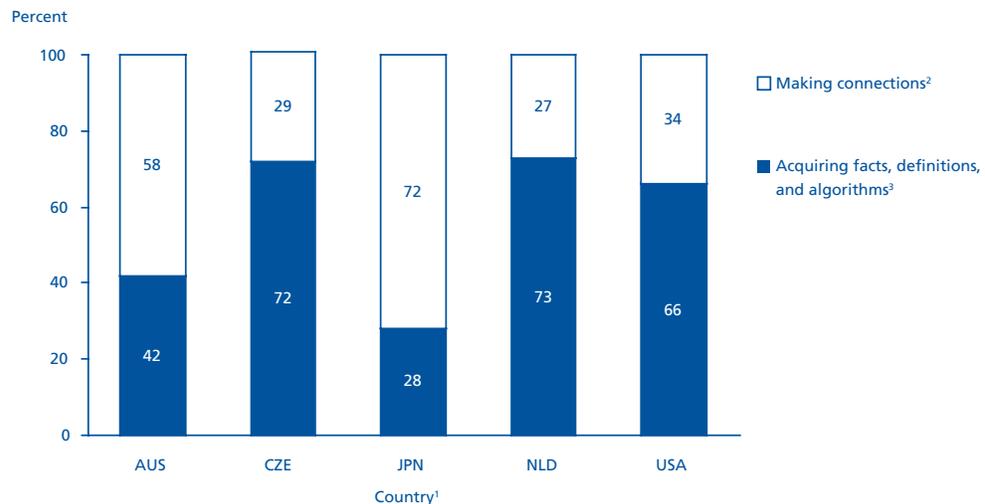
⁴ Learning content with strong conceptual links: AUS, JPN>NLD, USA; CZE>NLD.

NOTE: Detail may not sum to 100 because of rounding and data not reported.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Third International Mathematics and Science Study (TIMSS), Video Study, 1999*.

- Making connections versus acquiring information:** Japanese students were supported in activities that focused on making connections among ideas, experiences, patterns, and explanations in more science lessons (72 percent) than in any other country except Australia. More Australian lessons focused primarily on making connections (58 percent) than did Czech and Dutch science lessons (figure 7). In contrast, students in eighth-grade science lessons within the Czech Republic, the Netherlands, and the United States were more likely to be focused on acquiring knowledge in the form of facts, definitions, or algorithms (72, 73, and 66 percent of lessons, respectively) than on making connections. 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 in 43 and 57 percent of lessons, respectively (data not shown).

FIGURE 7. Percentage distribution of eighth-grade science lessons that developed science content primarily by making connections and by acquiring facts, definitions, and algorithms, by country: 1999



¹AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

²Making connections: AUS, JPN>CZE, NLD; JPN>USA.

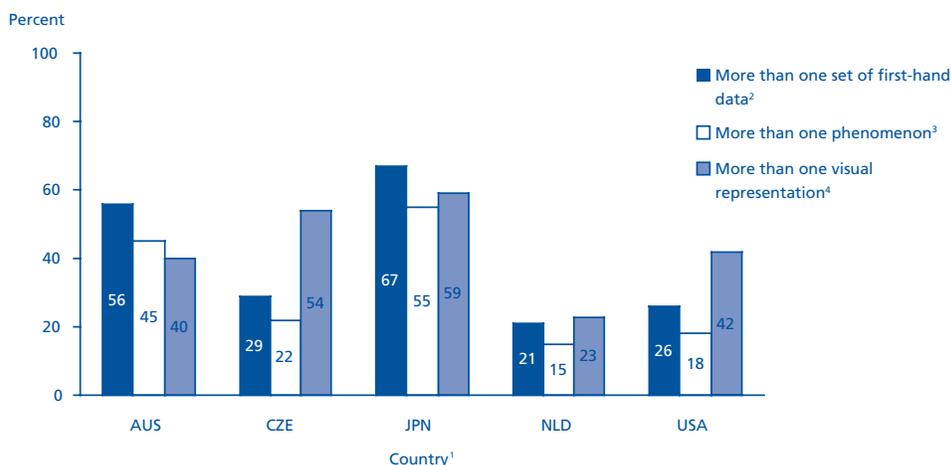
³Acquiring facts, definitions, and algorithms: CZE, NLD>AUS, JPN; USA>JPN.

NOTE: Detail may not sum to 100 because of rounding.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Third International Mathematics and Science Study (TIMSS), Video Study, 1999*.

