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Results From the TIMSS 1999 Video Study

Statistical Analysis Report

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Chapter 1: Introduction

This report presents the results of a study of eighth-grade science teaching, conducted as part of the Third International Mathematics and Science Study (TIMSS) 1999 Video Study.[1] The Video Study is a supplement to the TIMSS 1999 student assessment, a successor to the TIMSS 1995 student assessment.[2] The TIMSS 1999 Video Study had the broad purpose of investigating and describing teaching practices in eighth-grade mathematics and science in a variety of countries.[3] Results for the science portion are presented in this report and in a summary document entitled *Highlights From the TIMSS 1999 Video Study of Eighth-Grade Science Teaching* (Roth et al. 2006).

The TIMSS 1999 Video Study of science teaching included the participation of five countries: Australia, the Czech Republic, Japan, the Netherlands, and the United States. It had the following broad objectives:

- Develop objective, observable measures of classroom instruction that can be quantified appropriately to develop indicators of eighth-grade science teaching practices in each country;
- Describe patterns of science teaching practices within each country; and
- Compare science teaching practices between countries and identify similarities and differences in lesson features across countries, with a focus on differences between higher- and lower-achieving countries.

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

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

The TIMSS 1999 Video Study was funded by the National Center for Education Statistics (NCES), the former Office of Educational Research and Improvement of the U.S. Department of Education, and the National Science Foundation (NSF). It was conducted under the auspices of the International Association for the Evaluation of Educational Achievement (IEA), based in Amsterdam, the Netherlands. Support for the project was also provided by each participating

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[1] Since the 2003 administration, TIMSS is now known as the Trends in International Mathematics and Science Study.

[2] The TIMSS student assessments were conducted in 1994-95, in 1998-99, and again in 2003. For convenience, reference will be made to the student assessments as TIMSS 1995, TIMSS 1999, and TIMSS 2003 throughout the remainder of the report. In other documents, TIMSS 1999 is referred to as TIMSS-R (TIMSS-Repeat). The supplementary video studies will be referred to as the TIMSS 1995 Video Study and the TIMSS 1999 Video Study.

[3] The results for the mathematics portion were presented in a report titled *Teaching Mathematics in Seven Countries* (Hiebert et al. 2003) with an accompanying technical report (Jacobs et al. 2003).

country through the services of a research coordinator who guided the sampling and recruiting of participating teachers. In addition, Australia contributed direct financial support for data collection and processing of its respective sample of lessons.

The current report focuses on the findings of the TIMSS 1999 Video Study of science teaching with brief descriptions of the methods used (see appendix A). A supplementary technical report that only addresses additional details specific to the science portion of the TIMSS 1999 Video Study will be released separately (Garnier et al. forthcoming). A brief description of the methods used for sampling, questionnaire development, video data coding, and statistical analyses is provided in appendix A and a list of participants is provided in appendix B of this report. In some cases, definitions of constructs and variables that appear in the report are included in appendix D.

This chapter describes the rationale for the study and provides an overview of the conceptual framework, coding dimensions, and guiding principles used in developing valid and reliable codes for the analyses of the science lessons. The chapter highlights the importance of international comparisons of teaching and the use of video in this process. The overview of the science conceptual framework highlights the importance of developing a shared language that links terms and concepts about science teaching with actual classroom images of science teaching.

Why Study Science Teaching in Different Countries?

There are at least four reasons to study science teaching in different countries and to select countries that have historically achieved at a variety of levels.

- ***Identify alternatives:*** Comparative studies of science teaching can suggest alternative ways of teaching science. Such country variations were found in both the TIMSS 1995 (Stigler et al. 1999) and the TIMSS 1999 Video Studies of mathematics teaching (Hiebert et al. 2003). No single method of teaching eighth-grade mathematics was observed across the relatively higher achieving countries in the study but significant variations were found. Detecting variations across countries with higher achievement may reveal alternative choices in the teaching of eighth grade science. Similar discoveries may emerge from comparative study of eighth grade science teaching.
- ***Reveal one's own science teaching practices more clearly:*** Comparative studies, like the TIMSS 1995 and 1999 Video Studies, can reveal taken-for-granted and hidden aspects of science teaching (Stigler, Gallimore, and Hiebert 2000; Stigler and Hiebert 1999). Seeing one's own practices is a first step toward re-examining them (Carver and Scheier 1981; Tharp and Gallimore 1989), and ultimately improving them.
- ***Stimulate discussion about choices within each country:*** Importing practices wholesale from one cultural context to another is likely to be problematic (Stigler and Hiebert 1999). However, comparing practices across cultures, and uncovering alternative practices, can underscore the idea that classroom practices are the result of choices rather than inevitabilities. Choices made in the past can be re-examined from a fresh perspective, and may be a stimulus to discussion about ways to improve teaching.

- ***Deepen educators' understanding of teaching and students' opportunities to learn science:*** Cross-cultural studies of teaching provide information about different systems of teaching, including different ways in which the basic ingredients of teaching can be configured (Stigler, Gallimore, and Hiebert 2000) and different kinds of opportunities for student learning that can be provided. Comparative studies of science lessons can help researchers construct hypotheses about effective science teaching practices and then use these hypotheses to guide future research.

How Should Science Teaching Across Countries Be Described?

The TIMSS 1999 Video Study of science teaching analyzed 439 eighth-grade science lessons to produce descriptions and comparisons of science teaching in five different countries. In the science education community, a video data set of this size and international scope has never before been collected and analyzed. To accomplish this challenging task, the development of coding strategies for an international team of coders was needed that would generate valid and reliable descriptions of science teaching.

Guiding 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 (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.[4] This led to the development of a brainstormed list of possible research questions and associated lesson features to identify in the videos. Five U.S. science educators serving as advisors 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

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[4] Of 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.

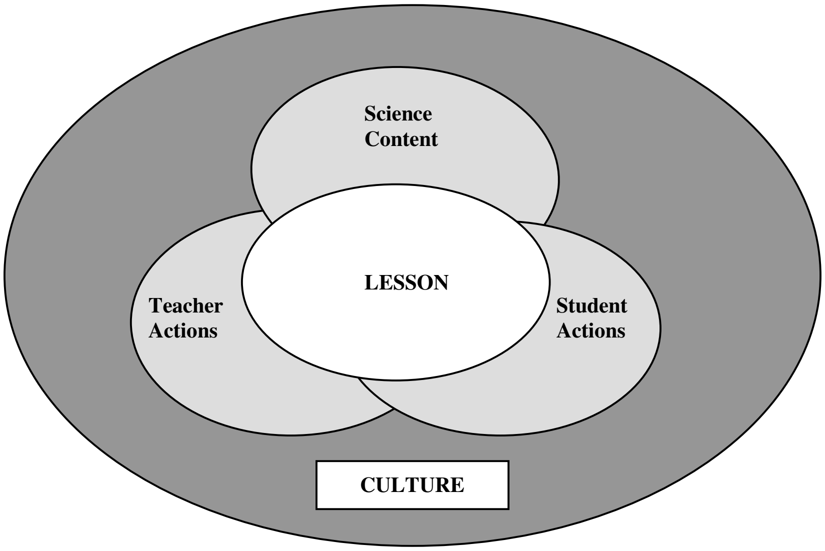
priority lesson features to examine, and their own review of lessons from the dataset to develop an overarching conceptual framework and a set of research questions that guided decisions about coding priorities as well as the organization of the presentation of the results in this report.

Figure 1.1 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 students' actions, and the science content.

The important influence of the larger culture on all aspects of the science lesson is also emphasized in the conceptual framework. To say science teaching is a cultural activity means that teaching is situated in a bed of routines, traditions, beliefs, expectations, and values of students, teachers, administrators, parents, and the interested public (Gallimore 1996). For example, research demonstrates that teachers have deeply held beliefs about their students, about teaching and learning, about their roles as teachers, and about science (Carlsen 1991; Clark and Peterson 1986; Cronin-Jones 1991; Gallagher 1994; Hollon, Anderson, and Roth 1991: Martens 1992; Olson 1981; Pajares 1992). These beliefs can influence how teachers represent science in their classrooms and the kinds of opportunities they provide for students to learn about science. In this study, cultural differences will not be directly observed but will be revealed through unique country patterns that emerge from observations of the teachers, students, and science content in the lessons.

While the framework acknowledges the importance of Schwab's four commonplaces of teaching, analysis of each of these aspects of teaching is limited to observable features related to the teacher, the students, and the science content which are then used to describe country patterns of teaching. The teacher and student focus, for example, is on their observed actions rather than on important but unobservable activities such as teachers' decision making processes or teachers' or students' understanding of the science content. Although the study focuses primarily on features of science teaching that are observable in the videotapes, information about teachers' background, planning practices, and goals are included in in-depth teacher questionnaires (see chapter 2).

Figure 1.1. TIMSS 1999 Video Study: Science conceptual framework



Guiding Research Questions

The main research question guiding the conceptual framework was: What opportunities did the lesson provide for students to learn science? As shown in table 1.1, the 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. Each guiding question was then explored through a set of four to fourteen more specific questions and codes. Although this is a study of classroom teaching, the focus of analysis was placed on students and the ways in which teaching decisions provided different kinds of opportunities for students to learn science. This focus on student opportunity to learn fits well with the research literature on student thinking and learning, and with one of the key stimuli for the study—the differences in student achievement as evidenced on TIMSS 1995 and 1999 assessments (Martin et al. 2000).

Table 1.1. Research questions for the TIMSS 1999 Video Study of Science Teaching

Main research question	What opportunities did the lesson provide for students to learn science?
Teacher Actions: Instructional Organization (Chapter 3)	How did the teacher organize the lesson to support students' opportunities to learn science? ▪ How much time was spent studying science? ▪ How was the lesson organized for different instructional purposes? ▪ How was the lesson organized for practical and seatwork activities? ▪ How was the lesson organized for whole-class and independent work?
Science Content (Chapters 4-6)	How was science represented to students in the lesson? ▪ Which scientific disciplines and topics were addressed in the lessons? ▪ What types of science knowledge were addressed in the lessons? ▪ What was the source of the science content and its organization? ▪ How much science content was in the lesson? ▪ How coherent was the science content? ▪ How challenging was the science content? ▪ What types of evidence were used to develop science content ideas in the lesson? ▪ Were main ideas supported with multiple sources of evidence?
Student Actions (Chapters 7- 11)	What opportunities did students have to participate in science learning activities? ▪ What were the features of independent practical activities? ▪ What science inquiry actions did students practice during independent work and during whole-class work? ▪ How much did students work in pairs or groups versus individually? ▪ What features characterized students' collaboration during group work? ▪ Did students have opportunities to talk about science? ▪ Did students have opportunities to write about science? ▪ Did students have opportunities to read about science? ▪ Did students have different kinds of opportunities to communicate science? ▪ Did lessons include relevant issues for students? ▪ Did lessons involve students in hands-on, practical work? ▪ Did lessons involve students in motivating activities? ▪ Did lessons use different strategies to engage students? ▪ What responsibilities did students have during the lesson? ▪ What responsibilities did students have outside the lesson?

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

Developing a Shared Language for Describing and Comparing Science Teaching in Five Countries

Comparative studies of teaching pose many challenges. One is development of a shared understanding of the terms and concepts to describe and compare teaching across countries. As demonstrated in a recent study of science lessons (Matsubara et al. 2002), even experts see science teaching differently. Like research on teaching in other fields, science education research typically describes teaching in words without links to images of practice. Science educators may use common terms (such as inquiry teaching or constructivist teaching), but that does not guarantee the words refer to identical practices.

Using videos to study teaching offers another way to develop a shared language (Stigler, Gallimore, and Hiebert 2000). Videos allow investigators to view and review teaching events many times in order to develop a shared set of referents for terms and definitions that are linked to images. This is especially crucial in a study involving multiple languages and countries, especially during the code development phase. In addition, video facilitates the study of complex processes, by permitting investigators to parse data analysis into more manageable portions. Observers can code video in multiple passes, coding different dimensions of science teaching in each pass. This same quality increases inter-rater reliability, and decreases training difficulties. Researchers from different locations and different cultural and linguistic backgrounds can work together, in the same geographic location, to develop codes and establish their reliability using a common set of video data. Video enables coding from multiple perspectives, allowing researchers with different areas of expertise and points of view to examine the same lessons. Although videotaping classroom lessons brings its own challenges, the method has significant advantages over other means of recording data for investigating teaching. Extended discussions of video as a tool in teaching research are available elsewhere (Hiebert et al. 2003; Stigler, Gallimore, and Hiebert 2000; Stigler and Hiebert 1999).

To accomplish the goal of a shared language grounded in images of science teaching, the research team developed a set of guiding principles for the code development process. These principles are:

- ***Involve cultural insiders in the code development and coding process:*** The Science Code Development Team included representatives from each participating country. In addition, National Research Coordinators, high level educational researchers and leaders in their respective countries, were consulted at key points during the code development process. After code development, the codes were applied by the International Video Coding Team that included at least two representatives from each country.
- ***Involve scientists in the code development process:*** The Science Code Development Team, a team of science consultants, and Steering Committee members with science backgrounds representing the fields of biology, chemistry, geology, and physics helped develop and review codes. In addition, a team of science experts representing the different science disciplines helped develop codes and code the lessons for science content features (the Science Content Coding Team).

- ***Involve teachers and teacher educators in the code development process:*** The code development team included experienced science teachers and teacher educators. In addition, teachers were consulted to review and give input to the development of specific codes.
- ***Employ an iterative process of code development:*** Once the conceptual framework, research questions, and coding priorities had been identified (as described previously in the Guiding Conceptual Framework and Guiding Research Questions sections), the next step in the code development process was to organize the prioritized coding dimensions into sets of lesson features that could be coded by video analysts in one viewing of the lesson. For example, Dimension 1 focused on identifying the beginning and end of the lesson and segments of time devoted to science instruction, classroom organization, and non-science activities, while Dimension 10 included a cluster of lesson features related to the science content, its coherence, and level of complexity. Focusing on one set of lesson features, the Science Code Development Team first reviewed a few lessons qualitatively, with each member proposing strategies for capturing the selected lesson features. Descriptions for each code were developed collaboratively as the group watched and discussed video examples together. Science Code Development Team members then independently applied the proposed definitions to a new lesson(s). Afterwards, the group compared their independent coding decisions and used differences in opinion as a strategy for clarifying the written definitions and for reviewing the effectiveness of the proposed codes in capturing the desired lesson feature. This process of independent review of lessons followed by group review and consensus building continued until 85 percent or higher inter-rater agreement was reached by the Science Code Development Team members or until a decision was made to drop, revise, or create new codes. Once the team established inter-rater agreement, the coding manual was finalized and the team coded one lesson from each country to serve as “masters” to use in reliability tests for the coding teams (the International Video Coding Team and the Science Content Coding Team). Across a two- and one-half-year period, the International Video Coding Team and the Science Content coding Team examined the lessons to code for 11 different dimensions.
- ***Create multiple-layered, concrete descriptions and definitions from loosely defined pedagogical principles***: Pedagogical principles that are complex and difficult to define, such as inquiry teaching or practical work, were coded in stages. In the first stage, for example, coders marked all segments of the lesson that engaged students in doing hands-on, practical science work. In the second stage, these segments were revisited to consider whether students engaged in various inquiry activities before, during, or after each hands-on segment. In yet another stage, codes were developed about the type of hands-on activity (e.g., model building, observation of phenomena, classification, controlled experiment, etc.). These specific codes were used to create a concrete picture of various aspects of inquiry and practical work that were observed in the lessons.

- ***Use codes that capture occurrences of events, duration of events, characteristics of events, and quality of events.*** Achieving inter-rater agreement in a study of this type is challenging because of the complexity of classroom events, the large number of videotapes being analyzed, the cultural differences in the science lessons, and the international make up of the main coding team. It is easier, of course, to get inter-rater agreement when simply marking the occurrence of clearly observable events (e.g., use of science notebooks, assignment of homework, and student-initiated questions). To create a more complicated view of the lessons, the coding teams:

- Used detailed procedures to identify events that are not easily observable.

  The number of main ideas in the lesson is an example of a lesson feature that was not easily observed. To make such difficult observations reliably, the content coding team followed a detailed procedure that included first marking all the ideas presented in the lesson and then looking for ideas that the teacher explicitly linked together to identify sets of ideas that hung together around one main idea.

- Identified the duration as well as the occurrence of some events.

  To capture the length of time spent on different kinds of lesson events, many lesson features were marked with in- and out-points. For example, the time spent on examining real-world issues, the time spent on independent practical activities, and the time spent on organizational matters was identified.

- Described the characteristics of events.

  Follow-up questions about many of the identified lesson events enabled the coder to describe the characteristics of the lesson event. For example, when students were coded as writing, a follow-up question asked about the type of writing that students were doing (copying notes, providing one-word or multiple choice responses, generating a sentence-length response, and generating a paragraph-long response).

- Judged the overall quality of selected events.

  Overall judgment codes were applied to a limited set of content-related codes by science experts. For example, overall quality judgments were made about the content coherence of the lesson and the level of content complexity in the lesson.

What Are the Methods for Studying Teaching in Different Countries?

A brief description of the methods used for sampling the participating countries and the science lessons, developing codes to be applied to the videotaped lessons, and establishing code reliability follows. More detailed information can be found in appendix A and the TIMSS 1999 Video Study technical report (Garnier et al. forthcoming).

Selection of Countries

The TIMSS 1999 Video Study extended the 1995 study that explored whether eighth-grade teachers in higher-achieving countries taught mathematics in similar ways by including more higher-achieving countries and including eighth-grade science teaching. The selection of the participating countries was based on the results of the TIMSS 1995 assessments. The TIMSS 1999 and 2003 science assessments were administered after the TIMSS 1999 Video Study was underway and played no role in the selection of countries for the Video Study. Table 1.2 lists the countries that participated in the TIMSS 1999 Video Study of eighth-grade science along with their average scores on TIMSS 1995, 1999, and 2003 science student assessments. On the TIMSS 1995 science assessment, eighth-grade students in Japan and the Czech Republic performed significantly above the other three countries. Students in the United States performed significantly below all four of the other countries. In 1995 and again in 1999, eighth-grade students in the United States scored, on average, significantly lower than their peers in the other four countries. Since that time, however, the U.S. experienced a significant improvement in average science performance at grade 8. 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.

Table 1.2. Average science scale scores of eighth-grade students, by country: 1995, 1999, and 2003

	1995		1999		2003	
Country	Average score	Standard error	Average score	Standard error	Average score	Standard error
Australia[1]	527[1]	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[1]	6.0	545	6.9	536	3.1
United States[2]	513	5.6	515	4.6	527	3.1

[1] Nation did not meet international sampling and/or other guidelines in 1995. See Beaton et al. (1996) for details.
[2] Nation did not meet international sampling and/or other guidelines in 2003. See Gonzales et al. (2004) for details.
—Not available. The Czech Republic did not participate in the 2003 assessment.
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., Arafeh, S., Williams, T., and Tsen, W. (2000). Pursuing Excellence: Comparisons of International Eighth-Grade Mathematics and Science Achievement from a U.S. Perspective, 1995 and 1999 (NCES 2001– 028). 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 (NCES 2005-005) Washington, DC: Government Printing Office.

Selection of Lessons

The methods followed to select the science lessons to be videotaped in each of the participating countries was based on the standards and procedures agreed to and implemented for the TIMSS 1999 assessments (Martin, Gregory, and Stemler 2000). The sample of schools drawn for the study within each country was required to be a probability proportionate to size (PPS) sample. Using this method, the probability of a school being selected was proportional to the number of eligible students in the eighth-grade in schools countrywide. Each randomly selected school submitted a list of the science classes offered for eighth-graders. From this list, one science class per school was randomly selected to be videotaped. The goal was to videotape 100 randomly selected eighth-grade science lessons in each participating country. The participation rate of schools in the study ranged from 81 to 100 percent (weighted, with replacement schools).

No substitutions of teachers or class periods were allowed. The randomly selected eighth-grade science class was videotaped once, in its entirety, without regard to the science topic being taught or the type of activity taking place. The only exception was that teachers were not videotaped on days they planned to give a test or examination for the entire class period.

Science lessons were videotaped throughout a regular school year, making accommodations for how academic years were organized in each country. This allowed for the collection of science lessons that, because they were evenly distributed over the school year, likely represented the topics and activities that eighth-graders would encounter during a regular academic school year. Detailed information on sampling and participation rates is included in appendix A and in the forthcoming technical report (Garnier and Rust forthcoming).

Code Development

Three teams were assembled to develop and apply codes that would capture teaching activities and behaviors to the video data (see appendix B for list of team and advisory group members). The Science Code Development Team included science specialists, researchers, and representatives from each of the participating countries. This team was responsible for developing codes, writing coding manuals, training coders, and tracking reliability. They discussed coding ideas, created code definitions, wrote a coding manual, gathered examples and practice materials, designed a coder training program, trained coders and established reliability, organized quality control measures, consulted on difficult coding decisions, and managed the analyses and write-up of the data. To help identify and develop codes, 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 North American science education researchers.

The International Video Coding Team represented all of the participating countries and the members were fluent in the language of the lessons they coded. This team coded lessons for features that did not require science content expertise.

The Science Content Coding Team consisted of U.S. experts in science content (including biology, physics, chemistry, and geology). This team coded for features that required science content knowledge. Their primary responsibility was to apply a series of codes to all of the scientific content of the videotaped lessons. The codes included the nature of scientific topics, types of science knowledge, level of difficulty of the science content, and different modes of content development. The science content coders also assisted the code development team in making revisions to the coding manual that improved coding reliability.

Code Reliability

Developing and applying codes to observations of science teaching requires clear reliability procedures to ensure consistency and accuracy. Extensive training for the International Video Coding Team was the first step and critical since they came from different countries with a variety of backgrounds. Reliability was established for three types of video codes that were applied by this team. These codes identified whether an activity or behavior occurred and measured how long the activity or behavior took place. Coders marked the videotapes on category, in-point, and out-point of the activity or behavior. The consistency of the different coders applying the same codes to the same behaviors was measured with percentage agreement between the coders within and across countries. Percentage agreement was estimated by dividing the number of agreements by the number of agreements plus disagreements. The codes were evaluated at the beginning and midpoint of the coding process for each coding dimension (see appendix A for more details on the reliability of each code). The minimum acceptable reliability estimate for all coders, averaging across countries, was 85 percent. Additional training was provided until an acceptable level was achieved for coders not meeting the minimum acceptable criterion. Codes that did not demonstrate minimum acceptable reliability after multiple attempts were dropped from the study. For selected codes, consensus coding was used. Two coders independently coded a lesson and then met to reconcile any differences in their coding decisions. The procedures used to measure reliability are described in Bakeman and Gottman (1997). The members of the Science Content Coding Team each established reliability through consensus coding of all the team members.

Limitations of the Study

Sample of Participating Countries

The sample of countries participating in the TIMSS 1999 Science Video Study includes five countries. The four relatively higher-achieving countries may not be representative of all the countries with students performing well on international assessments of science. The one relatively lower-achieving country, the United States, ranks higher than some other countries with lower average student performance on international assessments (Gonzales et al. 2000, 2004). National policy changes implemented after the data collection also may be associated with changes in teaching in the science classrooms.

Coverage of Topics

The lessons in the TIMSS 1999 Science Video Study cover a wide range of topics drawn from the science disciplines of biology, chemistry, earth science, health, physical science, and technology.[5] Because of the range of content and the small number of lessons collected on any given topic (e.g., electricity) or even within a given science discipline, descriptions in this report can focus on the average experience of eighth-grade students in their classroom science lessons. That is, it is not possible to describe the average chemistry or physics lesson in the eighth-grade,

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[5] The science discipline "Technology" includes the nature of technology, interaction of science, mathematics, and technology, and the history of science and technology.

for example. This is an important limitation, since some of the differences observed in science teaching practice across countries may be an artifact of the disciplines emphasized. Thus, the observation that some countries use more first-hand observations of phenomena during science lessons may be explained either by country differences in science teaching practices or by differences in the science discipline that is being taught at the eighth grade. At grade 8, Australia, Japan, and the United States offer science as a single general or integrated subject; in the Czech Republic and the Netherlands, grade 8 science is offered through separate subject courses in physics, chemistry, life science, and earth science (Martin et al. 2000).

Student Behaviors

A video study of eighth-grade science teaching is limited to a subset of factors that may affect student achievement. While the TIMSS 1999 Science Video Study focused on recording and interpreting a complex set of teaching practices, reliably capturing some student behaviors and characteristics was not feasible. Student behaviors and characteristics, such as being "on task" or being motivated and ready to learn, would require a high level of inference. Differences may be so subtle and culturally bound as to make it impossible to reliably code such behaviors from video data.

Caution About Drawing Inferences With Student Achievement

No direct inferences can or should be made to link descriptions of teaching in the TIMSS 1999 Video Study with students' levels of achievement as documented by TIMSS assessments. The relationships between classroom teaching and learning are complicated. While there is evidence that teaching makes a difference in students' learning (Brophy and Good 1986; Hiebert 1999; NRC 2000), eighth-graders' science achievement is the culmination of many factors and many years spent both inside and outside of school (Floden 2001; NRC 2000; Wittrock 1986). Moreover, such inferences are not warranted because in most of the participating countries, the videotaped classrooms were not the same ones in which students took the achievement tests. Furthermore, even if student assessment data were available to link to video-based indicators, it would be unwise to use data from a single lesson to assess the impact of teachers' instructional practices on student learning outcomes. The sampling frame was a random selection of lessons meant to represent the practices within a country and not to obtain a reliable estimate of the average practice of an individual teacher.

The descriptions of science classroom lessons in this report reveal a complex variety of features and patterns of teaching. Countries are similar to, and different from, each other in interesting and sometimes subtle ways. Interpretation of these results requires a thoughtful and analytic approach. This study looked at common patterns of science teaching shared by the participating high-achieving countries, but did not attempt to identify which specific practices are related to higher student achievement.

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.

What Can Be Found in This report?

The presentation of results is organized around the conceptual framework and the three guiding research questions (figure 1.1 and table 1.1). After a presentation of the context of the lessons as reported by the participating teachers on a questionnaire (chapter 2), the focus is placed on the teacher's organization of the lesson (chapter 3).

Chapters 4–6 describe how science content is represented to students in the lesson. Chapter 4 presents the content topics and knowledge types addressed in the science lessons, while chapter 5 describes the density, coherence, organization, and challenge of the science content. Chapter 6 explores the ways in which the science ideas are supported by evidence in the form of data, phenomena, or visual representations. Together, these chapters examine how lessons provide students with opportunities to understand science as a set of ideas.

Chapters 7–11 present different aspects of students' opportunities to participate in learning science. In chapter 7, the attention focuses on students' opportunities to engage in doing practical work and to use selected science inquiry behaviors. Students' opportunities to collaborate in carrying out science activities are examined in chapter 8. Chapter 9 explores student and teacher communication about science. The ways in which science is presented as interesting and relevant to students' lives are presented in chapter 10, while chapter 11 examines the ways in which students are expected to take responsibility for their own learning.

The report concludes by describing observable country patterns of science teaching, based on the analyses presented in this report, and a consideration of inferences that may be drawn from the patterns evident across the countries and across the various lesson features (chapter 12).

For all analyses presented in this report, differences between averages or percentages that are statistically significant are discussed using comparative terms such as "higher" and "lower." Generally, differences that are not found to be statistically significant are either not discussed or referred to as "no measurable differences found." 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 be due to sampling or measurement error. To determine whether differences reported are statistically significant, ANOVAs and two-tailed *t*-tests, at the .05 level of significance, were used. When more than two groups were compared simultaneously (e.g., a comparison among all five countries), the significance tests were based on a Bonferroni procedure for multiple comparisons that holds to 5 percent probability of erroneously declaring the mean of one country to be different from another country. The analyses were weighted with survey weights developed specifically for this study. They were needed to produce estimates that are unbiased estimates of national means and distributions. The weight for each classroom reflects the overall probability of selection for that classroom, with appropriate adjustments for non-response (see Rust forthcoming for a more detailed description of weighting procedures). In some cases, large apparent differences in data are not significant due to large standard errors, small sample sizes, or both. Standard errors for all estimates displayed in the figures and tables in the report are included in appendix C.

In some cases, the reported estimates are marked with an exclamation point (!). This indicates that the estimate is unstable. Unstable estimates were identified by calculating the coefficient of variation (CV), by dividing the standard error of the estimate by the estimate. Estimates are marked as unstable in all cases in which the CV was found to be .50 or greater.

To assist readers in interpreting data presented in tables and figures, results of the statistical tests are listed below each table and figure in which data are compared. Results are indicated by the use of the greater than (>) symbol and three-letter country codes, e.g., AUS>CZE, meaning that Australia's average is greater than the Czech Republic's average. Only those comparisons that were determined to be significant ($p \leq .05$) are listed.

Accompanying the printed version of this report is a CD-ROM on which are presented short video clips that illustrate many of the codes used to analyze the lesson videos. For the United States and the Czech Republic, the video clips are taken from lessons filmed specifically for the purpose of public display. These lessons were not included in the sample analyzed for this report. For Japan and Australia, video clips are taken from lessons collected for the TIMSS 1999 Video Study. For the Netherlands, some lessons were filmed specifically for the purpose of public display, while others were taken from the sample collected for the TIMSS 1999 Video Study. In all cases, permission to display the video clips was granted by all participants or their legal guardians. The CD-ROM is entitled "Teaching Science in Five Countries: Video Clip Examples." In chapters 3–11 of the published version of this report, a camera icon (🎥) and note is provided that indicates the number of the video clip on the CD-ROM relevant to the discussion. For the CD-ROM version of this report, a hyperlink to the relevant example is provided.

In addition to this report, highlights from the study are published in a separate document, entitled *Highlights From the TIMSS 1999 Video Study of Eighth-Grade Science Teaching* (Roth et al. 2006; NCES 2006-017), and five full-length lesson videos from each of the five participating countries are available on CD-ROM discs. These 25 public-release videos are presented as a set of CD-ROMs and include, in addition to lesson videos, accompanying materials with a transcript in English and the native language, as well as commentaries by teachers, researchers, and national research coordinators in English and the native language. These public release videos and materials are intended to augment the research findings, support teacher professional development programs, and encourage public discussion of teaching and how to improve it.

All of the products related to the TIMSS 1999 Video Study can be accessed or ordered by going to the NCES web site (http://nces.ed.gov/timss).

Chapter 2: Context of the Lessons

This chapter presents background information on the videotaped teachers and the context of the lessons based on teachers' responses to a questionnaire after their science lessons were videotaped. Analyses of their responses to questionnaire items help assess the typicality of the videotaped lesson and of the sample of teachers who participated in the study. Questionnaire data were obtained from teachers in 100 percent of the eighth-grade science lessons videotaped in Australia, the Czech Republic, and Japan, 98 percent of the Dutch lessons, and 95 percent of the U.S. lessons.

More information on teacher response rates, as well as the development of the questionnaires and how they were coded, can be found in appendix A and in the technical report (Garnier forthcoming).

The context of an eighth-grade science lesson is defined by, among other things, characteristics of the teachers, their expectations for science teaching and learning, their current ideas about teaching and learning science, and where the lesson fits in the curricular sequence. To collect information on these factors, questionnaire items addressed the following three questions:

- What are teachers' background experiences and workloads?
- What factors do teachers report as influencing the content of the lessons?
- What are teachers' perceptions of the typicality of the lessons?

What Are Teachers' Background Experiences and Workloads?

Science teachers bring a variety of educational and professional experiences to the classes they teach. These experiences can influence their planning and implementation of a lesson (National Research Council (NRC) 2001). To better understand the eighth-grade science lessons taught by teachers who participated in the video study, data were collected on teachers' educational preparation, professional background, and current teaching responsibilities. When interpreting results, the reader should keep in mind that some results could be influenced by national requirements or support, which can vary by country. Information on the measures used can be found in appendix D.

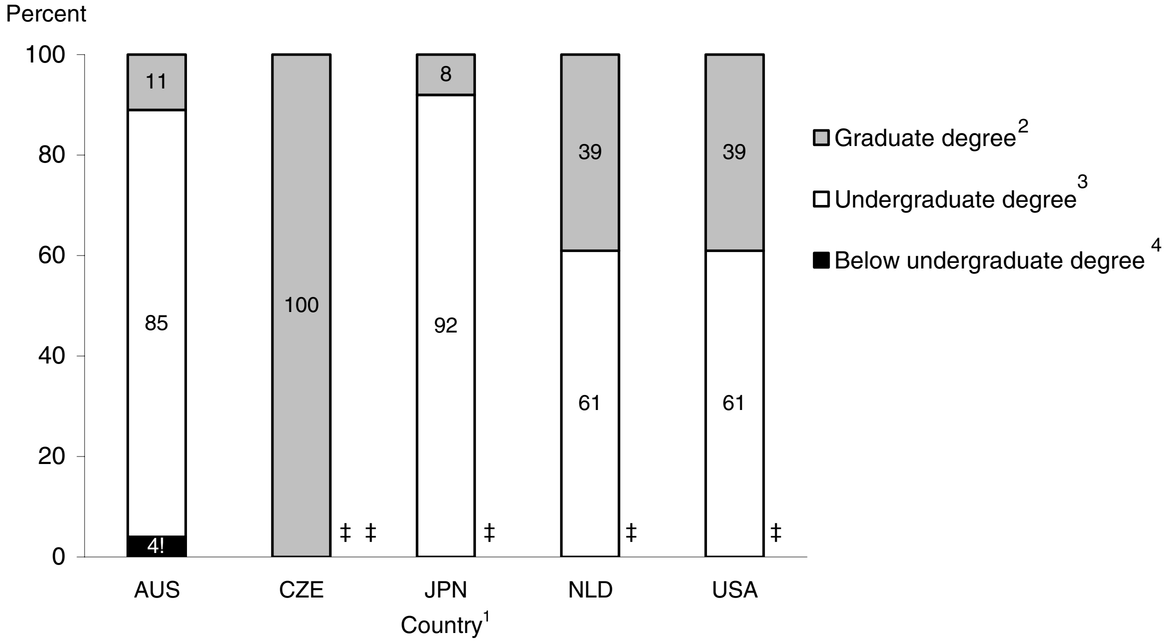
Educational Preparation

- Teacher reports indicated that the average eighth-grade science lesson in each of the five countries was taught by a teacher with, at a minimum, postsecondary education in science or science education and certification to teach eighth-grade science. Figure 2.1 shows that at least 96 percent of the eighth-grade science lessons in the five countries were taught by teachers who attained at least an undergraduate degree or the equivalent. All of the Czech lessons were taught by teachers who reported that they had attained graduate degrees, a larger proportion of lessons than in all other countries, ranging from 8 to 39 percent. At least 98 percent of the eighth-grade science lessons in all of the participating countries except the

United States were taught by teachers who were certified to teach science in eighth-grade or grades higher than eighth grade (data not shown).

- Ten percent of U.S. eighth-grade science lessons were taught by teachers who reported they were certified to teach science only in grades lower than eighth grade.
- As table 2.1 indicates, fewer eighth-grade science lessons in the United States were taught by teachers who majored in one or more areas of science (64 percent) compared to lessons in the other countries (87 to 100 percent). Furthermore more U.S. lessons were taught by teachers who majored in areas other than science, such as general education (36 percent), compared to Australia and Czech lessons (13 and 5 percent, respectively).
- On average, eighth-grade science lessons in the Czech Republic were taught by teachers who reported more experience teaching in general (21 years) and teaching science specifically (19 years) compared to lessons in the other four countries (ranging from 12 to 15 years teaching, in general, and 10 to 14 years teaching science; table 2.2).

Figure 2.1. Percentage distribution of eighth-grade science lessons, by teacher's highest level of education and country: 1999



!Interpret data with caution. Estimate is unstable.

‡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] Graduate degree: CZE>AUS, JPN, NLD, USA; NLD, USA>AUS, JPN.

[3] Undergraduate degree: AUS, JPN, NLD, USA>CZE; AUS, JPN>NLD, USA.

[4] Below undergraduate degree: No measurable differences detected.

NOTE: Results based on the classification of science teachers' reports of their educational attainment according to the International Standard Classification of Education (ISCED) (OECD 1997).

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

Table 2.1. Percentage of eighth-grade science lessons, by teacher's undergraduate or graduate major and country: 1999

Major area of study	Australia (AUS)	Czech Republic (CZE)	Japan (JPN)	Netherlands (NLD)	United States (USA)
Science[1] – Total	87	95	100	99	64
Life sciences[2]	47	48	20	41	46
Physics[3]	15	33	30	44	‡
Chemistry[4]	29	32	31	37	4
Earth sciences[5]	11	48	10	6!	6
General science[6]	4!	‡	100	‡	11
Other than science[7]	13	5	‡	‡	36

!Interpret data with caution. Estimate is unstable.

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

[1] Science: AUS, CZE, JPN, NLD>USA; JPN, NLD>AUS.

[2] Life sciences: AUS, CZE, USA>JPN.

[3] Physics: JPN, NLD>AUS.

[4] Chemistry: AUS, CZE, JPN, NLD>USA.

[5] Earth sciences: CZE>AUS, JPN, NLD, USA.

[6] General science: JPN>AUS, USA.

[7] Other than science: USA>AUS, CZE.

NOTE: Results based on science teachers' reports. Science includes teachers' response to any of the fields of science: life science, physics, chemistry, earth science, and general science. Teachers were free to define "major area" and to mention as many areas of study that applied. Areas of study include life sciences, physics, chemistry, earth sciences, general sciences, and other area of study. Since teachers could list more than one area for undergraduate and graduate studies, the percentages presented in table 2.1 could add to more than 100 percent within a country.

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

Table 2.2. Summary and dispersion measures for eighth grade science teachers' teaching experience, by country: 1999

Teaching experience	Australia (AUS)	Czech Republic (CZE)	Japan (JPN)	Netherlands (NLD)	United States (USA)
Years teaching					
Mean[1]	15	21	15	14	12
Median	16	21	15	11	7
Range	0-39	1-41	1-34	1-36	1-35
Years teaching science					
Mean[2]	14	19	14	12	10
Median	15	18	15	9	7
Range	0-39	1-39	1-34	1-33	1-35

[1] Mean years teaching: CZE>AUS, JPN, NLD, USA.

[2] Mean years teaching science: CZE>AUS, JPN, NLD, USA.

NOTE: Results based on science teachers' reports. Mean years per country are calculated as the sum of the number of years reported by teachers divided by the number of lessons within a country. For each country, the median is calculated as the number of years below which 50 percent of the lessons fall. Range describes the lowest number of years and the highest number of years reported within a country. A response of zero (0) indicates that a teacher was in the first year of teaching at the time of data collection.

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

Professional Development Opportunities

- Teachers typically participated in some professional development activities in all five of the countries, but varied in the types of activities in which they participated. Between 38 and 56 percent of lessons in all the countries except Australia were taught by teachers who took additional science or science education courses in the two years prior to the videotaping (table 2.3).
- The most frequently identified professional development activities included the use of technology, science instructional techniques, and standards-based teaching (table 2.4). More Australian, Dutch, and U.S. eighth-grade science lessons were taught by teachers who identified the use of technology (79, 68, and 84 percent, respectively) compared to lessons in the Czech Republic and Japan (45 and 42 percent, respectively). More U.S. science lessons were taught by teachers who participated in activities related to science instructional techniques (66 percent) compared to lessons in Australia (36 percent) and the Czech Republic (36 percent), and participated in standards-based teaching (52 percent) compared to the Netherlands (22 percent).

Table 2.3. Percentage of eighth-grade science lessons taught by teachers who participated in science-related education courses, and the average number of professional development activities teachers participated in the 2 years prior to data collection, by country: 1999

Country	Percentage of lessons taught by teachers who took at least one science or science education course[1]	Average number of professional development activities[2]
Australia (AUS)	9	3
Czech Republic (CZE)	56	2
Japan (JPN)	38	2
Netherlands (NLD)	50	2
United States (USA)	49	5

[1] Courses: CZE, JPN, NLD, USA>AUS.

[2] Professional development activities: AUS>CZE, JPN, NLD; NLD>JPN; USA>AUS, CZE, JPN, NLD.

NOTE: Results based on science teachers' reports of professional development activities in the two years prior to data collection. Average number of professional development activities calculated as the sum of the number of professional development activities divided by the number of lessons within a country.

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

Table 2.4. Percentage of eighth-grade science lessons, by teachers' participation in professional development activities or academic courses and country: 1999

Professional development activity	Australia (AUS)	Czech Republic (CZE)	Japan (JPN)	Netherlands (NLD)	United States (USA)
Classroom management and organization[1]	37	6	19	16	21
Cooperative group instruction[2]	29	7	12	36	48
Interdisciplinary instruction[3]	14	5	‡	3	48
Science instructional techniques[4]	36	36	50	43	66
Standards-based teaching[5]	36	—	29	22	52
Teaching higher-order thinking skills[6]	22	‡	‡	11	44
Teaching students from different cultural backgrounds[7]	13	‡	‡	8	31
Teaching students with limited proficiency in their national language[8]	5	‡	‡	5!	18
Teaching students with special needs[9]	23	7	6	12	36
Use of technology[10]	79	45	42	68	84
Other professional development activities[11]	46	42	18	25	44

—Not available.

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

[1] Classroom management and organization: AUS, USA>CZE.

[2] Cooperative group instruction: AUS, NLD, USA>CZE; NLD, USA>JPN.

[3] Interdisciplinary instruction: USA>AUS, CZE, NLD.

[4] Science instructional techniques: USA>AUS, CZE.

[5] Standards-based teaching: USA>NLD.

[6] Teaching higher-order thinking skills: USA>AUS, NLD.

[7] Teaching students from different cultural backgrounds: USA>AUS, NLD.

[8] Teaching students with limited proficiency in their national language: No measurable differences detected.

[9] Teaching students with special needs: AUS>JPN; USA>CZE, JPN, NLD.

[10] Use of technology: AUS, NLD, USA>CZE, JPN.

[11] Other professional development activities: AUS, CZE, USA>JPN.

NOTE: Results based on science teachers' reports of participation in professional development or academic coursework in the two years prior to the videotaping of lessons. Totals do not sum to 100 because more than one category could be selected. The option "standards-based teaching" was not appropriate for the Czech Republic and was excluded from the questionnaires and analyses. Use of technology includes but is not limited to using computers.

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

Time Spent on Different School Activities

- Table 2.5 shows that across all the countries, eighth-grade science lessons were taught by teachers who reported spending an average of 38 to 45 total hours per week on teaching and other school-related activities. At least a third of this time was spent teaching science classes. Teachers of Japanese science lessons reported spending less time, on average, teaching other classes and working at home on science teaching related matters compared to teachers in the other four countries. Teachers of Dutch science lessons spent less time doing work at school related to teaching science compared to teachers of the science lessons in the other four countries.

Table 2.5. Average weekly hours eighth-grade science teachers reported spending on teaching and other school-related activities, by country: 1999

Activity	Australia (AUS)	Czech Republic (CZE)	Japan (JPN)	Netherlands (NLD)	United States (USA)
All teaching and other school-related activities–Total[1]	38	42	40	40	45
Teaching science classes[2]	14	16	16	19	20
Teaching other classes[3]	3	6	1	4	4
Meeting with other teachers to work on curriculum and planning issues[4]	2	1	1	1	2
Work at school related to teaching science[5]	7	6	6	4	7
Work at home related to teaching science[6]	6	6	4	7	6
Other school-related activities[7]	5	7	12	5	6

[1] All teaching and other school related activities: No measurable differences detected.

[2] Teaching science classes: JPN, NLD, USA>AUS; NLD>CZE.

[3] Teaching other classes: AUS, CZE, NLD, USA>JPN; CZE>AUS.

[4] Meeting with other teachers to work on curriculum and planning issues: USA>CZE, JPN.

[5] Work at school related to teaching science: AUS, CZE, JPN, USA>NLD.

[6] Work at home related to teaching science: AUS, CZE, NLD, USA>JPN.

[7] Other school-related activities: JPN>AUS, CZE, NLD, USA.

NOTE: Results based on science teachers' reports. Hours may not sum to totals because of rounding. Average hours per week calculated by the sum of hours for each lesson divided by the number of lessons within a country.

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

What Do Teachers Report as Influencing the Content of the Lessons?

Teachers' decisions about what and how they teach are associated with many factors including their learning goals for students, curriculum guidelines, mandated textbooks, standardized tests, cooperative work with other teachers, and teachers' awareness of current ideas about teaching and learning science. The following section presents the eighth-grade science teachers' descriptions of factors that they perceive as having influenced the content taught in the videotaped lesson as well as their satisfaction in achieving lesson goals. Teachers provided responses after the lesson was videotaped.

Teachers' Learning Goals for Science Lessons

- More Czech eighth-grade science lessons were taught by teachers whose stated goals for the videotaped lessons were knowing science information compared to lessons in the other four countries (table 2.6). Teachers of more Australian and Japanese science lessons identified the lesson goal as understanding scientific ideas in comparison with the United States and the Czech Republic.
- Within Australia and Japan, more science lessons were taught by teachers who indicated they wanted students to understand scientific ideas than teachers who wanted students to know science information (table 2.6). On the other hand, within the Czech Republic, more science lessons were taught by teachers who wanted students to know science information than teachers who wanted students to understand scientific ideas.

Teachers' Decisions to Teach the Content of the Lesson

- In addition to their learning goals, teachers reported that the content of the videotaped lesson was influenced by a variety of factors that varied across countries. Curriculum guidelines were identified by teachers as a major influence on their decisions about lesson content in more Czech and U.S. science lessons than in the other three countries. Mandated textbooks were reported by teachers as playing a major role in more Czech and Dutch science lessons than in Australian and U.S. science lessons, and in more Japanese science lessons than in U.S. science lessons (table 2.7).
- Curriculum guidelines were reported by teachers as playing a major role in their decisions in more Czech and U.S. science lessons compared to Australian, Japanese, and Dutch science lessons (table 2.7). Also, in the U.S. science lessons, more teachers identified students' interests or needs compared to all the other countries.
- Within the Netherlands and Japan, more lessons were taught by teachers who indicated that the mandated textbook was a major influence on the videotaped lessons than all or almost all other available options, including teacher's assessment of students' needs in Japan. Within Australia, the Czech Republic, and the United States, more eighth-grade science lessons were taught by teachers who indicated that curriculum guidelines were major influences on the videotaped lessons than were taught by teachers who indicated that cooperative work with other teachers, the mandated textbook, and teacher's comfort with or interest in the topic

were major influences (table 2.7). More U.S. lessons were taught by teachers who identified curriculum guidelines as a major influence compared to external examinations, and more U.S. lessons were taught by teachers who identified students' interest or needs as a major influence compared to all other available options except curriculum guidelines.

Lesson Goals Achieved in the Classroom

- Although a majority of science lessons were taught by teachers who stated that they were satisfied that the videotaped lessons achieved their goals, fewer eighth-grade science lessons in Japan were taught by teachers who reported that they were satisfied that their lessons played out as they had intended (62 percent) compared to the other four participating countries (ranging from 87 to 94 percent) (data not shown).

Teachers' Awareness of Current Ideas About Teaching and Learning Science

- More Australian, Dutch, and U.S. eighth-grade science lessons were taught by teachers who reported they were familiar with "current ideas" of teaching science than science lessons in the Czech Republic and Japan (figure 2.2). At least 85 percent of science lessons in all the countries, except Japan, were taught by teachers who believed the videotaped lesson was at least "a little" in accord with current ideas (figure 2.3).

Table 2.6. Percentage of eighth-grade science lessons, by teacher-identified goals and country: 1999

Goal for videotaped lesson	Australia (AUS)	Czech Republic (CZE)	Japan (JPN)	Netherlands (NLD)	United States (USA)
Knowing and understanding science					
Knowing science information[1]	20	59	14	23	23
Understanding scientific ideas[2]	51	7	70	27	23
Understanding the nature of science[3]	4!	‡	‡	‡	4!
Doing science					
Carrying out a scientific experiment, project, or activity[4]	4!	6	10	15	17
Developing generic thinking skills[5]	‡	‡	3!	8	5!
Learning laboratory skills[6]	11	10	15	12	6
Using scientific inquiry skills[7]	13	6	8	11	22
Context of science					
Awareness of the usefulness of science in life[8]	19	12	9	17	22
Collaborative work in groups[9]	‡	‡	‡	10	8
Independent work[10]	5	‡	3!	11	7

!Interpret data with caution. Estimate is unstable.

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

[1] Knowing science information: CZE>AUS, JPN, NLD, USA.

[2] Understanding scientific ideas: AUS, JPN, NLD, USA >CZE; AUS>USA; JPN>NLD, USA.

[3] Understanding the nature of science: No measurable differences detected.

[4] Carrying out a scientific experiment, project, or activity: No differences detected.

[5] Developing generic thinking skills: No measurable differences detected.

[6] Learning laboratory skills: No measurable differences detected.