- **Content supported by evidence in the form of first-hand data and phenomena:** In Australia and Japan, more eighth-grade science lessons supported every main idea in the lesson with multiple sets of first-hand data and with multiple phenomena than in the science lessons of the other three countries (figure 8).
- **Content supported by evidence in the form of visual representations:** In the Czech Republic and Japan, multiple visual representations supported all the main ideas in science lessons more often than in the Netherlands (figure 8).
- **Content supported by multiple types of evidence:** Further analysis showed that more Japanese science lessons (65 percent) supported every main idea with at least one set of first-hand data, at least one phenomenon, and at least one visual representation than lessons in the other countries. Australian lessons were more likely to use all three types of evidence to support all the main ideas (47 percent) than Dutch and U.S. lessons (14 and 18 percent, respectively) (data not shown).
- **Content developed with real-life issues:** Science ideas were developed using real-life issues and examples in more Czech eighth-grade science lessons than in the lessons of the other countries except Australia (data not shown). In Australia, real-life issues were used to support the development of science ideas in more lessons than in Japan. Within the United States, a larger proportion of instruction time, on average, was spent presenting real-life issues as topic-related sidebars rather than using real-life issues to develop science ideas. The opposite was observed within Czech science lessons.

FIGURE 8. Percentage of eighth-grade science lessons that supported all main ideas with more than one set of first-hand data, phenomena, and visual representations, by country: 1999



¹AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

²More than one set of first-hand data: AUS, JPN>CZE, NLD, USA.

³More than one phenomenon: AUS, JPN>CZE, NLD, USA.

⁴More than one visual representation: CZE, JPN>NLD.

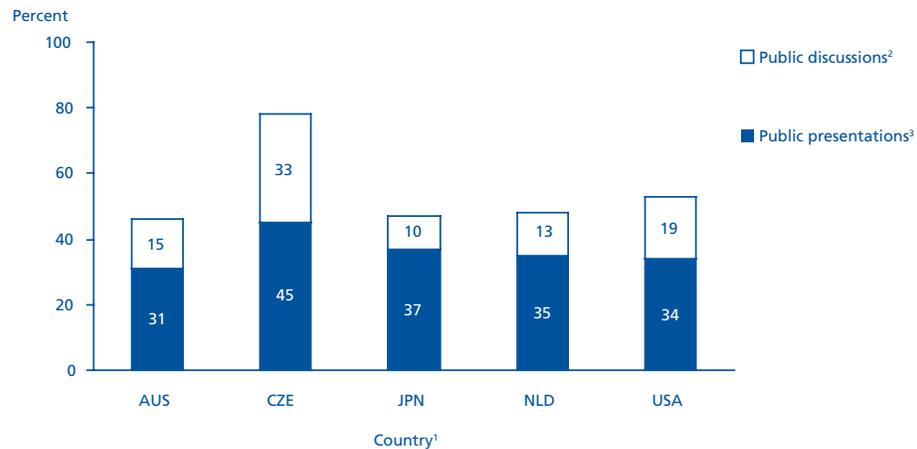
SOURCE: U.S. Department of Education, National Center for Education Statistics, *Third International Mathematics and Science Study (TIMSS), Video Study, 1999*

Differences in Student Actions

Among the major activity types examined in this study, independent practical activities (observing and manipulating objects), independent seatwork activities (reading, writing, and small group discussions), and whole-class discussions engage students most actively in doing science work.

- **Independent practical activities:** Across-country differences, described and presented previously in figure 2, indicated that Australian and Japanese science lessons focused more time on independent practical activities than did Czech and Dutch lessons.
- **Independent seatwork activities:** Dutch lessons focused more time on independent seatwork activities compared to Czech and Japanese lessons (figure 2).
- **Whole-class discussions:** Whole-class discussions accounted for 10 to 33 percent of the instruction time (figure 9), and they occurred in at least 81 percent of the lessons in all of the countries (data not shown). Lessons in the Czech Republic allocated a larger percentage of science instruction time, on average, to public discussions (33 percent) compared to all the other countries (figure 9).

FIGURE 9. Average percentage distribution of science instruction time per eighth-grade science lesson devoted to public presentations and discussions during whole-class work, by country: 1999



¹AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

²Public discussions: CZE>AUS, JPN, NLD, USA; AUS, USA>JPN.

³Public presentations: CZE>AUS, JPN, NLD, USA.

NOTE: Percentage of science instruction time devoted to public talk during independent work and to demonstrations is not reported. See figure 3.6, chapter 3 in Roth et al. (2006) for the distribution of instruction time between whole-class and independent work.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Third International Mathematics and Science Study (TIMSS), Video Study, 1999*

More detailed analysis within these three major activity types assessed students' opportunities to use textbooks and read about science, to write about science, to engage in a variety of science inquiry processes, to participate in potentially motivating activities, and to take responsibility for their own learning (through working independently on lesson-opening tasks without any direction from the teacher, organizing their own science notebooks, being prepared to work or be graded publicly in front of the class, monitoring their own pace on long-term homework assignments, and checking their own work as they proceeded on long-term assignments).

- Using textbooks and reading about science:** Students used textbooks and/or workbooks in more Dutch science lessons compared to lessons in the other countries (data not shown). In addition, Dutch students spent 20 percent of instructional time reading about science while students in Australia, the Czech Republic, and Japan spent no more than 8 percent of instructional time reading (data not shown).
- Writing about science:** Writing tasks included taking notes during whole-class work, selecting answers during independent work, and generating phrases, sentences, or paragraphs, such as a lab report or essay writing. Students in the Czech Republic were expected to write about science for less instructional time (15 percent) than students in all of the other countries (34 to 44 percent; data not shown). Within Dutch and U.S. science lessons, students were given more time to generate written responses than to provide labels or one-word answers. Within the Netherlands, for example, students spent 36 percent of instructional time generating written responses and only 6 percent of the time providing labels or one-word responses (data not shown).

- Scientific inquiry practices:** Teachers sometimes provide opportunities for students to engage in different types of inquiry practices, that is, scientific actions that students are asked to do before, during, and after independent practical activities. Before independent practical work, students may be expected to generate research questions, design procedures to investigate the research question, or make predictions about the outcomes. During independent practical work, students may collect and record data. After the investigation, students may be expected to manipulate the data collected, or to interpret the data. Students engaged in using a variety of scientific inquiry practices related to their work on independent practical activities (table 3). Students in Japan made predictions in 23 percent of the eighth-grade science lessons. Students had opportunities to collect and record first-hand data or phenomena related to independent practical activities in more Australian and Japanese science lessons than in Czech, Dutch, and U.S. science lessons. In addition, Australian and Japanese students were guided by the teacher or textbook to organize or manipulate data in more science lessons than in the Netherlands. Students in Australian science lessons were more likely to interpret results of independent practical activities than students in both Czech and Dutch lessons. Within Czech science lessons, students were more likely to be asked to interpret results than collect and record data.

TABLE 3. Percentage of eighth-grade science lessons in which students engaged in different inquiry activities before, during, and after independent practical work, by country: 1999

Student activity	Australia (AUS)	Czech Republic (CZE)	Japan (JPN)	Netherlands (NLD)	United States (USA)
Generated the research question ¹	3!	‡	‡	‡	‡
Designed procedures for investigations ²	10	‡	5!	‡	5
Made predictions ³	11	‡	23	4!	8
Interpreted the data or phenomena ⁴	56	20	43	24	33
Collected and recorded data ⁵	62	8	59	29	31
Organized or manipulated data collected independently ⁶	9	‡	‡	8	8
Organized or manipulated collected data guided by teacher or textbook ⁷	27	3!	37	8	19

‡ Reporting standards not met. Too few cases to be reported.

! Interpret data with caution. Estimate is unstable.

¹ Generated the research question: No measurable differences detected.

² Designed procedures for investigations: No measurable differences detected.

³ Made predictions: JPN>NLD.

⁴ Interpreted the data or phenomena: AUS>CZE, NLD; JPN>CZE.

⁵ Collected and recorded data: AUS, JPN, NLD, USA>CZE; AUS, JPN>NLD, USA.

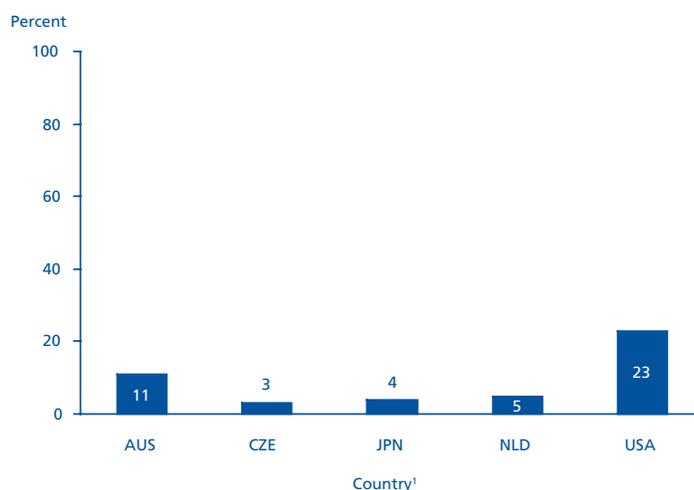
⁶ Organized or manipulated data collected independently: No measurable differences detected.