[7] Using scientific inquiry skills: No measurable differences detected.

[8] Awareness of the usefulness of science in life: No measurable differences detected.

[9] Collaborative work in groups: No measurable differences detected.

[10] Independent work: No measurable differences detected.

NOTE: Results based on science teachers' reports. Totals do not sum to 100 because teacher responses could be coded into more than one goal for the videotaped lesson. Only those goals which were identified by a sufficient number of teachers in at least two countries to produce reliable estimates are included.

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

Table 2.7. Percentage of eighth-grade science lessons taught by teachers who reported various factors played a “major role” in their decision to teach the content in the videotaped lesson, by country: 1999

Factor	Australia (AUS)	Czech Republic (CZE)	Japan (JPN)	Netherlands (NLD)	United States (USA)
Cooperative work with other teachers[1]	32	6	5!	44	25
Curriculum guidelines[2]	60	93	20	41	84
External examinations or standardized tests[3]	—	3!	5!	7	23
Mandated textbook[4]	32	67	52	74	26
Teacher’s comfort with or interest in the topic[5]	27	47	15	37	41
Teacher’s assessment of students’ interests or needs[6]	47	39	44	25	74

—Not available.

!Interpret data with caution. Estimate is unstable.

[1] Cooperative work with other teachers: AUS, NLD, USA>CZE, JPN.

[2] Curriculum guidelines: CZE, USA>AUS, JPN, NLD; AUS>JPN.

[3] External examinations or standardized tests: USA>CZE, JPN, NLD.

[4] Mandated textbook: CZE, NLD>AUS, USA; JPN>USA.

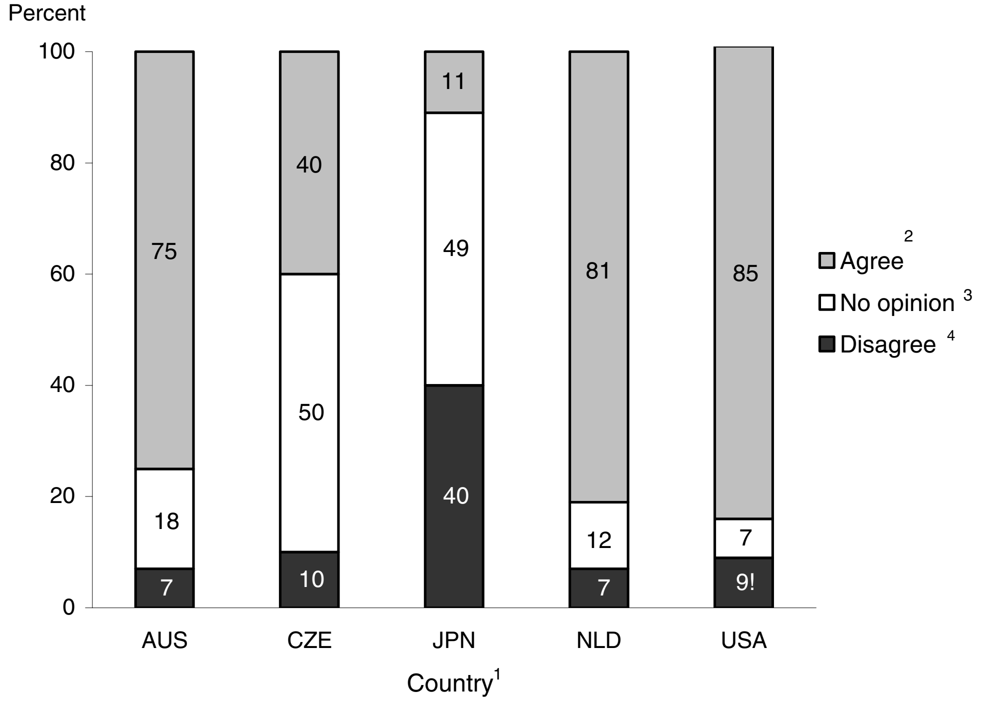
[5] Teacher’s comfort: CZE, NLD, USA>JPN.

[6] Teacher’s assessment of students’ needs: USA>AUS, CZE, JPN, NLD.

NOTE: Results based on science teachers’ reports. Totals do not sum to 100 because more than one category could be selected. The option “external examinations or standardized tests” was not appropriate for Australia and was excluded from the questionnaires and analyses.

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

Figure 2.2. Percentage distribution of eighth-grade science lessons taught by teachers who reported being familiar with current ideas in science teaching and learning, 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] Agree: AUS, NLD, USA>CZE, JPN; CZE>JPN.

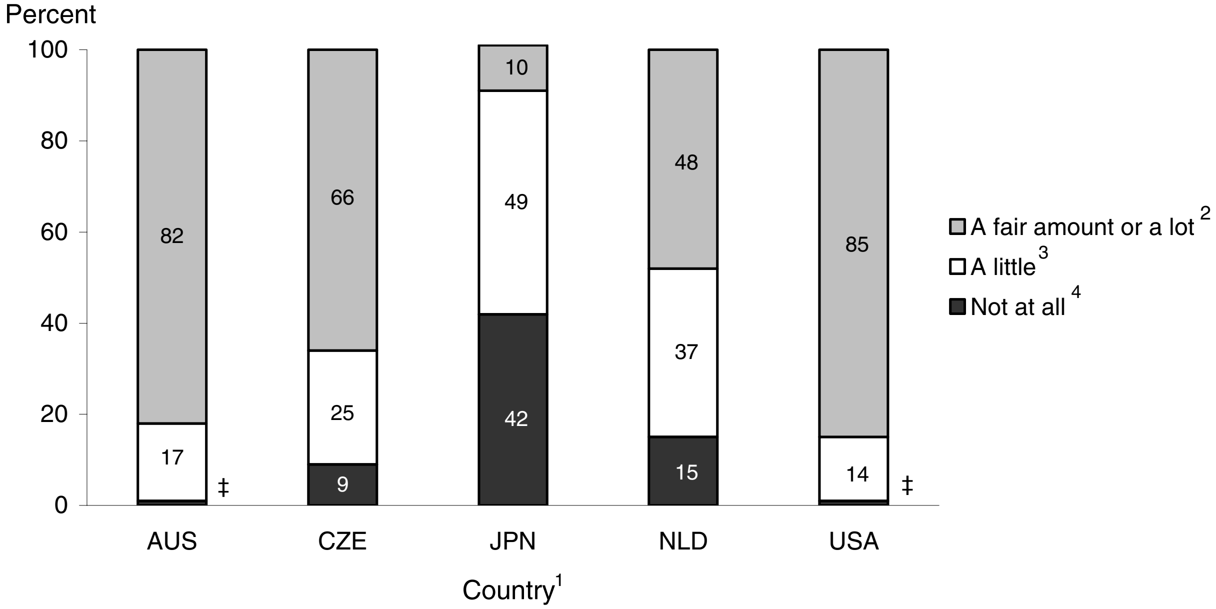
[3] No opinion: CZE, JPN>AUS, NLD, USA.

[4] Disagree: JPN>AUS, CZE, NLD, USA.

NOTE: Results based on science teachers' reports. Totals 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, Video Study, 1999.

Figure 2.3. Percentage distribution of eighth-grade science lessons taught by teachers who rated the extent to which the videotaped lesson was in accord with current ideas about teaching and learning science, 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] A fair amount or a lot: AUS, CZE, NLD, USA>JPN; AUS, USA>NLD.

[3] A little: JPN>AUS, CZE, USA.

[4] Not at all: JPN>CZE, NLD.

NOTE: Results based on science teachers' reports. Totals 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, Video Study, 1999.

What Are Teachers' Perceptions of the Typicality of the Lessons?

Typicality of the Course

- Teachers were asked if all students in the school took the videotaped course. In all Dutch eighth-grade science lessons, eighth-grade science teachers responded that all students in the school were required to take the science course that was videotaped (data not shown). In the four remaining countries, between 84 and 97 percent of lessons were in schools that required all eighth-graders to take the videotaped science course.

Typicality of the Videotaped Lesson

- The videotaped lesson, as perceived by teachers of the eighth-grade science lessons, generally provided a typical picture of everyday classroom instruction with regard to teaching methods (figure 2.4).
- Teachers' descriptions of their students' behavior also indicated that, overall, the lessons captured on the videotapes were typical of their usual behavior (data not shown). Between 68 percent and 77 percent of the science lessons in each country were taught by teachers who reported that the students behaved about the same as usual except in the Czech Republic (51 percent; data not shown).
- The difficulty of the lesson content in 81 to 91 percent of the videotaped lessons in the five countries was rated by eighth-grade science teachers as "about the same" as most lessons (data not shown). The science content was described as "more difficult" in 3 to 10 percent of the lessons across the five countries, and as "less difficult" in 4 to 12 percent of the lessons.

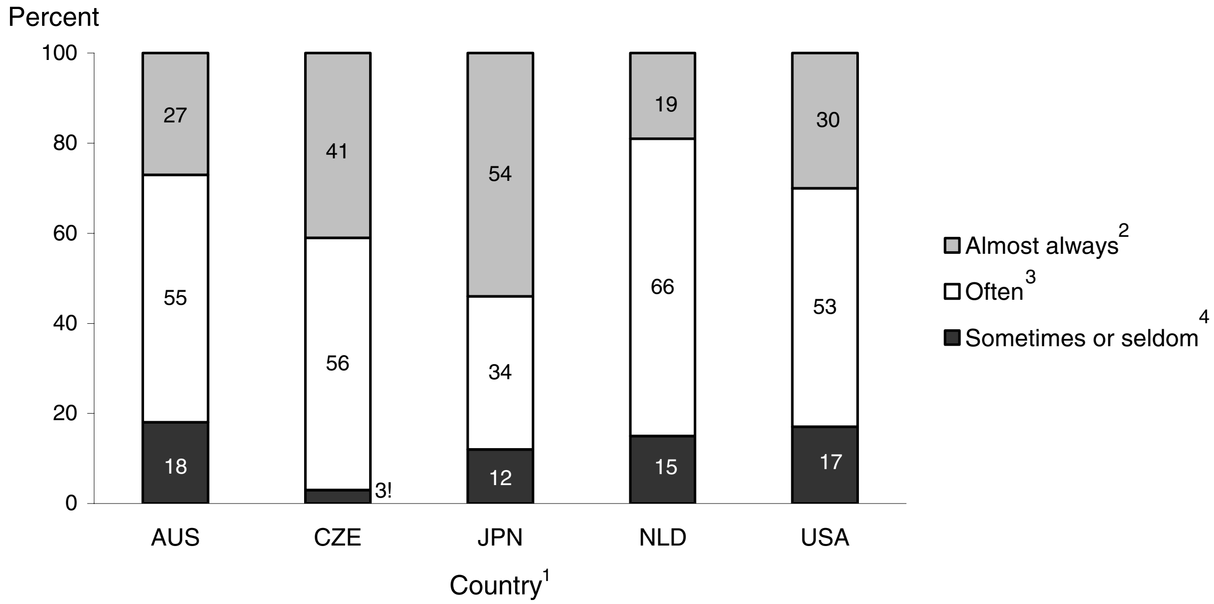
Influence of Videotaping

- More eighth-grade science lessons in Australia (72 percent), Japan (60 percent), the Netherlands (87 percent), and the United States (90 percent) were taught by teachers who reported that the camera did not influence their teaching of the science lesson compared to Czech lessons (39 percent; data not shown). In the Czech Republic, teachers in 23 percent of the science lessons responded that the presence of the camera caused them to teach a lesson that was "better than usual" and in 37 percent of the lessons "worse than usual."

Typicality of Planning for the Lesson

- Eighth-grade science lessons in Japan were taught by teachers who reported spending more time planning for the videotaped lesson (an average of 135 minutes) compared to teachers in the other four countries (25 to 57 minutes, on average; figure 2.5).
- Lessons within all the countries except the United States were taught by teachers who reported spending more planning time on videotaped lessons than on similar lessons (figure 2.5).

Figure 2.4. Percentage distribution of eighth-grade science lessons taught by teachers who rated how often they used the teaching methods in the videotaped lesson, 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] Almost always: JPN>AUS, NLD, USA.

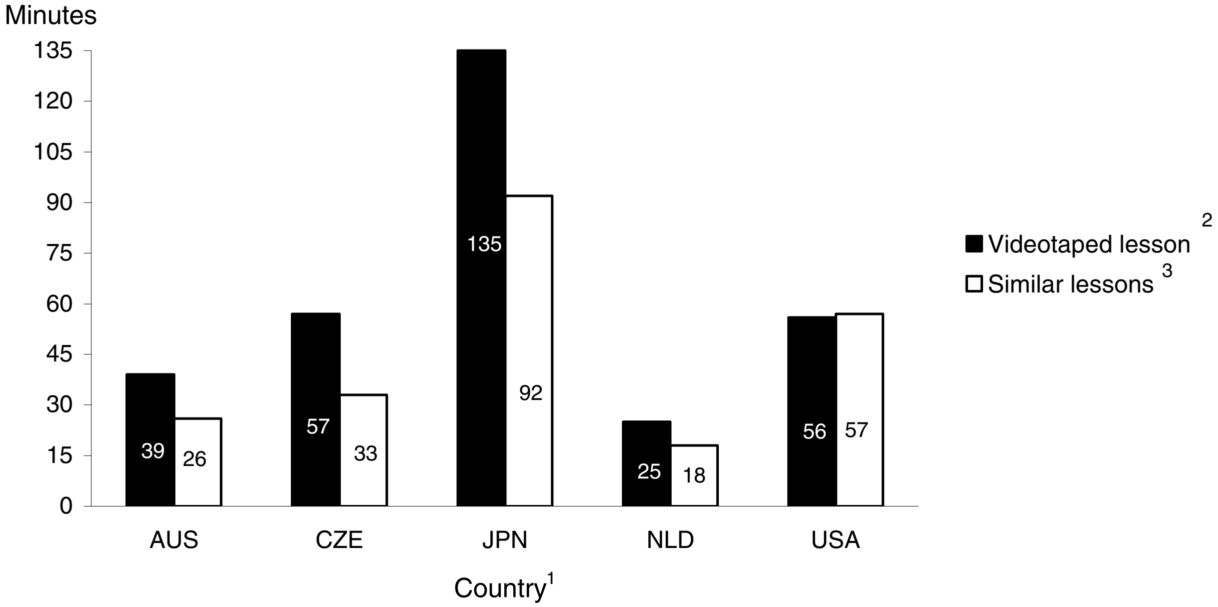
[3] Often: CZE, NLD>JPN.

[4] Sometimes or seldom: No measurable differences detected.

NOTE: Results based on science teachers' reports.

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

Figure 2.5. Average length of time eighth-grade science teachers spent planning for the videotaped lesson and for similar science lessons, by country: 1999



[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
[2] Videotaped lesson: JPN>AUS, CZE, NLD, USA; CZE, USA>NLD.
[3] Similar lessons: CZE, JPN, USA>AUS, NLD; JPN, USA>CZE.
NOTE: Results based on science teachers' reports. Average length of time per country calculated as the sum of minutes reported for each lesson divided by the number of lessons within a country.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study, Video Study, 1999.

Fit of the Lesson in the Curricular Sequence

A sequence of lessons is the usual structure teachers use to teach a particular topic in the curriculum. A lesson that is not identified as part of a sequence may indicate an atypical lesson conducted specifically for the benefit of this study. Teachers were asked to provide information on whether the videotaped lesson was part of a larger unit or sequence of related lessons, or whether it was a stand-alone lesson. If the videotaped eighth-grade science lesson was part of a unit or sequence, the teacher was asked to identify how many lessons were in the entire sequence and where the videotaped lesson fell in the sequence (e.g., lesson number 3 out of five lessons in the sequence).

- Between 96 and 99 percent of the eighth-grade science lessons in all the countries were taught by teachers who reported that the videotaped lesson was part of a sequence of lessons (data not shown). Table 2.8 shows that, on average, the total number of lessons in the larger sequence of which the videotaped lesson was a part ranged from 9 to 15 lessons across the participating countries. On average, the lessons captured on videotape were located mid-sequence in the lessons within the unit.

Table 2.8. Average number of eighth-grade science lessons in unit or sequence and placement of the videotaped lesson in unit, by country: 1999

Country	Average number of lessons in unit[1]	Average placement of the videotaped lesson in unit[2]
Australia (AUS)	15	8
Czech Republic (CZE)	9	4
Japan (JPN)	13	6
Netherlands (NLD)	11	6
United States (USA)	11	5

[1] Number of lessons: AUS>CZE, USA; JPN>CZE.

[2] Placement of the videotaped lesson in the unit: AUS>CZE, USA.

NOTE: Results based on science teachers' reports. Teachers were asked to provide information on whether the videotaped lesson was part of a larger unit or sequence of related lessons, or whether it was a stand-alone lesson. If the videotaped eighth-grade science lesson was part of a unit or sequence, the teacher was asked to identify how many lessons were in the entire sequence and where the videotaped lesson fell in the sequence.

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

Summary

The findings from analyses of the teacher questionnaire responses provide a context within which to interpret those results presented in the following chapters on the nature of the videotaped lessons. Among the findings is that most eighth-grade science lessons in the five participating countries were taught by teachers who described the videotaped science lesson as typical of their teaching, even though more time than usual was spent planning for the videotaped lesson in four of the participating countries and more Czech teachers thought the videotaping influenced their students' behavior than teachers in three other countries. These results suggest that the lessons captured on videotape were relatively typical of the lessons that eighth-graders would experience in school in these five countries.

Chapter 3: Instructional Organization of the Lessons

This chapter focuses on the ways teachers organize eighth-grade science lesson time. Examining how science lesson time is organized for different activity types and purposes lays the groundwork for understanding how science content ideas, processes, and structures are represented in the classroom (chapters 4-6) and the kinds of opportunities that students have to participate in learning science (chapters 7-11).

Research Background

Analysis of the use of time as related to lesson organization provides an indication of the potential learning time for eighth-grade students, an issue the research literature suggests is an important predictor of academic learning (Denham and Lieberman 1980; Marzano 2000; National Commission on Excellence in Education 1983; Scheerens and Bosker 1997). The effective use of time is also one of the most consistent school factors related to student achievement (Hossler, Stage, and Gallagher 1988; Kane 1994; National Research Council (NRC) 1996). Maximizing the amount of instructional time, and especially the amount of time students are engaged in academic tasks, is correlated with higher student achievement (Denham and Lieberman 1980; Marzano 2000; Scheerens and Bosker 1997).

Investigations of the use of time in science lessons can reveal to what extent the lesson focused on science instruction, science organization issues, and non-science matters. Examination of how time is allocated within lessons can also reveal patterns of time usage for different purposes, for example, by focusing on development of new ideas, review of previous content, student assessment and homework.

At a gross level, how science teachers in each of the five participating countries organized lessons, and how much time was spent during the lessons on different purposes, sets the stage for much of the work that is accomplished in eighth-grade science. The organization of the lesson can enable or limit both the science content that is taught and the way that content is taught. For example, lessons that include time for practical, hands-on science activities and lessons that focus entirely on whole-class lecture and discussion provide students with different images of science and different science learning opportunities (Monk and Dillon 2000).

Chapter 3 focuses on four main questions about different organizational elements of eighth-grade science lessons:

- How much time was spent studying science and how was that time allocated during the lesson?
- How was the lesson organized for different instructional purposes?
- How was the lesson organized for practical and seatwork activities?
- How was the lesson organized for whole-class and independent work?

Together, these elements of lesson organization can contribute to the shape of science learning opportunities available to eighth-grade students. The analyses of the video data presented in this report are not meant to portray which country creates the "right" environment for eighth-grade students. Rather, the comparisons of science teaching provide educators an opportunity to examine the choices made about the organization of the lessons and, as we will see later in the report, about how science is presented and represented to students.

How Much Time Was Spent Studying Science?

Lesson Length

- Although the eighth-grade science lessons had a mean length between 46 and 51 minutes across the countries, a wide range of lesson lengths was found in some countries (table 3.1). The median length is a better measure for gauging the length of a typical lesson. In four of the five countries, the median length of an eighth-grade science lesson was 45 to 46 minutes. In Japan, the median length was 51 minutes.
- Figure 3.1 graphically provides a more detailed look at the variation in lesson length, indicating the lessons that were extremes or outliers in terms of duration. In the Czech Republic, Japan, and the Netherlands, lesson length for the middle 50 percent of lessons varied by no more than 4 minutes. The middle 50 percent of U.S. lessons varied in length by up to 12 minutes and Australian lessons by 17 minutes. This pattern was found even when outliers and extremes were excluded from the analysis (see whiskers on figure 3.1).

Table 3.1. Mean, median, range, and standard deviation (in minutes) of the duration of eighth-grade science lessons, by country: 1999

Country	Mean[1]	Median	Range	Standard deviation[2]
Australia (AUS)	49	45	21–92	14
Czech Republic (CZE)	46	45	39–52	1
Japan (JPN)	50	51	40–65	4
Netherlands (NLD)	47	46	37–90	8
United States (USA)	51	46	33–119	16

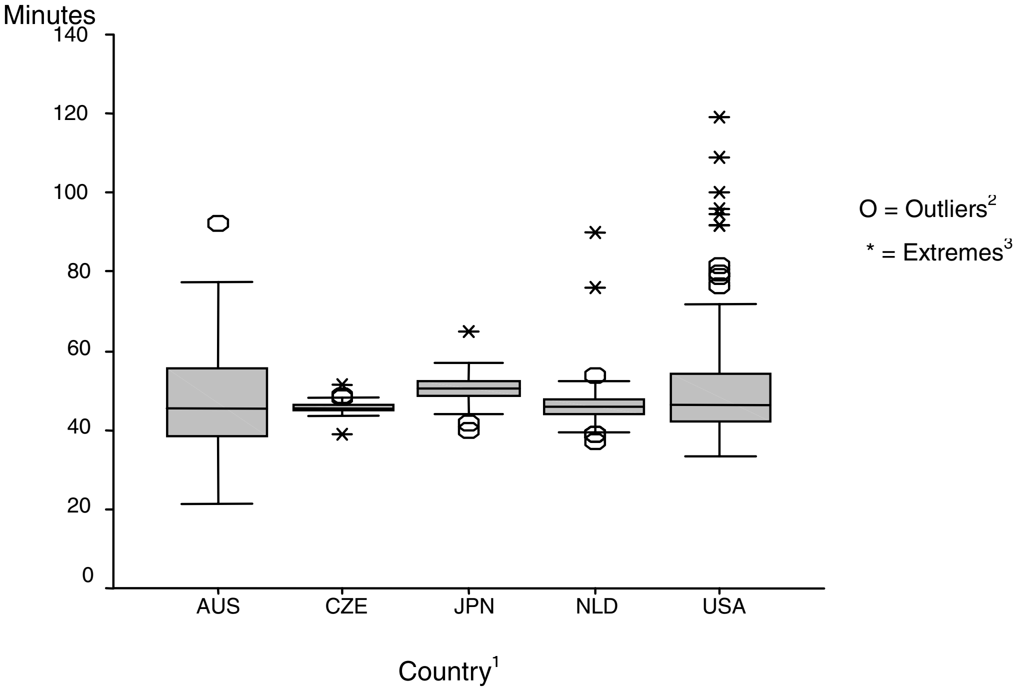
[1] Mean: JPN, USA>CZE; JPN>NLD.

[2] Standard deviation: AUS, JPN, NLD, USA>CZE; USA>JPN, NLD; AUS>JPN.

NOTE: Mean was calculated as the sum of the number of minutes of each lesson divided by the number of lessons within a country. For each country, median was determined by identifying the number of minutes in the lesson below which 50 percent of all lessons fell. Range describes the lowest number of minutes and the highest number of minutes observed within a country. 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.

Figure 3.1. Box and whisker plot showing the distribution of eighth-grade science lesson durations, by country: 1999



[1]AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
[2]Outliers (values are 1.5 to 3.0 box lengths from upper or lower edge of box).
[3]Extremes (values greater than 3.0 box lengths from the upper or lower edge of the box).
NOTE: The shaded box represents the interquartile range, containing 50 percent of the lessons. The lines extending from the box indicate the highest and lowest values, excluding outliers and extremes. The horizontal line within the box indicates the median lesson time (half of the numbers fall above or below this value).
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Science Instruction, Science Organization, and Non-Science

Not every moment between the beginning and the end of a lesson is spent on events and activities directly related to eighth-grade science. For example, there are times during the lesson when the teacher carries out administrative tasks, disciplines students, or organizes physical arrangements for the students to conduct a laboratory experiment. To measure the amount of time during which the students had an opportunity to learn science, the following four categories were defined to segment the lesson.

- ***Science instruction***: Time in the lesson when the teacher and at least one student engage in activities that provide opportunities for students to learn science. Examples of such activities include the teacher explaining science concepts, the class conducting and discussing experiments, and the students working on written assignments.
- ***Science organization***: Time in the lesson that the teacher sets aside for organizational activities and discussions that are related to science study. Organizational activities include

distributing or gathering papers or science materials, putting away or cleaning up science materials, talking about test grades or due dates without mentioning any science content, and students rearranging themselves to watch a science demonstration. These activities and discussions usually are connected to the preparation, follow-up, or completion of science instruction activities. No explicit science instruction is conducted during this time, and students do not have any obvious opportunity to work on a science assignment.

- ***Non-science***: Time in the lesson when no science-related activities or discussions take place and, therefore, students have no obvious opportunity to learn science. Non-science activities include the teacher taking attendance, announcing school events, disciplining students, and interruptions by outside sources such as a visitor.
- ***Technical difficulty***: Time in the lesson when a technical problem with the video occurs which prevents accurate categorizing.

Table 3.2 presents the length of science instruction time in minutes and Figure 3.2 illustrates the average percentage of lesson time spent on science instruction, science organization, and non-science.

- Between 43 and 48 minutes, on average, were devoted to science instruction across countries, with median durations ranging from 42 to 48 minutes (table 3.2). Japanese lessons devoted more average time to science instruction than Czech and Dutch lessons.
- Czech and Japanese science lessons maximized time focused on science instruction. Eighth-grade science lessons in the Czech Republic allocated more time for science instruction and less time for science organizational activities than the other four countries (figure 3.2). Japanese science lessons included more time for science instruction than Australian and Dutch science lessons.
- Eighth-grade science teachers and students within each of the five countries spent a higher percentage of lesson time engaged in science instructional work than in non-science work or science organization (figure 3.2).
- More science organization time may be expected in eighth-grade lessons where students carried out experiments or other practical activities. When science organization time was compared in lessons in which students carried out independent practical activities and in lessons in which students carried out independent seatwork activities,[6] the average percentage of science organization time was not measurably different within Japan and within the Netherlands (data not shown). In Australia, however, a larger average proportion of time was allotted for science organization in those lessons that involved students in doing hands-on practical work independently. Conversely, within the Czech Republic and the United States, a smaller proportion of time was allotted for science organization in lessons that involved students in doing hands-on practical work independently.

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[6] Independent practical activities are activities that provide students with the opportunity to observe and/or interact first-hand with science objects and science-related phenomena. Independent seatwork activities are those activities that did not involve the use of science objects or science-related phenomena. More comprehensive definitions of both types of activities are provided in the last section of this chapter.

Table 3.2. Mean, median, range, and standard deviation (in minutes) of actual science instruction time of eighth-grade science lessons, by country: 1999

Country	Mean[1]	Median	Range	Standard deviation[2]
Australia (AUS)	44	42	16-89	13
Czech Republic (CZE)	44	44	39-51	2
Japan (JPN)	48	48	38-59	4
Netherlands (NLD)	43	42	32-84	7
United States (USA)	47	43	30-119	15

[1] Mean: JPN>CZE, NLD.

[2] Standard deviation: AUS, JPN, NLD, USA>CZE; AUS, USA>JPN; USA>NLD.

NOTE: Mean was calculated as the sum of the number of minutes spent on science instruction of each lesson divided by the number of lessons within a country. For each country, median was determined by identifying the number of minutes in the lesson below which 50 percent of all lessons fell. Range describes the lowest number of minutes and the highest number of minutes observed within a country. 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.

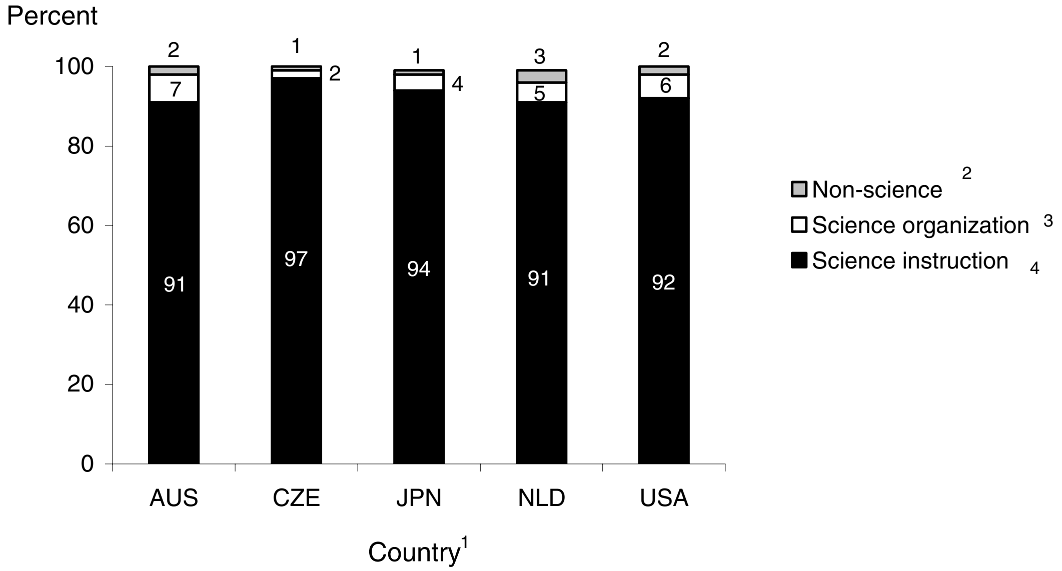
Lesson Interruptions

Interruptions by an outside source (e.g., telephone, intercom, or visitor), by non-science segments in the middle of the lesson, or by multiple science organization segments were examined. These types of interruptions to the lesson flow indicate how countries organize their lessons with a minimum of interruptions. See appendix D for definitions of interruptions and other constructs investigated in this study.

- Eighth-grade science lessons in the Czech Republic included fewer incidences of outside interruptions and science organization than Australian and U.S. lessons. Lessons in the Netherlands included fewer outside interruptions than Australian and U.S. lessons but more interruptions by non-science activities than Australian, Japanese, and U.S. lessons (figure 3.3).

A smaller percentage of science lessons in the Czech Republic and Japan experienced at least three or more interruptions (by outside sources, by non-science activities, and/or by science organizational activities) compared to science lessons in the other countries (figure 3.3).

Figure 3.2. Average percentage of eighth-grade science lesson time devoted to non-science, science organization, and science instruction, by country: 1999



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

[2] Non-science: NLD>CZE, JPN.

[3] Science organization: AUS, JPN, NLD, USA>CZE; AUS>JPN.

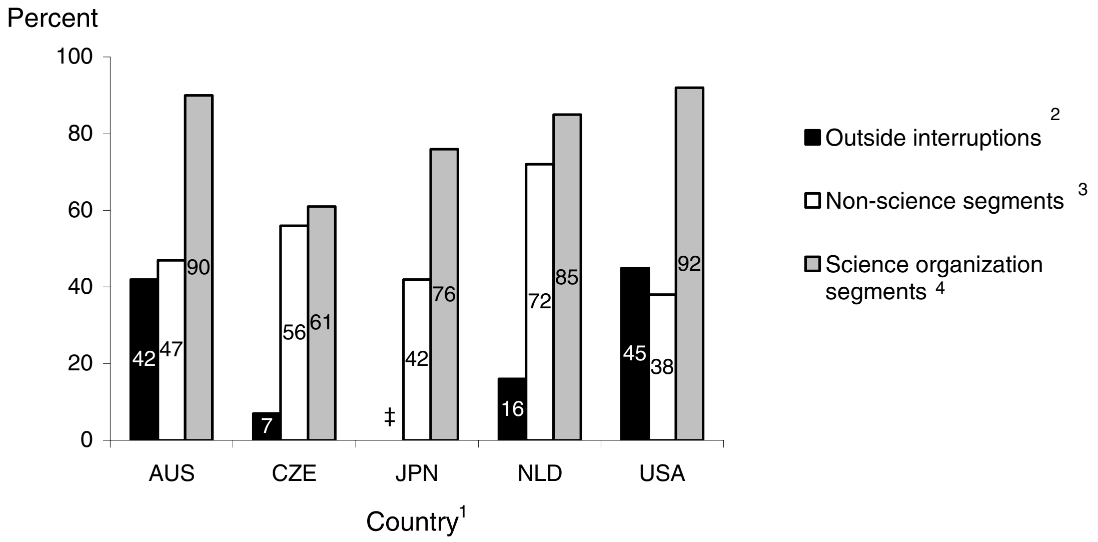
Science organization and non-science: AUS, JPN, NLD, USA>CZE; AUS, NLD>JPN.

[4] Science instruction: CZE>AUS, JPN, NLD, USA; JPN>AUS, NLD.

NOTE: Total may not sum to 100 because of rounding and data not presented for the category technical difficulties. 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.

Figure 3.3. Percentage of eighth-grade science lessons with any instance of outside interruptions, non-science segments, and science organization segments, 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] Outside interruptions: AUS, USA>CZE, NLD.

[3] Non-science segments: NLD>AUS, JPN, USA.

[4] Science organization segments: AUS, NLD, USA>CZE; USA>JPN.

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

How Was the Lesson Organized for Different Instructional Purposes?

To capture various purposes of lesson parts, the following five categories were developed and defined:

- ***Developing new content:*** Period of time when the main instructional activity takes place. The purpose of such activities is to present, develop, elaborate, or apply scientific concepts, ideas, and/or procedures.
- ***Reviewing previous content:*** Period of time during the lesson when the content presented to students in previous lessons is repeated or revisited. No new content information is provided during this time except for simple referencing (🎥 Video clip example 3.1).
- ***Going over homework:*** Period of time during the lesson that the teacher sets aside to correct, check, or go over students' homework after they had worked on or completed the assignment at home (🎥 Video clip example 3.2).
- ***Assessing student learning:*** Time period during the lesson that the teacher sets aside to formally assess and/or grade students' work individually, as a small group, or as a whole class, either orally or in writing, or to check and/or go over tests, quizzes or other assessments that were previously completed (in the videotaped lessons or in previous lessons) (🎥 Video clip example 3.3).

- ***Other purposes:*** A period during the lesson that the teacher sets aside for other purposes such as assigning homework or completing administrative tasks.

Table 3.3 presents the percentage of science lessons that contained at least one segment of a given type of lesson purpose and table 3.4 indicates the percentage of lesson time spent on each lesson purpose. Figure 3.4 shows the percentage distribution of lessons that only developed new content compared to lessons that included both review and new content development.

- Almost all of the eighth-grade science lessons in each country gave at least some attention to the development of new science content (table 3.3).
- Countries emphasized different purposes in their eighth-grade science lessons. Compared to the Czech Republic, the Netherlands, and the United States, a larger proportion of time in Japanese science lessons was spent on the development of new content (table 3.4). In contrast, science lessons in the Czech Republic were found to devote more time to the review of previously introduced content and more time for assessing student learning than lessons in three of the other countries. The Netherlands devoted more time during science lessons to going over homework than in the other countries. When examining only those Dutch lessons containing time to go over homework, it was found that an average of 25 percent of lesson time was focused on going over homework (data not shown).
- At least 57 percent of science lessons in all the countries except the Czech Republic focused only on developing new content with no review of previous content (figure 3.4). Science instruction in more Czech lessons both developed new content and reviewed previous learning compared to the other four countries.

How Was the Lesson Organized for Practical and Seatwork Activities?

Science lessons may include practical activities in which the teacher and/or students carry out experiments and other kinds of “hands-on” activities in addition to “seatwork” activities such as teacher lectures, class discussions, reading, and writing. Many countries emphasize the importance of practical activities, whether they describe them as involving investigations, inquiry, replications, demonstrations, project- or problem-based studies, or experimental work (Beatty and Woolnough 1982; Jenkins 1999; Kerr 1964; NRC 1996; Swain, Monk, and Johnson 1998; Watson 2000; Watson and Prieto 1994).

“Practical activities” is a term used in some countries to describe what may be referred to in other countries as “hands-on” or “laboratory” activities. The term “practical” is used in this report because it references or suggests a wider range of activities than may be suggested by the term “laboratory.” In this study, practical activities were defined as those activities that provide students with the opportunity to observe and/or interact first-hand with objects and related phenomena. Practical activities include teacher demonstrations of phenomena and objects as well as student participation in traditional laboratory experiments and other hands-on interactions with objects such as producing and observing phenomena, building models, designing and testing technological solutions to problems, and observing objects.

In contrast, some studies point to stronger learning outcomes as a result of participation in seatwork activities compared to practical activities (Hodson 1993; Watson, Prieto, and Dillon 1995). "Seatwork activities" in this study refers to those activities seen in the videotaped science lessons that did not involve the use of objects. Seatwork activities include teacher lecture, class discussion, reading text, copying notes, small group discussions, and students' work on paper-and-pencil activities. The term "seatwork" should not be interpreted as meaning that students always stayed in their seats. For example, students might be out of their seats working on a large poster drawing on the floor. It should also be noted that students are often in their seats during practical activities; however, for the purposes of this study practical activities are not considered seatwork.

Table 3.3. Percentage of eighth-grade science lessons that contained at least one segment of a given type of lesson purpose, by country: 1999

Purpose	Australia (AUS)	Czech Republic (CZE)	Japan (JPN)	Netherlands (NLD)	United States (USA)
Developing new content[1]	97	99	100	99	96
Reviewing previous content[2]	41	84	33	8	42
Going over homework[3]	2	3!	‡	45	17
Assessing student learning[4]	‡	50	5	18	14
Other purposes[5]	99	98	99	100	92

!Interpret data with caution. Estimate is unstable.

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

[1] Developing new content: No measurable differences detected.

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

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

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

[5] Other purposes: NLD>USA.

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

Table 3.4. Average percentage distribution of eighth-grade lesson time devoted to each type of lesson purpose, 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: Total may not sum to 100 because of rounding and data not reported. 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.

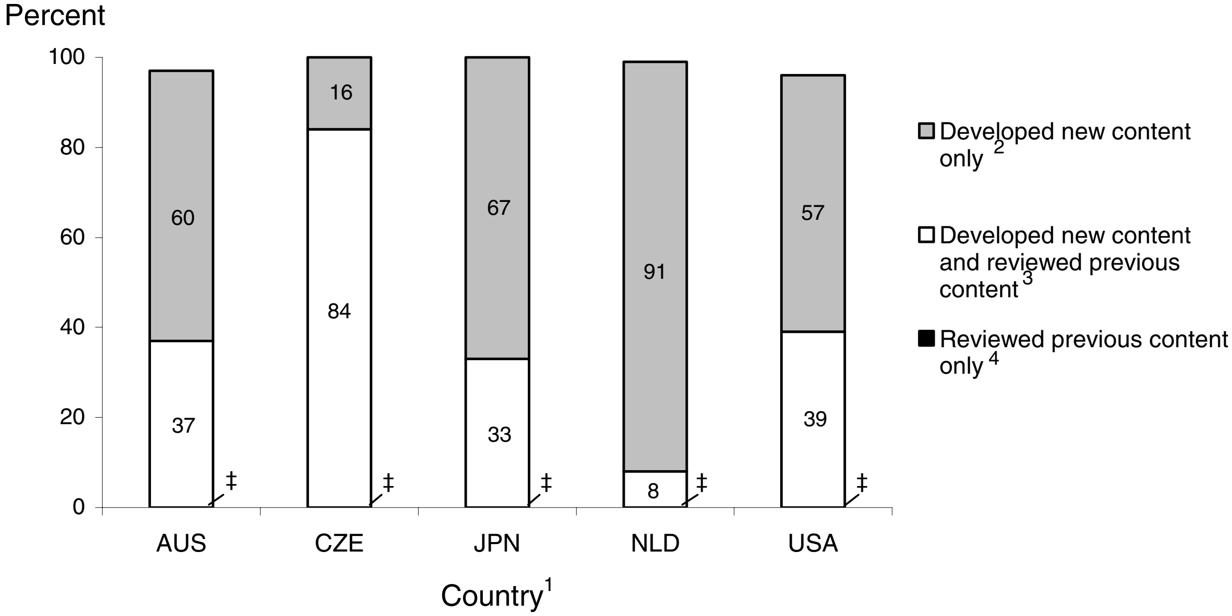
The percentage of lessons that contained practical and seatwork activities is presented below and the percentage of lesson time allocated to practical and seatwork activities is presented in figure 3.5.

- Practical activities occurred in at least 72 percent of eighth-grade science lessons in each country, with more lessons containing practical activities in Australia (90 percent) than in the Netherlands (72 percent) (data not shown). Seatwork activities occurred in 100 percent of the science lessons in all the countries.

- Australian and Japanese lessons allocated larger percentages of science instruction time to practical activities than the other three countries, and smaller percentages of science instruction time to seatwork activities than the Czech Republic and the United States. Science lessons in the Czech Republic allocated a larger percentage of science instruction time to seatwork activities than the science lessons in the other countries with the exception of the United States.

- On average, all of the countries allocated a larger proportion of science instruction time to seatwork activities (57 to 84 percent) than to practical activities (14 to 43 percent; figure 3.5).

Figure 3.4. Percentage distribution of eighth-grade science lessons that developed new content only, developed new content and reviewed previous content, and reviewed previous content only, 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] Developed new content only: AUS, JPN, NLD, USA>CZE; NLD>AUS, JPN, USA.

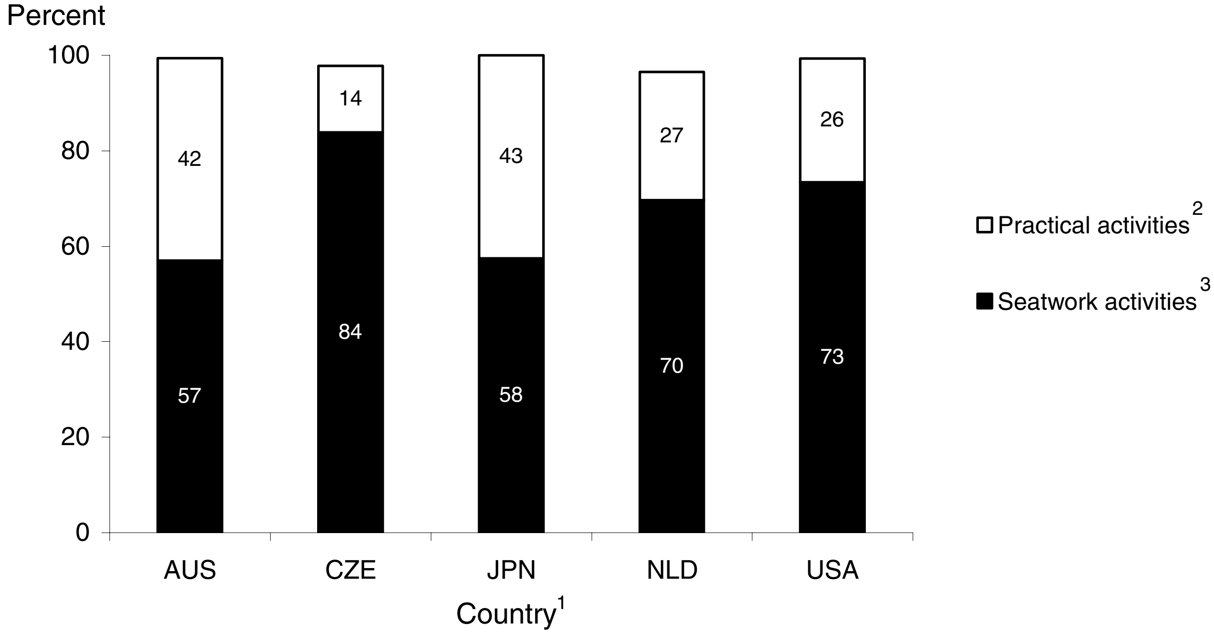
[3] Developed new content and reviewed previous content: CZE>AUS, JPN, NLD, USA; AUS, JPN, USA>NLD.

[4] Reviewed previous content only: No measurable differences detected.

NOTE: Total 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.

Figure 3.5. Percentage distribution of science instruction time in eighth-grade science lessons devoted to practical activities and seatwork activities, by country: 1999



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

[2] Practical activities: AUS, JPN>CZE, NLD, USA; USA>CZE.

[3] Seatwork activities: CZE, USA>AUS, JPN; CZE>NLD.

NOTE: Total may not sum to 100 because of rounding and data not presented for 'divided class work' (see figure 3.6). Analysis is limited to those portions of lessons focused on science instruction. See table 3.2 and figure 3.2 for more details.

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

How Was the Lesson Organized for Whole-Class and Independent Work?

Science activities were observed to take place as a whole class working together or as an independent activity where students worked either individually or in small groups. At times, science lessons were conducted in a divided class arrangement, where the teacher worked with part of the class while the rest of the class worked independently**.** See appendix D for more details on measures investigated in this study.

- The vast majority of eighth-grade science lessons contained at least some independent work (ranging from 92 percent of lessons in the Czech Republic to 100 percent in Australia) and at least some whole-class work (ranging from 98 percent in the Netherlands to 100 percent in the Czech Republic, Japan, and Australia; data not shown). Divided class work occurred in no more than 18 percent of the eighth-grade science lessons in all of the countries, accounting for no more than 4 percent of science instruction time in any of the countries (figure 3.6).

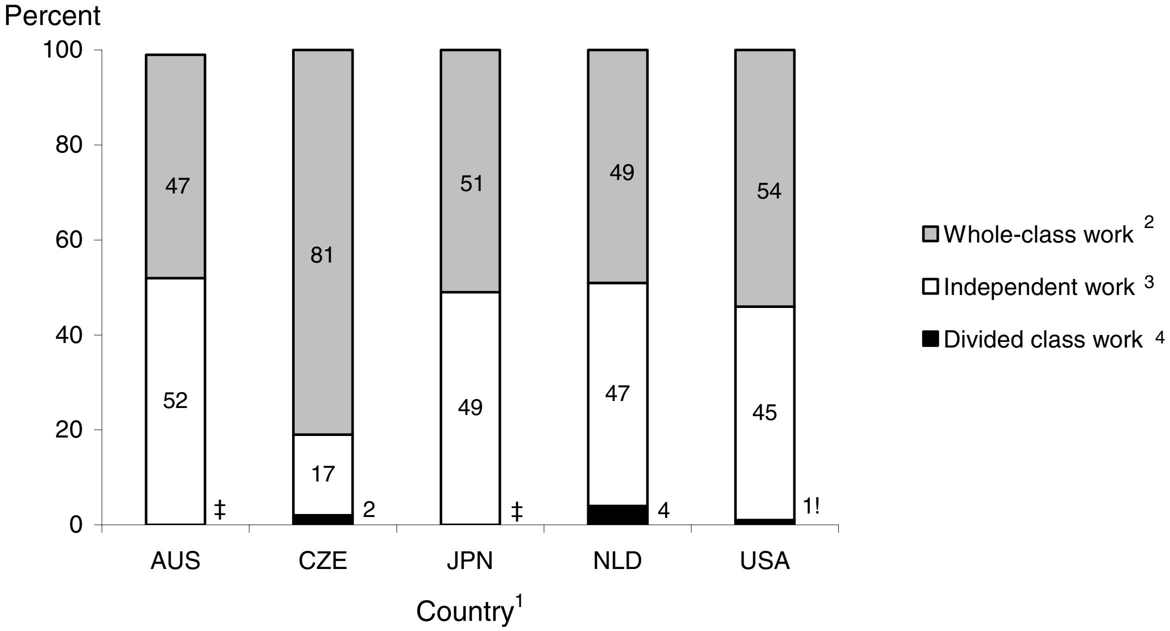
- Within all the participating countries except the Czech Republic, no measurable differences were found in the percentage of science instruction time that students worked as a whole-class or independently (figure 3.6). In the Czech science lessons, 81 percent of science instruction time was organized as a whole-class activity.

Practical and Seatwork Activities During Whole-Class and Independent Work

Practical and seatwork activities may occur in a whole-class setting or while students work independently. To explore further the nature of science activities across the countries, the relationship between practical and seatwork activities and the organization of the lesson in terms of whole-class or independent work was examined. The combination of activity and social organization types are described as follows:

- ***Independent practical activities:*** Hands-on work such as students conducting a laboratory experiment. Students are working either individually or in small groups on tasks that involve observing, handling, or manipulating objects, materials, 3-dimensional models, or organisms. Whole-class discussion time that precedes or follows the hands-on work is not included as part of the independent practical activity. (🎥 Video clip example 3.4)
- ***Independent seatwork activities:*** Students work individually or in small groups on student assignments, copying notes, and/or reading silently. Other examples of independent seatwork activities include answering questions in writing, writing an essay, drawing and/or labeling diagrams, completing worksheets, brainstorming ideas in a small group discussion, copying down or reading any written or drawn information presented on the blackboard, an overhead transparency, the textbook, or some other source. (🎥 Video clip examples 3.5 and 3.6)
- ***Whole-class practical activities:*** Teacher demonstrations ranging from simple displays of science-related objects ("this is an ammeter" or "this is a model of a heart") to displays of objects with related phenomena (for example, using objects to show a chemical reaction) to public demonstration of complete experiments. These activities do not include discussion time that precedes or follows the observations. (🎥 Video clip examples 3.7 and 3.8)
- ***Whole-class seatwork activities:*** Oral lectures or discussions, often augmented by visuals. Examples of seatwork whole-class activities include the teacher presenting a new idea by showing and talking about a diagram, graph, map, or photograph or the teacher playing a videotape that presents both audio and visual information about the science content. (🎥 Video clip examples 3.9 and 3.10)

Figure 3.6. Percentage distribution of science instruction time in eighth-grade science lessons devoted to whole-class work, independent work, and divided class work, by country: 1999



!Interpret data with caution. Estimate is unstable.

‡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] Whole-class work: CZE>AUS, JPN, NLD, USA.

[3] Independent work: AUS, JPN, NLD, USA>CZE.

[4] Divided class work: No measurable differences detected.

NOTE: Total may not sum to 100 because of rounding and data not reported. Analysis is limited to those portions of lessons focused on science instruction. See table 3.2 and figure 3.2 for more details.

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

Practical activities occurred in at least 72 percent of the eighth-grade science lessons in the five countries (data not shown). The organization of the work and the amount of time allotted to it varied across the countries.

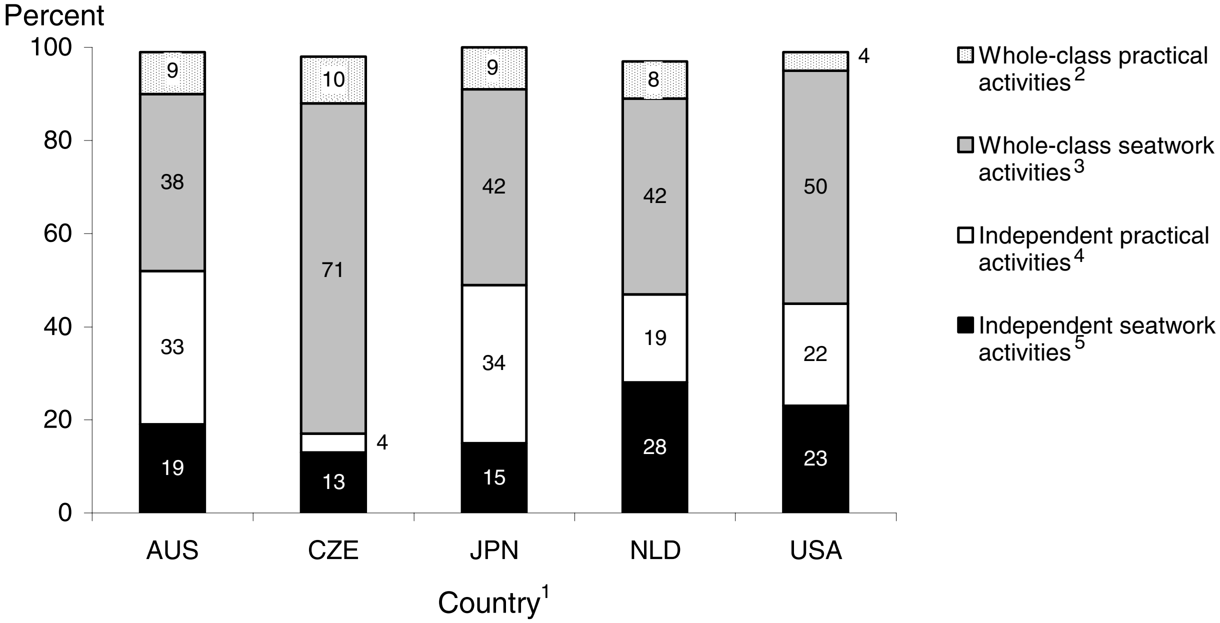
- Independent practical activities occurred in fewer Czech and Dutch science lessons than in Australian and Japanese science lessons. In the United States, fewer lessons than Australia and more lessons than the Czech Republic provided students with independent practical activities (table 3.5).
- Australian 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 3.7).
- Dutch science lessons allocated more time for independent seatwork activities than Czech and Japanese science lessons (figure 3.7).
- 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 3.7). (🎥 Video clip examples 3.7, 3.8, 3.9, and 3.10)

Table 3.5. Percentage of eighth-grade science lessons that contained at least one segment of each combination of science activity and lesson organization type, by country: 1999

Lesson organization type	Activity type	Examples of activities	Country[1]				
			AUS	CZE	JPN	NLD	USA
Whole-class	Practical[2]	Discussing and showing objects to whole class, demonstrations	81	80	77	62	69
	Seatwork[3]	Presentations, discussions	100	100	100	98	99
Independent	Practical[4]	Experiments, model building	74	23	67	30	47
	Seatwork[5]	Answering written questions, discussing in small groups, copying notes from blackboard, reading textbook	88	88	81	77	86

[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
[2] Whole-class practical activities: No measurable differences detected.
[3] Whole-class seatwork activities: No measurable differences detected.
[4] Independent practical activities: AUS, JPN>CZE, NLD; AUS>USA; USA>CZE.
[5] Independent seatwork activities: No measurable differences detected.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Figure 3.7. Percentage distribution of science instruction time in eighth-grade science lessons devoted to each combination of science activity and social organization type, by country: 1999



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

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

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

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

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

NOTE: Total 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 for more details.

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

Summary

In addition to setting the stage for examination of the science content of the lesson, the descriptions in this chapter also begin to address questions about how science was represented in the lesson and how students were involved in doing science work. The findings suggest differences among the countries in the time set aside for various purposes in science lessons, the kinds of activities that students work on, and whether these activities are carried out independently or in a whole-class setting. Czech and Japanese science lessons maximized lesson time spent on science instruction. Czech lessons devoted a larger percentage of time to reviewing previously introduced content than all the other countries, and allocated more time for assessing student learning than three of the other countries. Dutch lessons spent more time on going over homework than all of the other countries with reliable estimates. Students in Australian and Japanese classrooms worked independently on hands-on practical activities for a higher percentage of lesson time than students in the Czech Republic and the Netherlands. In contrast, students in Czech eighth-grade science lessons were engaged in whole-class activities for 81 percent of the lesson time, more than in all of the other countries.

Chapter 4: Science Content of the Lessons

This chapter describes the content of the eighth-grade science lessons according to disciplines (i.e., earth science, life science, physics, chemistry, and other areas), topics within those disciplines, and the types of science knowledge that were addressed in the lesson. Both the research literature and the standards and curriculum documents have different ways of thinking about content of the science curriculum.

Research Background

The history of science education is characterized by debates about what science content should be learned in school science classes. Current debates in the field focus on the appropriate balance of different types of knowledge in the science curricula. Among the many issues raised during these debates are the degree to which curricula should focus on mastering facts, definitions, and concepts versus developing scientific inquiry abilities (Bybee 2000; Lehrer et al. 2000; Metzenberg 1998a; Schultz 1998; Strauss 2004); the degree to which societal and technological issues linked to real-world problems should form the basis of science curricula (Bybee 1987; Eijkelhof and Voogt 2001; Moje, Collazo, Carillo, and Marx 2001); and the degree to which curricula should focus on student understanding of major themes about the nature of science and big ideas that cut across the traditional disciplines or on specific knowledge of the traditional science disciplines (California Department of Education 2000; Metzenberg 1998a, 1998b; National Science Teachers Association 1992a, 1992b).

In some countries, science teaching has been characterized as emphasizing science as a body of canonical knowledge (i.e., the body of knowledge taken to be fact) (Bybee and DeBoer 1994; DeBoer 1991; Osborne 2000). This is based on qualitative and survey studies that portray science teaching and science textbooks in these countries as focusing on the facts, concepts, theories, and ideas that are produced by the scientific community and paying less attention to the nature and history of science, the connections between science and societal applications, and the importance of science to society (Bybee and DeBoer 1994; DeBoer 1991; Eichinger and Roth 1991; Helgeson, Blosser, and Howe 1977; Kesidou and Roseman 2002; Stake and Easley 1978; Weiss 1978). In other countries, observations of science teaching suggest more emphasis on knowledge about scientific inquiry processes, the connections between canonical knowledge and societal applications, and the nature of scientific knowledge (e.g., Andersson 2000; Australian Education Council 1994; Board of Studies 1995; DeVos and Reiding 1999; Goto 2001; Millar and Osborne 1998; Moller Anderson, Schnack, and Sorensen 1995; NRC 1996; OECD/PISA 1999).

Including societal and real-life issues in the content of school science curricula is supported in some countries as a strategy for clarifying and illustrating science concepts, capturing students' interests and helping students see the usefulness of science concepts. In support of this, research on student learning suggests the need for students to see the wide usefulness of an idea in a variety of real-world contexts before that idea will become meaningfully understood (Anderson and Roth 1989; Driver et al. 1994; Hewson, Beeth, and Thorley 1998; Posner et al. 1982). Results from studies of learning and motivation have led many researchers to emphasize the importance of "situated cognition" and authentic contexts to promote learning (Brown, Collins, and Duguid 1989; Edelson 1998; Moje et al. 2001; Roth 1995). Other researchers advocate using real-life issues to develop students' conceptual understandings; they put real-life issues at the center of the curriculum, emphasizing knowledge about the interactions of science, technology, and society as the primary content in science instruction (Bybee 1987; Krajcik et al. 1998).

Cognitive science research describes another type of knowledge that may be explicitly addressed in science lessons. Meta-cognitive knowledge refers to information about strategies for learning (learning how to learn) or the importance of reflecting on one's knowledge and learning as part of the learning process. Meta-cognitive knowledge includes monitoring one's own comprehension, evaluating progress toward completing a task, and reflecting on how thinking and understandings have changed over time. Empirical research in various school subject matter areas provides promising evidence that teaching students to reflect on their thinking processes promotes content learning (Anderson and Roth 1989; Bielaczyc, Pirolli, and Brown 1995; Borkowski and Muthukrishna 1992; Novak and Gowin 1984; Otero and Companario 1990; Palincsar and Brown 1984; Pressley and Levin 1983; Scardamalia, Bereiter, and Steinbach 1984; Schoenfeld 1988).

Country Perspectives

Standards and curriculum documents from the countries in this study differ in the degree to which they emphasize different types of scientific knowledge.[7] The Czech Republic's national curriculum guidelines emphasize canonical knowledge (e.g., science facts, ideas, concepts or theories), communicating the science ideas that students are expected to learn about science (Kolavova 1998; Nelesovska and Spalcilova 1998). Documents in Australia, Japan, the Netherlands, and the United States suggest an approach which, in addition to canonical knowledge, also puts considerable emphasis on knowledge about scientific processes and real-life issues (Australian Education Council 1994; Board of Studies 1995; NRC 1996; Dutch Ministry of Education, Culture, and Science 1998; Ministry of Education, Science, and Culture [*Monbusho*] 1999). For instance, the Dutch document on science educational objectives highlights goals related to societal issues—for example, applications of biology in students' personal lives (consumer behavior, health, sexuality, and the environment), recognition and valuing biological aspects of social situations, and use of biological knowledge and skills to facilitate personal decisions (about education, employment, and social activity) (Dutch Ministry of Education, Culture, and Science 1998). Tenth-grade students are required to take an entire course that focuses on public issues in science education (DeVos and Reiding 1999). Current reform movements in Japan also call for increased emphasis on connecting science to real-life issues to make science more meaningful and interesting for students (Goto 2001). Earlier TIMSS 1999 findings indicated low percentages of Japanese students who report an interest in science or see science as important to their daily lives (Beaton et al. 1996; Goto 2001). The Czech Republic's curriculum guidelines, on the other hand, only briefly mention real-life issues (Czech

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[7] As stated in the introduction to this report, of the five participating countries, three (the Czech Republic, Japan, and the Netherlands) have national curricula and guidelines. Australia and the United States do not have national curricula, standards, or guidelines; rather, decisions regarding curricula are taken at the state, provincial, or local level. Therefore, in the case of Australia and the United States, references to standards, curricular guidelines, and reform documents should not be construed as official or definitive statements of national, state, provincial, or local governments. Rather, the documents cited for these two countries represent the most widely referenced and distributed curricular and standards documents available at the time the study was conducted.

Ministry of Education 1996). Public talk about issues such as the values and dispositions of science (e.g., open-mindedness, skepticism, and objectivity) and the nature of scientific knowledge (e.g., evidence-based or tentative) is one strategy for providing students with opportunities to learn about what it means to do science.

Australian and U.S. documents also emphasize understanding the nature of science, which includes understanding its history as an ongoing and changing enterprise, understanding the scientific values and habits of mind that underlie the doing of science, and understanding the role that science has played in the development of various cultures (Australian Education Council 1994; NRC 1996). Knowledge about the nature of science knowledge is not explicitly represented in curriculum documents in the other countries.

Knowledge about safety is specifically mentioned in standards and curriculum documents in each of the countries. For example, one of the general attainment targets in the Netherlands for science is "using materials, tools, and equipment safely and efficiently" (Dutch Ministry of Education, Culture, and Science 1998, p. 11). In the *National Science Education Standards* (NRC 1996) in the United States, safety is referenced within the content standard of "Design and Conduct of Scientific Investigations."

Defining Science Content

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

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

Chapter 4 focuses on two main questions about the nature of the science content of the eighth-grade science lessons in the five countries:

- Which science disciplines and topics are addressed in the lessons?

- What types of science knowledge are addressed in the lessons?

Which Science Disciplines and Topics Are Addressed in the Lessons?

The science topics in the lessons were identified using the TIMSS *Guidebook to Examine School Curricula* (McNeely 1997), which provided a common, international frame of reference for talking about science content. Although the guidebook identified frameworks for curriculum analysis other than science disciplines and topics (i.e., performance expectations and perspectives), analysis for this video study focused only on the science content disciplines and topics.

The content of each lesson was described at two levels: a content discipline category and a content topic subcategory. The major science disciplines include: earth science, life science, physics, chemistry, and other.[8] Eighth-grade students in the Czech Republic and the Netherlands are taught some of these science disciplines in separate courses (biology, chemistry, and physics), while in Australia, Japan, and the United States science is taught as integrated science disciplines or general science. An “other” category was used to describe disciplinary areas in science that were taught in only small percentages of eighth-grade science lessons. These include: science, technology, and mathematics; history of science and technology; environmental and resource issues related to science; nature of science; and science and other disciplines.

The content subcategories specify topics at the level typically used by the classroom teachers in describing the content of the lesson on the questionnaires (e.g., rocks and soil, organs and tissues, electricity, and chemical changes). Although multiple science topics may be included in one science lesson, only the primary science topic for each lesson was identified. The primary topic was defined as the topic that was addressed for the longest amount of science instruction time.

No statistical comparisons are made for curricular differences across countries because the video lessons were not sampled for specific disciplines or content. Therefore, discussion of the content disciplines covered in the videotaped lessons is limited to description of within-country content coverage only.

Content Disciplines

- At least 47 percent of Australian and Dutch eighth-grade science lessons addressed physics topics; 36 percent of Czech lessons addressed life science topics; 37 percent of Japanese lessons addressed chemistry and 36 percent addressed physics; and 28 percent of U.S. lessons addressed earth science (figure 4.1). Earth science appeared in 5 percent of Australian lessons and 7 percent of Japanese lessons.

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

- Except within the United States, the content disciplines observed within all of the other countries were not evenly distributed across the science lessons (figure 4.1). Within the United States, no measurable differences were found for any comparison between science content disciplines. Within Australia and Japan, more lessons addressed life sciences, physics, and chemistry than earth sciences, and physics than life sciences. More Australian lessons addressed physics than chemistry whereas more Japanese lessons addressed chemistry than life sciences. Within the Netherlands, more lessons addressed life science and physics than chemistry.
- The definition of earth science varied across the countries. Earth science was addressed in too few eighth-grade science lessons in the Czech Republic and the Netherlands to calculate reliable estimates. This fact could point to differing views of what qualifies as science and what qualifies as earth science. Educators in the Czech Republic and the Netherlands do not regard geology, meteorology, and other subject areas constituting earth science as a separate science (Dutch Ministry of Education, Culture, and Science 1998; Kolavova 1998; Nelesovska and Spalcilova 1998). Instead, these earth science topics are often included as part of physics or, more commonly, as geography which is considered a social science in other countries and, therefore, not sampled in this study.

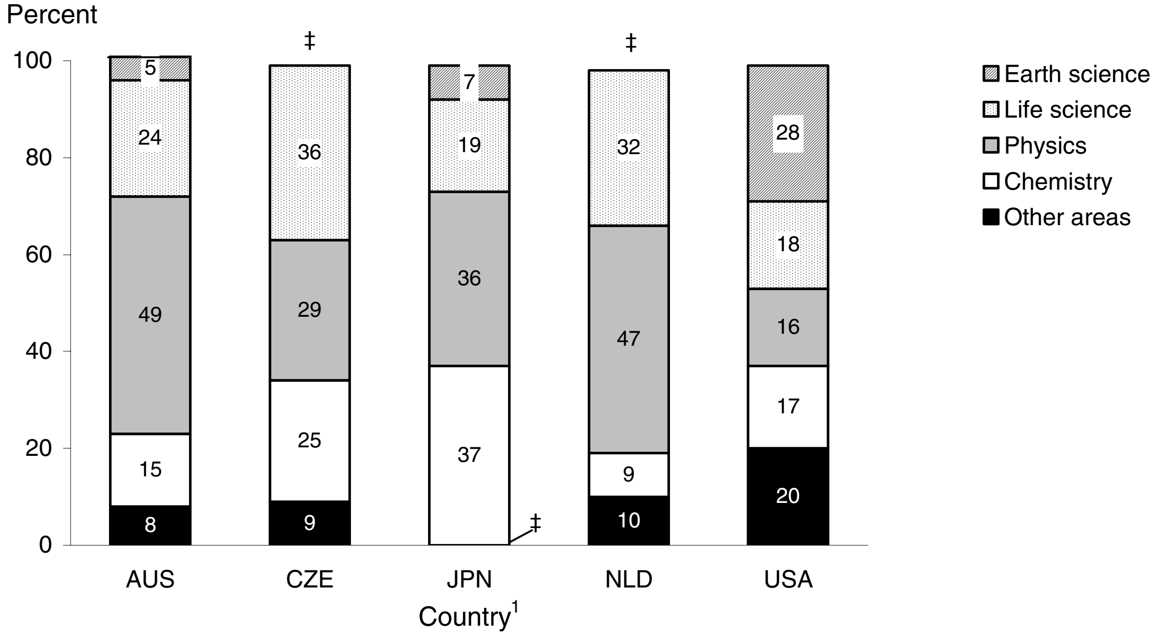
Content Topics

There were commonly taught topics in life and physical science areas:

- In life science, a commonly taught topic in the eighth-grade was organs and tissues which was the focus of 19 percent of Czech lessons, 13 percent of Japanese lessons, 16 percent of Dutch lessons, and 5 percent of Australian lessons. Organs and tissues was not a topic taught in any of the U.S. lessons.
- In physics, electricity was taught in all five countries, ranging from 3 percent of lessons in the Netherlands and the United States to 28 percent of the lessons in Japan. In Japan, two topics—chemical changes and electricity—accounted for 61 percent of the science lessons.
- Fourteen different topics were identified within the U.S. science lessons, and none accounted for more than 7 percent of the lessons. In comparison, Japanese lessons addressed seven different topics, with 33 percent of the lessons covering chemical changes, 28 percent targeting electricity, and 13 percent covering organs and tissues.

Tables E.1–E.5 in appendix E provide more specific information on the topics taught in the science lessons from the five countries.

Figure 4.1. 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.

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

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.

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

What Types of Science Knowledge Are Addressed in the Lessons?

During a science lesson many different types of science knowledge can be addressed. To identify and measure the amount of time during which the students had an opportunity to learn about different types of knowledge, the eighth-grade science lessons were segmented into the following six types of science knowledge.

- ***Canonical knowledge:*** Time in the lesson when the teacher or students publicly talk about or examine information about scientific facts, concepts, ideas, processes, or theories. Canonical knowledge is the "what" and "why" of science, or the knowledge that science produces. This type of propositional knowledge is commonly found in science textbooks. (🎥 Video clip example 4.1) Canonical knowledge can usually be characterized as one or more of the following types:
    - scientific conventions, labels, or identifications;
    - science concepts, or processes;
    - science-related patterns, trends, or laws; or
    - science-related explanations, theories, models, or interpretations.

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

- ***Real-life issues:*** Time in the lesson when the teacher and students publicly talk about or examine information about how science knowledge is used, applied, or related to societal issues or to students' personal lives. This type of knowledge includes any talk about real-life issues that is topically related to the content of the science lesson, but it may or may not be closely linked to the development of content ideas. (🎥 Video clip example 4.2) This type of knowledge includes:
    - talk about the relationship of personal experiences to science issues and ideas;
    - the uses of science knowledge in everyday life;
    - practical or motivational reasons to learn about science; or
    - everyday examples or illustrations of scientific ideas.

  For example, the teacher may lead a discussion about what it is like to ride a bike on the pavement as opposed to a gravel road to support an idea about friction.

- ***Procedural and experimental knowledge:*** Time in the lesson when the teacher or students publicly talk about or examine together information about how to do science-related practices such as manipulating materials and performing experimental processes. While canonical knowledge can be thought of as the products of scientific inquiry, procedural and experimental knowledge can be thought of as the knowledge used to arrive at these products. (🎥 Video clip example 4.3) The most common example of this kind of knowledge involves how to manipulate materials or perform experimental procedures (e.g., how to connect a circuit, how to use litmus paper to tell if a substance is an acid or a base). However, also included are teachers' directions about how to manipulate formulas (e.g., how to balance a chemical equation), and how to carry out scientific thinking practices in the lesson (e.g., "When you do this experiment, be sure to think about what evidence you are gathering that either supports or challenges your hypothesis").
- ***Classroom safety knowledge:*** Time in the lesson when the teacher or students publicly talk about science-related safety issues in the classroom environment. Examples of this type of knowledge include identifying dangerous materials and discussing how to handle materials safely (e.g., what to do if hydrochloric acid spills). (🎥 Video clip example 4.4)
- ***Nature of science knowledge:*** Time in the lesson when the teacher or students publicly and explicitly refer to issues about how science is conducted. Nature of science knowledge includes values of science and science dispositions (e.g., open-mindedness, skepticism, and objectivity), scientific methods, the scientific enterprise, how scientists work and communicate, the sociology of science, ethics in science, politics of science, and philosophy of science. For example, the teacher states: "In science, you must always support your explanations with evidence, and certain kinds of evidence are more persuasive than others." This would be considered nature of science because it makes explicit a view of science in general that goes beyond the particular activity or content being discussed. (🎥 Video clip examples 4.5 and 4.6)

- ***Meta-cognitive knowledge:*** Time in the lesson when the teacher or students publicly discuss or present information about strategies for learning (learning how to learn) or the importance of reflecting on one’s knowledge and learning as part of the learning process. Examples of this type of knowledge include the teacher modeling thinking (e.g., the teacher shows students how to work through a difficult problem or students reflect on how or why their thinking has changed). (🎥 Video clip example 4.7)

The above categories were applied to all the lessons but restricted to those sections of the lesson when the intended audience of the speaker (the teacher or a student) was the whole class. These sections of the lesson are identified as public talk segments. Public talk segments usually occurred during whole-class interactions, but there were occasions when the teacher spoke briefly to the whole class while they were working on an independent activity. Public talk during an independent activity was included in these analyses.[9] The above categories were not applied to non-public segments of the lesson because of the nature of independent work and the limits of the video methodology. During independent work, students were typically working independently on a set of tasks that may involve different types of knowledge occurring for different students at different points in time**.**

Canonical Knowledge

- Across all five participating countries, 84 percent or more of the eighth-grade science lessons publicly addressed canonical knowledge (figure 4.2). Lessons in the Czech Republic devoted a larger proportion of public talk time, on average, to addressing canonical knowledge (59 percent) than lessons in the other countries (figure 4.3).

Real-Life Issues

- Knowledge about real-life issues was publicly developed in at least 61 percent of the eighth-grade science lessons in all of the countries (figure 4.4). Japanese lessons allocated less public talk time to real-life issues than Czech, Dutch, and U.S. lessons (figure 4.5).

Procedural and Experimental Knowledge

- Across the five participating countries, at least 69 percent of the eighth-grade science lessons publicly addressed procedural and experimental knowledge (figure 4.6).
- Japanese science lessons devoted more time, on average, to publicly addressing procedural and experimental knowledge than lessons in each of the other countries (figure 4.7). Thus, although Australian and Japanese lessons were not found to differ measurably in the amount of time spent on independent practical activities (see chapter 3, figure 3.7), they varied in the amount of time allocated for public talk about procedures and experimental knowledge.

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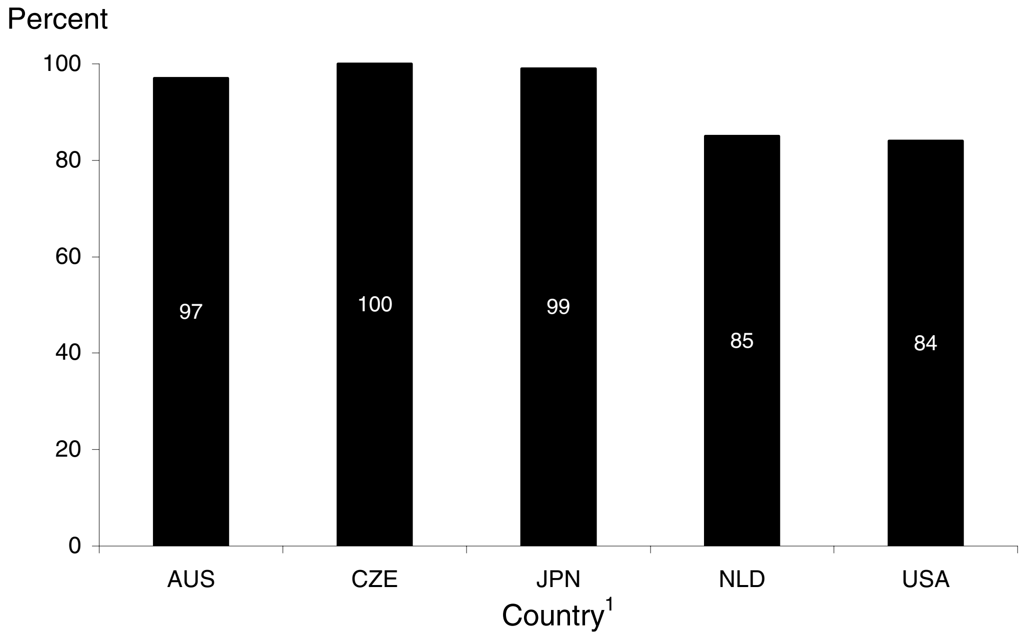
[9] For more details on public talk, see chapter 9.

Figure 4.2. Percentage of eighth-grade science lessons that addressed canonical knowledge during public talk, by country: 1999

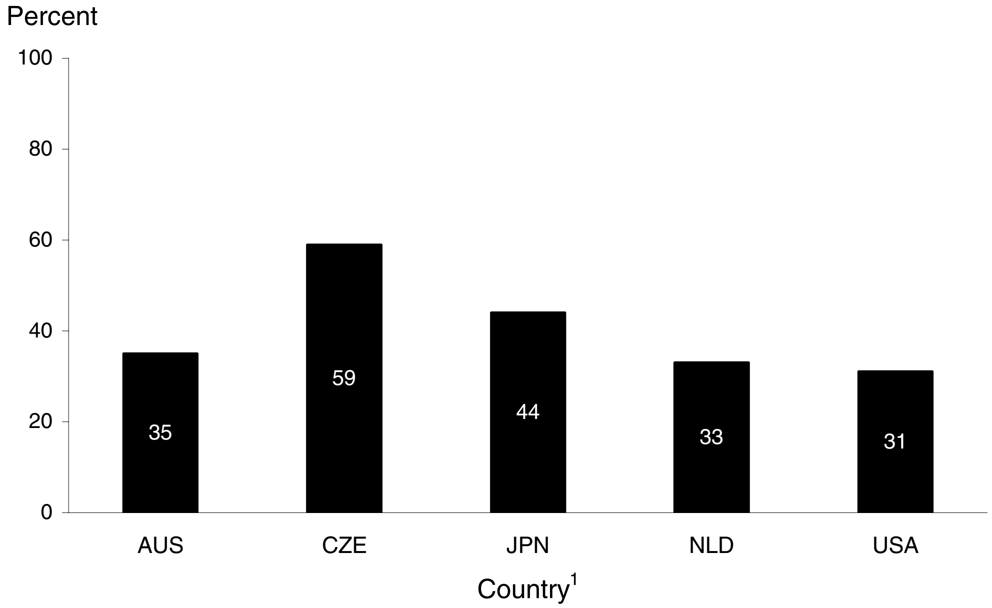


[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

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

Figure 4.3. Average percentage of public talk time in eighth-grade science lessons devoted to canonical knowledge, by country: 1999

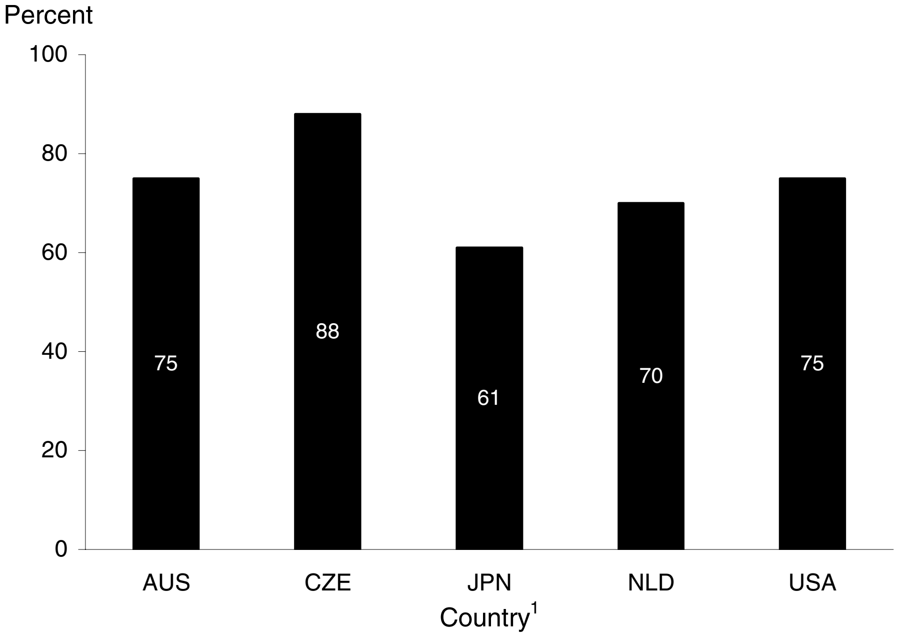


[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

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.

Figure 4.4. Percentage of eighth-grade science lessons that incorporated real-life issues during public talk, by country: 1999

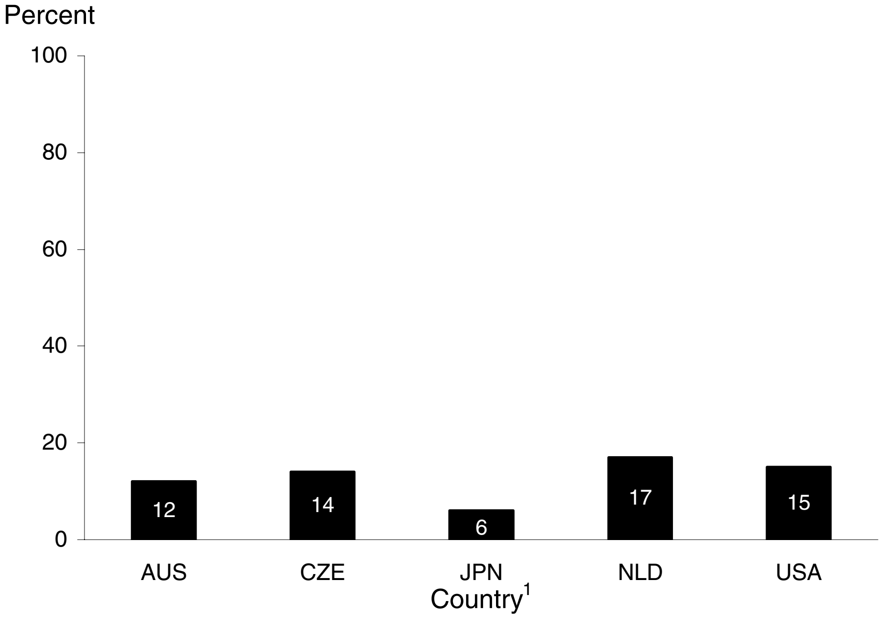


[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

NOTE: CZE>JPN. 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.

Figure 4.5. Average percentage of public talk time in eighth-grade science lessons devoted to real-life issues, by country: 1999

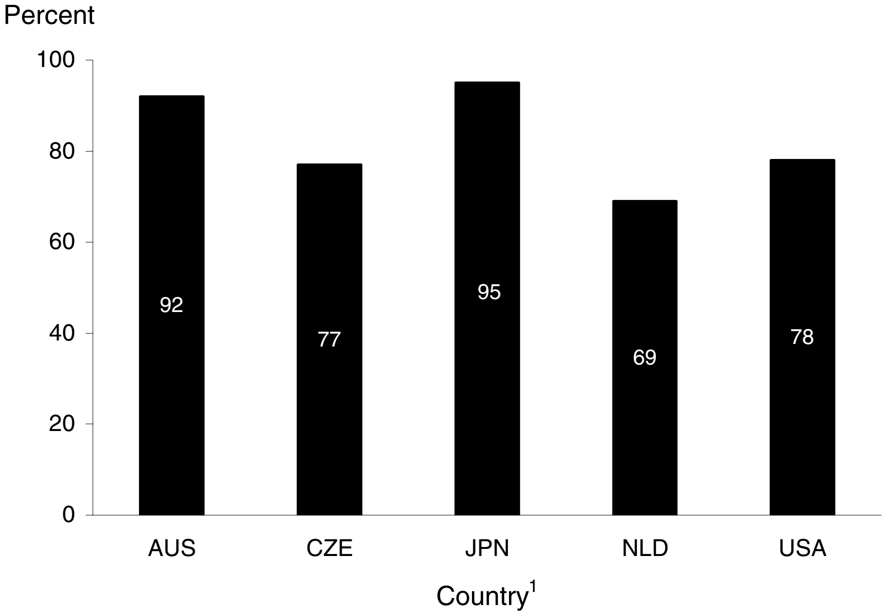


[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

NOTE: CZE, NLD, USA>JPN. 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.

Figure 4.6. Percentage of eighth-grade science lessons that addressed procedural and experimental knowledge during public talk, by country: 1999

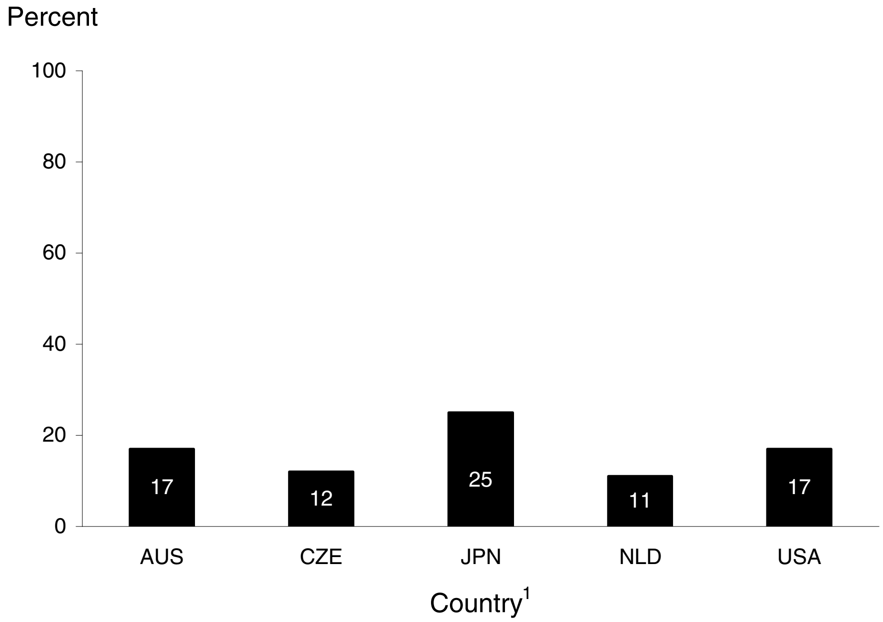


[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

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

Figure 4.7. Average percentage of public talk time in eighth-grade science lessons devoted to discussion of procedural and experimental knowledge, by country: 1999

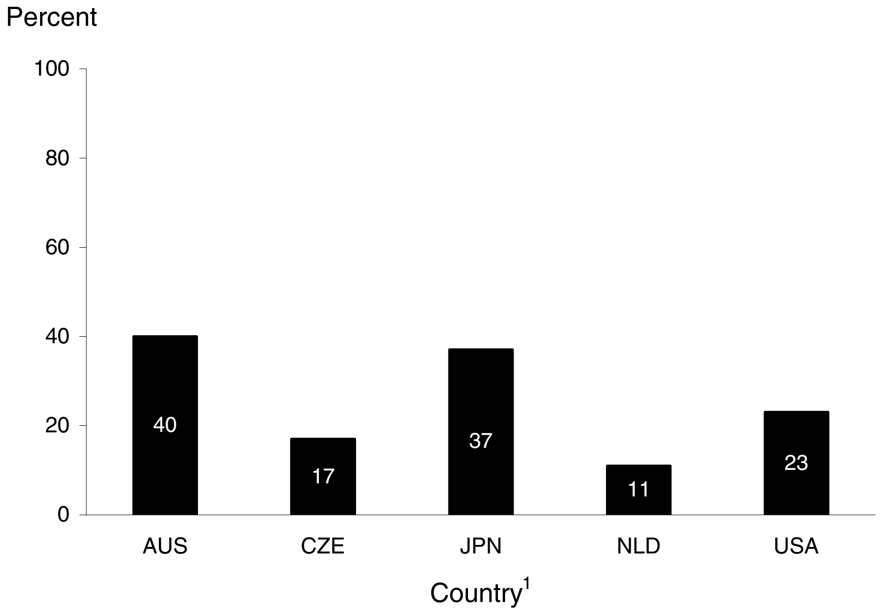


[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: JPN>AUS, CZE, NLD, USA. Analysis is limited to public talk time. The above category was not applied to non-public segments of the lesson because of the nature of independent work and the limitations of the 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.

Classroom Safety Knowledge

- Across the participating countries, the percentages of eighth-grade science lessons that publicly addressed information related to safety practices ranged from 11 percent in the Netherlands to 40 percent in Australia (figure 4.8).
- Across all of the countries, the average proportion of public talk time devoted to safety information was no more than 2 percent, suggesting that when teachers addressed safety knowledge, it was brief (data not shown).

Figure 4.8. Percentage of eighth-grade science lessons that addressed classroom safety knowledge during public talk, by country: 1999



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

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

Nature of Science Knowledge

- Across the countries, the percentages of eighth-grade science lessons that contained any publicly addressed information related to the nature of science ranged from 4 percent in Australia to 6 percent in the United States with too few cases in the Czech Republic to be reported (data not shown). Science lessons in the countries allocated no more than 1 percent of public talk time to discussions of the nature of science (data not shown).

Meta-Cognitive Knowledge

- The percentage of eighth-grade science lessons that contained any public talk about meta-cognitive strategies ranged from 17 percent in Japan to 24 percent in the United States. On average, no more than 1 percent of public talk time was allotted to the discussion of meta-cognitive strategies during science lessons (data not shown).

Summary

This chapter presented analyses of types of science knowledge that students had opportunities to learn during the public portion of the lessons that were presented. Among the key findings of this chapter is that all of the countries appeared to emphasize certain science disciplines and science topics except for the United States. Countries also differed in their emphasis on types of science knowledge. The Czech Republic provided more time to publicly discuss canonical knowledge, and Japan provided more time to discussing procedural and experimental knowledge than all the other countries. The Czech Republic, the Netherlands, and the United States emphasized knowledge about real-life issues more than did Japan. Each of the countries allocated relatively little time to discussing the nature of science, meta-cognitive strategies, and safety strategies.

Chapter 5: Developing Science Content

Science education research and reform documents as well as standards and curriculum documents from the five countries present different views about developing content. Such views include how many content ideas are reasonable to include in a science lesson, about how best to organize content so that it is coherent and understandable to students, and about which content ideas are appropriate for eighth-grade students to understand (DeBoer 1991; Fratt 2002; Kolavova 1998; NRC 1996; Nelesovska and Spalcilova 1998). Decisions about the science content in science lessons can be influenced by a variety of sources, including educational research knowledge about how science is learned, knowledge from the science community about what content is important for all students to learn, science knowledge as represented in textbooks and curriculum guidelines, and the goals and purposes of science education as defined at the country, state/province, or local level.

Research Background

A common theme in the science education and reform literature is the tension between including a large amount of content in the curriculum or covering fewer ideas but in more depth (AAAS 1990, 1993; DeBoer 1991; Fratt 2002; NRC 1996; Schmidt et al. 1997). In this chapter, the issue of depth versus breadth of content coverage is addressed not only by looking at how many ideas are addressed in a lesson but also through an examination of the organization and coherence of that content and the level of challenge of the content, in particular in terms of its abstractness and theoretical emphasis.

Providing opportunities for students to develop connected, evidence-based scientific understandings that students can apply to make sense of a variety of phenomena is a key idea coming out of international research on science teaching and learning (AAAS 1993; Gunstone and White 1992; Minstrell 1989; Mintzes, Wandersee, and Novak 2000; Monk and Osborne 2000; Resnick 1987b; Roth 1990; West and Pines 1985; Wiggins and McTighe 1998; Wiske 1997). Some studies document that even when students are able to memorize science information successfully, they often fail to develop the kinds of connected, conceptual understandings that enable them to use this knowledge to solve new problems or to explain phenomena in their everyday experience (Anderson and Roth 1989; Anderson, Sheldon, and DuBay 1990; Anderson and Smith 1987a, 1987b; Driver, Guesne, and Tiberghien 1985; Osborne and Freyberg 1985; West and Pines 1985). In addition, research on human learning suggests that unrelated ideas hold less meaning than those that are richly interrelated (Chi, Glaser, and Rees 1982; Larkin et al. 1980; NRC 2000; Resnick 1987b). One result of this research has been the widespread call for "less is more" in the science curriculum—covering less content in more depth and with more coherence so that students receive the support they need to develop meaningful understandings of the science content (AAAS 1990, 1993; NRC 1996, 2000).

However, critics challenge that, in practice, "less is less"—covering less content leads to a watered-down version of the science curriculum in which students learn less science (Olson 1998). Some scientists and science educators in the United States, for example, argue that the *National Science Education Standards'* (NRC 1996) emphasis on student-driven inquiry and minimal use of specialized vocabulary guarantee “misconceptions, fragmentation, and fog rather than clarity and comprehension” (Shea 1998, p 118). They argue that depth of understanding requires knowledge about basic science concepts and specialized terminology, and that inquiry activities void of such knowledge are promoting misconceptions about the nature of science (Cromer 1998; Metzenberg 1998a, 1998b; Schultz 1998).

Country Perspectives

Standards or curriculum documents as well as reform documents from the countries in this study differ in the degree to which they emphasize content coverage versus in-depth study of selected key concepts (Australian Education Council 1994; Czech Ministry of Education 1996; Dutch Ministry of Education 1998; Martin, Gregory, and Stemler 2000; Schmidt et al. 1997). Curriculum guides in the Czech Republic, for example, emphasize canonical knowledge and contain more content specifications than standards or curriculum guides in the other nations (Czech Ministry of Education 1996). Standards and reform documents in the United States, in contrast, emphasize covering less content in greater depth (AAAS 1990, 1993; NRC 1996). This focus is consistent with critics’ description of the science curriculum in the United States as “a mile wide and an inch deep”—trying to teach too much information and lacking in depth (Schmidt et al. 1997; Schmidt et al. 2001) as well as filled with activities having little or no meaningful connections to rich scientific content (Kesidou and Roseman 2002; Moscovici and Nelson 1998). National curriculum guides in Australia also emphasize focusing science teaching on a few key scientific ideas. For example, one of the key principles for science curriculum developers in *A Statement on Science for Australian Schools* is that "[s]tudents should explore a selection of ideas in science in depth rather than cover superficially a wide range of content" (Australian Education Council 1994, p. 10).

The countries also differ in the role of national standardization. In the Czech Republic, Japan, and the Netherlands, there is a national curriculum. By contrast, curriculum guides or standards statements distributed at the national level in Australia and the United States serve only as guidelines or suggestions, and state/provincial level guidelines have more authority. The TIMSS study of curricular visions and aims showed variations in the science content in both the curriculum guides and textbooks in the participating countries (Schmidt et al. 1997). These variations are likely to be associated with the types and amount of science content observed in the videotaped lessons, as well as the organization of that content.

Chapter 5 focuses on four main questions about development of science content in eighth-grade science lessons:

- What is the source of the science content and its organization?
- How much science content is in the lesson?
- How coherent is the science content?
- How challenging is the science content?

The results presented in this chapter relate to segments of the science lesson in which teachers developed new content, went over homework, and went over assessments (as defined in chapter

3). Segments focused on reviewing previously learned knowledge are excluded because, in our observations, these activities typically cover a large amount of content quickly and without any particular organization that would make the content coherent. Thus, lessons with longer periods of review would be assessed as less coherent because they include review activities. For the same reason, the relatively few science lessons in which the entire lesson was devoted only to review, with no time allocated to developing new content, going over homework, or going over assessments, are not included in the analyses presented in this chapter (see chapter 3, figure 3.4).

What is the Source of the Science Content and its Organization?

Several factors can influence the content in a science lesson. The amount of content, the coherence and organization of the content, and the level of challenge of the science content may be largely influenced by the organization of the textbooks or other curriculum materials being used and by national or state-level guidelines. Alternatively, the teacher may play a central role in designing the content organization of the lesson.

To identify the main source of the content organization during the eighth-grade science lessons, the videotaped lessons were analyzed to assess extent to which lesson content followed the outline of content in textbooks and worksheet pages used in the lessons. Although the content of a lesson could be organized by more than one factor, the intent of these measures was to identify the predominant source of the organization. The main sources were defined as follows:

- ***Teacher***: The source of the content organization is largely determined by the teacher during the lesson. For example, the class listens to the teacher, observes the teacher, follows the teacher's directions, has discussions with the teacher, or reads teacher materials that are different from the textbook, workbook, or worksheet. The organization of the content observed in the lesson is different from that presented in the textbook, workbook, or worksheet, or there is no textbook, workbook, or worksheet used.
- ***Textbook or workbook***: The teacher closely follows the content organization in the textbook or workbook by having students read from the textbook, by clarifying explanations that are in the textbook, by asking questions that are printed in the textbook/workbook, or by having students independently work through the textbook/workbook, etc.
- ***Worksheet***: The class closely follows the information in a worksheet (e.g., a handout or lab protocol). A typical worksheet contains directions for how to carry out a practical activity or a set of questions or problems for students to answer. This category was created to capture and distinguish the use of print materials that primarily guided the lesson from the use of textbooks or workbooks.
- ***Other source***: The content organization comes from some other source such as the students (e.g., student presentations, students design their own experiments, or students conduct independent library research) or a video.

The percentage of eighth-grade science lessons in which the content of the lesson was influenced by the teacher, the textbook or workbook, a worksheet, and another source are presented in figure 5.1.