⁷ Organized or manipulated collected data guided by the teacher or the textbook: AUS, JPN>CZE, NLD; USA>CZE.

NOTE: Totals for students organized or manipulated data on their own or under the direction of the teacher or textbook do not sum to students collected and recorded data because students do not always manipulate collected data. SOURCE: U.S. Department of Education, National Center for Education Statistics, *Third International Mathematics and Science Study, Video Study, 1999*.

- Motivating activities:** Although many kinds of activities may motivate students (e.g., practical activities, reading and writing activities), some teachers included activities in the science lessons that had the potential to be of high interest to students and motivate them to engage in the learning process. These activities included such things as games, puzzles, surprising and dramatic demonstrations, competitive activities, and role plays. More eighth-grade science lessons in the United States (63 percent) included potentially motivating activities (data not shown) and more instructional time was allocated for these motivating activities (23 percent; figure 10) than science lessons in all of the other countries except Australia.

FIGURE 10. Average percentage of science instruction time in eighth-grade science lessons allocated to motivating activities, by country: 1999



¹AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

NOTE: USA>CZE, JPN, NLD; AUS>CZE.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Third International Mathematics and Science Study (TIMSS), Video Study, 1999*.

- Taking responsibility for learning:** Students were expected to take responsibility for their own learning in a variety of ways, and these varied by country. Strategies included expecting students to start working independently, without any direction from the teacher, on a lesson-opening task that is posted on the board or overhead projector, to organize their notes and other science work in a special science notebook, to be prepared to work or be graded publicly in front of the class, to work on assigned homework outside the classroom, to monitor their own pace on long-term homework assignments, and to check their own work as they proceeded on long-term assignments. In the United States, students independently started their science lesson by working on posted lesson openers in 26 percent of the lessons. Students kept organized science notebooks in at least 50 percent of the lessons in all of the countries except the United States. Public work by students and public assessment of student learning was a more common practice in the Czech Republic

compared to most of the other countries. Assignment of homework occurred in 66 percent of Dutch lessons, more than in the Czech Republic and Japan. Dutch students frequently were expected to pace themselves on long-term assignments and to check their own work as they progressed on these assignments. In addition, Dutch students spent more time in class reviewing homework than students in all the other countries where reliable estimates could be made (data not shown).

How is Teaching Science Approached in Each Country?

Each of the countries has an observable pattern of science teaching.

Based on the analyses conducted for the study, the following observations can be made about the typical pattern of eighth-grade science teaching in each of the five countries.

Czech Republic: Talking About Science Content

The data suggest that eighth-grade science lessons in the Czech Republic can be characterized as whole-class events that focused on getting the content right. Instruction time focused on review, assessment, and development of canonical science knowledge, with relatively little time allocated for students to work independently on practical activities. Review and the public oral assessment of students was a prominent feature of Czech science lessons. The main topic areas addressed in science lessons were life science, physics, and chemistry. The content of Czech science lessons was judged to be challenging, dense, and theoretical, and also was found to be organized 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 organized as discrete bits of information, half of the science lessons were found to have weak or no conceptual links that tied ideas together. On the other hand, half of the science lessons were found to be connected with strong conceptual links and the frequent presence of goal and summary statements also may have contributed to content coherence. Main ideas in Czech science lessons often were developed with the use of visual representations. In fact, all of the main ideas in the majority of science lessons were supported by multiple visual representations. Czech eighth-grade students were 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 oral quizzes on science content in front of their peers.

Netherlands: Learning Science Independently

Eighth-grade science lessons in the Netherlands focused on students' independent learning of the science content. During independent seatwork activities, students read from the textbook and generated written responses to questions (beyond selecting answers) about life science and physics topics. 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 of class as well as during class.

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Students were expected to pace themselves on a long-term schedule of assignments, to check their own work in answer books, and to keep organized science notebooks. When Dutch science lessons included independent practical activities (30 percent 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 was infrequently observed. Whole-class time in Dutch science lessons included going over homework assignments together. Dutch students also demonstrated responsibility for their own learning by initiating their own content-related questions during whole-class interactions.