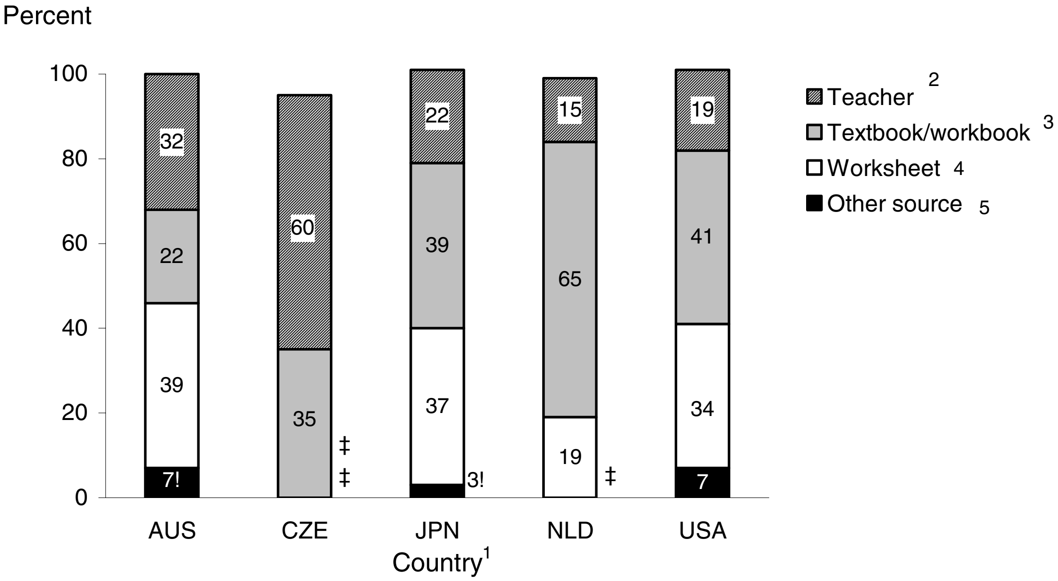
- The teacher influenced the content of more Czech eighth-grade science lessons (60 percent) than lessons in all the other countries, which ranged from 15 percent in the Netherlands to 32 percent in Australia (figure 5.1).

- The content of more Dutch lessons was influenced by the textbook or workbook (65 percent) than lessons in Australia, the Czech Republic, and Japan (22, 35, and 39 percent, respectively) (figure 5.1).

How Much Science Content Is in the Lesson?

Science lessons vary in terms of how much content is addressed. Lessons with fewer ideas may provide the opportunity for students to study a few ideas in depth and to develop conceptual understandings. On the other hand, lessons with more ideas may provide a strong base of vocabulary and factual knowledge that can be used to develop conceptual understanding. Lessons containing no science ideas are not likely to help students develop important science understandings at all. The science terminology spoken in a science lesson also provides opportunities for students to learn science content. Three indicators provide information about the amount of science content in the lesson: a) whether students had the opportunity to learn science content in the lesson, b) the number of publicly presented canonical ideas in the lesson, and c) the number of science terms in the lesson.

Figure 5.1. Percentage distribution of eighth-grade science lessons, by source of content and country: 1999



!Interpret data with caution.
‡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] Teacher: CZE>AUS, JPN, NLD, USA.
[3] Textbook or workbook: NLD>AUS, CZE, JPN.
[4] Worksheet: No measurable differences detected.
[5] Other source: No measurable differences detected.
NOTE: Totals may not sum to 100 because of rounding and data not reported. Lessons devoted entirely to review are not included in the analysis. See figure 3.4 for the percentages of lessons that reviewed previous content only..
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Opportunity to Learn Science Content

A first question to consider regarding the amount of content in the lesson is whether the teacher directed students’ attention to learning science content knowledge at all (see chapter 4 for definitions of knowledge types). Some lessons were largely devoid of science content and focused students instead on carrying out activities or procedures. Students’ opportunity to learn science content in the eighth-grade science lessons was determined using the following definitions:

- ***Learning science content***: With or without the use of independent student activities, the teacher provides students with the opportunity to learn science content knowledge. The lesson may focus mainly on whole-class presentation and discussion of content knowledge or it may devote a substantial amount of time to independent activities such as student work on experiments. In either case, the teacher or the text explicitly directs students to develop and/or use science knowledge. Thus, the teacher, the textbook, or another source explicitly draws students’ attention to content knowledge related to the lesson activities. If students were provided with at least some opportunity to learn science content, the lesson was categorized as providing the opportunity to learn science content. Examples of lessons focused on learning content include the following:

  - The teacher leads students through a series of simulation activities to demonstrate the relationship between population density and food supply (canonical knowledge).
  - Students work independently on a set of questions and problems about force throughout the entire lesson (canonical knowledge).
  - Students examine the pros and cons of becoming an organ donor (societal issues knowledge).
  - Students learn about fair tests and control groups, and use this knowledge to design and carry out investigations (nature of science knowledge).

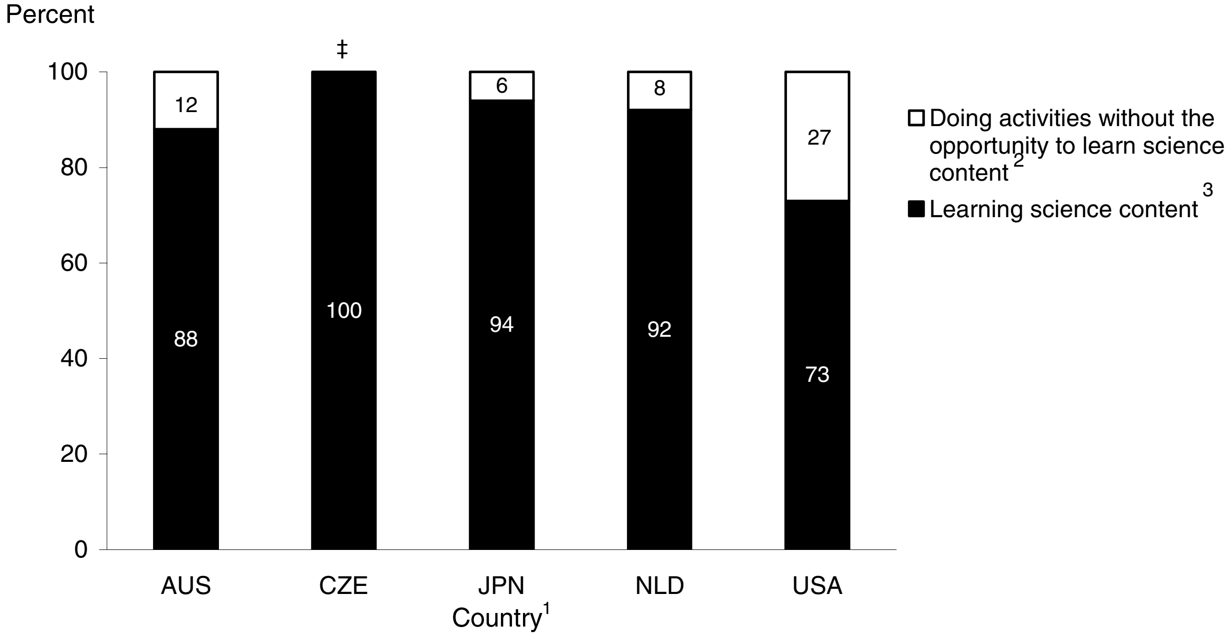
- ***Doing activities without the opportunity to learn science content***: The teacher provides opportunities for students to carry out science activities or procedures but does not direct or focus students' attention to learning content ideas. The activities engage students in following directions or practicing procedures without explicitly linking the activities to science content. Content may be briefly mentioned in the lesson at the topic level or as an isolated bit of information, or one or more students may develop some science content understanding in the process of carrying out an activity, but the teacher or instructional materials do not explicitly guide students to this understanding (🎥 Video clip example 5.1). Examples of lessons focused on doing activities include the following:
  - Students spend the class period building rockets, following procedures supplied by the teacher.
  - Students take their pulse before and after running, record their data, and graph the class results, but they are not directed to use this information to develop or support knowledge about blood circulation, about the effect of exercise, about graphical representations, or about the nature of scientific inquiry.
  - Students take weather measurements, without any discussion about science content knowledge.
  - The teacher directs students in organizing their science papers into a portfolio; the process does not involve discussion of science content beyond the topic level ("Put your weather maps in the next section").

Figure 5.2 displays the percentage of eighth-grade science lessons in each country that provided different opportunities to learn science content.

- At least 73 percent of science lessons in each of the five countries provided opportunities to learn science content (figure 5.2).
- Lessons that focused on doing activities accounted for no more than 12 percent of lessons in all the countries except the United States, where 27 percent of lessons focused primarily on activities with little to no explicit linkage to content (figure 5.2).

- More U.S. science lessons focused primarily on doing activities than lessons in both Japan and the Netherlands (6 and 8 percent, respectively) (figure 5.2).

Figure 5.2. Percentage distribution of eighth-grade science lessons that provided different opportunities to learn science, 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 without the opportunity to learn science content: USA>JPN, NLD.

[3] Learning science content: CZE>AUS, USA; JPN>USA.

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

Density of Publicly Presented Canonical Ideas

The quantity of ideas presented in a lesson provides one indication of the potential coherence, challenge, and depth of science content coverage. Lessons with many ideas may provide content that is challenging for students in its complexity and level of detail, whereas lessons with fewer ideas may provide time for in-depth, challenging treatment of each idea. A lesson that moves quickly from one fact or idea to another may have less coherence and be more difficult for students to understand than a lesson that focuses on few ideas, although it is also possible that a lesson with few ideas could lack coherence and focus only on superficial coverage of the science content.

For this analysis, a public canonical idea is defined as a publicly presented statement that describes a scientific fact, concept, pattern in data, natural process, scientific model or law, or theoretical explanation (🎥 Video clip example 5.2). This knowledge is canonical in the sense that it is an understanding that is generally shared by members of the scientific community. For example, a teacher draws a series circuit on the board and describes it. This public statement represents a canonical idea about the path of electron flow traveling through a series circuit. A public canonical idea can come from the teacher, the text, a video, from data collected in an experiment, from the students, etc.

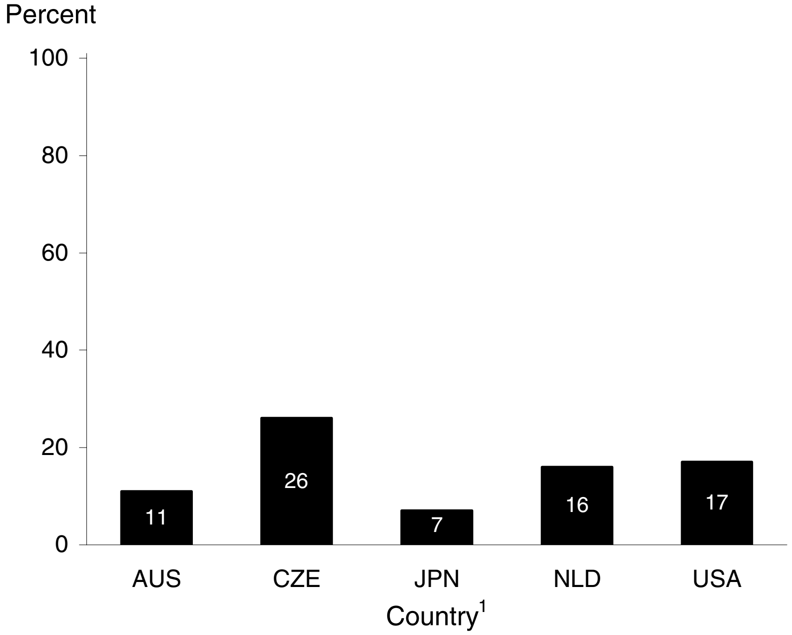
The number of public canonical ideas that are presented in a lesson provides an indication of the degree to which the lesson developed content by focusing on a few key ideas or on many ideas. A lesson with 18 ideas, for example, is more dense than a lesson with one idea.

- More eighth-grade science lessons in the Czech Republic contained a high number (at least 15) of publicly presented canonical ideas (26 percent, figure 5.3) compared to 7 percent of Japanese lessons. Japanese lessons tended to be less dense with canonical ideas.

Science Terms

- ***Science terms:*** A science term is defined as a one- to three-word expression (e.g., energy, photosynthesis, aneroid barometer, and relative molecular mass) with a specific scientific meaning. A count of unrepeated science terms in a lesson describes how many different terms are used in the lesson. Each term is counted only once regardless of how many times the term is repeated.
- ***Highly technical science terms***: A one- to three-word expression with a specific scientific meaning that is likely to be used to support science learning in the classroom, and is not likely to be encountered by students in everyday talk (e.g., photosynthesis, magma, and ions). A count of unrepeated highly technical science terms in a lesson describes how many different highly technical terms are used in the lesson, without repetitions of the same term. Unrepeated highly technical terms are a subset of unrepeated science terms.

Figure 5.3. Percentage of eighth-grade science lessons that contained a high number (at least 15) of public canonical ideas, by country: 1999



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

NOTE: CZE>JPN. A public canonical idea is defined as a publicly presented statement that describes a scientific fact, concept, pattern in data, natural process, scientific model or law, or theoretical explanation. A lesson that contains a high number of distinct publicly presented canonical ideas includes 15 or more publicly presented canonical ideas. For example, in addressing the big idea of how the digestive, respiratory, and circulatory systems work together to help all cells in the body get the energy they need, the lesson might include the names and functions of many different parts of the body as well as a description of the processes of digestion, circulation, and cellular respiration.

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

Figure 5.4 presents the average number of science terms and the number of highly technical science terms that were spoken during eighth-grade science lessons. See appendix D for more information on science terms identified in the lessons.

- Lessons in the Czech Republic contained more science terms and more highly technical science terms on average than lessons in all other countries (figure 5.4).

How Coherent is the Science Content?

In this section, the science lessons in the five countries are compared on three indicators of coherence that were observed in the lessons: (1) whether the pattern of content development focused on making connections or acquiring facts, definitions, and algorithms, (2) whether strong conceptual links were made among science ideas in the lesson, and (3) whether goal and summary statements were used to clarify the content organization of the lesson.

Patterns of Content Development

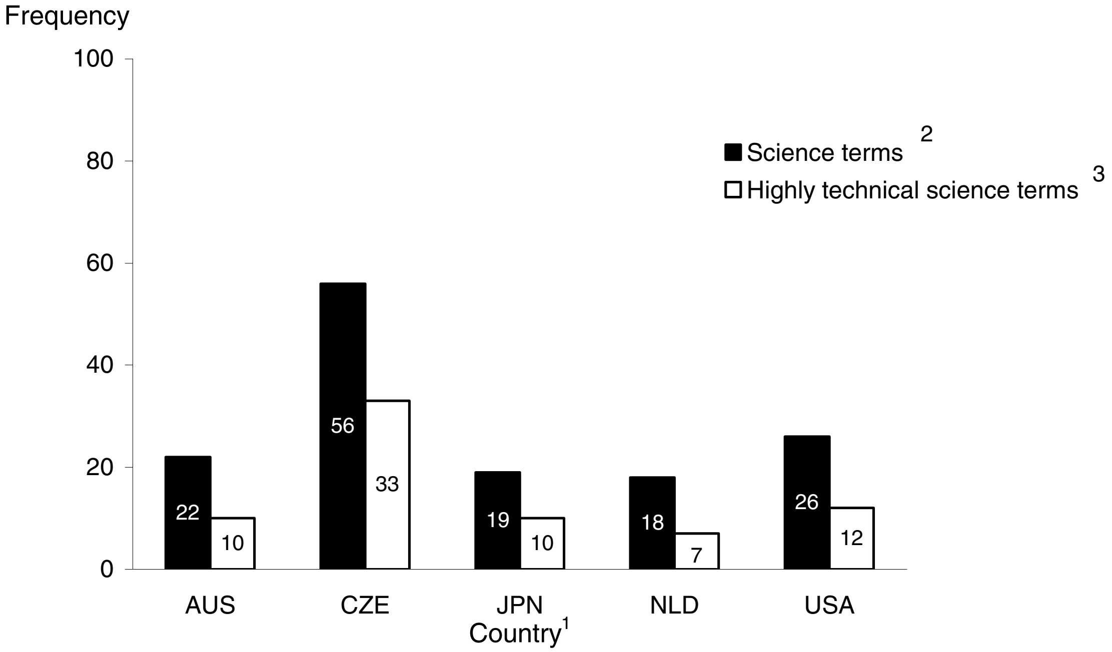
The participating countries were compared on observations of two primary ways teachers developed science content within the lesson: (1) making connections among experiences, ideas, patterns in data, and explanations through pattern-based reasoning, and (2) acquiring facts, definitions, and algorithms through memorization and practice:

- ***Making connections***: The primary approach of the lesson is to support students in making connections among experiences, ideas, patterns, and explanations. Teachers and/or students are engaged in pattern-based reasoning—that is, recognizing, explaining, and using patterns in data by working on such tasks as building a case or an argument to explain patterns observed in data, predicting patterns in data from scientific laws or theories, or collecting data to verify the predicted patterns. (🎥 Video clip example 5.3)
- ***Acquiring facts, definitions, and algorithms***: The primary approach in the lesson is to teach students a set of facts, definitions, or problem solving procedures that they will acquire primarily through memorization and practice. Problem solving is limited to following linear, step-by-step procedures. The information is presented as distinct pieces that are not organized within a larger conceptual framework that links experiences, data, and explanations.

Figure 5.5 displays the percentage of eighth-grade science lessons that primarily developed content by making connections or by acquiring facts, definitions, and algorithms.

- Within Japan, students were more likely to be in science lessons in which the content was developed primarily by making connections than in lessons with content developed by acquiring facts, definitions and algorithms (figure 5.5). Within the Czech Republic, the Netherlands, and the United States, on the other hand, students were more likely to be in science lessons in which the content was developed by acquiring facts, definitions, and algorithms than by making connections.
- Comparisons of the approach to developing content within each of the four science disciplines (excluding other areas; see figure 4.1) showed no clear relationship between the science discipline and the pattern of content development in the five countries (see table E.6, appendix E).

Figure 5.4. Average number of science terms and highly technical science terms per eighth-grade science lesson, by country: 1999



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

[2] Science terms: CZE>AUS, JPN, NLD, USA; USA>NLD.

[3] Highly technical science terms: CZE>AUS, JPN, NLD, USA; USA>NLD.

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

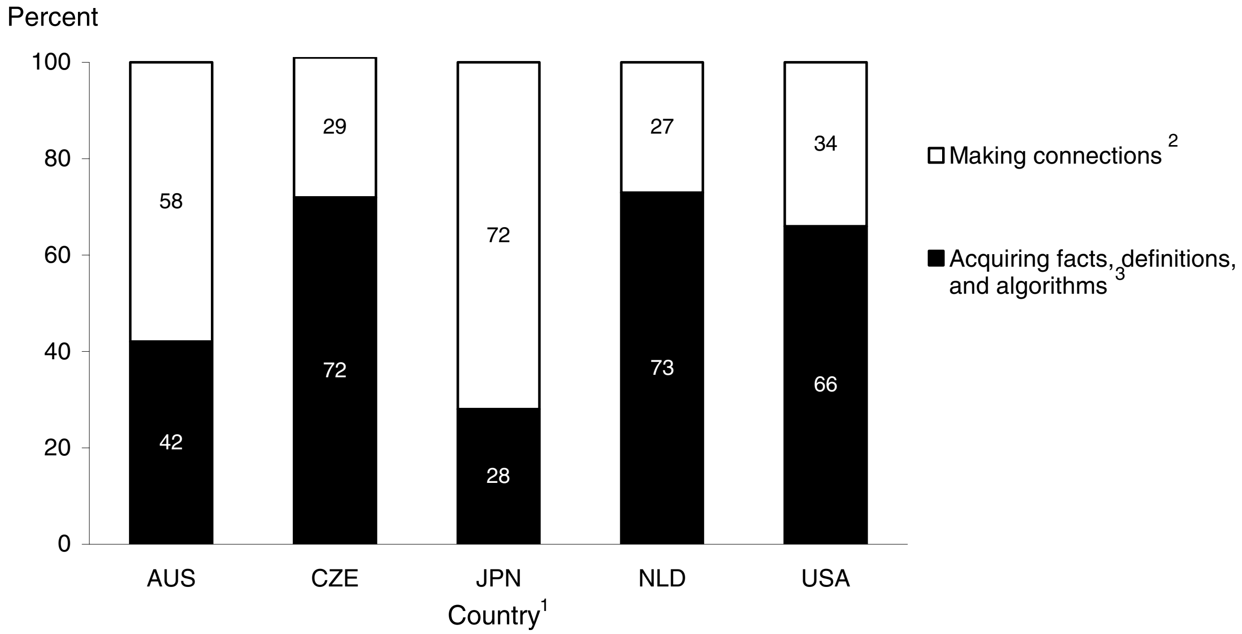
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Types of Making Connections

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

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

Figure 5.5. 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



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

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

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

NOTE: Totals 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.

Figure 5.6 displays the percentage of lessons that primarily developed science content by making connections through an inquiry or inductive approach or through an applications or deductive approach.

- Teachers in more Australian and Japanese science lessons used an inquiry or inductive approach to make connections among ideas, data, and experiences than did teachers of Czech, Dutch, and U.S. lessons (figure 5.6).
- Within Australia and Japan, more science lessons developed content by making connections primarily through an inquiry or inductive mode compared to lessons that developed content through an application or deductive mode; in the other three countries, there were no measurable differences detected (figure 5.6).

Types of Acquiring Facts, Definitions, and Algorithms

The primary way in which facts, definitions, and algorithms were used to develop science content was also identified for each lesson. The different approaches to acquiring facts, definitions, and algorithms included: a focus on algorithms and techniques, a focus on sequences of events, a focus on discrete bits of information, and other approaches. See appendix D for further details on the types of acquiring facts identified in the lessons.

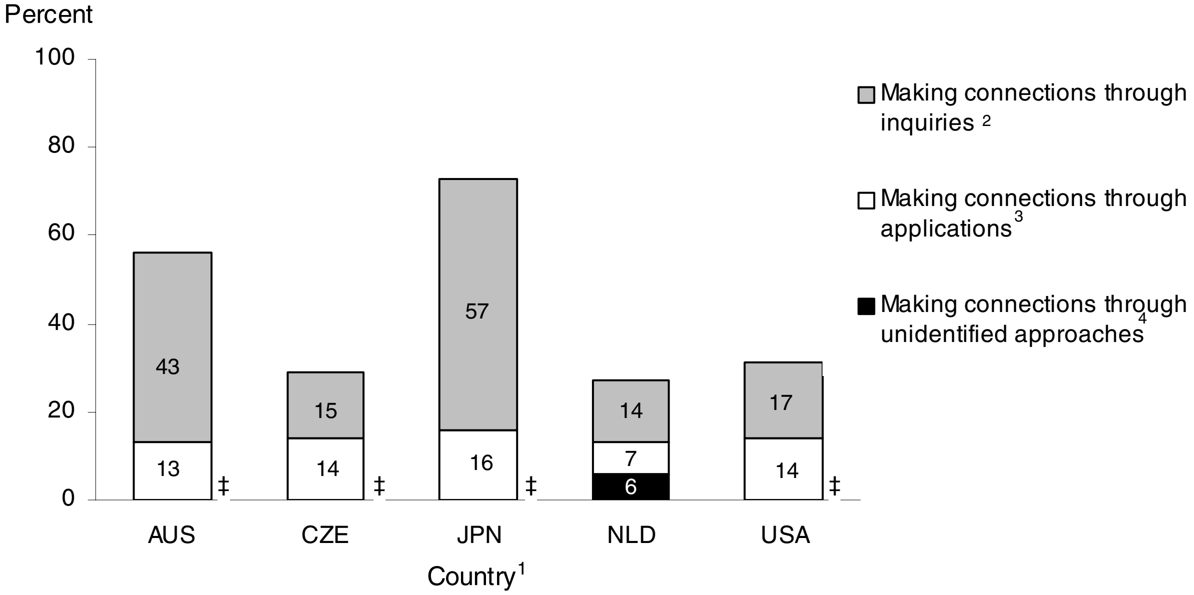
- Within the Czech Republic and the Netherlands, more eighth-grade science lessons developed content by helping students acquire facts by focusing on discrete bits of information than on algorithms and techniques or sequences of events. In the United States, lessons were as likely to focus on acquiring algorithms and techniques as on acquiring discrete bits of information. (see figure E.1, appendix E; see also 🎥 Video clip 5.4)

Conceptual Links

Conceptual links were identified as a second indicator of content coherence. The lessons were reviewed for the presence of statements or activities that organized ideas together in a conceptual framework (such as goal and summary statements, concept maps, highlighting statements, and outlines). The linking statements could be made by the teacher, supplied by the textbook or worksheet, the students, or some other source. The focus of each lesson was then categorized using the following definitions:

- ***Doing activities with no conceptual links***: The teacher focuses students' attention primarily on carrying out an activity or a procedure rather than learning a content idea. Students may encounter some science content in the process of carrying out an activity, but the information is presented as isolated bits of information without being linked to a larger concept (see the earlier definitions associated with figure 5.2).
- ***Learning content with weak or no conceptual links*****:** The lesson contains at least some content but there are only weak or no obvious conceptual links that integrate the information and activities. The information and tasks presented are connected only by a shared topic or by one or two concepts that tie together some of the ideas or activities but do not connect all the information together. An example of such lessons includes the following:
- Information about the different parts of the heart and the different kinds of blood vessels and blood cells is presented. The teacher then briefly states that the heart, blood vessels, and blood cells are all part of the circulatory system and then engages students in an activity about pulse rate. The conceptual idea about the
    - circulatory system is only briefly mentioned and is never connected to the pulse rate activity, developed further, or used by the students; it is not used as an organizing framework to tie together the ideas and activities in the lesson.

Figure 5.6. Percentage distribution of eighth-grade science lessons that primarily developed science content through various approaches for making connections, 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] Making connections through inquiries: AUS, JPN>CZE, NLD, USA.

[3] Making connections through applications: No measurable differences detected.

[4] Making connections through unidentified a roaches: No measurable differences detected.

NOTE: Only those lessons identified as developing science content primarily by making connections are included in the analysis. See figure 5.5 for the percentage of science lessons in each country that were coded as making connections. The unequal distribution of developing content by making connections among the five countries means that different ways of making connections will be unequally distributed among the countries as well. The analyses that follow highlight the relative emphasis of different ways of making connections within each country.

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

- ***Learning content with strong conceptual links***: The lesson is focused on content with conceptual links that strongly connect and integrate the information and activities. The information presented consists primarily of interlocking ideas, with one idea building on another with strong conceptual links. The lesson contains a strong conceptual thread that weaves the entire lesson into an organized whole. An example of a content-focused lesson with strong conceptual links follows:
    - The lesson begins with the teacher pointing to metals and nonmetals on the Periodic Table and saying: “Today we will explore the chemical differences between metals and nonmetals, and you will learn how all these metals here and these nonmetals here behave chemically in similar ways.” After demonstrating the differences in how sulfur (a nonmetal) burns compared to magnesium (a metal), the teacher instructs the students to carry out independently a series of reactions with metals and nonmetals to find patterns and common features across the different reactions. The teacher then helps students link these activities to concepts about metals and nonmetals through a discussion and

> interpretation of the results. At the end of the lesson, the teacher asks students to write their own conclusions, and then ends the lesson with a discussion and summary about the differences between metals and nonmetals.

Figure 5.7 presents the percentage of lessons that were judged to be activity-focused with no conceptual links, content-focused with weak or no conceptual links, and content-focused with strong conceptual links.

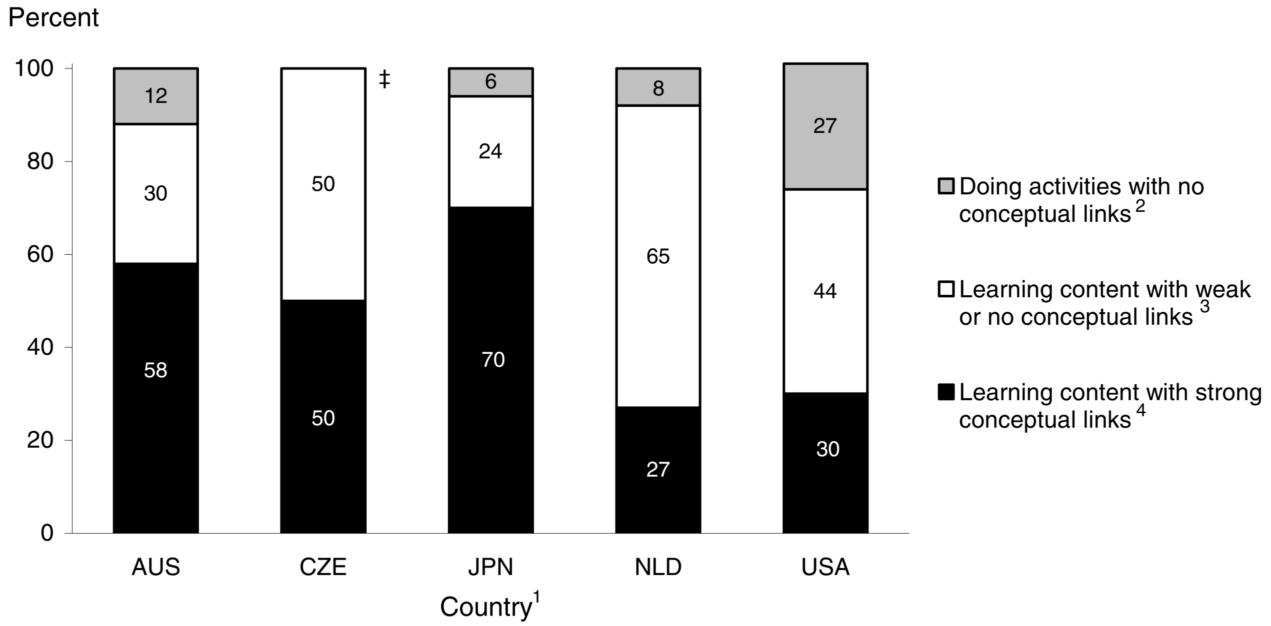
- More Australian and Japanese eighth-grade lessons focused on learning content with strong conceptual links compared to Dutch and U.S. lessons (figure 5.7). More Czech lessons also included content with strong conceptual links than did lessons in the Netherlands.

Goal and Summary Statements

One way teachers can make the content organization of a lesson more explicit for students is by providing goal and summary statements for a lesson.

- Teachers in more Australian eighth-grade science lessons explicitly conveyed the goal of the lesson than did teachers in Japanese and U.S. science lessons (figure 5.8). Teachers in more Czech lessons explicitly conveyed the lesson goal compared to teachers in U.S. lessons.
- Goal statements in Japanese lessons were more likely to include a main idea presented as a research question compared to lessons in the Czech Republic, the Netherlands, and the United States (figure 5.9) (🎥 Video clip example 5.5).
- Goal statements that mentioned the topic only occurred in more Czech lessons compared to all the other countries and in more U.S. lessons compared to Australian and Japanese lessons (figure 5.9 (🎥 Video clip example 5.6).).
- Summary statements were more common in Czech and Japanese lessons than in U.S. lessons (figure 5.8).
- Goal and summary statements of any type occurred in more Czech and Japanese lessons than in U.S. lessons (figure 5.10).
- Both goal and summary statements included more than just naming a topic in more Japanese lessons than in Czech lessons (figure 5.10).

Figure 5.7. 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.

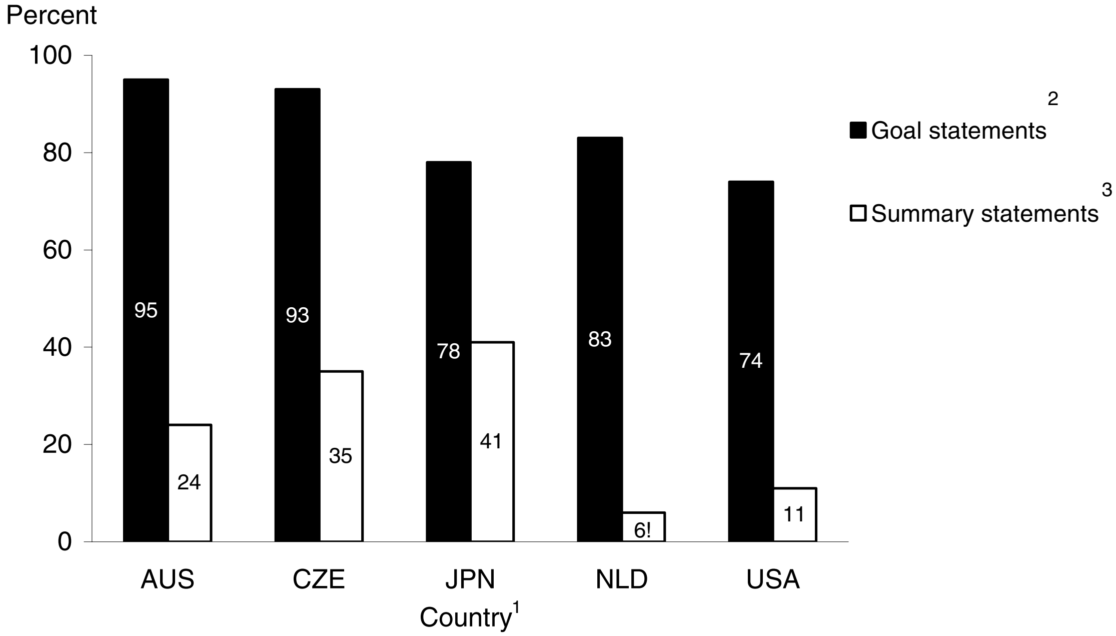
[3] Learning content with weak or no conceptual links: CZE>JPN; NLD>AUS, JPN.

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

NOTE: Totals 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.

Figure 5.8. Percentage of eighth-grade science lessons with goal statements and summary statements, by country: 1999



!Interpret data with caution. Estimate is unstable.

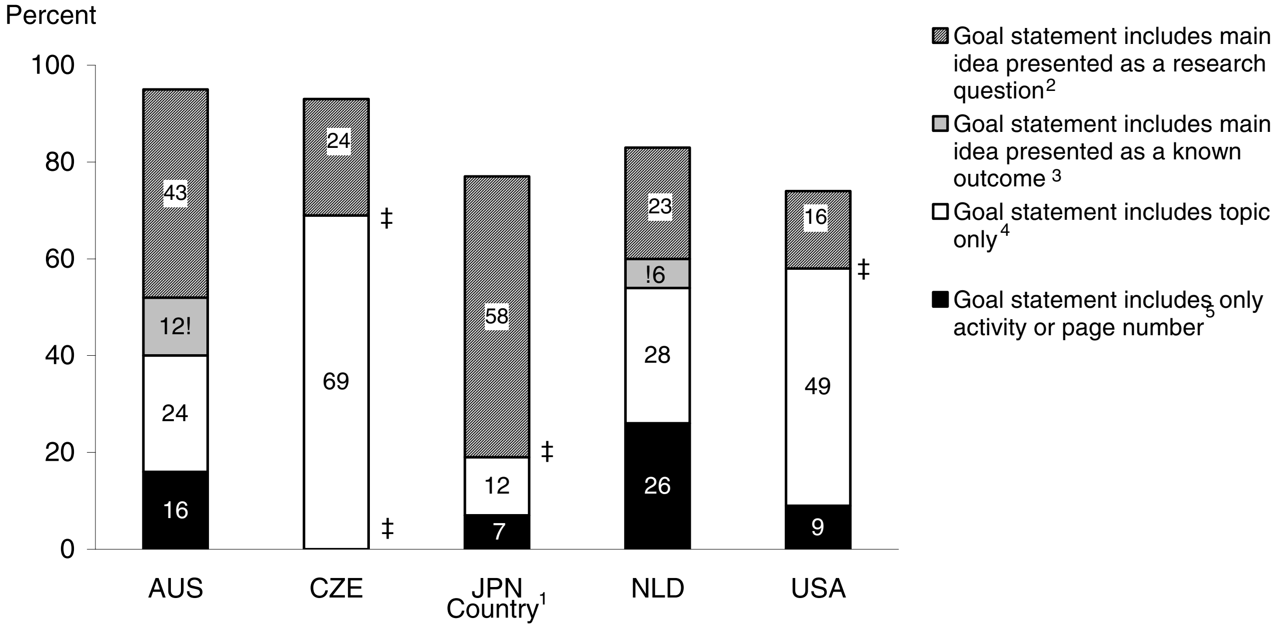
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

[2] Goal statements: AUS>JPN, USA; CZE>USA.

[3] Summary statements: AUS, CZE, JPN>NLD; CZE, JPN>USA.

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

Figure 5.9. Percentage distribution of eighth-grade science lessons with various types of goal statements, by country: 1999



!Interpret data with caution. Estimate is unstable.

‡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] Main idea presented as a research question: AUS>USA; JPN>CZE, NLD, USA.

[3] Main idea presented as a known outcome: No measurable differences detected.

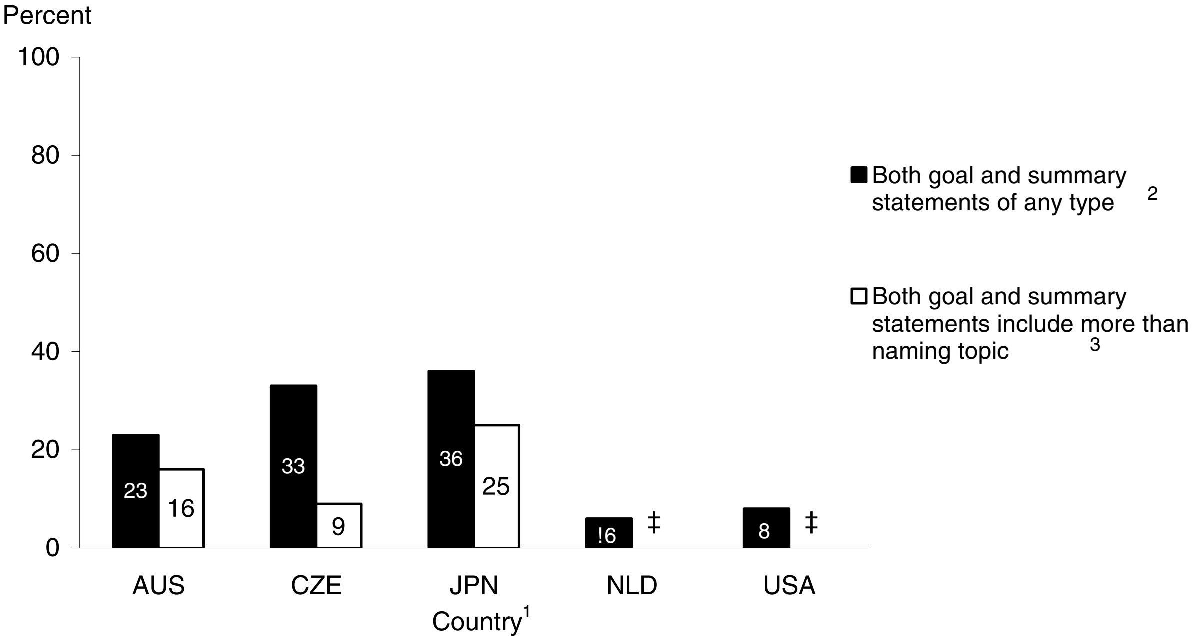
[4] Topic only: CZE>AUS, JPN, NLD, USA; USA>AUS, JPN.

[5] Activity or page number only: NLD>JPN.

NOTE: Totals may not sum to 100 because of rounding and data not reported. Lessons without goal statements are not included in analyses. See figure 5.8 for percentages of lessons with goal statements.

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

Figure 5.10. Percentage of eighth-grade science lessons with both goal and summary statements, 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] Both goal and summary statements of any type: CZE, JPN >NLD, USA.

[3] Both goal and summary statements include more than naming topic: JPN>CZE.

NOTE: See figure 5.9 for a list of types of goal statements.

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

How Challenging is the Science Content?

The level of challenge of science content can be examined in various ways. For example, content may be judged as challenging if a lesson is dense with many canonical ideas. Using this measure, Czech lessons would appear to be more challenging than Japanese lessons, for example (see figure 5.3). But the level of challenge of the content can also be assessed in terms of the quality of the content, rather than the quantity. Two indicators are used to assess the level of challenge of the content in the eighth-grade lessons: (1) the difficulty and complexity of the ideas for eighth-grade students, and (2) the inclusion of more abstract, theoretical knowledge.

Challenging and Basic Science Content

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

For these analyses, a science content coding team was assembled to separately evaluate each lesson (see appendix B for a list of team members). Because the lessons varied in terms of the disciplinary areas covered (e.g., biology, chemistry, geology, or physics), team members coded lessons within their disciplinary expertise for the level of challenge. When disagreements were encountered among the coding team, differences were resolved through discussion. Training and reliability checks assured consistent judgments based on the inherent complexity of the science content being taught and the level of challenge of the information for eighth graders according to a review of the curricular and standards documents from the five countries. The science content coding team achieved at least 98 percent agreement within and across pairs during the monitoring of reliability.

To code the lessons, the science content coding team followed these definitions:

- ***Challenging content***: The science information includes a substantial amount of difficult and/or complex ideas for eighth-grade students, relative to the overall information presented in the lesson. Ideas were judged as difficult if they were represented as standards or curriculum goals for students in grades or at ages above those participating in the study in the participating countries. Ideas were considered complex if they involved multiple steps or interrelated parts, if they required putting different pieces of information together, or required higher level thinking in order to be understood (📹 Video clip example 5.7). Examples of challenging content include discussions of nuclear reactions, the role of adenosine triphosphate (ATP) in cell respiration, differences between organic and inorganic materials, oxidation/reduction reactions, balancing chemical equations, radioactivity, electromagnetic forces within atoms, heat and energy patterns inside the earth, wave theory, mathematical calculations about sound travel, and mathematical representations of Archimedes's Law.
- ***Basic and challenging content***: The science information includes mostly simple and basic ideas in the overall lesson, but there are also some challenging or complex ideas for eighth-grade science. For example, a lesson on electricity may focus on presenting students with basic definitions and examples of parallel and series circuits, but also include some attention to the more challenging concept of Ohm's law.
- ***Basic content***: The science information includes predominantly simple and basic ideas in the overall lesson, which are likely to be more easily understood by eighth-grade students. In a lesson containing predominantly basic science content and procedures, the teacher may discuss the physical characteristics of acids and bases (for example, acids taste sour and corrode metal; bases taste bitter and feel slippery), instruct students on how to use litmus paper, and require students to test several household liquids to determine whether they are acids or bases.

Figure 5.11 displays the percentage of eighth-grade science lessons that the science content coding team judged to contain challenging content, a mix of basic and challenging content, and basic content.

- Students were presented with predominantly basic content in 47 percent to 65 percent of the eighth-grade science lessons in all the countries except the Czech Republic (figure 5.11).

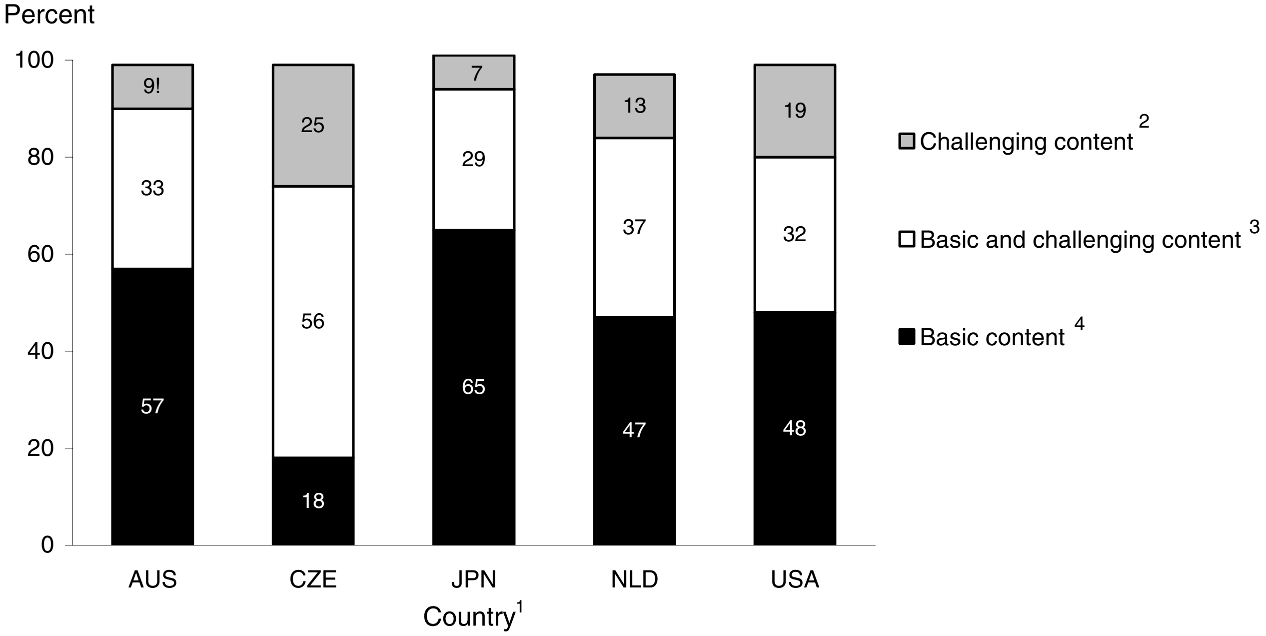
- More Czech lessons presented students with a mix of basic and some challenging content compared to Australian, Japanese, and U.S. lessons (figure 5.11).
- More Czech lessons presented students with predominantly challenging content (25 percent) compared to Japanese lessons (7 percent) (figure 5.11).
- Only in the Czech Republic were lessons more likely to present a mix or more challenging content than basic content (figure 5.11).
- Comparisons within the countries identified few instances in which the content of one science discipline was more challenging than another (see table E.7, appendix E for details).

Scientific Laws and Theories

Scientific laws and theories are publicly presented generalized explanations of patterns of data and events in the real world that have been established and more or less verified to account for known facts and phenomena. Laws and theories predict across a large range of phenomena or contexts that students cannot directly observe. Examples include Newton’s First Law of Motion, the conservation of mass, and Archimedes’ Law. Theoretical ideas include, for example, explanations of sound behavior based on the particulate theory of matter, plate tectonics and the relationship to earthquakes, and evolution (🎥 Video clip example 5.8).

- Scientific laws and theories were observed being publicly presented in more Czech science lessons than in Japanese or Dutch lessons (figure 5.12). More U.S. lessons included the public presentation of scientific laws and theories than lessons in Japan.

Figure 5.11. 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.

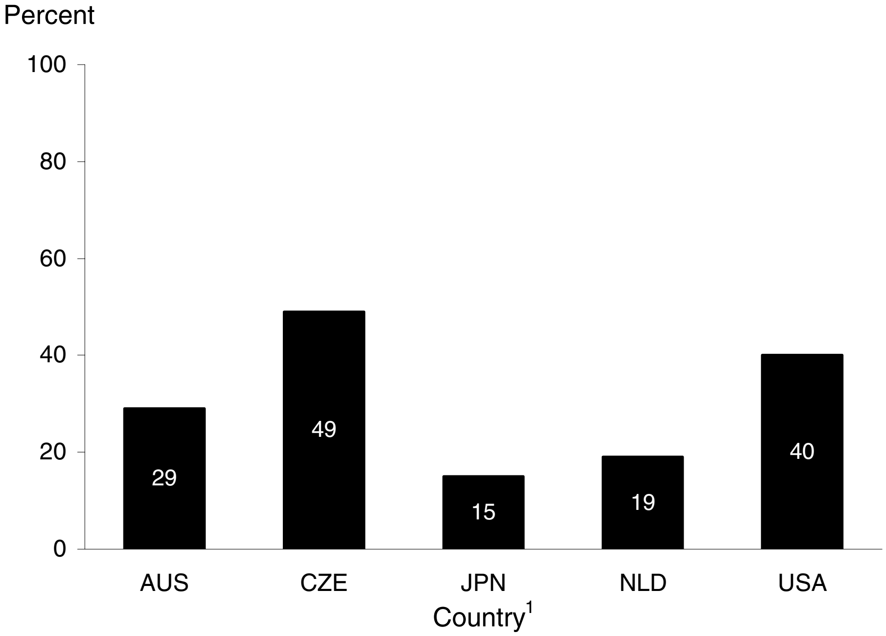
[3] Basic and challenging content: CZE>AUS, JPN, USA.

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

NOTE: Totals may not sum to 100 because of 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.

Figure 5.12. Percentage of eighth-grade science lessons that publicly presented scientific laws and theories, by country: 1999



[1]AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: CZE>JPN, NLD; USA>JPN.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Summary

This chapter identified country differences in the source and organization of lesson content, the pattern of content development, the coherence of the lesson, and the level of challenge of the content. Interesting country patterns include the observation that the textbook provided the content organization in a high percentage of Dutch lessons. Australian and Japanese lessons were distinguished for organizing content in a "making connections" pattern and for using strong conceptual links to create content coherence. In contrast, over a quarter of U.S. lessons involved students in doing activities without providing the conceptual links that would enable students to have the opportunity to learn science content from these activities. Czech lessons contained more challenging content and more highly technical science terms than some of the other countries. These findings contribute important pieces in the construction of country patterns of science teaching.

Chapter 6: Using Evidence to Develop Science Ideas

This chapter focuses on the evidence used to develop the science content in eighth-grade science lessons. A central practice of the scientific community is supporting knowledge claims with various forms of evidence such as data, natural phenomena, and visual representations of data and phenomena (Kelly and Chen 1999; Lemke 1990). Investigating the extent to which science knowledge in the lessons is supported by various kinds of evidence provides an important picture of how science is represented in the classroom.

Research Background

A substantial body of research suggests that the use of first-hand data, observations of real phenomena, and visual representations of ideas and data may support student learning of science by providing concrete contexts and examples that help students make sense of more abstract ideas. For example, some studies have found that strategic use of data, phenomena, and visual representations can help students bridge the gap between their initial, more intuitive ideas and scientific concepts and explanations (Guzetti et al. 1993; Leach and Scott 2000; Minstrell 1982, 1989, 1992; NRC 2000; Roth 1990-91; Scott, Asoko, and Driver 1992; Sokoloff and Thornton 1997; Wandersee, Mintzes, and Novak 1994). Other research indicates that coordinating different types of evidence, such as data, phenomena, and graphical representations, may enable students to acquire scientific discourse practices (for example, identifying patterns in data, generating scientific explanations, and evaluating the fit between evidence and theory) (Lehrer and Schauble 2000, 2002; Samarapungavan 1993). Furthermore, an association between changes in students' knowledge and reasoning abilities and their opportunities to engage in these processes has been found (Lehrer and Schauble 2002; Rosebery, Warren, and Conant 1992).

Although using evidence in the classroom can provide a concrete context for science learning (Kesidou and Roseman 2002), some studies have indicated that students might fail to transfer the knowledge they learn to new situations when learning focuses too heavily on one context or one set of phenomena (Bjork and Richardson-Klavhen 1989; Cognition and Technology Group at Vanderbilt 1997; Gick and Holyoak 1983; NRC 2000). There is growing empirical support for the usefulness of multiple representations of knowledge to promote a broad transfer of learning in science and in other subject-matter learning (Ainsworth 1999; Brenner et al. 1997; Stenning 1998; Wilson, Shulman, and Richert 1987). The ability to move among different types of representations and data sources is also an important characteristic of scientific practice (Anderson 2003; Duschl 2000; Kelly and Chen 1999; Lehrer and Schauble 2002; Lemke 1990).

Teaching a subject in multiple contexts, with multiple representations (e.g., graphs, figures, formulas, and 3-dimensional models) or multiple phenomena supporting the same idea demonstrates the connectedness of ideas and the wide applications of what is being taught, and may encourage students to develop understandings that are flexible and transferable to new situations (Brenner et al. 1997; Gick and Holyoak 1983; Posner et al. 1982). For example, students' understanding of electric current may be enhanced if they have the opportunity to see and make sense of different phenomena using variations of a simple series circuit (e.g., with one battery-one bulb-one wire, with multiple wires, with multiple bulbs, with switches, and so forth), to observe and diagram the interior of a light bulb, and to study a diagram of a light bulb. This kind of teaching may help students to make sense of key ideas and to coordinate ideas, phenomena, experiences, and data in meaningful ways (Ainsworth 1999; Anderson and Smith 1987a; Posner et al. 1982; Stenning 1998).

Country Perspectives

The stated goals of science education in each of the participating countries provide rationales for investigating the extent to which ideas are supported by evidence in the eighth-grade science lessons. Describing how data, phenomena, and visual representations are used in instructional practices informs the science education community about the extent to which these goals are being implemented.

In Australia, one stated goal is for students to use scientific language appropriately to create visual representations such as drawings and graphs. In addition, practical work in which students generate data is emphasized for its value in enabling students to "work back and forth between theoretical ideas and direct experience" (Australian Education Council 1994, p. 6). In the Czech Republic, the use of evidence to support science learning plays an integral role in both general and subject-specific goals. For example, *Didaktika,* a Czech curriculum guide (Nelesovska and Spalcilova 1998), calls for students to learn by experiencing phenomena through observations and experiments in which they generate, record, and evaluate data to find explanations for various phenomena. Czech teaching goals emphasize the importance of balance between theoretical knowledge and empirical knowledge developed through demonstrations and independent practical work (Nelesovska and Spalcilova 1998). In Japan, current secondary school reforms emphasize scientific ways of thinking, which include drawing on direct experience and observation to construct analytical and integrated points of view (Goto 2001). A goal of science education in the Netherlands is to enable students to describe and interpret phenomena from a scientific point of view. This goal includes acquiring abilities such as observing, data collecting and representing, and relating scientific concepts and skills to phenomena observable in daily life (Dutch Ministry of Education, Culture, and Science 1998; Schmidt et al. 1997). Documents in the United States emphasize the need for students to engage in scientific inquiries in which they actively collect data and represent data in different forms in order to detect patterns and communicate findings to others. Teachers are encouraged to focus these inquiries predominantly on real phenomena and to use these phenomena to support conceptual understandings and to provide experiences with multiple representations, phenomena, and data sets to give students opportunities to apply new ideas in multiple contexts (AAAS 1990, 1993).

Chapter 6 focuses on two main questions:

- What types of evidence are used in the lessons?
- Are main ideas supported with multiple sets and types of evidence?

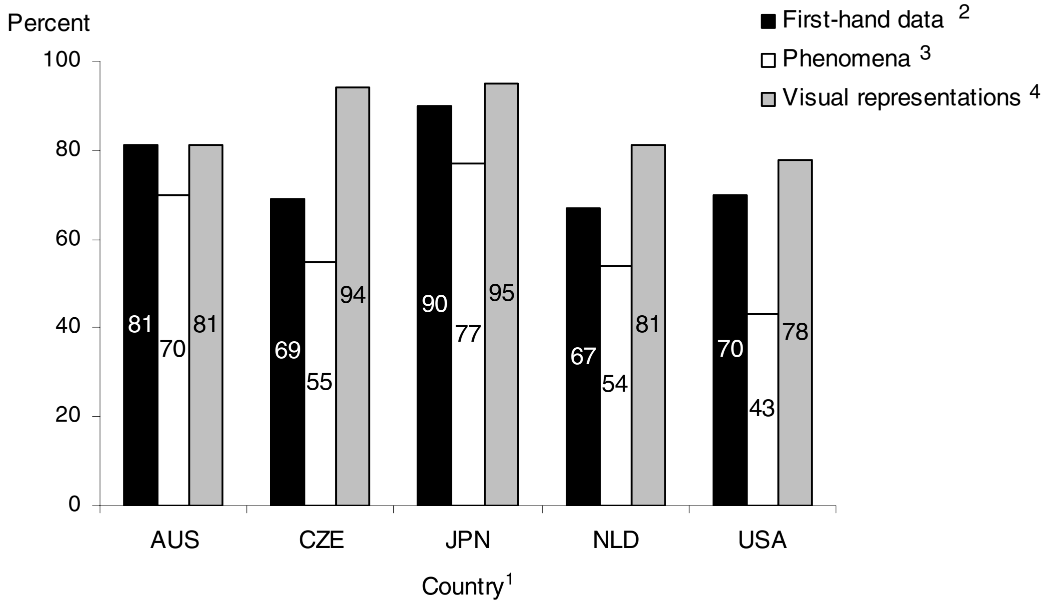
What Types of Evidence Are Used in the Lessons?

This section describes the kinds of evidence that teachers use to support the development of the science content, either publicly or privately, in eighth-grade science lessons. Three types of evidence were used to develop and illustrate the different types of scientific knowledge described in chapter 4: first-hand data, phenomena, and visual representations. These types of evidence are defined as follows:

- ***First-hand data:*** Observations or measurements of specific change events (phenomena) or real-world objects observed by students in the classroom. Examples include both phenomena (the sound that a tuning fork produces; the brightness of a light bulb observed by students while building electric circuits; or the air temperature in sunny and shady locations on the playground) and real-world objects (the teacher displays a jar of vinegar as an example of a common acidic substance; the teacher passes around a rock as an example of a sedimentary rock) (🎥 Video clip example 6.1).
- ***Phenomena:*** Change events of scientific interest that students have the opportunity to observe and/or experience. Phenomena are a subcategory of first-hand data. Except for simulated phenomena, phenomena always generate first-hand data, whereas first-hand data can be produced without the occurrence of observable phenomena in the classroom (e.g., observing different kinds of rocks).The teacher demonstrating the use of a tuning fork is an example of a phenomenon, with the change in sounds being the “change event.” Other examples of phenomena include the teacher melting ice in a glass so that students can see condensation appear on the sides of the glass, or students observing a pea plant at different stages of development to learn about plant growth. Phenomena are commonly produced by the teacher or students through first-hand observations; however, phenomena may occur through simulated experiences as well (🎥 Video clip example 6.2).
- ***Visual representations:*** Visual images that provide compact descriptions or drawings to illustrate real objects, data, processes, or procedures. Visual representations often include words along with some kind of organizing framework to help students imagine or better understand the real object, process, or procedure. For example, students observe a diagram, a 3-dimensional model, or a photograph of a human heart, rather than an actual heart. The diagram can include arrows and words that help students visualize the process of blood flow. Thus, the visual representation highlights concepts and processes as well as the object or data (🎥 Video clip example 6.3).

Figure 6.1 presents the percentage of eighth-grade science lessons that incorporated first-hand data, phenomena, and visual representations.

Figure 6.1. Percentage of eighth-grade science lessons that incorporated at least one instance of first-hand data, phenomena, and visual representations, by country: 1999



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

[2] First-hand data: JPN>CZE, NLD.

[3] Phenomena: AUS>USA; JPN>CZE, NLD, USA.

[4] Visual representations: JPN>AUS.

NOTE: The tests for significance take into account the standard error for the reported differences. Thus, a difference between averages of two countries may be significant while 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.

- First-hand data were used to develop the science content of most eighth-grade science lessons, ranging from 67 percent in the Netherlands to 90 percent in Japan (figure 6.1).
- Japanese lessons were more likely to include first-hand data to support science ideas than lessons in the Czech Republic and the Netherlands (figure 6.1).
- Observations of phenomena were incorporated into more Japanese science lessons than in the science lessons of the other countries except Australia (figure 6.1).
- Visual representations were incorporated into most science lessons, from 78 percent of U.S. lessons to 95 percent of Japanese lessons (figure 6.1).
- Visual representations were used more often than phenomena within all the countries except in Australia (figure 6.1).

Types of Visual Representations

Five distinct types of visual representations were observed as incorporated into the lessons: three-dimensional (3-D) models, graphic representations, diagrams, formulas, and other visual representations.

- Diagrams were used more often in Japanese lessons than in the lessons of any of the other countries except the Czech Republic (see figure E.2, appendix E).
- Formulas were used more often in Czech science lessons than in the lessons of any of the other four countries (figure E.2, appendix E) and 3-D models were used more often in Czech lessons than in Japanese (5 percent) and U.S. lessons (see figure E.2, appendix E).
- Countries did not differ on the use of graphic representations which were used in 36 percent of the lessons in the Netherlands to 53 percent of the lessons in Australia (see figure E.2, appendix E).
- Teachers in Czech lessons were more likely to present eighth-graders with multiple distinct types of visual representations compared to the other four countries. Seventy-three percent of Czech science lessons used at least two types of visual representations, and 36 percent included at least three types of visual representations (data not shown). In all the other countries, 40 to 47 percent of the lessons used at least two types of visual representations and 7 to 11 percent used at least three types of visual representations.

Are Main Ideas Supported with Multiple Sets and Types of Evidence?

This section of the chapter describes to what extent the science content in the lesson was supported with multiple instances of evidence in the form of first-hand data, phenomena, or visual representations. As described in the introduction to this chapter, numerous studies indicate that the use of multiple examples, phenomena, and representations of ideas may be linked to increased understanding of science ideas and ability to transfer learning to new situations (Ainsworth 1999; Brenner et al. 1997; Lehrer and Schauble 2000; Minstrell 1989, 1992; Rosebery, Warren, and Conant 1992; Roth 1990-91; Stenning 1998). The opportunity to examine different ways of supporting and representing ideas may help students see the usefulness of science ideas in different contexts, thus allowing for deeper understanding (Hewson and Hewson 1984; Posner et al. 1982; Roth 2002).

Main Ideas

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

- ***Main idea:*** A main idea was defined as a set of related information that includes ideas, procedures, activities, and/or other types of knowledge that are explicitly connected by the teacher, text, or instructional materials. A main idea explicitly combines smaller, related ideas and activities that are developed by the teacher or worked upon by the students at some length (not just a quick reference). A main idea can be developed during public and private interactions, and it can address any type of science knowledge described in chapter 4 (canonical, procedural, societal issue, safety, and nature of science).

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

Multiple Sets of the Same Type of Evidence

Countries were compared on percentages of lessons in which teachers developed all main ideas with more than one set of first-hand data, more than one phenomenon, and/or more than one visual representation (figure 6.2).

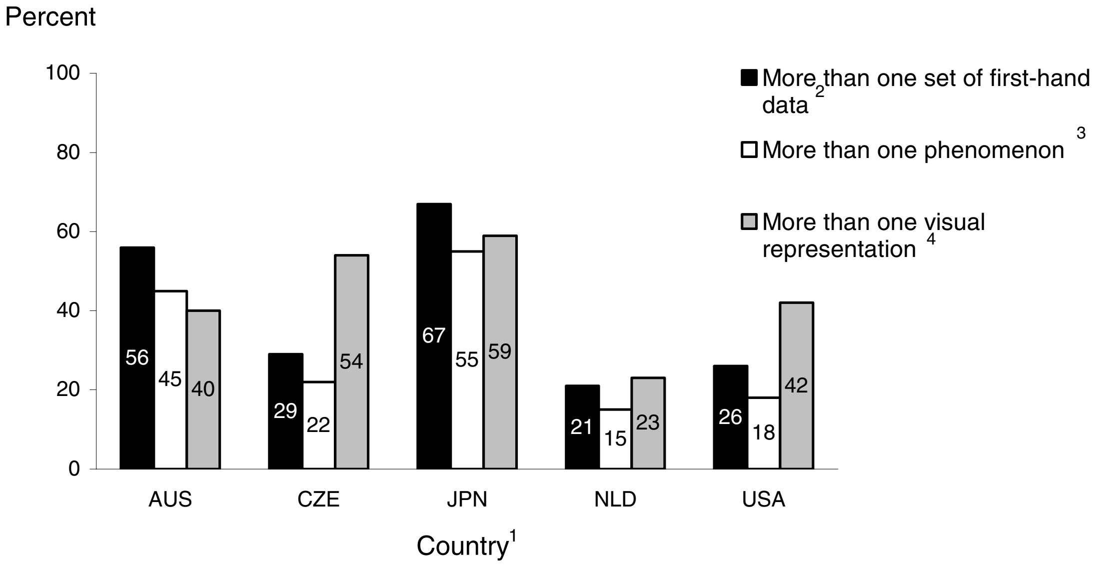
- In Australia and Japan, more eighth-grade science lessons incorporated multiple sets of first-hand data and multiple sets of phenomena to support all of the main ideas than in the science lessons of the other three countries (figure 6.2).
- More Czech and Japanese lessons supported all of the main ideas with multiple visual representations compared to lessons in the Netherlands (figure 6.2).
- Czech and U.S. science lessons more often used visual representations to support all of the main ideas than first-hand data or phenomena (figure 6.2).

Multiple Types of Evidence

Figure 6.3 displays the percentage of eighth-grade science lessons in which all of the main science ideas were supported with three distinct types of evidence: first-hand data, phenomena, and visual representations. That is, each main idea was supported by at least one example of each type of evidence.

- More Japanese science lessons used all three types of evidence (first-hand data, phenomena, and visual representations) to support main ideas than the science lessons in the other four countries (figure 6.3).
- Australian lessons were more likely to incorporate all three types of evidence to support all main ideas than Dutch and U.S. lessons (figure 6.3).

Figure 6.2. Percentage of eighth-grade science lessons that supported all main ideas with more than one set of first-hand data, phenomena, and visual representation, by country: 1999



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

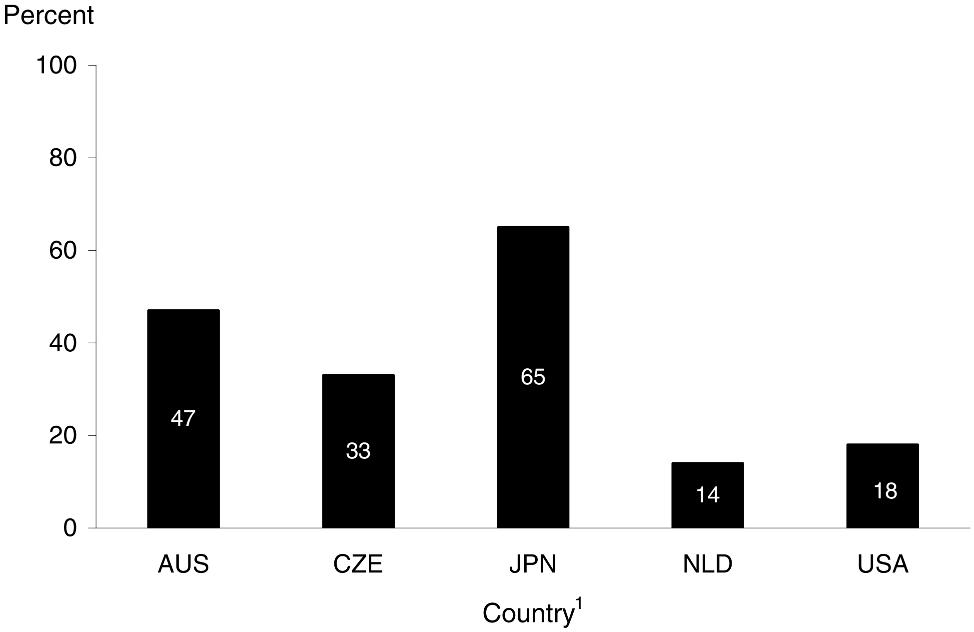
[2] More than one set of first-hand data: AUS, JPN>CZE, NLD, USA.

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

[4] More 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.

Figure 6.3. Percentage of eighth-grade science lessons that supported all main ideas with first-hand data, phenomena, and visual representations, by country: 1999



[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: AUS>NLD, USA; CZE>NLD; JPN>AUS, CZE, NLD, USA.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Summary

The findings presented in chapters 5 and 6 describe instructional practices designed to develop science content in eighth-grade science lessons (chapter 5) and to support science content ideas with evidence (chapter 6). While first-hand data, phenomena, and visual representations were used in many lessons across all the countries, a higher percentage of Japanese lessons included phenomena, supported all main ideas with more than one phenomenon, and supported all main ideas with more than one set of first-hand data than all of the other countries except Australia. More Japanese lessons also supported each main idea with all three types of evidence than all the other countries.

Portraying how teachers develop science knowledge through cohesive lessons and challenging content, and support science ideas with concrete and varied evidence informs us about the content students have the opportunity to learn. This picture lays the groundwork for understanding how students learn science, but it does not describe how students actively work on this content when they participate in "doing" science. The next five chapters explore ways in which students were engaged in doing science work during the lesson, starting with an examination in chapter 7 of the opportunities provided for students to engage in hands-on, practical and science inquiry activities.

Chapter 7: Doing Inquiry with Practical Activities

This chapter examines the ways in which students in the eighth-grade science lessons were engaged in science through participation in practical activities and through the use of various science inquiry practices. Chapter 3 defined practical activities as opportunities for students to observe and/or manipulate science-related objects, and described the amount of time spent on such practical activities. Practical activities provide students with the opportunity to observe and/or interact first-hand with objects and related phenomena. They include both traditional laboratory experiments and other hands-on interactions with objects such as producing and observing phenomena, building models, designing and testing technological solutions to problems, classifying materials, and drawing observations of objects. As discussed in Chapter 3, practical activities can be carried out independently by students working in small groups or individually. They also can occur during whole-class interactions, typically when the teacher performs a demonstration for the entire class to view and discuss together. This chapter explores the nature of these practical activities.

Inquiry practices describe scientific actions that students are asked to do in relationship to their practical activities. The facets of the science inquiry process included in this analysis focus on students' work with first-hand data and phenomena:

- asking questions to investigate;
- designing procedures for investigation;
- making predictions;
- gathering qualitative or quantitative data;
- making observations and recording data;
- manipulating data into graphs or charts; and
- interpreting data and linking predictions to results.

Research Background

Practical activities often are justified as important because they reflect the nature of work in the larger science community, where heavy reliance on the use of empirical evidence supports the building of knowledge (Jenkins 1999; Ntombela 1999; Solomon 1980; Watson 2000). However, there are other reasons given for including practical activities in science lessons. Many research and reform documents suggest that the opportunity to use science inquiry actions in science classes will enhance students' understanding of both science and science inquiry processes (Assessment Performance Unit 1982, 1985; Carey et al. 1989; Harmon, Smith, and Martin 1997; Klopfer 1990; Lazarowitz and Tamir 1994; Metz 1998; NRC 1996; Schauble, Klopfer, and Raghavan 1991; White 1994). In particular, some assert that first-hand data and observations of phenomena help students to build and understand scientific concepts by making the ideas more concrete or by challenging students' experience-based but scientifically naive conceptions (Hodson 1993; Lazarowitz and Tamir 1994; Watson 2000). Others believe that practical activities stimulate and maintain student interest and engagement (Ben-Zvi et al. 1977; Henry 1975) or provide students with opportunities to practice using science inquiry skills, tools, or processes (Bryce and Robertson 1985; Hegarty-Hazel 1990; Klopfer 1990; Tamir, Nussinovitz, and Friedler 1982; Woolnough and Allsop 1985). Still others advocate for the usefulness of practical work in helping students learn to cooperate and to understand the collaborative nature of science (Beatty and Woolnough 1982; Kerr 1964; Watson 2000).

Despite the apparent widespread inclusion of practical activities in the science curriculum in many countries, critiques of practical work in science teaching abound (Millar and Driver 1987; Millar, LeMarechal, and Tiberghien 1999; Tiberghien 1999; Watson 2000). Many of the critiques of practical work point to the mixed evidence regarding the effectiveness of practical activities in helping students attain these learning goals (Gott and Duggan 1995; Harmon, Smith, and Martin 1997; Hodson 1993; Jones et al. 1992; Kempa and Dias 1990). Reviews of the literature by Hodson (1993), Sjoberg (1990), and White (1996) revealed little evidence that practical work improves student understanding of science concepts and even suggested that it is sometimes less effective than other methods (Watson 2000). In fact, many qualitative studies show that without carefully structured guidance in which teachers selectively and gradually assist students, students sometimes use first-hand data to develop ideas unintended by the curriculum (Leach and Scott 2000; McRobbie, Roth, and Lucas 1997; Roth 1990-91; Smith and Anderson 1984; Watson, Prieto, and Dillon 1995). These unintended ideas are sometimes about the nature of science. For example, students carrying out inquiry practices (e.g, predicting, measuring, and graphing) in isolation of the development of conceptual knowledge may develop the belief that science is only about observing and predicting and that these inquiry activities have no connection to the development of conceptual knowledge (Millar and Driver 1987; Roth 1990-91). Studies also raise doubts about the effectiveness of practical activities in helping students develop positive attitudes toward science (Head 1982; Lynch and Ndyetabura 1984) or in improving students' skills in carrying out practical tasks (Assessment Performance Unit 1982, 1985; Gott and Duggan 1995).

In spite of these critiques, some science educators continue to study the ways in which practical activities may be structured to achieve more success with student learning, such as involving students in first-hand inquiry activities that increase student interest and improve student understanding of the nature of science (NRC 1996; Psillos and Niedderer 2003; Schauble et al. 1995; White 1993) or increase student responsibility for their science learning by having them ask their own questions and design their own investigations (Jenkins 1999; Moje et al. 2001; Roth, W-M. 1995; Roth and Bowen 1995). Researchers are also examining the ways in which project-based, "authentic" science inquiries, such as a study of a local stream, may better support student learning (Blumenfeld et al. 2000; Krajcik 2001; Woolnough 2000). In connection with hands-on science work, many researchers support increased attention to "minds on" work in science in which students predict, analyze, represent, and interpret first-hand data to build scientific arguments and to support science ideas (Driver et al. 1994; Kesidou and Roseman 2002; Lehrer and Schauble 2000, 2002; Michaels and O'Connor 1990; Rosebery et al. 1992; Roth 2002).

Country Perspectives

Engaging students in practical work in the science classroom is addressed in all of the curricula and standards documents of the five countries in this study. The documents in all the participating countries specify that during such practical work students should learn to use science inquiry practices (AAAS 1993; Australian Education Council 1994; Czech Ministry of Education 1996; Dutch Ministry of Education, Culture and Science 1998; Goto 2001; NRC 1996). In Australia, Japan, and the United States, curriculum and standards documents emphasize students' involvement in generating questions and designing procedures for investigating these questions (AAAS 1993; Australian Education Council 1994; Ministry of Education, Science, and Culture [*Monbusho*] 1999; NRC 1996). In the United States, the *National Science Education Standards* (NRC 1996) also include the following as abilities necessary to do science inquiry that eighth-grade students should develop: gathering, analyzing, and interpreting data; developing descriptions, explanations, predictions, and models using evidence; and communicating their inquiry work to their peers. The Australian curriculum profile identifies "working scientifically" as a major strand throughout the science curriculum, (Australian Education Council 1994). The Japanese Course of Study (Ministry of Education, Science, and Culture [*Monbusho*] 1999) prioritizes experimentation and scientific observation, with the overall objective being to enable students to "develop the capacity to undertake investigations in a scientific manner" (Goto 2001, p. 32). Dutch attainment goals include "designing tests to investigate simple problems" as a goal within the physics and chemistry strand (Dutch Ministry of Education, Culture, and Science 1998, p. 64). Czech documents put more emphasis on content learning goals, but students are also expected to learn how to conduct simple experiments and to develop skills such as observing and using scientific tools (e.g., the microscope) (Czech Ministry of Education 1996).

In addition to developing the ability to carry out scientific inquiry practices, eighth-grade students in the United States and Australia are also expected to learn about the nature of science and scientific knowledge. Nature of science learning goals described in the national standards and curriculum documents from these countries include: understanding about the importance of skepticism in science inquiry, the need to scrutinize methods used in investigations, and the provisional and incomplete status of scientific knowledge (AAAS 1993; NRC 1996; Australian Education Council 1994).

Data from the TIMSS 1999 achievement study indicate that the goals described in these documents are reflected in the intended eighth-grade science curriculum in both Japan and the United States. These curricula placed a major emphasis on three aspects of practical work—involving students in performing science experiments, using laboratory equipment, and designing and conducting scientific investigations (table 7.1; data from Martin et al. 2000).

Table 7.1. Relative emphasis given to using laboratory equipment, performing science experiments, and designing and conducting scientific investigations of science instruction in the intended curriculum, by country: 1999

Function	Australia (AUS)	Czech Republic (CZE)	Japan (JPN)	Netherlands (NLD)	United States (USA)
Using laboratory equipment	Moderate	Minor/ none	Major	Moderate	Major
Performing science experiments	Moderate	Minor/ none	Major	Moderate	Major
Designing and conducting scientific investigations	Moderate	Minor/ none	Major	Moderate	Major

NOTE: Data provided by TIMSS national research coordinators.
SOURCE: Martin et al. (2000). TIMSS 1999 International Science Report: Findings from IEA's Repeat of the Third International Mathematics and Science Study at the Eighth Grade. Exhibit 5.8. Chestnut Hill, MA: Boston College.

These three facets of practical work received a moderate emphasis in Australia and the Netherlands, and minor or no emphasis in the Czech Republic. The companion TIMSS 1999 Video Study generally concurs, showing that in four of the five participating countries, there is some degree of emphasis on students doing practical work independently, while in the Czech Republic there is less emphasis on such practical work (see chapter 3, table 3.5 and figure 3.7).

As previously shown in chapter 3, the eighth-grade science lessons in the countries, with the exception of lessons in the Czech Republic, allocated more instructional time for students to work on independent practical activities than on whole-class practical activities (figure 3.7). Therefore, the primary focus of this chapter is on different aspects of students' independent work on practical activities, although selected aspects of inquiry during whole-class work will be described.

Chapter 7 focuses on three main questions about student participation in practical activities and through the use of various inquiry behaviors:

- What are the features of independent practical activities?
- What science inquiry actions do students practice during independent work?
- What science inquiry actions do students practice during whole-class work?

What Are the Features of Independent Practical Activities?

Types of Independent Practical Activities

The percentages of eighth-grade science lessons that provided students with any opportunity to engage in independent practical activities presented in table 3.5 ranged from 23 percent of Czech lessons to 74 percent of Australian lessons. The proportions of instructional time over the entire science lesson spent on a single segment of an independent practical activity varied in each of the five countries, ranging from 6 to 100 percent in Australia (2 to 49 minutes), 1 to 68 percent in the Czech Republic (1 to 30 minutes), 3 to 95 percent in Japan (1 to 46 minutes), 16 to 99 percent in the Netherlands (5 to 42 minutes), and 3 to 95 percent in the United States (1 to 67 minutes). The unequal distribution of independent practical activities observed among the five countries (see table 3.5, chapter 3) means that lesson features that may be related to practical activities (e.g., conducting experiments, posing research questions, interpreting results) are likely to be unequally distributed among the countries as well. In order to keep the overall analysis on independent practical activities in perspective, the analyses that follow are shown to highlight the relative emphasis of particular features of practical activities within each country.

During the eighth-grade science lessons collected for this study, students were observed engaging in the following types of practical activities:

- ***Create models:*** The activity requires students to design and make models or prototypes. Models may be designed for the purpose of illustrating scientific principles. For example, students may be asked to use materials to build a model of a cell, or they may be asked to use materials to demonstrate one of Newton's Laws. Alternatively, models or prototypes may be built for the purpose of testing a design to see if it will work better than another design. For example, students may design and build hovercrafts and then race them to see which design is fastest.
- ***Display or classify objects:*** The activity requires students to learn how to present an object, or set of objects, to display certain features of it clearly. For example, students carry out a dissection to show the parts of the circulatory system in a frog or organize a set of rocks into categories (🎥 Video clip example 7.1).
- ***Use tools, procedures, and science processes:*** The activity requires students to practice using a scientific instrument or to master a scientific procedure. The main focus is on learning the procedure or science process skill rather than on generating data to be used to support idea development. For example, students learn how to use the microscope or to carry out a filtration procedure.
- ***Conduct an experiment:*** The activity is a traditional controlled scientific experiment or "fair test" that involves making comparisons of a control and a test case. An independent variable is manipulated to have an effect on a dependent variable, while controlling all other relevant variables. For example, students may conduct an experiment to determine if the temperature of water rises faster when heating water alone, when heating water with copper in it, or when heating water with gold in it. Observations of phenomena are a key part of a controlled experiment.

- ***Produce or observe phenomena:*** The activity requires students to produce or observe phenomena that are not part of a controlled experiment. For example, students observe a series of chemical reactions and, for each one, describe evidence that a chemical reaction has taken place. Or students may use batteries, bulbs, and wires to build a circuit that will enable a bulb to light (📹 Video clip example 7.2).

Table 7.2 presents the percentage of eighth-grade science lessons by the different types of independent practical activities described above.

- Producing or observing phenomena during one continuous segment of science instruction time was the most common type of independent practical activity observed in the science lessons of the five participating countries (table 7.2).

Table 7.2. Percentage distribution of eighth-grade science lessons in which students performed various types of independent practical activities, by country: 1999

	Country				
Student activity	Australia (AUS)	Czech Republic (CZE)	Japan (JPN)	Netherlands (NLD)	United States (USA)
Created models[1]	3!	‡	‡	‡	7
Displayed or classified objects[2]	5!	‡	‡	‡	7!
Used tools, procedures, and science processes[3]	8	3!	‡	4	3
Conducted an experiment[4]	8	‡	‡	5!	‡
Produced or observed phenomena[5]	50	16	65	21	26

!Interpret data with caution. Estimate is unstable.

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

[1] Created models: No measurable differences detected.

[2] Displayed or classified objects: No measurable differences detected.

[3] Used tools, procedures, and science processes: No measurable differences detected.

[4] Conducted an experiment: No measurable differences detected.

[5] Produced or observed phenomena: AUS, JPN>CZE, NLD, USA.

NOTE: Totals may not sum to percentage of lessons with independent practical activities because of rounding and data not reported. See table 3.5, chapter 3 for total percentage of lessons with independent practical activities.

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

Setting Up Independent Practical Activities

Set-Up Talk

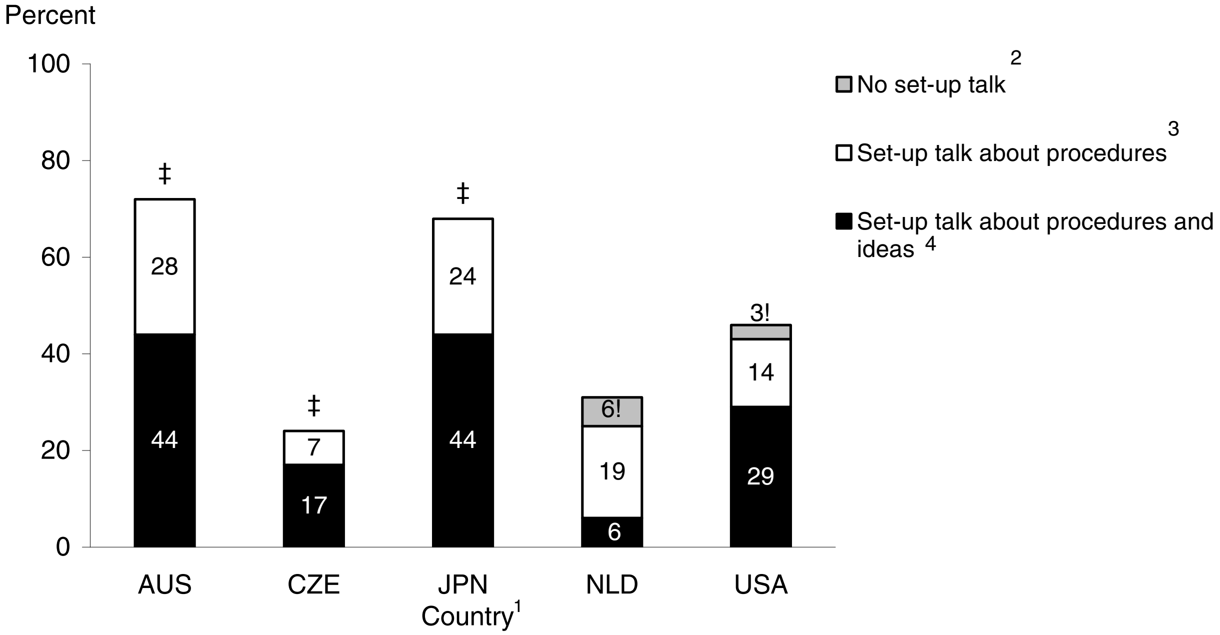
To help students undertake practical activities independently, teachers may set up the activities with discussions about how the activity will proceed, or what the purpose of the activity is, for example. When teachers include such discussions, students may be asked to generate hypotheses, be provided with theoretical background information, or be given instructions for completing the activity. In order to understand how science teachers prepared students for the independent practical activities, each lesson was examined for the following characteristics:

- ***No set-up talk***: The teacher provides no explicit discussion of the nature or purpose of the practical activity prior to its commencement. For example, the teacher gives students a set of written procedures and immediately sends them off to work independently.
- ***Primarily procedures***: The teacher primarily discusses with students the procedures to be followed during the practical activity. Ideas are mentioned at the topic level only or are focused only on how to use tools or how procedures and equipment worked.
- ***Mix of procedures and ideas***: The teacher discusses both procedures and the idea(s) that relate to the main purpose of the independent practical activity. Discussion of ideas exceeds simply naming the topic or stating the goal of the activity. For example, prior to a practical activity in which students will investigate whether saliva plays a chemical or a physical role in digestion, the teacher leads a discussion about differences in starch and sugar molecules and reviews the differences between physical and chemical changes (📹 Video clip example 7.3).

Figure 7.1 displays the percentage of eighth-grade science lessons in which the teacher set up the independent practical activities in different ways.

- Preparation for the independent practical activities in the eighth-grade science lessons involved discussions of procedures in all five countries (figure 7.1).
- Japanese and Australian eighth-grade science lessons more often included discussions of both procedures and the ideas of an independent practical activity than Czech and Dutch lessons (figure 7.1).
- Dutch lessons more often set up independent practical activities through discussions of procedures only than both discussions of procedures and ideas. In contrast, more Japanese lessons set up independent practical activities with both ideas and procedures (figure 7.1).

Figure 7.1. Percentage distribution of eighth-grade science lessons in which the teacher explicitly set up an independent practical activity, by country: 1999



!Interpret data with caution. Estimate is unstable.
‡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] No set-up talk: No measurable differences detected.
[3] Set-up talk about procedures: AUS>CZE.
[4] Set-up talk about procedures and ideas: AUS, JPN>CZE, NLD; USA>NLD.
NOTE: Totals may not sum to percentage of lessons with independent practical activities because of rounding and data not reported. See table 3.5, chapter 3 for total percentage of lessons with independent practical activities.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Purpose of the Practical Activity

Another way students were prepared for independent practical activities was through explanations about the purpose, or learning goal, of the activity. This was done in three different ways:

- ***Verifying knowledge***: The teacher, text, or worksheet communicates the scientific knowledge, fact, or idea that will be demonstrated through the practical activity. For example, a teacher may explain to students that light travels in straight lines, using the practical activity to “demonstrate that this is true.” Or the teacher may review the formula for density and then have students practice calculating the densities of a various objects by collecting data about their mass and volume (🎥 Video clip example 7.4).
- ***Following procedures***: The teacher, text, or worksheet identifies an observation, measurement, or procedure that will be conducted through the practical activity but does not state why students will be making these observations, or measurements (e.g., there is no knowledge outcome to be verified and no question to be investigated). For example, a teacher

may tell students that they will “measure the current in a series circuit” or “observe different kinds of rocks” (📹 Video clip example 7.5).

- ***Exploring a question***: The teacher, text, or worksheet poses a main question or idea that students will explore through the practical activity (the intended learning outcome is unknown to students). For example, a teacher may explain to students that in the practical activity they “will measure current to determine if there are differences between series and parallel circuits” (📹 Video clip example 7.6).

Figure 7.2 presents the percentage of eighth-grade science lessons in which the teacher, text, or worksheet oriented students to the purpose of a practical activity.

- Teachers of Japanese and Australian science lessons were more likely to present a question as the purpose of a practical activity than teachers of Czech and U.S. lessons (figure 7.2).
- Students more often were provided with a question to explore than with knowledge to be verified within Australian lessons (figure 7.2).
- Within U.S. lessons, students were more often provided with knowledge to be verified than with a question to be explored (figure 7.2).

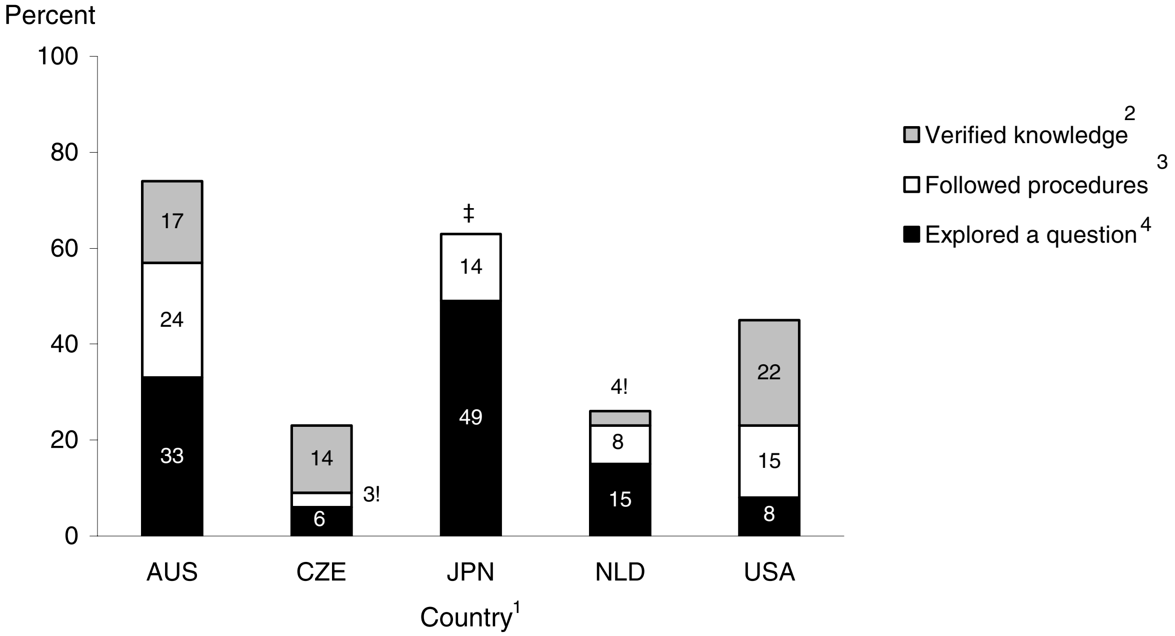
Following up Independent Practical Activities

Discussion of Results

Following the independent practical activities in the eighth-grade science lessons, the class could engage in public discussions of the results of the activities. When discussions are held, some might focus only on the data and observations (📹 Video clip example 7.7) while others might focus on making interpretations and drawing conclusions. Multiple conclusions could be raised or mentioned without emphasizing or linking them together to draw a larger, overarching conclusion. In other cases, the class could discuss how the outcomes of the practical activity were connected to and supported a single main conclusion or idea (📹 Video clip example 7.8). Appendix D includes a more detailed description of four types of discussion of results observed in the lessons.

- In the Netherlands, 30 percent of lessons involved students in working on independent practical activities (table 3.5), and in 25 percent of lessons the results of the independent practical activities were not discussed (figure 7.3).
- Looking within Australia and Japan, students more often engaged in discussions following independent practical activities than not (figure 7.3). In Japanese lessons, discussions about the results of practical activities were most often focused on drawing one main conclusion (figure 7.3)

Figure 7.2. Percentage distribution of eighth-grade science lessons in which students were oriented to the purpose of an independent practical activity, by country: 1999



!Interpret data with caution. Estimate is unstable.

‡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]Verified knowledge: AUS, CZE, USA>NLD.

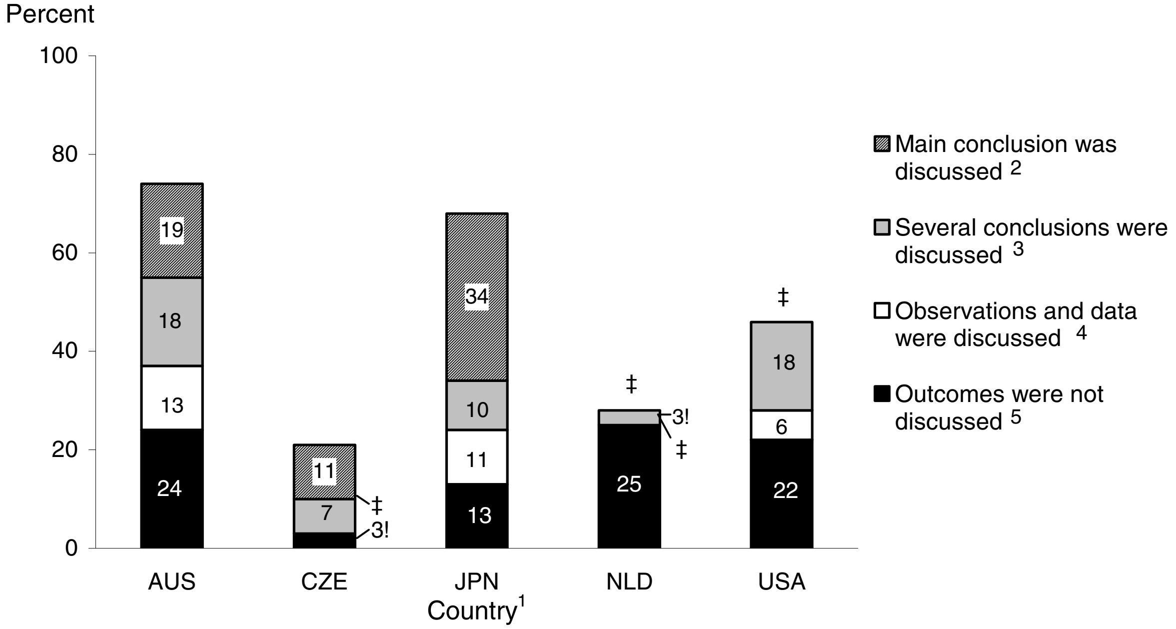
[3]Followed procedures: AUS>CZE, NLD.

[4]Explored a question: AUS, JPN>CZE, USA; JPN>NLD.

NOTE: Totals may not sum to percentage of lessons with independent practical activities because of rounding and data not reported. Lessons with no known outcome are not included in the analyses. See table 3.5, chapter 3 for total percentage of lessons with independent practical activities.

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

Figure 7.3. Percentage distribution of eighth-grade science lessons in which outcomes of independent practical activities were discussed publicly, by country: 1999



!Interpret data with caution. Estimate is unstable.
‡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]Main conclusion was discussed: JPN>CZE.
[3]Several conclusions were discussed: AUS>NLD.
[4]Observations and data were discussed: No measurable differences detected.
[5]Outcomes were not discussed: AUS, NLD, USA>CZE.
NOTE: Totals may not sum to percentage of lessons with independent practical activities because of rounding and data not reported. See table 3.5, chapter 3 for total percentage of lessons with independent practical activities.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

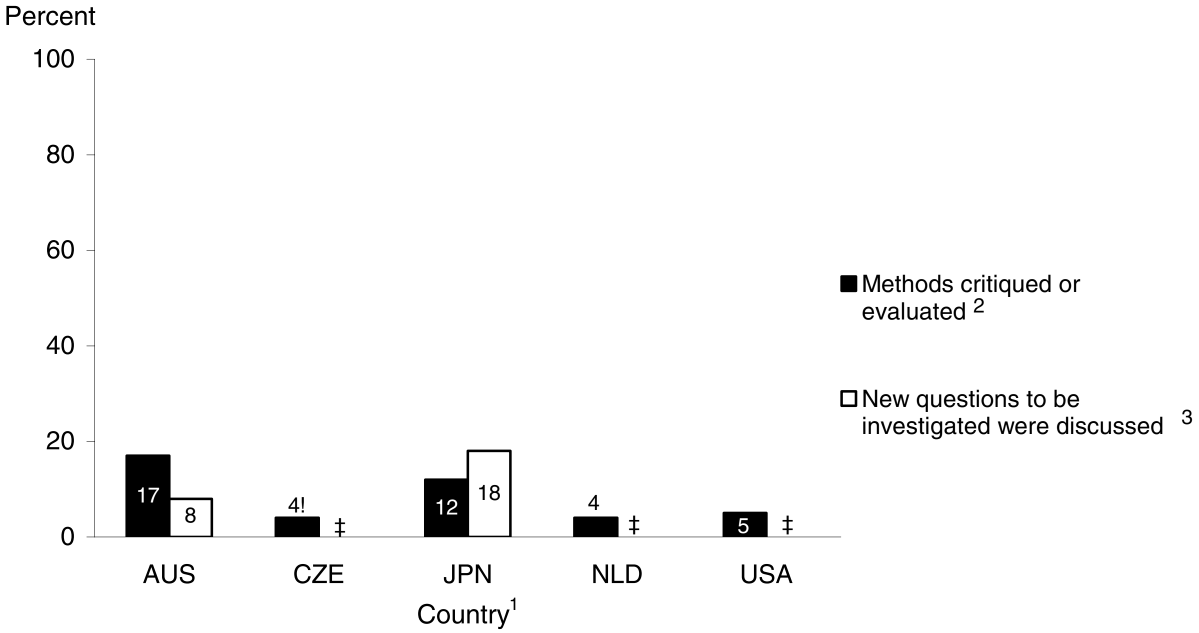
Critique Methods and Raise New Questions

Teachers can help students learn about the nature of scientific knowledge and thinking in many ways. For example, the class may discuss why a certain procedure was used and consider the limits and possible inaccuracies of the data provided by the procedure (🎥 Video clip example 7.9). Alternatively, the teacher may help students raise a new question to be asked, demonstrating that scientific knowledge is always tentative, incomplete, and subject to further exploration.

- Eighth-graders evaluated or critiqued the procedures and limitations of the independent practical activities in 4 to 17 percent of the science lessons across the five countries (figure 7.4).

- By the end of the lesson, students developed new questions to be investigated derived from their practical activities in 18 percent of Japanese and 8 percent of Australian science lessons (figure 7.4).

Figure 7.4. Percentage of eighth-grade science lessons in which methods of the independent practical activity were evaluated or critiqued and new questions to investigate were discussed, by country: 1999



!Interpret data with caution. Estimate is unstable.

‡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] Methods critiqued or evaluated: No measurable differences detected.

[3] New questions to investigate were discussed: No measurable differences detected.

NOTE: See table 3.5, chapter 3 for total percentage of lessons with independent practical activities.