Japan: Making Connections Between Ideas and Evidence

Japanese eighth-grade science lessons typically focused on developing a few physics and chemistry ideas by making connections between ideas and evidence through an inquiry-oriented, inductive approach in which data were collected and interpreted to build up to a main idea or conclusion. Based on observations of the videotapes, 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. Before carrying out such activities, Japanese eighth-grade students were usually 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 organizing 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 public canonical ideas were presented in Japanese science lessons, and these ideas were not judged to be challenging or theoretical. However, all of the main ideas in Japanese science lessons were developed with the use of data and/or phenomena. In fact, all main ideas were often supported by more than one set of data or more than one phenomenon. Thus, it appears that few ideas were developed in Japanese science lessons, but each idea was treated in depth, with multiple sources of supporting evidence.

Australia: Making Connections Between Main Ideas, Evidence, and Real-Life Issues

Like the Japanese eighth-grade science lessons, Australian lessons tended to focus on developing a limited number of ideas 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. During and after the practical work, Australian students were often guided in manipulating and organizing the data and in interpreting the data. All of the main ideas in Australian science lessons were supported by data or phenomena in at least 45 percent of lessons.

Australian science lessons used real-life issues (69 percent) and first-hand data (56 percent) to support the development of science ideas, most often in the area of physics.



In addition, students in Australian lessons typically participated in two or more types of activities 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.

United States: Implementing a Variety of Activities

The data suggest that U.S. eighth-grade science lessons can be characterized by a variety of activities that may engage students in doing science work, with less focus on connecting these activities to the development of science content ideas. In terms of student activities, U.S. eighth-grade science lessons kept students busy on a variety of activities, with a roughly equal emphasis on involving students in independent practical activities (e.g., hands-on, laboratory), independent seatwork activities (e.g., reading, writing, small-group discussions), and whole-class discussions. In addition, U.S. science teachers attempted to engage students' interest and active involvement through the use of real-life issues and motivating activities (e.g., games, puzzles, role play). Twenty-three percent of U.S. instructional time was spent on motivating activities.

Variety was found in science content topics as well, with lessons spread across the areas of earth science, life science, physics, chemistry, and other topics (nature of science, and interactions of science, technology, and society). Students in U.S. eighth-grade 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). These various sources of evidence, though, were not frequently linked to larger science ideas to create coherent, connected, in-depth treatment of science content in the lessons. Instead, the various pieces of content were typically organized 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 U.S. lessons as interesting sidebars rather than being used as an integral part of developing science content ideas. In addition, the content of 44 percent of lessons included weak or no conceptual links while 27 percent of the lessons did not develop science content ideas at all, but instead focused almost completely on carrying out activities.

Do the Four Relatively Higher-Achieving Countries (Compared to the United States) Share Any Commonalities?

The four higher-achieving countries share two commonalities: high content standards and a content-focused instructional approach.

The data suggest that compared to the United States, the four relatively higher-achieving countries (based on the TIMSS 1995 assessments and consistent with the 1999 assessments) in eighth-grade science participating in this study—Australia,

the Czech Republic, Japan, and the Netherlands—shared two commonalities. First, eighth-grade science lessons in these four countries appeared to focus on high content standards and expectations for student learning. However, there were varying definitions across these four countries 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 science content ideas, and the instructional approach focused on talking in a whole-class setting about science ideas. 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 connecting ideas and data through an inquiry, inductive process. In the Netherlands, science content expectations 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-centered reading and writing activities.

Summary

The results of the TIMSS 1999 Video Study of eighth-grade science teaching suggest different country-specific patterns of eighth-grade science teaching in each of the participating countries and highlight the role of content and a core instructional approach in the relatively higher-achieving countries. Despite some commonalities across the countries, each of the countries, including the four higher-achieving countries, had a distinct approach to science teaching, providing students with different opportunities to learn science and different visions of what it means to understand science. The countries varied in the organizational features, content features, and the ways in which students were involved in actively doing science work in the science lessons. Thus, no single approach was shared by the four higher-achieving countries, but science lessons in the higher-achieving countries were all characterized by a core instructional approach that included a consistent instructional and content organization strategy that held students to some type of high content standards. Eighth-grade science lessons in the United States were also observed to have a core instructional approach, but that approach focused on variety rather than consistency in the science lessons. Although students were exposed to a variety of organizational structures, variety of content, and variety of activities, these features were not typically used to develop content ideas in ways that would make the science content storyline visible, coherent, and challenging for eighth-grade students.

To learn more about the results of this study and to view video clip examples on CD-ROM, see the information below about how to access the full report, *Teaching Science in Five Countries: Results From the TIMSS 1999 Video Study* (Roth et al. 2006).

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Content contact:

Patrick Gonzales, patrick.gonzales@ed.gov or (415) 920-9229.



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