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

What Science Inquiry Actions Do Students Practice During Independent Work?

Teachers sometimes provide opportunities for students to engage in different types of inquiry practices 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.

Patterns of Student Use of Science Inquiry Practices

The types of inquiry activities that were related to independent practical work and in which students engaged before, during, and after the independent practical work were defined as follows.

- ***Students generate the research question:*** Students generate the research questions related to a practical activity, with either complete freedom or with several options provided by the teacher
- ***Students design procedures for investigation:*** Students design procedures for their own investigation related to a practical activity, with either complete freedom or with several options provided by the teacher
- ***Students make predictions:*** Students predict the outcome of a practical activity. Students also can provide the reason for the predictions (🎥 Video clip example 7.10).
- ***Students interpret data or phenomena***: Students use first-hand data or phenomena from the independent practical activity as evidence to explain patterns, draw conclusions, make generalizations, and/or link the first-hand data or phenomena to predictions or hypotheses made before beginning the activity. Students may work independently on generating interpretations of their first-hand data or phenomena (either individually or in pairs/small groups), or the teacher may guide students in making interpretations during public, whole-class discussions (🎥 Video clip example 7.11).
- ***Students collect and record data***: Students are involved in recording first-hand data or observations of phenomena during independent practical activities (🎥 Video clip example 7.12).
- ***Students organize or manipulate data collected independently***: Students independently organize or manipulate first-hand data or observations into tables, graphs, or charts. They design the structure or form of the table, graph, or chart (🎥 Video clip example 7.13).
- ***Students organize or manipulate collected data as directed by the teacher or the textbook***: First-hand data or observations are organized or manipulated into tables, graphs, or charts under the direction of the teacher or textbook. In many cases, the teacher, textbook, or workbook provides the table, graph, or chart templates, and students fill in the data. In other cases, the teacher uses student-generated data and demonstrates on the board or overhead how to organize the data into a graph or chart.

Table 7.3 displays the percentage of lessons in which students engaged in the following types of inquiry activities related to and occurring before, during, and after independent practical work.

- Independent practical activities in the eighth-grade science lessons seldom involved students in generating their research questions or designing their investigations (table 7.3). Students generated research questions related to the independent practical activities in 3 percent of Australian science lessons, and they designed procedures for investigation in 10 percent of Australian science lessons and in 5 percent of Japanese and U.S. science lessons (table 7.3).
- Students made predictions or hypotheses about the independent practical activities in 4 to 23 percent of the eighth-grade science lessons in the countries except in the Czech Republic (table 7.3). Further analyses revealed that students were expected to give reasons for their predictions in 6 percent of Australian science lessons and 8 percent of Japanese lessons (data not shown).
- 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 (table 7.3).
- Within all countries where reliable estimates could be made, eighth-graders were more likely to interpret results of the independent practical activities during science lessons than to make predictions (table 7.3).
- In Czech science lessons, students were more likely to be asked to interpret results than to collect and record data (table 7.3).
- Students organized and manipulated data collected independently in no more than 9 percent of lessons in any of the countries. In Australia, such work was done more often under the guidance of the teacher or textbook than independently (table 7.3)

Table 7.3. 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	3!	‡	‡	‡	‡
Designed procedures for investigations	10	‡	5!	‡	5
Made predictions	11	‡	23	4!	8
Interpreted the data or phenomena	56	20	43	24	33
Collected and recorded data	62	8	59	29	31
Organized or manipulated data collected independently	9	‡	‡	8	8
Organized or manipulated collected data guided by teacher or textbook	27	3!	37	8	19

!Interpret data with caution. Estimate is unstable.

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

[1] Students generated the research question: No measurable differences detected.

[2] Students designed procedures for investigations: No measurable differences detected.

[3] Students made predictions: JPN>NLD.

[4] Students 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 teacher or 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. See table 3.5, chapter 3 for total percentage of lessons with independent practical activities.

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

What Science Inquiry Actions Do Students Practice During Whole-Class Work?

Teachers can also engage students in science inquiry practices during whole-class practical activities such as demonstrations, although the range of possible inquiry practices may be more limited. In the videotaped lessons, students were asked to generate predictions, to interpret the first-hand data or phenomena, and to organize and manipulate first-hand data into tables, graphs, or charts during whole-class practical activities. However, since whole-class practical activities involve students in watching someone else (usually the teacher) generate and collect the data, students in the videotaped lessons were not observed formulating their own questions to investigate, designing procedures to investigate their questions, or collecting their own first-hand data from observations during whole-class practical activities.

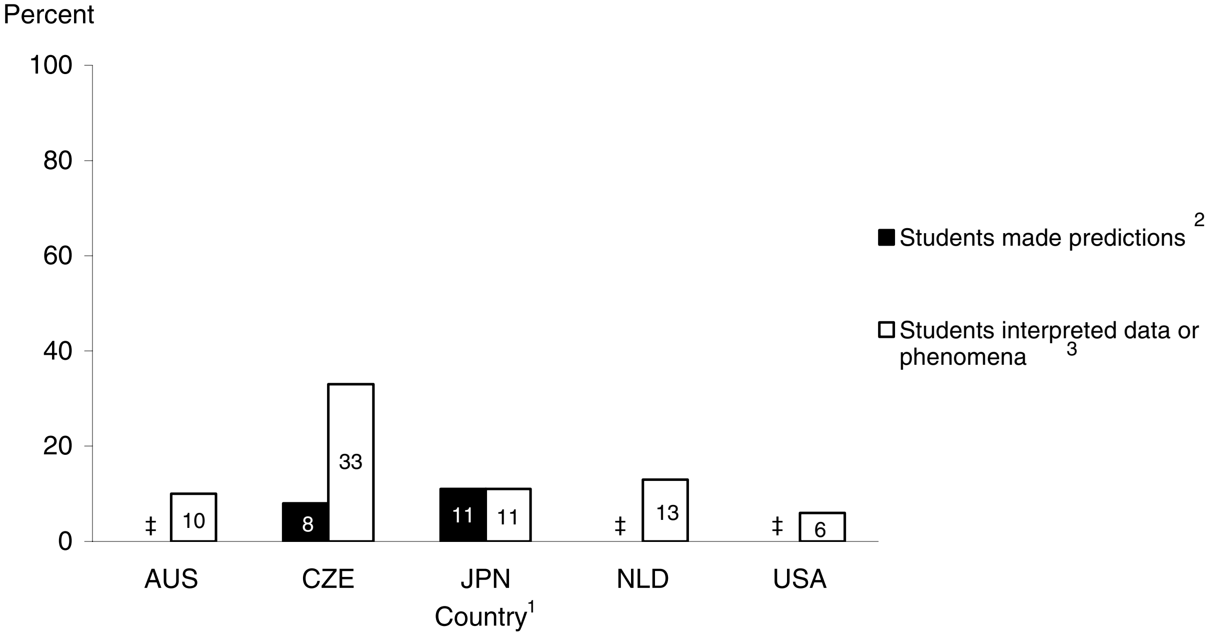
Students participated in whole-class practical activities in a large percentage of the eighth-grade science lessons in all the participating countries, ranging from 62 percent in the Netherlands to 81 percent in Australia (see table 3.5, chapter 3). Countries were not found to vary on the distribution of lessons with whole-class practical activities unlike the distribution of independent practical activities (see table 3.5, chapter 3). However, as described in chapter 3, it is important to keep in mind that even though practical whole-class activities occurred in a large percentage of the science lessons, countries allocated a small average proportion of time to whole-class practical activities, ranging from 4 to 10 percent of total science instruction time (figure 3.7).

Students Make Predictions and Interpret First-Hand Data or Phenomena

Predictions can be derived from previously known science knowledge, such as science theories or laws of science, with the expectation that students will be able to generate an accurate prediction. Alternatively, teachers can ask students to make predictions in situations where students do not have enough information to necessarily make a correct prediction (🎥 Video clip example 7.14). In these situations, the teacher may expect a wider array of student responses. Students can also be expected to interpret the results of the whole-class practical activities by explaining patterns, drawing conclusions, making generalizations, and/or linking the data or phenomena to predictions they made before the activities (🎥 Video clip example 7.15).

- No more than 11 percent of the eighth-grade science lessons in any of the five countries provided opportunities for students to make predictions related to whole-class practical activities (figure 7.5).
- Students were more likely to interpret the first-hand data or phenomena related to the whole-class practical activities in Czech science lessons (33 percent) than lessons in the other four countries (figure 7.5).
- More opportunities were provided within Czech science lessons for interpreting the results of these activities than making predictions (figure 7.5).

Figure 7.5. Percentage of eighth-grade science lessons in which students made predictions and interpreted data or phenomena related to whole-class practical activities, 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]Students made predictions: No measurable differences detected.
[3]Students interpreted the first-data or phenomena: CZE>AUS, JPN, NLD, USA.
NOTE: See table 3.5, chapter 3 for total percentage of lessons with independent practical activities.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Summary

The opportunities for eighth-grade science students to participate in independent practical activities were described and compared across the participating countries in this chapter, revealing similarities and differences among the countries. Across all of the countries, the most common type of independent practical activity was generating and observing phenomena (rather than creating models, conducting experiments, classifying or dissecting objects, or using tools or science processes). Students rarely were engaged in critiquing or evaluating procedures and methods or considering new questions to be investigated.

Investigating practical activities revealed distinct patterns in Japan, the Netherlands, and the Czech Republic. Independent practical activities in Japan most often engaged students in exploring a question with an answer unknown to the students, included set up talk about science ideas as well as procedures, and were followed up with discussions that focused on one main idea or conclusion. Independent practical activities in the Netherlands, in contrast, were preceded most often with talk about procedures (not ideas) and were not followed by any discussion of the activity. Dutch students were most often given the instructions and sent off to work independently until the end of the period. Czech students were given fewer opportunities to participate in independent practical activities than at least three other countries resulting in fewer opportunities to make predictions, collect data, manipulate and organize data, or interpret data related to these activities. Even with these activities limited to 23 percent of Czech lessons, Czech students did interpret data in 20 percent of all the lessons. In addition, Czech students had opportunities to interpret data related to whole-class practical activities in a higher percentage of lessons than all of the other countries.

One aspect of students' practical work not discussed in this chapter is the social organization of the science classroom. The next chapter describes students' opportunities to work collaboratively during both practical and seatwork activities.

Chapter 8: Collaboration

This chapter describes the ways in which the eighth-grade science lessons provided opportunities for students to work collaboratively in small groups independently of the teacher.

Research Background

In science lessons, teachers have traditionally grouped students together to work on laboratory activities for two major reasons: to share limited materials and to provide opportunities for students to collaborate with their peers. Peer collaboration has been studied for its role in fostering student learning through social interactions (Bianchini 1997; Cohen 1994; Collins, Brown, and Newman 1989; Johnson, Johnson, and Holubec 1993; Kelly and Green 1998; Slavin 1995, 1996). In the field of science education, collaborative work is viewed by some researchers as particularly important because it can mirror the nature of work in scientific communities (Garfinkel, Lynch, and Livingston 1981; Gooding 1992; Latour and Woolgar 1986). It has been noted in the research literature, however, that students often work in groups without collaborating with each other—they may share materials and talk with each other but complete the tasks individually (Cohen 1994). Nonetheless, collaborative work continues to be a regular feature of science teaching.

Many educators across the world also have overarching citizenship goals for student learning that cross disciplinary learning boundaries. These goals often include the importance of learning to work collaboratively in groups. For example, in the Netherlands, there are general attainment targets that specify that students should learn to converse and work as part of a team (Dutch Ministry of Education, Culture, and Science 1998). In Japan, there is emphasis on building harmony and cooperation within the school and the classroom; competition among individual students in the classroom is discouraged. Teachers work to develop team spirit, and grouping is an important technique to build a cooperative atmosphere (Matsubara et al. 2002). The *National Science Education Standards* in the United States point out that collaborative group work enhances students' respect for each other by encouraging interdependency among group members and heightening students' awareness of the different kinds of expertise brought by different group members (NRC 1996, p. 36).

Seven features of groupwork are presented in this chapter in an effort to ascertain whether groupwork activities involved students in collaborating versus simply sharing materials. These seven features, though not exhaustive of all possibilities, provide a multifaceted description of students' opportunities to collaborate on their science work. The features of small groupwork investigated in this study include

- students are sitting together;
- students are sharing materials;
- students are talking with their group members;
- the task is designed to require collaboration;

- students are assigned roles within groups;
- students are expected to make a group product; and
- the gender composition of the groups is mixed.

These features were selected because the research literature suggests that effective groupwork depends on genuine collaboration among students, and that the teacher can encourage such collaboration by assigning roles within the group, designing tasks that require students to collaborate, requiring a group product, and including a mix of students in each group (ability, gender, and ethnicity; Cohen 1994; Johnson, Johnson, and Holubec 1993). The structural features of groupwork described in this section provide some indication of the degree to which groupwork in the eighth-grade science classrooms involved students in collaborating with one another.

Country Perspectives

Although groupwork is emphasized as an important goal in most of the curriculum and standards documents of the participating countries, it should be noted that individual work and responsibility are also highlighted as important goals in some of the countries. In the Czech Republic, for example, students are expected to work and think individually (to find and organize information independently, to develop new knowledge through independent thinking, and so forth), while groupwork and collaboration are not explicitly named as curriculum goals (Czech Ministry of Education 1996). In the Netherlands, both individual learning and collaborative learning are emphasized. One of the three overarching, cross-disciplinary curriculum goals is to develop “active, independent learning” students with an emphasis on student-directed education, while more specific attainment targets focus on working with people who are different from oneself, conversing and working as part of a team, and dealing with similarities and differences between the sexes (Dutch Ministry of Education, Culture, and Science 1998, pp. 7-12).

Thus, for various reasons, national standards and curriculum documents or other policy documents in some of the countries encourage teachers to involve students in groupwork activities. This chapter explores two main questions:

- How much did students work in pairs or groups versus individually?
- What features characterized students’ collaboration during group work?

The descriptions of collaborative work presented in this chapter focus on students’ independent pair or group work (apart from the teacher) and not on whole-class interactions. It is only during such independent work that students may have the opportunity to experience the kinds of social interactions in which they learn to converse with each other and work as part of a team—activities students engage in apart from the teacher. For reference, the data in figure 3.6 and table 3.5 in chapter 3 indicated that, with the exception of the Czech Republic, the proportion of time that students spent in independent work was not found to differ measurably from the proportion of time spent in whole-class work. In Australia, Japan, the Netherlands, and the United States, around half of lesson time, on average, was spent in independent student work (ranging from 45 to 52 percent of science instruction time; figure 3.6). In the Czech Republic, 17 percent of science instruction time was spent having students work independently. The time students worked in groups or individually is most likely linked to the pattern of differences between countries found for the opportunities for independent work described above. Although pair/group work could be linked to the content of the lesson, the science lessons were selected across the school year to assure that a variety of content topics would be sampled, giving us a typical sample of lessons from each country.

How Much Did Students Work in Pairs or Groups Versus Individually?

This section begins with a description of the percentage of lessons and the percentage of science instruction time when students, independent of the teacher, worked in different social participation structures: individually or in pairs/groups. Next, the social organization is compared during practical and seatwork activities: Were students engaged in groupwork only during practical, hands-on activities, or did groupwork also characterize seatwork activities such as paper-and-pencil tasks? To assess students' opportunities to collaborate in pairs or small groups, two predominant types of social participation structures[10] were defined:

- ***Individual work:*** The teacher instructs students to work alone, or the task is structured in a way that suggests that students should work alone (e.g., "Think about the hypothesis and write it down in your notebook"). At least half of the students are observed to be working alone for more than 50 percent of the independent work time.
- ***Pair/group work:*** The teacher instructs students to work in groups of two or more, or the task is structured in a way that suggests students should work together in pairs or small groups. At least half of the students are observed to be working in pairs or small groups during more than 50 percent of the independent work time.

Figure 8.1 presents the percentage of eighth-grade science lessons that provided opportunities for independent individual and pair/group work. Figure 8.2 displays the percentage of science instruction time allocated to independent individual and pair/group work.

- Eighth-graders worked in groups of two or more in a greater number of Australian, Japanese, and U.S. science lessons than in Czech and Dutch lessons (figure 8.1).
- Compared to Czech lessons, eighth-grade science lessons in Australia, Japan, the Netherlands, and the United States devoted a greater average percentage of science instruction time to students working in groups of two or more (figure 8.2).
- Dutch students worked individually for a larger proportion of science instruction time than students in Czech and Japanese lessons (figure 8.2).

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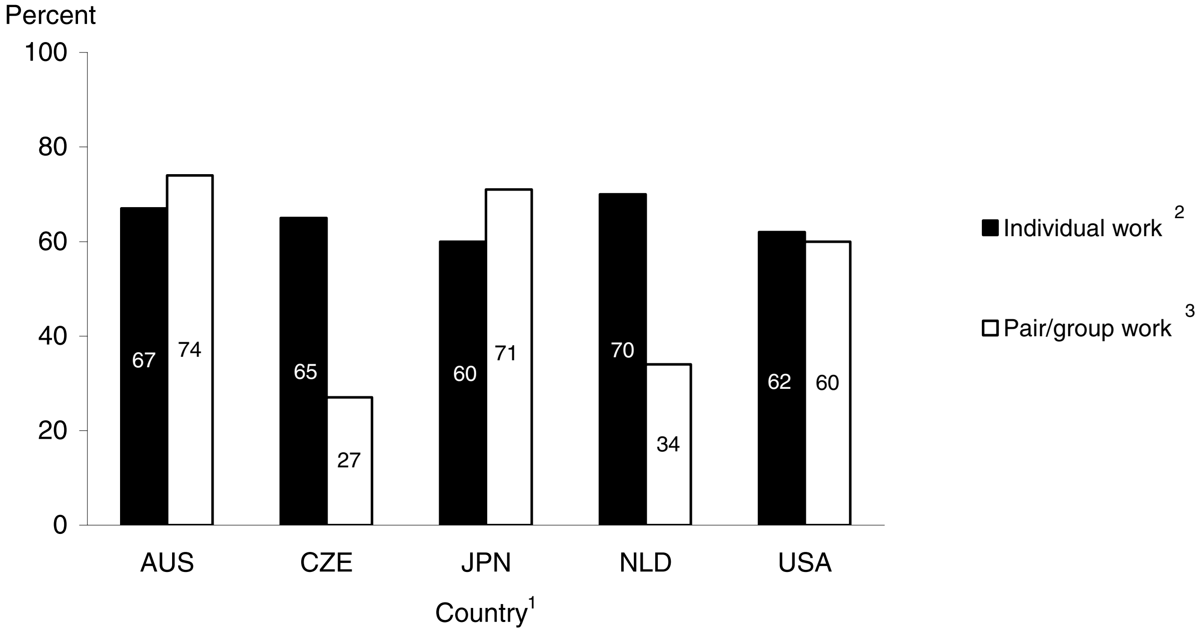
[10] A third social participation structure occurred when students moved back and forth between individual and pair/group structures during independent work. Such changing of social participation structures was observed in 3 percent of Australian and U.S. eighth-grade science lessons; there were not enough cases in the other three countries to calculate reliable estimates. Due to its relatively rare occurrence, information on this social participation structure was not included in figures and tables in this chapter.

Figure 8.1. Percentage of eighth-grade science lessons with independent individual work and pair/group work, by country: 1999

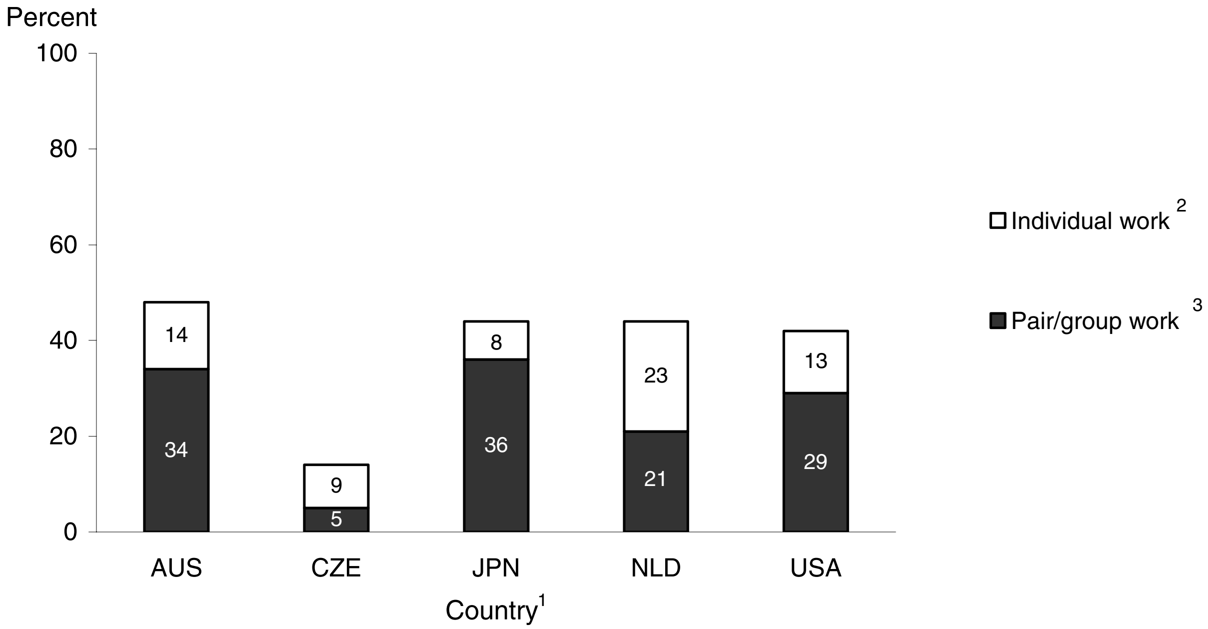


[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
[2] Individual work: No measurable differences detected.
[3] Pair/group work: AUS, JPN, USA>CZE, NLD.

NOTE: Percentage of lessons does not include lessons where students moved freely between independent and pair/group work. This occurred in no more than 3 percent of U.S. and Australian lessons, and was observed too infrequently in the other countries to produce reliable estimates.

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

Figure 8.2. Average percentage distribution of science instruction time during eighth-grade science lessons devoted to individual work, and pair/group work, by country: 1999



[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
[2] Individual work: NLD>CZE, JPN.
[3] Pair/group work: AUS, JPN, NLD, USA>CZE; JPN>NLD.
NOTE: Percentage of science instruction time devoted to changing social participation structures, taking notes and silent reading, divided class work, and whole class work are not presented (see chapter 3, figure 3.7).
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

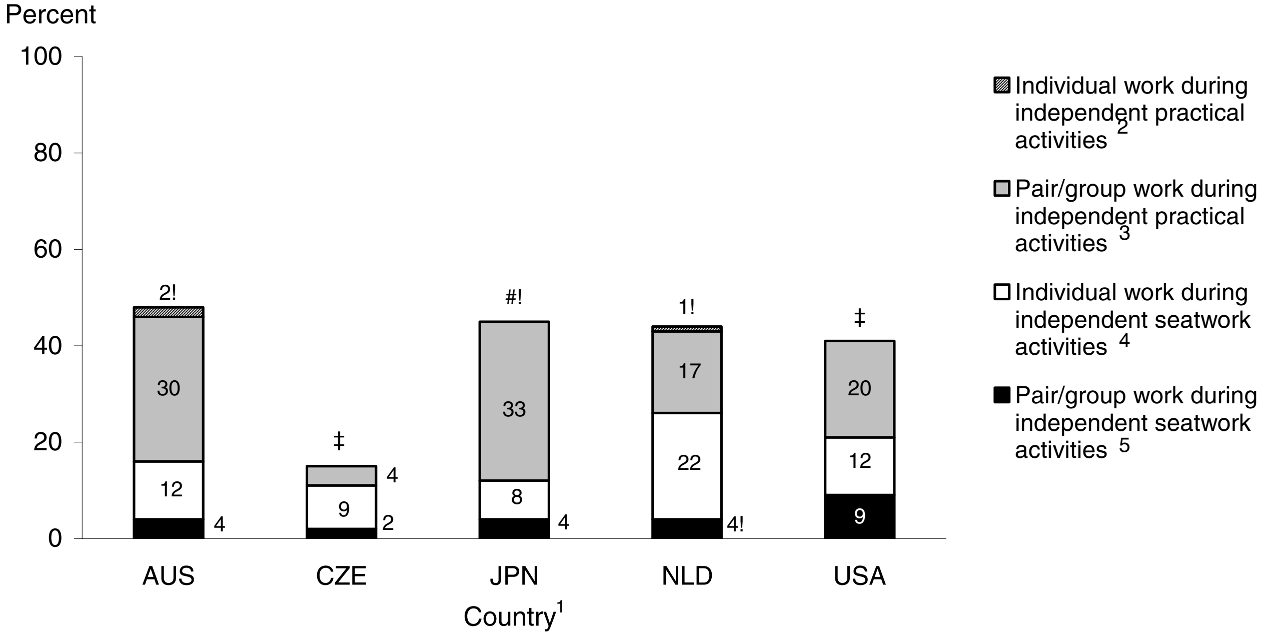
Groupwork During Independent Practical and Seatwork Activities

Figure 8.3 presents the percentage of science instruction time devoted to individual work and pair/group work during independent practical and seatwork activities.

- Students in Czech eighth-grade science lessons worked in groups of two or more for a smaller percentage of independent practical work time than in all of the other countries (figure 8.3).
- During independent seatwork activities, students in Dutch lessons worked individually for a larger average percentage of science instruction time than all the other countries except the United States (figure 8.3).
- When students were given the opportunity to work independently on practical activities, it was done typically in pairs or groups (figure 8.3). Students in eighth-grade science lessons were rarely observed to work individually during practical, hands-on activities (figure 8.3).

- When given the opportunity to work on independent seatwork activities, students more often worked individually than in pairs or groups within the countries where reliable estimates could be made, except within the United States where no measurable differences were found (figure 8.3).

Figure 8.3. Average percentage distribution of science instruction time during eighth-grade science lessons devoted to individual work and pair/group work during independent practical and seatwork activities, by country: 1999



#Rounds to zero.

!Interpret data with caution. Estimate is unstable.

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

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

[1] Individual work during independent practical activities: No measurable differences detected.

[2] Pair/group work during independent practical activities: AUS, JPN, NLD, USA>CZE; JPN>NLD.

[3] Individual work during independent seatwork activities: NLD>AUS, CZE, JPN.

[4] Pair/group work during independent seatwork activities: No measurable differences detected.

NOTE: Percentage of science instruction time devoted to changing social participation structures, copying notes and silent reading, divided class work, and whole class work are not presented (see chapter 3, figure 3.7).

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

What Features Characterized Students' Collaboration During Groupwork?

Students can be organized to work collaboratively in groups in many ways. In some eighth-grade science lessons, students were observed sitting together and sharing materials, but they created individual products. Thus, in these lessons, group collaboration was limited to sharing materials and talking to each other. In other lessons, the group task was designed to encourage greater collaboration among students either by requiring multiple hands/minds to complete the task successfully, assigning different roles to different students within the group, and/or requiring a group product. The groupwork research literature suggests that features that encourage interaction among students may enhance student learning (Cohen 1994; Johnson, Johnson, and Holubec 1993).

Seven features were identified that characterize students' opportunities to collaborate during pair/group work. These features enable a multifaceted description of students' opportunities to collaborate that extends beyond simple identification of the occurrence of pair/group work. Did students merely share materials, or were they required to collaborate in order to complete the task successfully? How often did pair/group work include features that encourage collaboration, such as assigned roles within the group and group products? The seven features of pair/group work investigated are:

- ***Sitting together:*** Students' desks are set up for groupwork; two or more desks are joined together or students sit in groups of two or more at tables.
- ***Sharing materials:*** Students share special materials (beyond paper, pencils, worksheets, textbooks) with other students in their group. Students work together with the materials, even if one student is doing the manipulating at a given time. Such special materials include lab equipment, chemicals, science tools such as Bunsen burners, specimens to be studied such as rocks or plants, maps, globes, and construction tools (scissors, glue, rulers). In fact, groups are sometimes formed specifically for students to share a limited supply of special materials (📹 Video clip example 8.1).
- ***Talking among students:*** A few or many students constantly talk with each other in their groups. Little talking among a few students or occasional interactions are not included.
- ***Working on tasks requiring collaboration:*** The group task is designed in such a way that students have to work together to complete it successfully; the task is not carried out by one student alone. The task is not completed unless the group members work together because it is designed in such a way that each student contributes a part of the process or the end product of the task. Students collaborate with each other in several ways. One type of collaboration task requires physical as well as mental collaboration. For example, the task requires one student to throw a ball, another student to catch it, and another student to measure the time the ball spent in the air. Another experiment requires multiple simultaneous actions such as reading the temperature of several liquids at exactly the same time. A second type of collaboration task requires students to survey one another. For example, students interview each other and collect and compute statistics, or students in a group share opinions and then build a group consensus. A third type of collaboration task requires each student to

provide different information that has to be shared with the group members. For example, the group works on constructing a presentation that includes information gathered by each group member (🎥 Video clip example 8.2).

- ***Assigning roles to group members:*** The teacher assigns particular roles to students within a group, or students assign roles within their groups. For example, one student is designated as the recorder for the group, another as the person who retrieves and returns materials, and another as the group facilitator.
- ***Creating science group products:*** Students are assigned to produce a science product as a group such as a completed worksheet, a lab report, a written design for an experiment, or a constructed 3-dimensional model or object. Each group is responsible for its science group product (🎥 Video clip example 8.3).
- ***Working in all mixed gender groups:*** All of the observed pairs/groups include both girls and boys regardless of the type of other groupwork features described above. This category includes those situations where an uneven number of boys and girls in the class required some students to work in a single gender group, but the intent was to create a mix of gender groups for the entire class.

Table 8.1 presents the average percentage of science instruction time in the eighth-grade science lessons allocated to pair/group work and to the seven features of pair/group work.

- Eighth-graders in the science lessons sat together, shared materials, and talked to each other during almost the entire average time devoted to pair/group work time in the five countries (table 8.1).
- Students in Japanese science lessons spent more instructional time creating science group products than students in Czech lessons, and spent more time working in all mixed gender groups than students in U.S. lessons (table 8.1).
- Within all the countries with enough lessons to calculate reliable estimates, students spent less instructional time working on tasks requiring collaboration, creating science group products, or working with assigned roles than sitting together, sharing materials, or talking among themselves (table 8.1).

Table 8.1. Average percentage of science instruction time in eighth-grade science lessons allocated to pair/group work and selected features of pair/groupwork, by country: 1999

Features of pair/group work	Australia (AUS)	Czech Republic (CZE)	Japan (JPN)	Netherlands (NLD)	United States (USA)
Total[1]	34	5	36	21	29
Sitting together[2]	33	5	36	18	27
Sharing materials[3]	32	5	35	18	26
Talking among students[4]	34	5	36	21	29
Working on tasks requiring collaboration[5]	4	‡	3	‡	6
Assigning roles to group members[6]	3	‡	2	‡	6
Creating science group products[7]	6	2	10	5!	9
Working in all mixed gender groups[8]	1!	‡	15	‡	3

!Interpret data with caution. Estimate is unstable.

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

[1] Pair/group work: AUS, JPN, NLD, USA>CZE; JPN>NLD.

[2] Sitting together: AUS, JPN, NLD, USA>CZE; AUS, JPN>NLD.

[3] Sharing materials: AUS, JPN, NLD, USA>CZE; AUS, JPN>NLD.

[4] Talking among students: AUS, JPN, NLD, USA>CZE; JPN>NLD.

[5] Working on tasks requiring collaboration: No measurable differences detected.

[6] Assigning roles to group members: No measurable differences detected.

[7] Creating science group products: JPN>CZE.

[8] Working in all mixed gender groups: JPN>AUS, USA.

NOTE: Percentage of science instruction time devoted to changing social participation structures, individual work, divided class work, and whole class work are not presented (see chapter 3, figure 3.7).

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

Summary

Presented in this chapter were descriptions of students' opportunities to collaborate independently in the eighth-grade science lessons. Across countries, the most common features of groupwork were students talking with each other, students sharing materials, and students seated together. Other features of groupwork, such as assigned roles, group products, and tasks that required collaboration, occurred infrequently. Dutch students spent more time than students in all of the other countries except the United States working individually during independent seatwork activities. Japanese students spent more time working in groups of two or more than students in the Czech Republic and the Netherlands.

Collaboration provides opportunities to learn and practice talking about science among students and with experts. Chapter 9 explores students' opportunities to communicate in the eighth-grade science lessons.

Chapter 9: Communicating Science

This chapter describes students' opportunities to talk, write, and read about science. Both the research literature and the curriculum and standards documents for the countries involved in this study indicate that students' opportunities to communicate in these ways about science is an important issue to examine in science lessons.

Research Background

Research literature suggests at least three reasons why students should be supported in talking, writing, and reading about science. First, communication is viewed as an essential, not adjunct, feature of science and the scientific inquiry process (Hand, Prain, and Yore 2001; Norris and Phillips 2003; Osborne 2002). From this perspective, discussion, writing, and reading are just as much a part of "doing science" as carrying out experimental, hands-on work (AAAS 1993; Goldman and Bisanz 2002; Halliday and Martin 1993; Hand et al. 2003; Wellington and Osborne 2001), and students should have the opportunity to do all aspects of scientific work.

Second, communication can play a critical role in supporting the science learning process (Jones 2000). Research on learning conducted in a variety of fields and from differing methodological approaches and theoretical perspectives[11] points to the need for the learner to play an active role in the sense-making process, interacting with experts (whether this is a teacher or text) to develop new understandings (Brown and Campione 1994; Collins, Brown, and Newman 1989; Gee 1999; Halliday and Martin 1993; Lemke 1990; NRC 2000; Posner et al. 1982; Rosebery, Warren, and Conant 1992; Saul 2003; Schoenfeld 1988, 2002; Vygotsky 1978). Consistent with these theoretical perspectives and findings, research on science teaching and learning suggests that students could benefit from being active learners rather than passive recipients of knowledge (Anderson, Holland, and Palincsar 1997; Millar, Leach, and Osborne 2000; NRC 2000; Wellington and Osborne 2001; Zohar and Nemet 2002). That is, students might benefit from speaking, listening, reading, and writing about science while interacting with others who can challenge and shape their thinking. A number of studies provide support for the position that writing tasks that require active processing and sense-making are effective in supporting students' science learning (Eggleston et al. 1976; Keys et al. 1999; Roth 1992).

Third, one goal of science education is to prepare students to function as scientifically literate citizens who can continue to learn about science throughout their lives (AAAS 1993; NRC 2000). For most individuals, this learning will occur primarily through interpretation of print and media accounts of science news and issues. Science teaching can support students in learning how to become critical listeners and readers who can communicate their ideas and responses clearly (Alvermann 2006; Goldman and Bisanz 2002; Hand, Prain, and Yore 2001; Hand et al. 2003).

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[11] Examples of other fields include cognitive psychology, literacy education, science education, and mathematics education. Examples of methodological approaches include expert/novice comparisons, discourse analysis, and design studies, and theoretical perspectives include cognitive apprenticeship, conceptual change, constructivist, and social constructivist.

Despite the important role of communication in supporting student learning about science, many studies suggest that there are few opportunities for students to communicate in science classes. For example, a variety of studies provide evidence that students do little talking in classrooms (Cazden 1986; Dillon 1994; Edwards and Mercer 1987; Goodlad 1984; Lemke 1990; Mehan 1979; Sinclair and Coulthard 1975); Tharp and Gallimore 1989; Wellington and Osborne 2001) and that students have few opportunities to read about science during science lessons (Davies 1984; Lunzar and Gardner 1979; Wellington and Osborne 2001). While some studies suggest that students spend a significant amount of time writing in science classes (e.g., Newton, Driver, and Osborne 1999), many researchers and educators are concerned that the increased focus on hands-on practical work and inquiry activities "pushes writing into the background, denying children access to the genres of science that store information" (Wellington and Osborne 2001, p. 67). In addition, writing in science classrooms can involve copying notes or low level, writing tasks that require only reproduction of knowledge by students (Davies 1984; Eggleston, Galton, and Jones 1976; Newton et al. 1999; Wellington and Osborne 2001). More generative writing that requires active processing on the part of the learner seems to occur less frequently (Eggleston et al. 1976; Keys et al. 1999).

Country Perspectives

Communication is of interest in this study because curriculum and standards documents in most of the participating countries indicate that learning to communicate is a goal of science education. In Australia, a national statement on science for Australian schools specified two of nine goals for science education related to communication: (1) to learn to communicate scientific understanding to different audiences for a range of purposes, and (2) to use scientific language to communicate effectively and to further one's understanding of science. One of seven principles for effective learning experiences in science emphasizes the importance of helping students use scientific language appropriately:

> The language students use, whether speaking, writing, or drawing, is a critical part of their learning as they try to express their ideas, grasp the ideas of others, and extend their understanding….. (Australian Education Council 1994, p. 8)

Standards documents in the United States also emphasize the importance of communication in science teaching (AAAS 1993; NRC 1996). The American Association for the Advancement of Science benchmarks document highlights communication skills as one of the five habits of mind that students should develop. The *National Science Education Standards* encourages teachers to require students to record their work and to use different forms of communication (spoken, written, pictorial, graphic, mathematical, and electronic) (NRC 2000).

In the Czech Republic and the Netherlands, communication goals are identified as important general attainment goals for education in all subject areas (Czech Ministry of Education 1996; Dutch Ministry of Education, Culture, and Science 1998; Kolavova 1998). The Czech standards call for students to be able to clearly articulate, listen, read with understanding, and interpret what is read. Students should be able to work independently with the textbook, to look for information, to organize it, and to make notes. In the Netherlands, one of the six general attainment target areas across subject areas is learning to communicate. In another general attainment category—learning to do, goals focus on comprehending written and spoken Dutch and English as well as speaking and writing correct Dutch. These communication goals are expected to contribute to the goals for physics/chemistry education and for biology education.

Chapter 9 focuses on three main questions about the different opportunities to communicate about science in the eighth-grade science lessons:

- What kinds of opportunities do students have to talk about science?
- What kinds of opportunities do students have to write about science?
- What kinds of opportunities do students have to read about science?

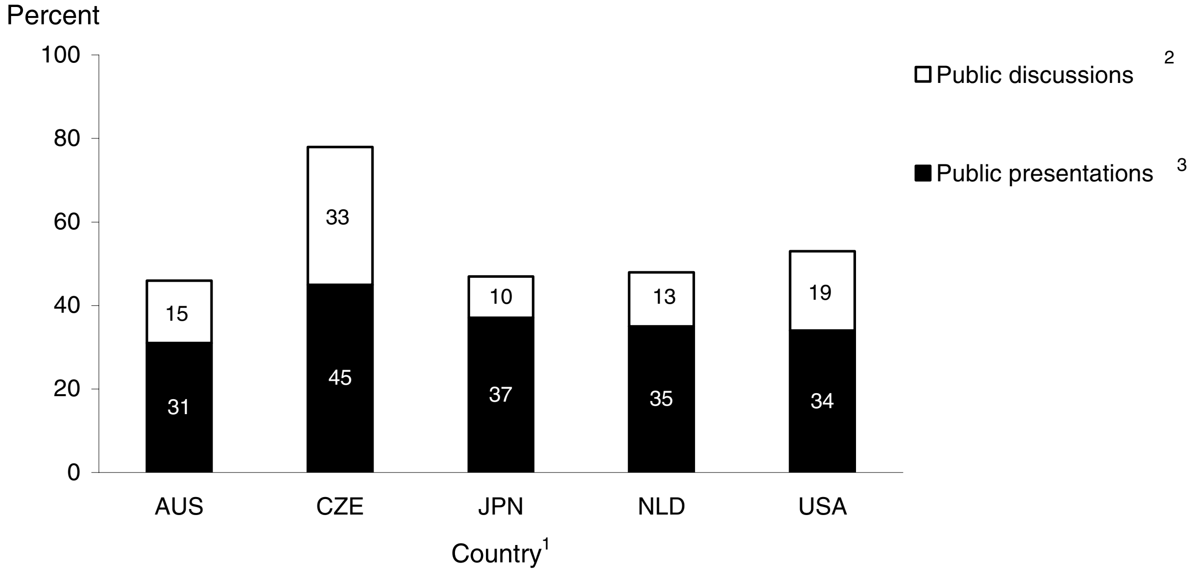
What Kinds of Opportunities Do Students Have to Talk About Science?

Teacher-Student Talk During Whole-Class Work

The lessons were analyzed for any type of whole-class discussion in order to identify students' opportunities to verbally interact with the teacher and/or other students in a public setting. In contrast to presentations by teachers, students, and/or other sources (🎥 Video clip example 9.1), discussions most often took the form of a series of teacher questions, student responses, and evaluations of the responses by the teacher known as the initiation-student response-teacher evaluation (IRE) pattern (Cazden 1986; Roth, Anderson, and Smith 1987; Sinclair and Coulthard 1975) (🎥 Video clip example 9.2). Discussions could include both everyday forms of talk and scientific terms. Discussions where students played a more central role, such as those described elsewhere as "highly interactive discourse structures" (Schoenfeld 2002), "argumentation discourse" (Kelly and Chen 1999), "diagnostic teaching" (Bell and Purdy 1985), and "science talks" (Gallas 1995), were rarely observed.

- Although discussions accounted for 10 to 33 percent of the instruction time (figure 9.1), 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 9.1).
- Within the science lessons of the five participating countries, whole-class talk was more likely to take the form of a public presentation (usually by the teacher) than a back and forth public discussion among students and teachers (figure 9.1).

Figure 9.1. 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



[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
[2] Public discussions: CZE>AUS, JPN, NLD, USA; AUS, USA>JPN.
[3] Public 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 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.

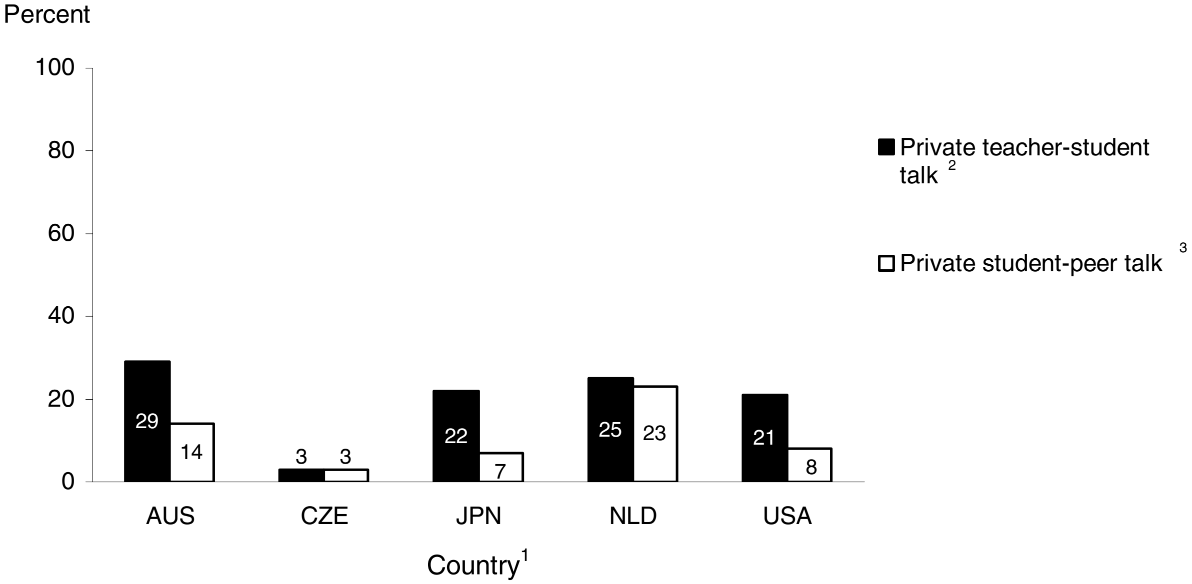
Teacher-Student Talk and Student-Peer Talk During Independent Work

As students work independently, they may be given opportunities to talk privately with the teacher or with their peers. Each lesson was examined for the amount of time students were given to interact in these two ways. Teachers could speak privately with students, either individually or in small groups, as they worked on independent activities (🎥 Video clip example 9.3). Since the teachers in the eighth-grade science lessons wore remote microphones, it was possible to transcribe their private talk with students during these interactions. The talk among students could have been related to science but it was not possible to identify the content of the talk. The intent of measuring private student-peer talk was to capture how much opportunity students had to talk about science with each other.

- Although Czech lessons provided students with more instruction time for public discussions than all the other countries (see figure 9.1), Czech students were less likely to have opportunities to discuss science privately with their teacher and with their peers than students in science lessons in all the other countries (figure 9.2).

- Compared to the Czech Republic, eighth-graders in all the other countries were provided with larger average percentages of science instruction time during independent work to communicate privately with their teacher (21 to 29 percent) and to talk with their peers (7 to 23 percent) (figure 9.2).

Figure 9.2. Average percentage of science instruction time in eighth-grade science lessons with student opportunity for private teacher-student talk and private student-peer talk, by country: 1999



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

[2]Private teacher-student talk: AUS, JPN, NLD, USA>CZE.

[3]Private student-peer talk: AUS, JPN, NLD, USA>CZE.

NOTE: Percentage of science instruction time devoted to copying notes, silent reading, divided class work, and whole-class work is not reported.

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

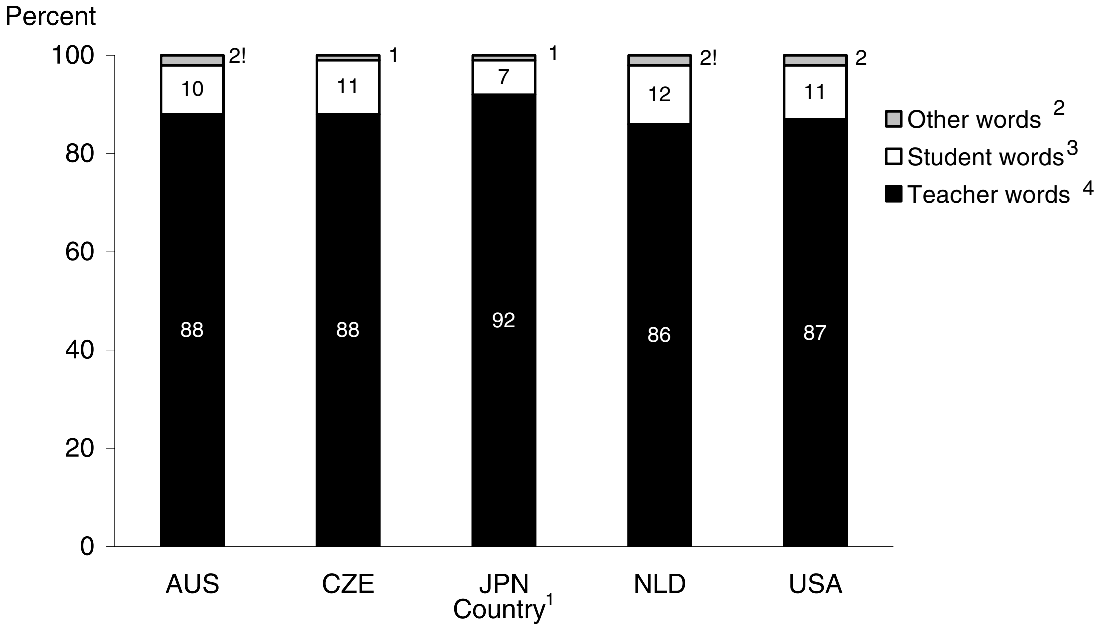
Teacher and Student Words During Public Talk

Since public talk includes words spoken by both teachers and students, word-based measures were used as proxies to indicate the extent to which students talked publicly. These measures also were used to identify the average length of student utterances. It was assumed that an utterance of five words or more is likely to represent a sentence and, therefore, constitute a complete thought constructed by the student. Computer-assisted analyses were applied in the TIMSS 1999 Video Study to English-language transcripts of the public portions of eighth-grade science lessons.

- During public talk, Czech and Dutch students spoke a higher percentage of words than students in Japanese lessons (figure 9.3).

- When eighth-graders spoke publicly in Czech lessons, they were more likely to use five or more words than students in Australian, Dutch, and Japanese lessons. They were less likely to use five or more word utterances during private teacher-student talk than students in lessons in all the other countries (figure 9.4).
- Eighth-grade students within all of the five countries publicly spoke a lower percentage of total words compared to their teachers (figure 9.3).

Figure 9.3. Average percentage distribution of total words during public talk within science instruction per eighth-grade science lesson that were spoken by other sources, the student, and the teacher, 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] Other talk: No differences detected.

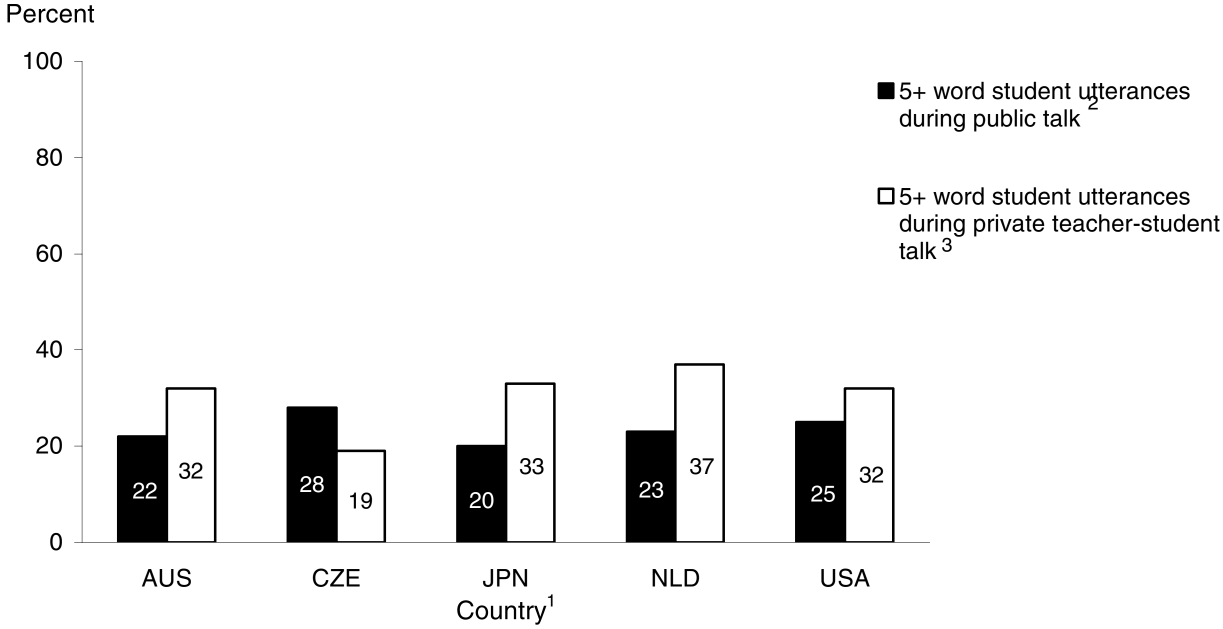
[3] Student talk: CZE, NLD>JPN.

[4] Teacher talk: JPN>CZE, NLD, USA.

NOTE: Percentages may not sum to 100 because of rounding and percentages do not include private talk time. 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. Other words include entire class responses, video, audio, adult teaching assistants, and words that were written on the chalkboard and included in the transcript.

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

Figure 9.4. Average percentage of student utterances that were 5 or more words per eighth-grade science lesson during public talk and private teacher-student talk, by country: 1999



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

[2] 5+ words student utterances during public talk: CZE>AUS, JPN, NLD.

[3] 5+ words student utterances during private teacher-student talk: AUS, JPN, NLD, USA>CZE.

NOTE: Analyses based on English-language transcripts.

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

What Kinds of Opportunities Do Students Have to Write About Science?

Types of Writing

The lessons were examined for students' opportunities to engage in different types of writing that required students to only put letters or words on paper (versus diagrams, graphs, or mathematical representations). Writing ranged from less cognitively demanding tasks, such as taking notes during whole-class work and selecting answers during independent work, to potentially more cognitively demanding writing that required students to generate phrases, sentences, or paragraphs, such as lab report or essay writing. The types of writing that students were expected to do during whole-class and independent work were defined as follows.

- ***Take notes:*** Teachers set aside time during whole-class work for students to take notes from the blackboard, computer screens, overhead projectors, or some other source.
- ***Select answers:*** Students write only a letter or a few words, such as choosing an answer from a set of options, writing single words, or labeling diagrams, but they do not write sentences, during independent work.
- ***Generate written responses:*** Students generate phrases or sentences in their own words rather than copying, selecting, labeling, or providing one-word responses during independent work. For example, students write answers to a question or a sequence of questions. Each question requires students to generate at least a phrase or a one-sentence response. Alternatively, students could brainstorm multiple ideas and prepare a written list of phrases or sentences. Students also may produce an essay, a written report, journal entry, or a report about a topic (🎥 Video clip example 9.4).

The eighth-grade science lessons were compared on the percentage of science instruction time in which students were expected to take notes during whole-class work, to select answers during independent work, and to generate written responses during independent work.

- Students in the eighth-grade science lessons in Australia, Japan, the Netherlands, and the United States were provided with more total instruction time, on average, to write about science (i.e., to take notes, select answers, and/or generate written responses) during independent and whole-class work combined than in Czech lessons (figure 9.5).
- Students in Czech science lessons were provided less average instruction time to generate written responses during independent work (5 percent) compared to all the other countries (22 to 36 percent; figure 9.5).
- In the Netherlands and the United States, students generated written responses for longer average proportions of instruction time than they selected answers or copied notes during independent work (figure 9.5).
- Similar patterns of differences appeared when countries were compared on the percentages of eighth-grade science lessons that provided any opportunity for students to engage in the different writing tasks. Again, compared to Czech science lessons, students independently generated written responses in more Australian, Dutch, and U.S. eighth-grade science lessons

(70, 72, and 56 percent, respectively) (data not shown). Students in Dutch lessons also independently selected answers in fewer lessons (18 percent) than Australian, Czech, and Japanese lessons (54, 40, and 49 percent, respectively). Students took notes during whole-class work in more Czech and Japanese lessons (45 and 43 percent, respectively) compared to students in Dutch and U.S. lessons (13 and 16 percent, respectively).

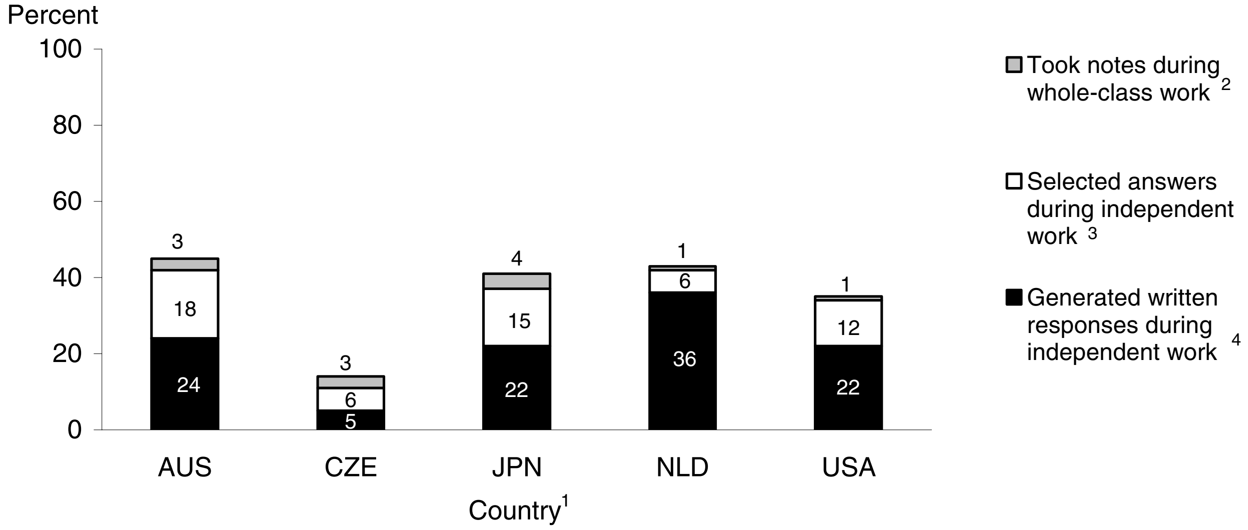
- Students were expected to write at least a paragraph related to independent work in no more than 11 percent of the lessons in any of the participating countries (data not shown).

Diagrams, Graphs, and Mathematical Calculations

Students also independently worked on writing tasks that used representations other than words. These tasks required students to make graphs, diagrams (including concept maps), and mathematical calculations.

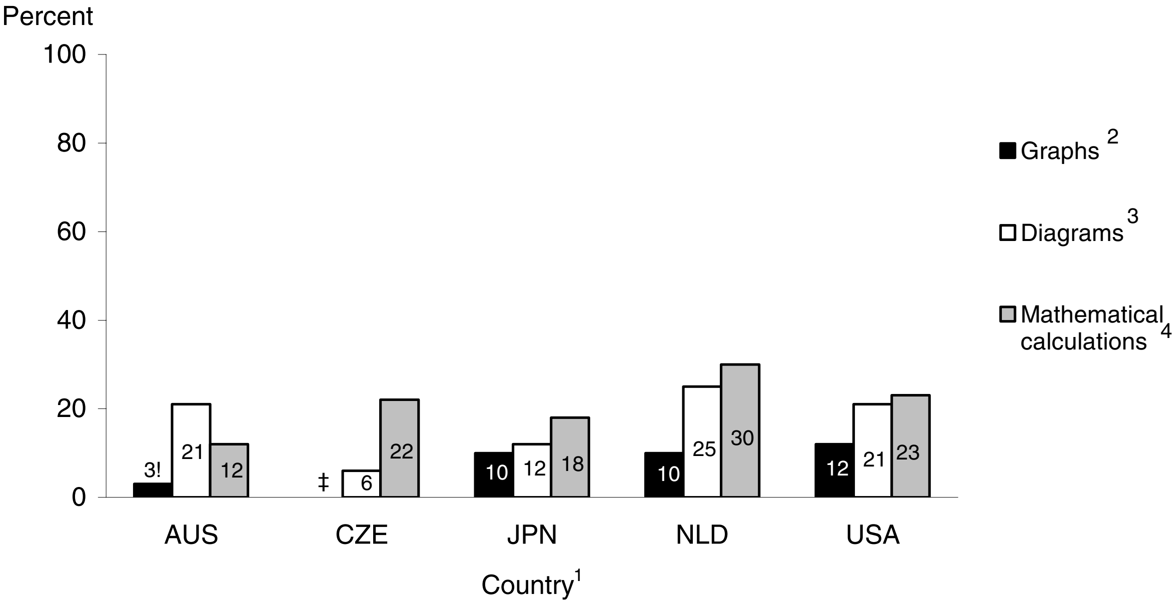
- Tasks that included graphs were observed in 3 to 12 percent of the science lessons, with too few observations in the Czech Republic to calculate reliable estimates (figure 9.6).
- Students were observed working independently on diagrams in 6 to 25 percent of the science lessons, and working on mathematical calculations in 12 to 30 percent of the science lessons (figure 9.6). Students worked on diagrams during independent work in more Dutch eighth-grade science lessons than Czech lessons.

Figure 9.5. Average percentage distribution of science instruction time in eighth-grade science lessons during which students took notes during whole-class work, selected answers during independent work, and generated written responses during independent work, by country: 1999



[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
[2] Took notes during whole-class work: CZE, JPN>NLD, USA.
[3] Selected answers during independent work: AUS>CZE, NLD; JPN>CZE.
[4] Generated written responses during independent work: AUS, JPN, NLD, USA>CZE.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Figure 9.6. Percentage of eighth-grade science lessons that included independent work on graphs, diagrams, and mathematical calculations, by country: 1999



!Interpret data with caution. Estimate is unstable.

‡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] Graphs: No differences detected.

[3] Diagrams: NLD>CZE.

[4] Mathematical calculations: No differences detected.

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

What Kinds of Opportunities Do Students Have to Read About Science?

In the videotaped lessons, teachers provided students with opportunities to read about science aloud to the whole class and silently on their own. When reading to the class, a student would read from a source such as the textbook, a teacher-prepared worksheet, an Internet source, or an overhead transparency prepared by the teacher. When reading silently, students would read at least a paragraph of a book, magazine, or other source.

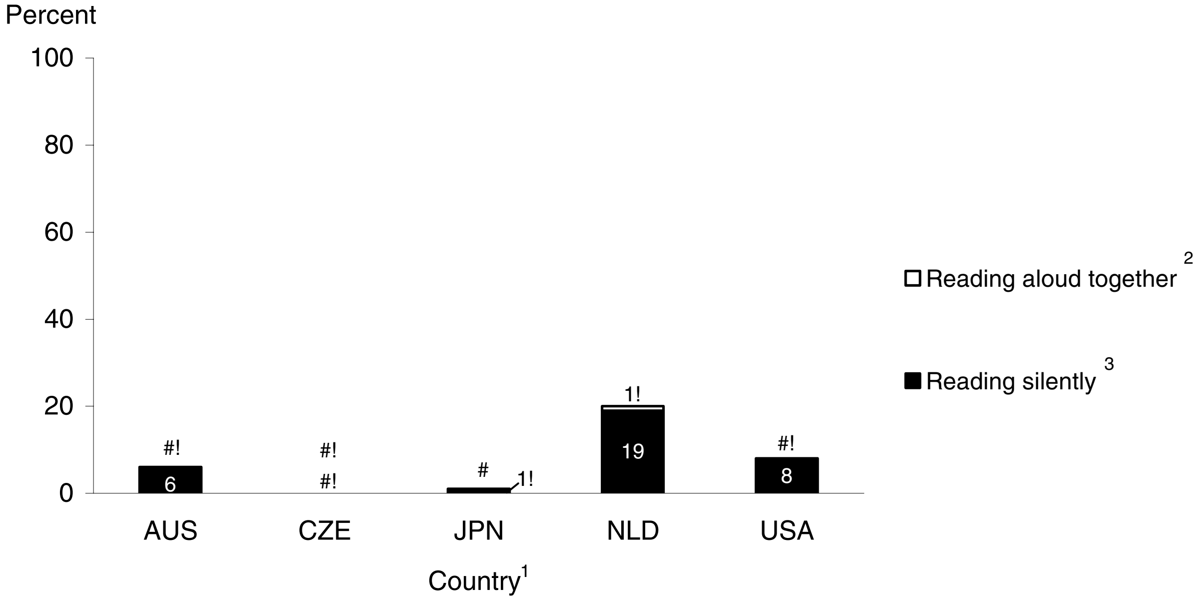
- Dutch eighth-grade science lessons provided a larger average proportion of instruction time for students to read about science compared to lessons in Australia (figure 9.7).
- Teachers allocated between 6 and 19 percent of instruction time for silent reading in Australian, Dutch, and U.S. lessons. Students read silently for longer average percentages of instruction time in Dutch lessons compared to lessons in Australia (figure 9.7).
- Students infrequently were observed reading aloud together in the eighth-grade science lessons in all the countries (figure 9.7).

Do Students Have Different Kinds of Opportunities to Communicate Science?

The lessons were examined for the total amount of time that students had the opportunity to talk (either publicly or privately), write, and read (aloud and silently) about science.

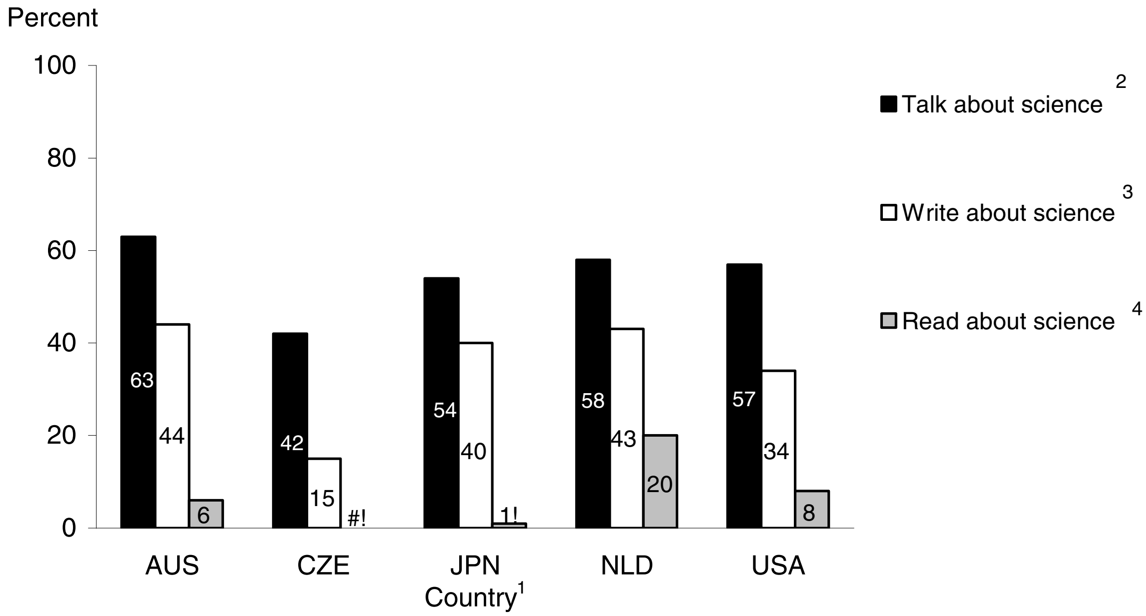
- Compared to science lessons in the other four countries, lessons in the Czech Republic provided less instruction time, on average, for students to talk with their teacher and/or peers about science (42 percent) and to write about science (less than 1 percent) (figure 9.8).
- Dutch eighth-grade science lessons provided more instruction time for students to read about science (20 percent) compared to lessons in Australia (6 percent) (figure 9.8).
- Within all the countries where reliable estimates could be made, more instructional time, on average, was provided for students to talk about science than to write or read about science, and more time to write about science than to read about science (figure 9.8).

Figure 9.7. Average percentage distribution of science instruction time in eighth-grade science lessons with reading aloud together and silently, by country: 1999



#Rounds to zero.
!Interpret data with caution. Estimate is unstable.
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
[2] Reading aloud together: No measurable differences detected.
[3] Reading silently: AUS, NLD, USA>CZE; NLD>AUS, JPN.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Figure 9.8. Average percentage of science instruction time in eighth-grade science lessons allocated to opportunities for students to talk about science, to write about science, and to read about science, by country: 1999



#Rounds to zero.
!Interpret data with caution. Estimate is unstable.
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
[2] Talk about science: AUS, JPN, NLD, USA>CZE.
[3] Write about science: AUS, JPN, NLD, USA>CZE.
[4] Read about science: NLD>AUS, CZE, JPN; AUS, USA>CZE.
NOTE: Talk about science is defined as students having opportunities to talk to their teacher or peers during discussion, private teacher-student talk, and independent work. Totals do not sum to 100 because instruction time could be provided for more than one type of opportunity to communicate about science.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Opportunities to Communicate During Seatwork Activities

Further analyses examined differences between students' opportunities to communicate during practical and during seatwork activities. Of particular interest are the Dutch patterns that emerged.

- During seatwork activities, Dutch science lessons provided more opportunities for students to communicate through talking, writing, and reading than in some other countries (data not shown). Dutch lessons allocated more instruction time, on average, for students to discuss science with their teacher and peers (39 percent) than Australian and Japanese lessons (29 and 20 percent, respectively); more instruction time per lesson for students to write about science (25 percent) than the Czech Republic and Japan (12 and 13 percent, respectively);

and more time to read about science (16 percent) than Australia and Japan (4 and 1 percent, respectively) with too few lessons in the Czech Republic for reliable estimates.

Summary

Students' opportunities to learn how to communicate about science through talking, writing, and reading were described and compared across the participating countries in this chapter. The Czech Republic stands out as distinct from the other countries in terms of science talk. Czech students were allocated less total time to talk about science in science lessons (during whole-class discussions and independent work), and they had little opportunity to talk with each other or with the teacher during independent work. However, they spent more time in whole-class discussions than students in all of the other countries, and they spoke longer utterances during these discussions than all of the other countries except the United States. In support of this, Czech teachers were often observed requesting students to restate their response in a sentence.

Opportunities for students to write and read about science were of particular interest in the Dutch lessons. Dutch students had the opportunity to write for a similar amount of time as three of the other countries, but in Dutch lessons most of this time was spent on more generative types of writing where they had to create their own statements rather than simply providing a word, label, list, definition, or copying notes. There was more time allotted for reading in the Dutch lessons than all the other countries except the United States. Analyses of students' opportunities to talk, write, and read during independent seatwork showed that Dutch students had more time allotted for talking with their peers and with their teacher, for writing about science, and for reading about science than some of the other countries.

The next chapter describes strategies that teachers in the eighth-grade science lessons used to also engage students' interest in learning science.

Chapter 10: Engaging Students

Real-life issues, hands-on independent practical activities, and motivating activities are three types of activities used by teachers in the eighth-grade science lessons to engage students' interest and active involvement in their science learning. Many strategies are available for engaging students actively in their learning, including the student inquiry practices described in chapter 7, the groupwork activities described in chapter 8, and the reading, writing, and speaking activities described in chapter 9. Lesson features related to content coherence, organization, and challenge discussed in chapters 5 and 6 may also contribute to students' interest in the lesson. The focus in this chapter, however, is on three types of activities that have been identified in the research literature as particularly likely to engage students' interest and active involvement in science.

Research Background

Research on science teaching provides at least two reasons that support the inclusion of real-life issues in science teaching. First, real-life applications of science have been found to play a role in helping students reconcile their experience-based prior knowledge about the world with scientific explanations. Studies of science learning as a process of conceptual change, as well as studies of knowledge transfer, suggest that students need to use ideas and concepts in multiple real-world contexts in order to understand their meaning (Driver et al. 1985; Gardner 1993; Gick and Holyoak 1983; Hewson et al. 1998; NRC 2000; Posner et al. 1982; Roth 1995; Wandersee, Mintzes, and Novak 1994; West and Pines 1985). Second, research suggests that real-life applications may be a way to engage students' interest in learning science (McComas 1996; Simon 2000). From a learning theory perspective, it is hypothesized that students become more engaged in their learning when they see the wide usefulness of the knowledge they are studying (McCombs 1996; Pintrich and Schunk 1996; Posner et al. 1982). Many studies provide evidence supporting the idea that student interest is enhanced by involvement in real-world science projects and investigations (Barron et al. 1998; Barrows 1985; Edelson 2001; Hallinger, Leithwood, and Murphy 1993; Hmelo 1995; Krajcik et al. 1998; Moje et al. 2001;. Resnick 1987a; Roth and Roychoudhury 1994; Siegal and Ranney 2003; Songer 1993; Williams 1992).

Carrying out hands-on practical activities can also be engaging to students (Fraser 1980; Freedman 1997). Although studies suggest that many students lose interest in science class after age 11 and find school science boring (Doherty and Dawe 1988; Ebenezer and Zoller 1993; Hadden and Johnstone 1983; Simon 2000; Simpson and Oliver 1985; Yager and Penick 1986), the aspect of science that students consistently report as most appealing is hands-on laboratory work (Millar, LeMarechal, and Tiberghien 1999; Molyneux-Hodgson, Sutherland, and Butterfield 1999; Myers and Fouts 1992).

Teachers also employ other kinds of motivating activities that may help capture students' interest. For example, teachers may use jokes and humor, games, role plays, artistic projects, dramatic events, physical activity, prizes or other rewards or outdoor excursions. Telling anecdotal stories has been shown to be related to changes in students' attitudes (Shrigley and Koballa 1992). Studies of attitudes toward science suggest that science lessons that use a variety of teaching strategies and unusual or novel learning activities positively influence student attitudes (Corno and Rohrkemper 1985; HM Inspectors of Schools 1994; Myers and Fouts 1992; Piburn and Baker 1993; Stipek 1993).

That being said, the research literature points to potential limitations of making science engaging for students through the use of real-life applications, hands-on independent practical activities, and motivating activities. Approaches to teaching that claim to incorporate these strategies have been criticized for being light on science and for lacking strong evidence of positive impact on student learning. For example, U.S. teachers have been criticized as conducting lessons filled with activities that may be fun or engaging, but that have little or no meaningful connections to rich scientific content (Kesidou and Roseman 2002; Moscovici and Nelson, 1998; Roth 1984). Reviews of the research literature on the relationship between students' hands-on, practical work and learning outcomes report that there is little evidence that practical work improves student understanding of science concepts (Hodson 1993; Sjoberg 1990; White 1996). In fact, many studies suggest that students often use first-hand data to develop ideas unintended by the curriculum (Leach and Scott 2000; McRobbie et al. 1997; Roth 1990-91; Roth et al. 1997; Smith and Anderson 1984; Watson, Prieto, and Dillon 1995). In addition, project-based science teaching, in which students investigate real-life problems in their community, has been criticized because it often embeds student learning of a rich, interdisciplinary set of ideas in only one learning context that is unlikely to support students' transfer of knowledge to other contexts (Bjork and Richardson-Klavhen 1989; Cognition and Technology Group at Vanderbilt 1997).

There is also debate about whether students can be engaged by intellectual stimulation with science ideas as well as by hands-on, real-life, and entertaining activities. In support of a focus on engaging students with scientific ideas and ways of thinking, studies demonstrate that students in first grade through high school science classrooms can become engaged with debating, questioning, and making sense of science ideas (Gallas 1995; Herrenkohl et al. 1999; Hogan, Nastasi, and Pressley 2000; Howes 2002; Minstrell 1982; Newton, Driver, and Osborne 1999; Rosebery, Warren, and Conant 1992; Nuthall 2002; Nuthall and Alton-Lee 1993; Roth 2002; Varelas and Pineda 1999). Some of these studies provide evidence that this engagement with ideas results in positive student learning outcomes (Nuthall 2002; Nuthall and Alton-Lee 1993; Roth 2002; Schauble et al. 1995) and increased student interest (Von Aufschnaiter, Scoster, and von Aufschnaiter 1999).

Country Perspectives

Results from the TIMSS 1999 student questionnaires show that eighth graders in three countries—Australia, Japan, and the Netherlands—held relatively less positive attitudes towards science than many of their international counterparts (Martin et al. 2000). The importance of making science enjoyable and relevant to students' lives is codified in the curriculum and standards documents in each of the five countries in this study. In Australia, for example, one of the seven "principles for effective learning experiences in science" is "engaging in relevant and useful activities" (Australian Education Council 1994, p. 7).

In the Czech Republic, curriculum guidelines stress the importance of practical applications of science knowledge so that students can use and apply knowledge and experiences from life outside school (Czech Ministry of Education 1996; Nelesovska and Spalcilova 1998). Science teacher education in the Czech Republic also emphasizes strategies for making science interesting for students by using “handy ways of creating motivation” (Ctrnactova 1997, p. 2). For example, biology teachers are encouraged to use engaging activities such as dramatic situations, scenarios, field trips, and walks in nature.

The Japanese course of study promotes scientific inquiry as the core feature of the learning program for science at the lower secondary level, with an emphasis on students’ first-hand involvement with practical science activities. In part as a response to Japanese students’ less positive attitudes toward science, recent reforms in Japan emphasize the importance of applications of science to everyday life (Goto 2001).

Dutch guidelines recommend that lessons emphasize linking science to daily life contexts and to a variety of vocations (Eijkelhof and Voogt 2001). In both biological and the physical sciences, reform efforts focus on applications in real-life contexts such as health, the environment, science in jobs, and connections with other subjects (Eijkelhof and Voogt 2001). Four of the six general objectives in the Netherlands for physics, chemistry, and biology include applications to daily life (Dutch Ministry of Education, Culture, and Science 1998).

In the United States, standards documents emphasize the importance of science literacy for all students (AAAS 1990, 1993; NRC 1996). Science literacy includes the ability to adapt scientific knowledge and processes to personal decision making and to civic and cultural affairs. For example, these documents define scientifically literate citizens as able to understand articles about science in the popular press, to see scientific issues involved in national and local political decisions, and to evaluate the quality of scientific information in light of its source. The standards documents also emphasize the importance of making the curriculum responsive to students’ “interests, knowledge, understanding, abilities, and experiences” (NRC 1996, p. 30).

The chapter focuses on three main questions:

- Do lessons include real-life issues for students?
- Do lessons involve students in hands-on, practical work?
- Do lessons involve students in motivating activities?

Do Lessons Include Real-life Issues for Students?

To determine the extent to which teachers actually engaged students in thinking about real-life issues, the videotaped lessons were analyzed for real-life issues that were raised in the lessons and how teachers used real-life issues in the lessons.

Real-Life Issues

Real-life issues were defined as follows:

- ***Real-life issues***: Information about how science knowledge is used, applied, or related to societal issues or students’ personal experiences. Real-life issues include attention to students’ personal experiences, the uses of science-related knowledge in everyday life, science-related societal issues, and everyday examples or illustrations of scientific ideas. Examples include:
    - discussing the differences in riding a bicycle on pavement and on gravel to support an idea about friction;
    - discussing the advantages and disadvantages of being an organ donor;
    - weighing the trash students collected in their homes across a 3-day period; and
    - learning about careers that use knowledge about electricity.

Figure 10.1 presents the percentage of eighth-grade science lessons that raised at least one real-life issue during science instruction, and figure 10.2 presents the percentage of science instruction time during which real-life issues were presented, discussed, or worked on.

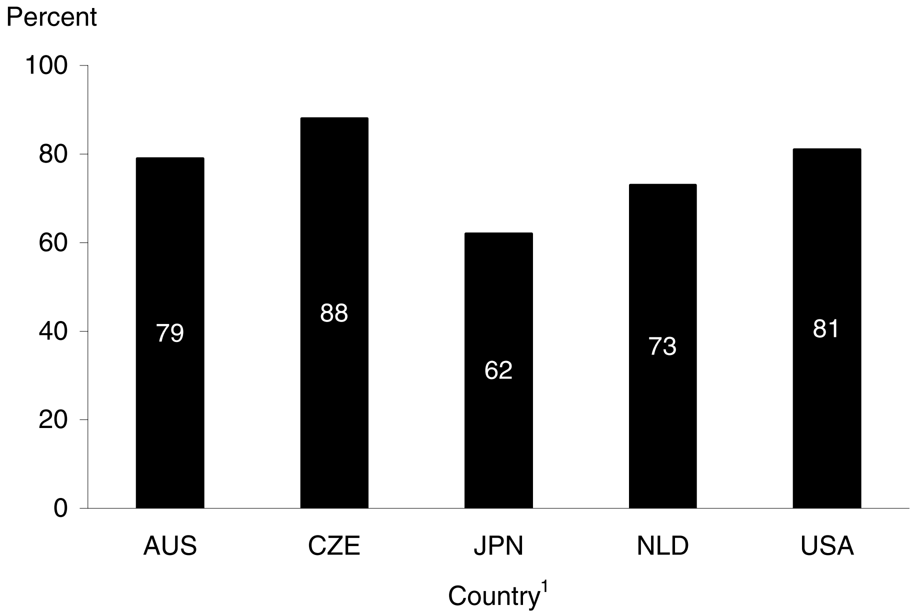
- One or more real-life issues were included in at least 62 percent of eighth-grade science lessons in the five countries (figure 10.1). Nine to 23 percent of instructional time, on average, was devoted to real-life issues across the countries (figure 10.2).

Role of Real-Life Issues in the Lessons

The real-life issues addressed in the eighth-grade science lessons were examined to assess whether they were used to develop canonical science ideas or mentioned as topic-related sidebars. The following definitions were used:

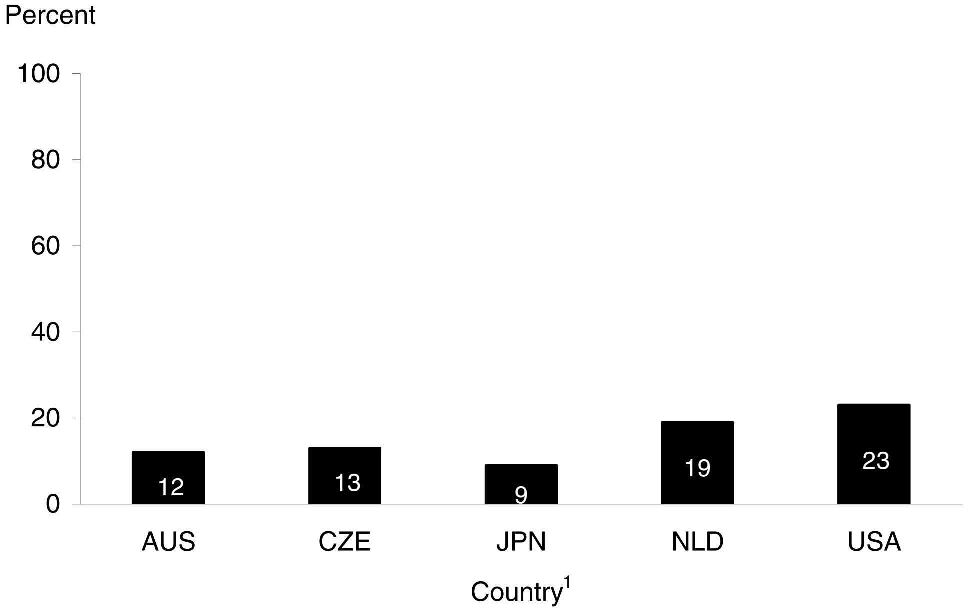
- ***Real-life issues used to develop science ideas***: Real-life issues are used to develop, clarify, and/or support science ideas beyond a simple topic connection. The teacher can tell students about how the real-life issues support the science ideas or engage students in making the links themselves (e.g., through class discussions or independent activities) (📹 Video clip example 10.1). Examples include:
    - showing the students a flashlight from home and explaining how the batteries, bulb, and wires in the flashlight form a simple series circuit; and
    - examining a compost bin that the class has constructed to consider how matter is being changed (chemical and physical changes).
- ***Real-life issues mentioned as topic-related sidebars***: Real-life issues are not used to develop, clarify, and/or support science ideas in the lesson. Instead, the real-life issues are mentioned as sidebars related to the science topic (📹 Video clip example 10.2). For example, the students or the teacher talk about personal experiences related to the science topic, information is presented about topic-related science careers, examples related to the topic in students’ everyday life are named or shown, or topic-related news stories are discussed but are not used to develop specific science ideas. For example, as an introduction to a unit on weather, students might be asked to tell about personal experiences with rapid weather changes.

Figure 10.1. Percentage of eighth-grade science lessons in which at least one real-life issue was raised during science instruction, by country: 1999



[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: CZE>JPN.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Figure 10.2. Average percentage of science instruction time in eighth-grade science lessons during which real-life issues were raised, by country: 1999

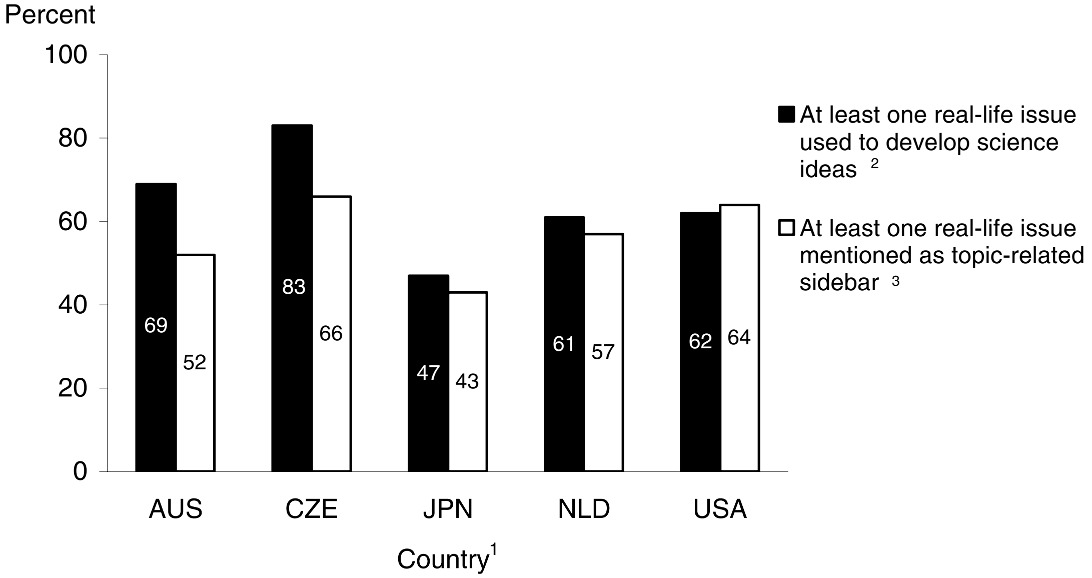


[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: No measurable differences detected. Analysis is limited to those portions of the lessons focused on science instruction. See chapter 3, table 3.2 and figure 3.2 for more details.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Figure 10.3 displays the percentage of eighth-grade science lessons and figure 10.4 displays the percentage of instruction time in which at least one real-life issue was used to develop science ideas and at least one real-life issue was mentioned only as a topic-related sidebar.

- Teachers in more Czech science lessons used one or more real-life issues to develop science ideas than did teachers in Dutch, Japanese, and U.S. science lessons (figure 10.3).
- Teachers of Czech and Dutch eighth-grade science lessons spent more lesson time, on average, developing science ideas through real-life issues than teachers in Japanese lessons (figure 10.4). Compared to Czech lessons, teachers of U.S. science lessons allocated a larger proportion of time, on average, to mentioning real-life issues only as topic-related sidebars.
- Within the United States, teachers of science lessons allocated more instructional time to mentioning real-life issues as topic-related sidebars than to using real-life issues to develop science ideas. The opposite pattern was observed within the Czech Republic (figure 10.4).

Figure 10.3. Percentage of eighth-grade science lessons that contained at least one real-life issue used to develop science ideas and as a topic-related sidebar only, by country: 1999



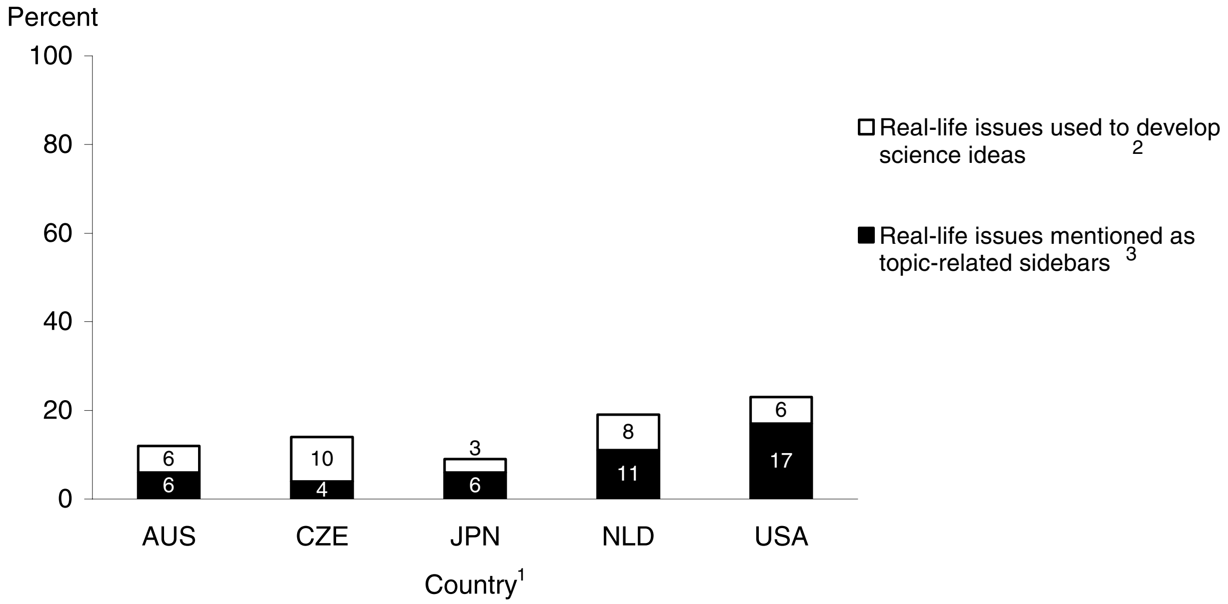
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

[2] Real-life issue used to develop science ideas: AUS>JPN; CZE>JPN, NLD, USA.

[3] Real-life issue mentioned as topic-related sidebar: CZE>JPN.

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

Figure 10.4. Average percentage distribution of science instruction time in eighth-grade science lessons allocated to real-life issues used to develop science ideas and topic-related sidebars, by country: 1999



[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
[2] Real-life issues used to develop science ideas: CZE, NLD>JPN.
[3] Real-life issues mentioned as topic-related sidebars: USA>CZE.
NOTE: Analysis is limited to those portions of the lessons focused on science instruction. See chapter 3, table 3.2 and figure 3.2 for more details.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study, Video Study, 1999.

Do Lessons Involve Students in Hands-On, Practical Work?

Independent practical activities provide students with opportunities to carry out hands-on science work such as experiments, observations of phenomena, model building, and so forth.

- In Australia and Japan, more eighth-grade science lessons contained independent practical activities and more instructional time was allocated to these activities compared to lessons in the Czech Republic and the Netherlands (table 3.5 and figure 3.7, chapter 3).

Do Lessons Involve Students in Motivating Activities?

Teachers in the eighth-grade science lessons used motivating activities in their lessons to appeal to some or all students. These activities had the potential to motivate students to engage in science learning, though their actual effect cannot be determined.

Motivating activities were defined as follows:

- whole-class or independent activities that include at least one of the following elements:
    - surprising, exciting, and/or dramatic phenomena or demonstrations;
    - dramatic presentations or stories such as personal experience stories and role plays (🎥 Video clip example 10.3);
    - unusual, creative, or competitive student activities such as creating a travel brochure to a planet, making a battery out of citrus fruits, racing cars, shooting off rockets, and writing poems or songs about science content (🎥 Video clip example 10.4) (also, a crime lab activity, simulation or scenario activities, competitions, games, or puzzles);
    - presentation and/or use of materials or objects that appeal to students' fascination such as novel gadgets or mysterious substances such as "goop"; and
    - new environments such as activities that require going outside of the classroom to do things such as collect rocks, observe clouds, shoot off rockets, or run up and down the stairs to get timed for speed.

The percentage of eighth-grade science lessons that contained at least one potentially motivating activity is presented in figure 10.5, and the percentage of instructional time provided for students to engage in these motivating activities are displayed in figure 10.6.

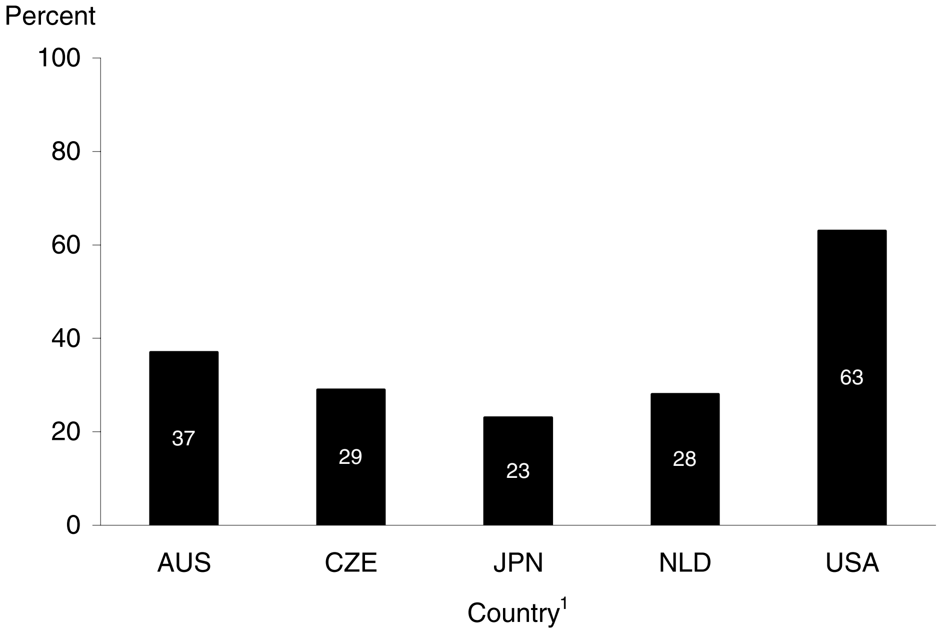
- More eighth-grade science lessons in the United States included potentially motivating activities (figure 10.5), and more instructional time was allocated for these motivating activities, than science lessons in the Czech Republic, Japan, and the Netherlands (figure 10.6).

Do Lessons Use Multiple Strategies to Engage Students?

Figure 10.7 presents the percentage of eighth-grade science lessons that used one or more of the three types of activities that can potentially engage students in science (real-life issues, independent practical activities, and motivating activities).

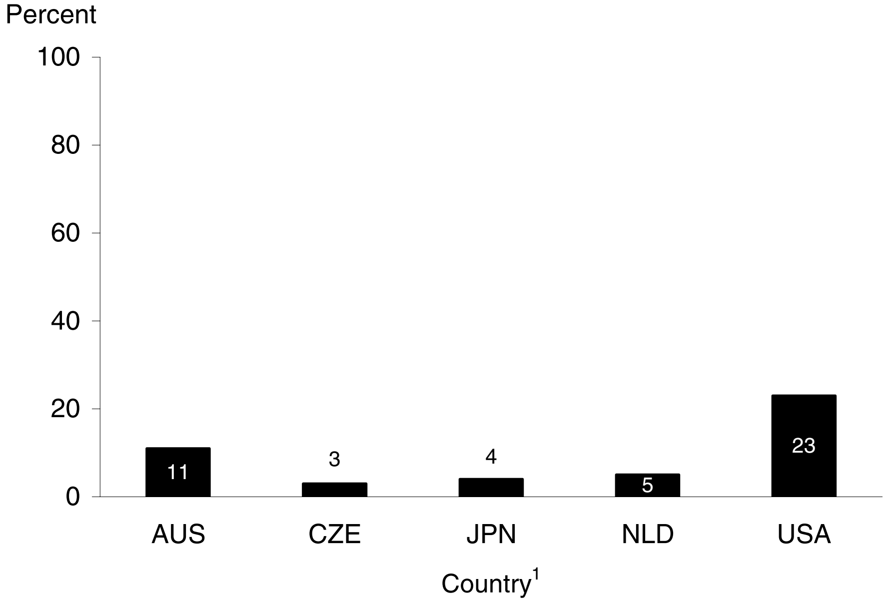
- Teachers in more U.S. science lessons used three types of activities to try to make science engaging to students (real-life issues, independent practical activities, and motivating activities) compared to lessons in the Czech Republic and Japan (figure 10.7).

Figure 10.5. Percentage of eighth-grade science lessons that had at least one motivating activity, by country: 1999



[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: USA>CZE, JPN, NLD.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Figure 10.6. Average percentage of science instruction time in eighth-grade science lessons allocated to motivating activities, by country: 1999

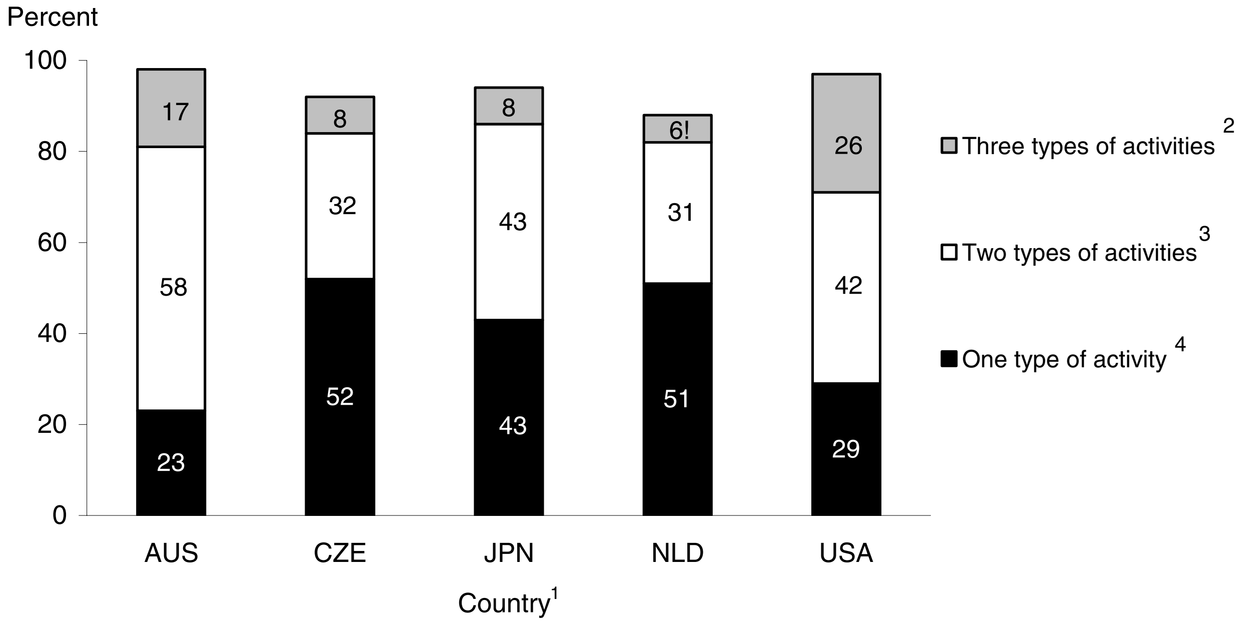


[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

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.

Figure 10.7. Percentage distribution of eighth-grade science lessons in which teachers used one, two, and three types of activities to engage students' interest, 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] Three types of activities: USA>CZE, JPN, NLD.

[3] Two types of activities: AUS>CZE, NLD.

[4] One type of activity: CZE>AUS, USA; NLD>AUS.

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

Summary

This chapter described three types of strategies that teachers in the eighth-grade science lessons employed that may engage students' interest and involvement in learning science. A higher percentage of Czech lessons included real-life issues that were used to develop science ideas compared to all the other countries except Australia. Australian and Japanese lessons allowed a greater percentage of time for student work on hands-on practical activities compared to the Czech Republic and the Netherlands. Science lessons in the United States included more time for motivating activities compared to all the other countries except Australia. Chapter 11 presents instructional practices that were directed at increasing students' responsibilities in the science learning process and facilitating their independent learning.

Chapter 11: Student Responsibility for Science Learning

This chapter describes a variety of ways in which science lessons required students to take responsibility for their own learning. Both research findings and the curriculum and standards documents in each of the participating countries describe various aspects of helping students become self-directed learners.

Research Background

Research in the areas of adult and lifelong learning, student self-direction and self-efficacy, and self-regulated learning provide insights about ways in which science teaching may be organized to support students in becoming independent learners. In addition, research on the role of homework is relevant to the development of students' responsibility for their own learning.

The research literature suggests that instructional practices can influence students' self-efficacy— their beliefs about their ability to learn particular kinds of knowledge or to perform certain skills—and positive self-efficacy can influence motivation and achievement (Bandura 1986, 1994, 1997; Schunk and Pajares 2002). For example, the literature indicates that students might benefit from having specific attainable goals and from receiving prompt feedback about their progress in meeting these goals (Bandura 1986; NRC 2000). Moreover, there is research indicating that students can become more self-directed learners if they are taught strategies that enable them to monitor their own progress towards goals (Schunk 1995) and if they participate in setting their own goals (DeBacker and Nelson 2000; Hom and Murphy 1983; Pinkerton 1994). Some research also suggests that students need opportunities to make choices and decisions if they are going to develop skills of self-management and the ability to be self-directed learners (Barell 1995; Cranton 1992; Goodlad 1984; Jones et al. 1995; Pajares 1996; Schunk 1995). These choices put students in the position of being responsible for directing and assessing their own learning and can contribute to more "engaged learning" (Jones et al. 1995).

In a technology-rich world, students need to learn the skills that will enable them to take responsibility for their own learning. Computers could be used to support their own learning, such as looking for information, organizing that information, making notes, and working with databases. Although the support for this strategy has resulted in more computers in classrooms, evidence indicates computers remain underutilized by students (Cuban 2001).

Homework is one strategy that may contribute to developing students' independence in directing their own learning, especially if students play a role in pacing and monitoring their progress on longer-term assignments or if they play some role in defining their homework tasks (Schunk 1995; Pajares 1996). However, there is conflicting evidence about the role of homework in developing self-directed learners and in improving student achievement (Cooper 1989; Cooper et al. 1998; Kralavec and Buell 2000). Cooper's research synthesis, as well as subsequent analyses, reports a consistent pattern of correlations between time spent on homework (up to two hours per night) and school achievement for middle school and high school students (Cooper 1989; Cooper et al. 1998). Although many studies such as these have examined the relationship between homework and achievement, little research has explored the relationship between homework and the development of students as responsible, self-directed learners.

During classroom lessons, teachers sometimes challenge students to take responsibility for their own learning by sharing their thinking, knowledge, and problem-solving strategies publicly with the teacher and their peers (NRC 1996). This can be done in the form of students describing their work to the class using the blackboard/overhead, students demonstrating and explaining phenomena to the class, or students being orally assessed by the teacher, among others. The expectation that students will share their work or thoughts publicly places responsibility on the student to prepare for such events, by attending during the lesson and by preparing outside the lesson. Although some research suggests that public comparisons and assessments of students' work can be detrimental to their intrinsic motivation (Lowman 1990; McMillan and Forsyth 1991), other more recent reviews of the research literature suggest that such public activities may be positiviely associated with students' intrinsic motivation (Kilpatrick, Swafford, and Findell 2001). It has been suggested that such public displays of student knowledge can be used in ways that create rich communities of learners where student learning is not just the teacher's responsibility, but is also the responsibility of each learner and the larger community of learners (Bloom 2001; Roth 1992).

Country Perspectives

Curriculum documents from the five countries reveal different intentions regarding students' responsibilities in the science learning process. In both the Czech Republic and the Netherlands, an overarching, cross-subject matter curriculum goal emphasizes that students should become independent learners. In the Netherlands, the "focus on an active, independently learning student" is one of three main foci of the revised education program attainments for Dutch secondary education (Dutch Ministry of Education, Culture, and Science 1998, p. 7). The Dutch document calls for student-directed versus teacher-directed education, with students analyzing and controlling the learning process by planning their work and monitoring the learning process. In the Czech curriculum document, independent learning is emphasized, suggesting that students learn how to work with the textbook, dictionaries, other books, computers, audio-visual sources, and databases to look for information, to organize that information, and to make notes (Czech Ministry of Education 1996).

Australian and U.S. science curriculum and standards documents do not describe independent learning as an overarching goal, but it is included as one of the stated goals. In Australia, for example, students at the early secondary level are expected "to reflect on and evaluate their own understandings and purposes, using them for planning their own further learning" (Australia Education Council 1994, p. 31). In the United States, the *National Science Education Standards* state that "students must accept and share responsibility for their own learning" (NRC 1996, p. 27), and "teachers must make it clear that each student must take responsibility for his or her work" (p. 36).

In Australia, Japan, the Netherlands, and the United States, national curriculum and standards documents emphasize that a specific responsibility of science learners is to take responsibility for generating questions and planning science investigations. The *National Science Education Standards* (NRC 1996) emphasize the importance of U.S. students generating and pursuing their own questions, taking active roles in the design and implementation of investigations, and preparing and presenting work to their peers. Similarly, the Dutch attainment goals include “designing tests to investigate simple problems” as a goal within the physics and chemistry strand (Dutch Ministry of Education, Culture, and Science 1998, p. 64). The Australian curriculum profile identifies “working scientifically” as a major strand in the science curriculum, emphasizing students’ roles in planning and conducting investigations (Australian Education Council 1994, p. 2). The Japanese Course of Study (Ministry of Education, Science, and Culture [*Monbusho*] 1999) prioritizes experimentation and scientific observation, with the overall objective of enabling students to “develop the capacity to undertake investigations in a scientific manner” (Goto 2001, p. 32).

The curriculum documents of the countries suggest that students take responsibility for their own learning. In Australia, the Czech Republic, and the Netherlands, the emphasis is on students becoming independent, self-directed learners. In Australia, Japan, the Netherlands, and the United States, students are expected to take responsibility for their own learning by generating their own questions and designing their own investigations.

Chapter 11 focuses on two main questions about student responsibility for science learning:

- What responsibilities do students have during the science lesson?
- What responsibilities do students have outside the lesson?

What Responsibilities Do Students Have During the Science Lesson?

Routine Lesson Openers

Some of the science lessons may begin with students entering the classroom and immediately starting to work independently, without any direction from the teacher, on a lesson-opening task that is posted on the board or overhead projector (🎥 Video clip example 11.1). Although the task itself is teacher-directed, the students must take responsibility for identifying the task and starting to work on it.

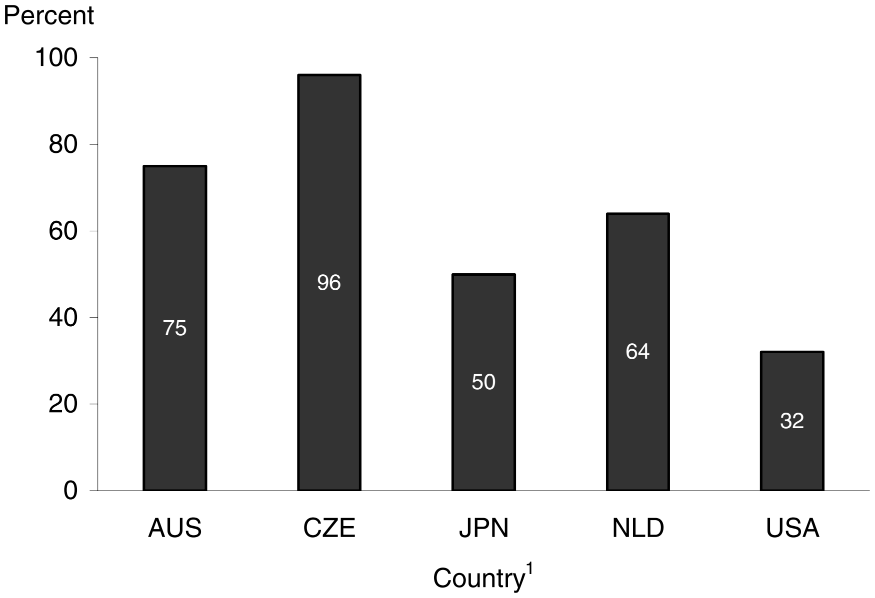
- Students independently started their science lesson by working on routine lesson openers in 26 percent of U.S. eighth-grade science lessons and in 5 percent of Japanese lessons (data not shown).

Organized Science Notebooks

In some science lessons, students were observed organizing their notes and other science work in a special science notebook. In many classes, the record was organized chronologically in a sewn notebook format, so that students created a chronological record, or text, of their experiences in science class. In other cases, loose-leaf, ringed binders were used, with special sections for different types of science class records. In all cases, however, students were responsible for using the notebook to organize their science work and the notebook included only science work.

- Organized science notebooks were used by students in at least 50 percent of the eighth-grade science lessons in all the countries except the United States (figure 11.1) (🎥 Video clip example 11.2). See appendix D for more information on organized science notebooks observed in this study.
- Students in almost all science lessons in the Czech Republic created organized science notebooks, which is a greater percentage of lessons than in all the other countries (figure 11.1).

Figure 11.1. Percentage of eighth-grade science lessons in which students created organized science notebooks, by country: 1999



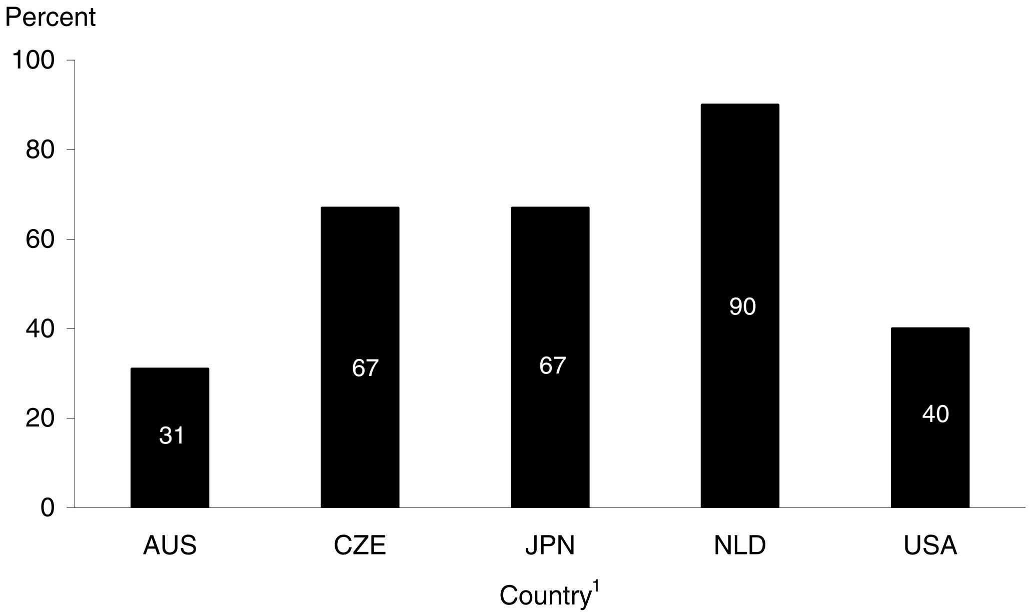
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: CZE>AUS, JPN, NLD, USA; AUS>JPN, USA; NLD>USA.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Textbooks and/or Workbooks

Students in science lessons are sometimes required to use assigned textbooks and/or workbooks. Textbooks are pre-printed materials that are designed to provide, rather than to write in, science information. Workbooks are pre-printed materials that present information and also provide spaces for students to write notes, answer questions, record data, and draw diagrams and/or graphs.

- Students used textbooks and/or workbooks in more Dutch science lessons compared to lessons in the other countries, and in more Czech and Japanese lessons than in Australian and U.S. lessons (figure 11.2).

Figure 11.2. Percentage of eighth-grade science lessons in which students used textbooks and/or workbooks, by country: 1999



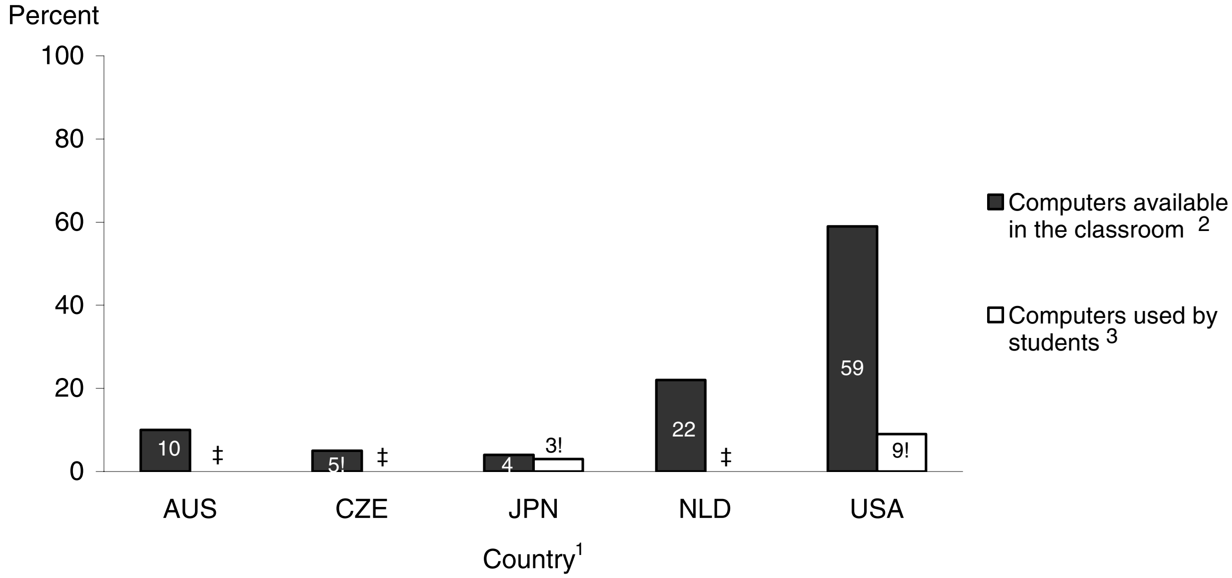
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: NLD>AUS, CZE, JPN, USA; CZE, JPN>AUS, USA.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Computers

Occasionally, students were expected to use the computer during lessons to support their own learning, such as looking for information, organizing that information, making notes, and working with databases. Student use of the computer included the creation of presentations, the use of special instructional software, and the analysis of data.

- While computers were available in more U.S. eighth-grade science lessons (59 percent) than in lessons in all the other four countries, U.S. students were observed using computers in 9 percent of all the science lessons (🎥 Video clip example 11.3). Computers were used in 3 percent of all the Japanese lessons (figure 11.3).

Figure 11.3. Percentage of eighth-grade science lessons in which computers were available in the classroom and used by students during the lesson, by country: 1999



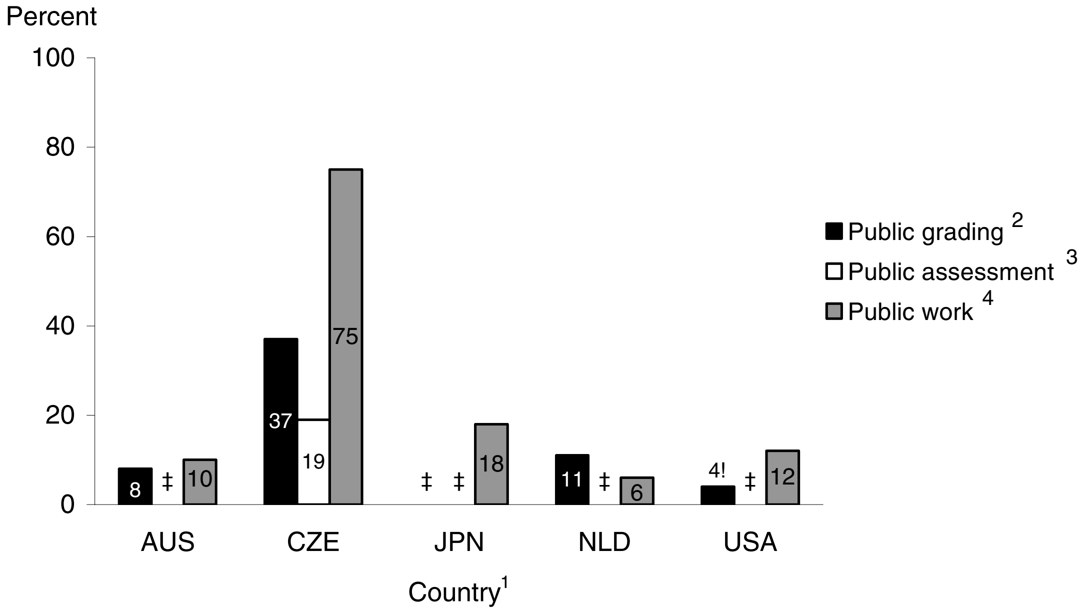
‡Reporting standards not met. Too few cases to be reported.
!Interpret data with caution. Estimate is unstable.
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
[2] Computers available in the classroom: USA>AUS, CZE, JPN, NLD; NLD>CZE, JPN.
[3] Computers used by students: No measurable differences detected.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Public Grading, Assessment, and Work

Students' work was sometimes put up for public scrutiny and grading, a practice that may motivate students to take responsibility for studying and preparing for class. Sometimes teachers would return tests and comment on individual student grades publicly, enabling students to hear the grades of other students (🎥 Video clip example 11.4). Other times, a student would be called to the front of the class for an oral quiz while the rest of the class watched or worked on a different assignment. Students occasionally were responsible for doing other science work publicly, in front of the rest of the class (🎥 Video clip example 11.5). For example, they may go to the board to work out a problem, draw a diagram, or balance an equation.

- Public work by eighth-grade science students was a more common practice in the Czech Republic than in all the other countries (figure 11.4).
- Students in Czech lessons also were more likely to be graded publicly than students in lessons in all the other countries for which reliable estimates could be calculated (figure 11.4).
- Public assessment occurred in 19 percent of Czech science lessons, with too few cases to be reported in the other four countries (figure 11.4).

Figure 11.4. Percentage of eighth-grade science lessons that included public grading, public assessment, and public work of students, by country: 1999



!Interpret data with caution. Estimate is unstable.

‡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] Public grading: CZE>AUS, NLD, USA.

[3] Public assessment: No measurable differences detected.

[4] Public work: CZE>AUS, JPN, NLD, USA.

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

Student Presentations

Formal student presentations to peers and the teacher have been identified as examples of how students can take responsibility for their own learning (NRC 1996). These presentations usually required preparation ahead of time (either outside the class or during the lesson) and subsequently were presented either individually or by a small group of students.

- Students made presentations in 4 to 9 percent of eighth-grade science lessons (data not shown).

Student-Initiated Science Questions

Students can play a more active role in taking responsibility for their learning by monitoring their own understanding of the science content and raising questions to help them better understand the science content. Student-initiated science questions were identified in the eighth-grade science lessons (🎥 Video clip example 11.6). These questions were related to science content and were initiated by a student who directed them to the teacher or another student. The questions reflect students' efforts to make sense of the science content by asking for clarifications, elaborations, connections, and so forth.

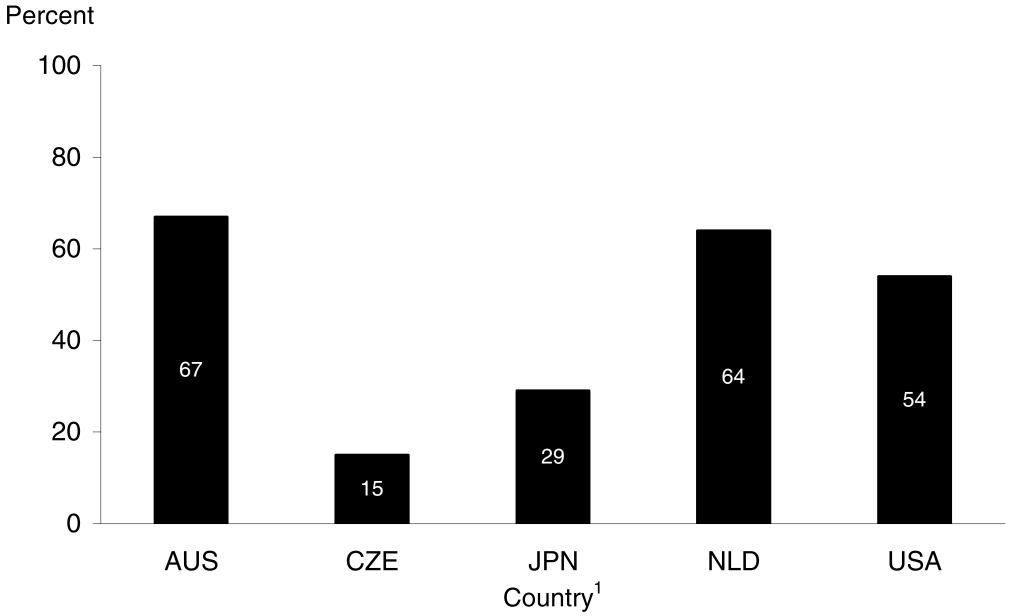
- Students publicly initiated science questions in more Australian and Dutch science lessons than in Japanese lessons, and in more Australian, Dutch, and U.S. lessons than in Czech lessons (figure 11.5).
- In Australian, Dutch, and U.S. eighth-grade science lessons, students initiated a greater number of science questions, on average, than in Czech and Japanese lessons (figure 11.6).
- Although Czech lessons included more instruction time for public talk and discussions than the other four countries (see figures 9.1 and 9.2, chapter 9), Czech students rarely were observed to initiate science questions during these interactions (figure 11.6).
- Although Japanese lessons did not provide a measurably different percentage of public talk time compared to Australian, Dutch, and U.S. lessons (see figure 9.1, chapter 9), students in Japanese lessons initiated fewer questions, on average, than students in these other countries (figure 11.6).

Research Questions, Procedures for Investigation, and Data Collection

Students could be encouraged to take responsibility for their learning by generating research questions to explore, designing procedures for investigating these questions, and collecting data during their investigations. See Appendix D for more detail on student activities.

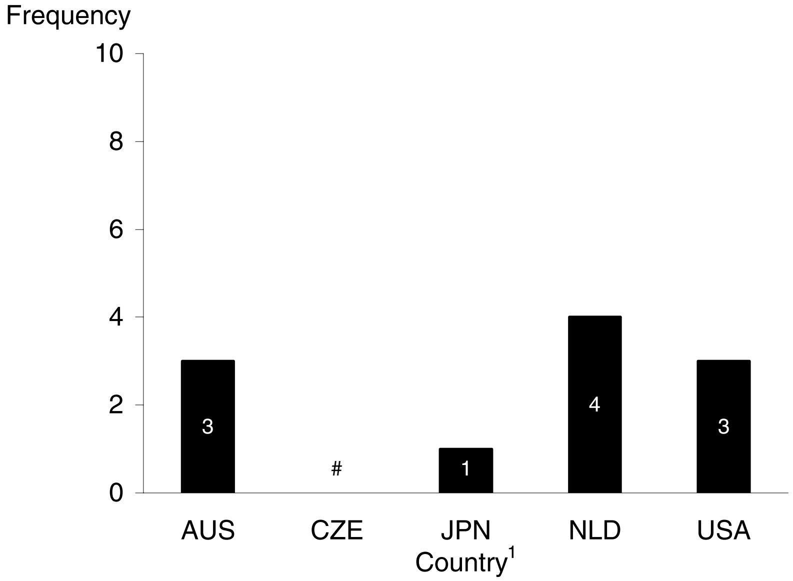
- Students generated their own research questions in 3 percent of Australian science lessons (data not shown).
- Students played a role in designing procedures for investigations in no more than 10 percent of Australian, Japanese, and U.S. lessons (data not shown).
- Students collected data independently or as a whole class in more Australian and Japanese lessons (77 and 81 percent, respectively) compared to Czech and Dutch lessons (41 and 38 percent, respectively; data not shown). In the United States, students collected data in 62 percent of lessons.

Figure 11.5. Percentage of eighth-grade science lessons that included at least one student-initiated science question, by country: 1999



[1]AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: AUS, NLD>CZE, JPN; USA>CZE.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Figure 11.6. Average number of student-initiated science questions per eighth-grade science lesson, by country: 1999



#Rounds to zero.
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: AUS, NLD, USA>CZE, JPN.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

What Responsibilities Do Students Have Outside the Lesson?

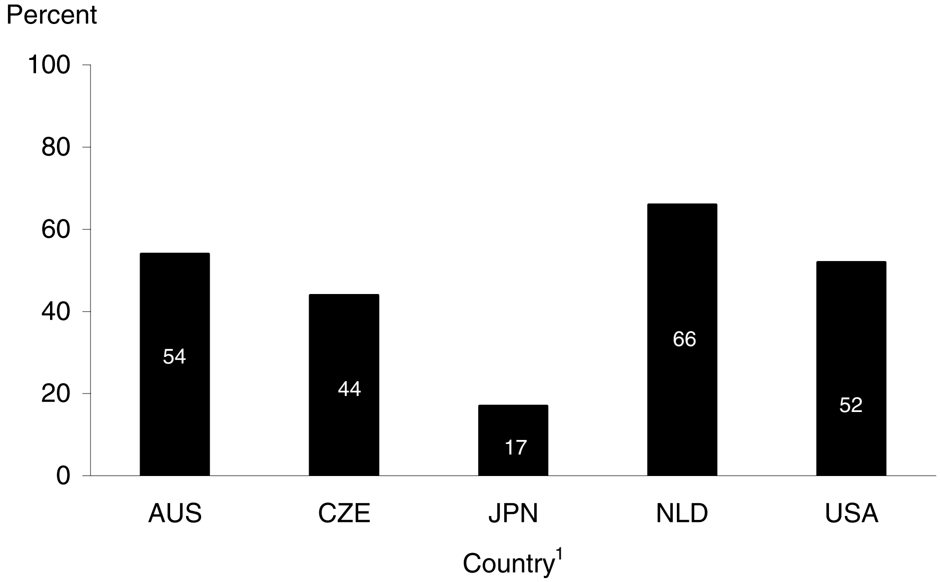
The frequency and nature of assigned homework was examined as an indicator of student responsibility for their own learning outside the classroom. Two aspects of interest were students' responsibility in monitoring their own pace on long-term homework assignments and in checking their own work as they proceeded on long-term assignments.

Working on Homework

- Homework was assigned for future lessons in fewer Japanese eighth-grade science lessons compared to lessons in the other four countries, and in more Dutch lessons than in Czech lessons (figure 11.7).
- Homework assignments in more of the Czech lessons required students only to review previously covered content compared to U.S. lessons (figure 11.8). Too few lessons were observed in all of the other countries for reliable estimates.
- More science lessons provided students with the opportunity to start working on homework assignments in class in Australia and the Netherlands than in the Czech Republic and Japan (figure 11.9).

- Dutch students had the opportunity to review completed homework in class in more science lessons than students in all of the countries with reliable estimates (figure 11.9).
- In 27 percent of all the Dutch science lessons, the class went over completed homework together and students had time to start work on new homework assignments (figure 11.9).

Figure 11.7. Percentage of eighth-grade science lessons in which the teacher assigned homework for future lessons, by country: 1999

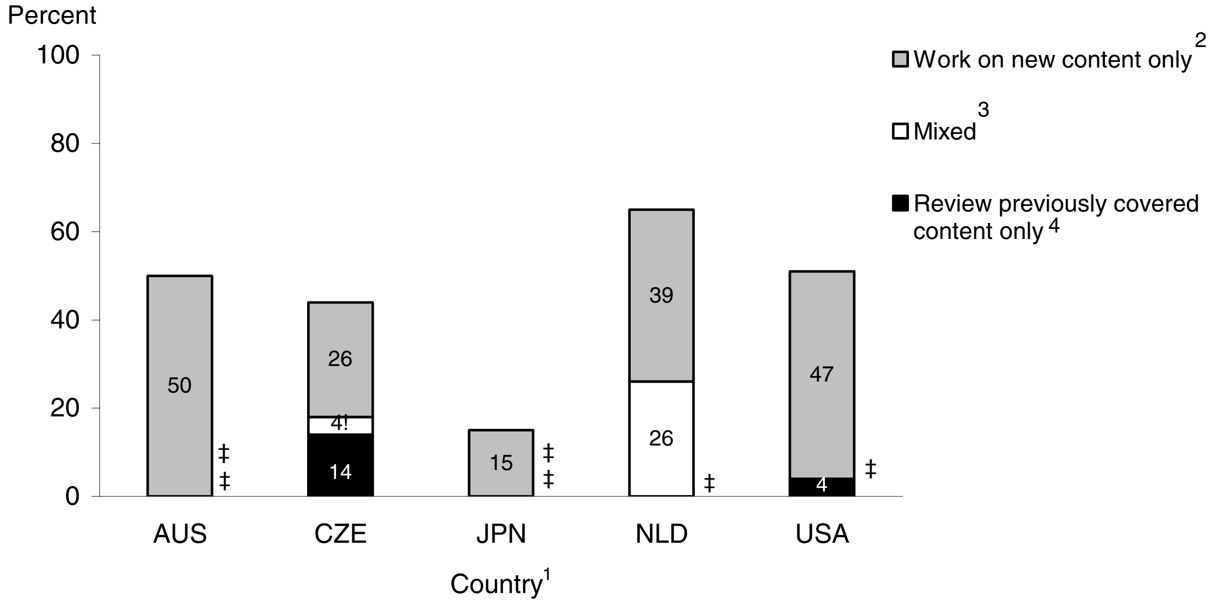


[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.

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

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

Figure 11.8. Percentage distribution of eighth-grade science lessons in which the homework assignment focused on new content, review, and both, by country: 1999



!Interpret data with caution. Estimate is unstable.

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

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

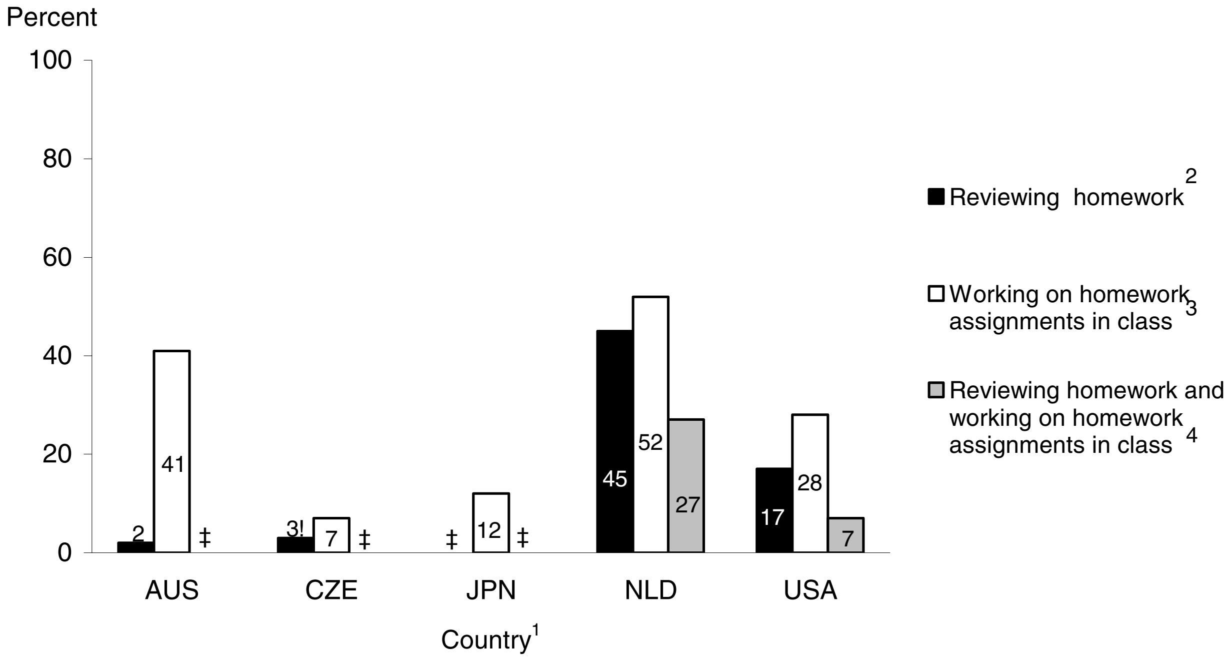
[3] Work on new content only: AUS>CZE, JPN; NLD, USA>JPN.

[2] Mixed: NLD>CZE.

[4] Review previously covered content only: CZE>USA.

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

Figure 11.9. Percentage of eighth-grade science lessons that included reviewing homework and working on homework assignments in class, by country: 1999



!Interpret data with caution. Estimate is unstable.

‡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] Reviewing homework: NLD>AUS, CZE, USA; USA>AUS.

[3] Working on homework assignments in class: AUS, NLD>CZE, JPN; USA>CZE.

[4] Reviewing homework and working on homework assignments in class: NLD>USA.

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

Self-Pacing and Checking Long-Term Assignments

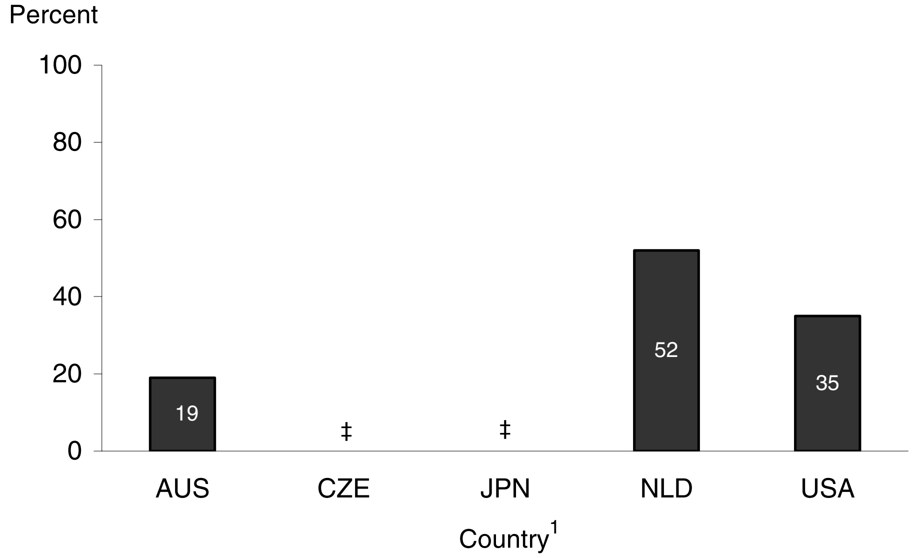
When students are given assignments for future lessons, the homework could be due for the next lesson or the homework could have multiple parts and require several days or weeks to complete. When students are given two or more days to complete an assignment or set of assignments, they have the responsibility of monitoring and pacing themselves in order to complete these long-term assignments on time. Examples of self-pacing long-term assignments include assignment schedules that specify a set of tasks to be completed by a certain date, science fair projects, and library research reports (📹 Video clip example 11.7).

Another indicator of students' responsibility for their own learning includes the expectation that students will check their own work on long-term assignments as they progress through various stages of the work, in some cases using an answer book to check their work.

- Students worked at their own pace on long-term assignments in more Dutch science lessons (52 percent) than Australian lessons (19 percent; figure 11.10).

- In 37 percent of Dutch eighth-grade science lessons, students were expected to check their own work using an answer book or some other strategy (data not shown).

Figure 11.10. Percentage of eighth-grade science lessons in which students worked at their own pace on long-term assignments, 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.

NOTE: NLD>AUS.

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

Summary

This chapter presented indicators that students are expected to take responsibility for their own learning. Some strategies to encourage student independence and responsibility occurred predominantly in one particular country. For example, the use of routine lesson openers occurred primarily in U.S. lessons, public grading of students occurred in Czech lessons and the self-checking of work on long-term assignments was observed in Dutch lessons.

There were a number of indicators in which one country differed from all or three of the others. Japanese lessons differed from all the other countries for their infrequent assignment of homework, and the U.S. lessons less frequently required students to keep an organized science notebook. Students in Czech lessons were required to keep organized science notebooks and complete science work publicly. Dutch students spent more time going over homework during science lessons.

Dutch lessons were notable for including a variety of strategies to encourage student independence. In addition to spending more time going over homework during class and self-checking their work on long-term assignments (mentioned above), Dutch students used textbooks during the lesson in a higher percentage of lessons than students in all of the other countries. In addition, Dutch students initiated science-related questions, were assigned homework, and worked on homework during class more often than students in the Czech Republic and Japan

The preceding chapters described different dimensions of science teaching with a focus on details regarding instructional organization, science content, and student activities involving science work. Comparisons made among and within the five participating countries helped to identify commonalities and differences in alternative approaches to teaching science. Chapter 12 summarizes across these findings and compares patterns of instruction in the five participating countries.

Chapter 12: Similarities and Differences in Eighth-Grade Science Teaching Across Five Countries

The TIMSS 1999 Video Study investigated similarities and differences in eighth-grade science teaching in five countries and addressed a set of broad objectives. The objectives are rephrased here as three broad questions around which this concluding chapter is organized:

- To what extent do the five countries in the sample teach eighth-grade science in similar or different ways?
- Is there a unique pattern of science teaching within each country that is different from others in the sample?
- Do relatively high-achieving countries share a common approach to eighth-grade science teaching?

To address these questions, this chapter synthesizes findings from preceding chapters. Taken from a broad view, there are some general features of science teaching common in all five countries' lessons. However, it is interesting to note that a closer inspection of each country's practices reveals that practices common to all were combined and carried out during the lesson in different ways. Each country has a distinctive pattern of science teaching, but the typical U.S. eighth-grade science lesson differs from lessons in the other higher-achieving countries in ways that may have important implications for the reform of science teaching in the U.S.

Science teaching is a complex activity, as evidenced in the many different features of science teaching analyzed in this study as well as additional features not examined here. Adding in the country variations further complicates the investigative task. Yet despite these complexities, three main findings emerged.

- Eighth-grade science teaching shares some commonalities across the five countries included in the study.
- Each of the countries has an observable pattern of science teaching, although the pattern in the United States is distinct from the other countries in its use of a variety of teaching approaches rather than one consistent instructional approach. This suggests that science teaching, like teaching in other domains, is a cultural activity (Stigler and Hiebert 1999).
- The four countries that have, until recently, outperformed the United States in middle school science do not share a common science teaching approach but, in contrast with the United States, they each have a core instructional strategy for organizing the science content and engaging students in doing science work.

In the major sections that follow in this chapter, each of these findings will be described in more detail. First, a few caveats. A sample size of five countries is a factor that limits this investigation; the four relatively higher performing countries may not be representative of all countries in which students perform well on international assessments of science. In addition, there is only one relatively lower-achieving country (the United States), and there are countries in which students' average science scores were significantly lower than that country, based on the TIMSS assessments (Gonzales et al. 2000, 2004). Also, changes in national policies put into effect after the collection of the video data may have resulted in changes in the teaching approaches taken in the science classrooms. Finally, a video study of eighth-grade science lessons cannot capture all the factors that may affect student achievement. Interpretation of the findings should thus be considered with these limitations in mind. Indeed, the findings from the TIMSS 1999 Video Study of eighth-grade science teaching are best interpreted alongside other sources of data, such as the TIMSS assessments and national-level indicators that are broadly descriptive of education in the participating countries.

In the section that follows, common features of eighth-grade science lessons observed in the five countries are discussed. Following that section, observed patterns of science teaching in each of the five countries are presented. The final section of this chapter examines the evidence for common approaches to science teaching among the four relatively higher-achieving countries in the study.

Are There Common Features of Science Teaching Across Countries?

The analyses contained in this report reveal some general features of science teaching that were shared in the five countries—including the teacher's instructional organization, the science content, and student actions. These features can be divided into two categories—features that occurred commonly in all five countries (at least 70 percent of lessons or accounting for at least 70 percent of instruction time) and features that occurred less frequently in all five countries (occurring in less than 20 percent of lessons or accounting for less than 10 percent of instruction time in all countries).

A common feature related to lesson organization was the prevalence of whole-class presentations and/or discussions during the science lessons (at least 98 percent of lessons across the countries; table 3.5). Moreover, almost all science lessons devoted at least some time to the development of new science content (at least 96 percent of lessons across the countries; table 3.3); and some form of practical activity (at least 72 percent of lessons across the countries; data not shown), although there were measurable differences in the amount of time spent on these activities among the countries.

Common features with regard to science content included a relatively wide spread focus on canonical science knowledge in the science lessons of the five countries (at least 84 percent of lessons across the countries; figure 4.2). Visual representations were also common in the science lessons of the five countries (at least 78 percent of lessons across the countries; figure 6.1). Moreover, explicit lesson goal statements were a relatively common feature of science lessons across the countries (at least 74 percent of lessons across the countries; figure 5.8).

A few features related to engaging students in actively doing science work appeared fairly commonly in the eighth-grade science lessons in the five countries. During whole-class interactions, students' active participation in the science lessons was accomplished primarily in the form of discussion. Discussion segments occurred in at least 81 percent of the lessons in all of the countries (data not shown, chapter 9). Independent practical activities occurred with quite different frequencies across countries (ranging from 23 percent of lessons in the Czech Republic to 74 percent of the Australian lessons; table 3.5). While students could engage in different types of independent practical activities in a science lesson (e.g., designing and making models or conducting a controlled experiment), students in lessons in all of the countries were most likely to observe phenomena during these activities (table 7.2). Beyond these basic similarities, there was much diversity in the ways students were involved in doing science.

In this study, certain features of science teaching occurred with relatively low frequencies in all five countries. The low frequency of these practices is of interest because many of them are recommended in most of these countries as effective or preferred teaching strategies by national standards, national or state curriculum documents, or by results from research on science teaching and learning. These low frequency activities and practices—defined in this study as occurring in less than 20 percent of lessons or for less than 10 percent of instructional time—suggest but do not confirm that recommended activities and strategies are being ignored, have not been effectively communicated to education practitioners, or are too difficult to be implemented in the classroom, among other possibilities. The results of this study cannot be used to distinguish among these or other possibilities, and so should not be construed as an indication of the failure or emerging success of government- or professionally recommended policies. Furthermore, because neither policy recommendations nor the research literature makes clear the relative frequency with which these strategies and practices should be implemented, let alone their potential effect on student learning, the results of the study cannot be used to gauge the effectiveness of teaching practices in any of the five countries. The basis of the observations that follow thus rests on the assumption that recommended activities and strategies should be observed in enough lessons to at least produce reliable estimates, and should occur with enough frequency to be viewed as a relatively widespread practice. Other researchers and separate analyses may come to different conclusions in this regard. These less frequent lesson features fall into all three major categories used to organize the analysis and presentation in this report: instructional organization, science content, and student actions.

In terms of organizational structures, certain features of groupwork described in the education literature as strategies for stimulating or supporting student collaborative work accounted for no more than 10 percent of science instruction time in the eighth-grade science lessons of the five countries (e.g., Cohen 1994; Johnson, Johnson, and Holubec 1993; Slavin 1996). For example, groupwork tasks that were designed in ways that required students to collaborate in order to successfully complete the task were allotted no more than 6 percent of instruction time (table 8.1). In addition, group products were created instead of individual products during no more than 10 percent of science instruction time (table 8.1), and students held assigned roles during independent activities for no more than 6 percent of science instruction time (table 8.1). Instead, groupwork in all five countries was characterized primarily by students sitting together in groups, sharing materials, and talking to each other during independent activities (table 8.1).

In the content arena, science lessons in the five countries allocated little instruction time to metacognitive knowledge and knowledge about the nature of science during whole-class talk (public talk; data not shown; chapter 4). Metacognitive knowledge, which refers to explicit talk about learning strategies and thinking processes, accounted for no more than 1 percent of public talk time in the science lessons of any country. Public talk about the nature of science, such as the values, dispositions, history, politics, and processes of science, received attention in no more than 7 percent of lessons and was allocated no more than 1 percent of public talk time. This may be of special interest in Australia and the United States, where curriculum and standards documents emphasize the importance of teaching students to reflect on the nature of science (AAAS 1993; Australian Education Council 1994; NRC 1996).

A number of eighth-grade science lesson features related to student actions were observed in a relatively low percentage of the instruction time or percentage of lessons across all the countries. For example, students spoke no more than 12 percent of the words during public talk (figure 9.3). In each of the countries for which reliable estimates could be made, students made presentations to the whole class in no more than 9 percent of the lessons (data not shown, chapter 11). In terms of independent writing activities, students in the eighth-grade science lessons were expected to write at least a paragraph related to independent practical or seatwork activities in no more than 11 percent of the lessons in any of the participating countries with reliable estimates (data not shown, chapter 9). In addition, students created graphs in no more than 12 percent of lessons in any of the countries (data not shown, chapter 9). Students in the eighth-grade science lessons also were observed using computers infrequently. While eighth-graders in the United States had access to computers in 59 percent of the lessons, they were observed using computers in 9 percent of lessons. Students in Japanese science lessons used computers in 3 percent of lessons and students in the other countries used computers in too few lessons to calculate reliable estimates (figure 11.3).

Certain lesson features related to students' work on independent practical activities occurred in relatively small percentages of eighth-grade science lessons across the five countries. Small percentages of lessons, for example, engaged students in model building (no more than 7 percent), displaying or classifying objects (no more than 7 percent), using tools, procedures, and science processes (less than 8 percent), or conducting a experiment (no more than 8 percent; figure 7.2). In all of the countries except Australia, one or more of these types of practical activities occurred in too few lessons to calculate reliable estimates.

Students were also asked to do certain types of science inquiry actions in a relatively small percentage of lessons. For example, students were involved in defining the question to be explored during independent practical activities in 3 percent of Australian lessons and in too few lessons to report reliable estimates in the other four countries (table 7.2). Students played a role in designing procedures to be used during independent practical activities in no more than 10 percent of lessons, with too few cases to report reliable estimates in the Czech Republic and the Netherlands (table 7.2). Methods used during independent practical activities were critiqued or evaluated for sources of error in no more than 17 percent of the lessons (figure 7.4). Raising new questions to investigate that were based on results from independent practical activities occurred in no more than 18 percent of science lessons in any country, with this occurring in too few cases to be reported in the Czech Republic, the Netherlands, and the United States (figure 7.4).

Are There Characteristic Country Patterns of Teaching Eighth-Grade Science Lessons?

Although eighth-grade science lessons in each of the five countries included many of the same basic elements, lessons in each of the five countries also displayed observable patterns. The features that appear to distinguish among science teaching in the five countries were examined to create the country patterns described in this section. The presentation of country patterns is organized by the three guiding research questions related to the teacher's instruction organization, the science content, and student actions (see figure 1.1 and table 1.1, chapter 1) which contribute to the development of a science lesson:

- ***Teacher's instructional organization***: How did the teacher organize the lesson in terms of lesson time, purposes, activities, and social organization?
- ***Science content***: How was science represented to students in the lesson?
- ***Student actions***: What opportunities did students have to participate actively in science learning activities?

Each country pattern also includes a description of key aspects of the lesson context, with a focus on information about the teachers' backgrounds and goals for the lesson. The countries are presented in an order that highlights the country variations in teaching science. Czech lessons differed from all four of the other countries on 48 features presented in earlier chapters, and they differed from three of the other countries on an additional 31 features investigated in this study. Dutch lessons are presented next because they also have distinct features that set them apart from the other countries and because they share some of the features common in Czech lessons. The Japanese and Australian lessons are described next because they share many similarities that contrast with the Czech and Dutch lessons. The U.S. lessons differed from the other four countries on 7 features, mainly because there was so much variability and there appeared to be little evidence of a common country approach to teaching science.

Eighth-Grade Science Teaching in the Czech Republic: Talking About Science Content

The Czech pattern of science teaching in the eighth-grade appears to be the most distinct from the other four countries, at least as described in this study (see figures 12.1 and 12.2). The Czech pattern is characterized by whole-class teacher-student talk about challenging, often theoretical content.

Instructional Organization of Czech Science Lessons

Time appears to be used carefully in Czech science lessons. Two percent of lesson time was spent on science organization while 97 percent of lesson time was devoted to science instruction (figure 3.2). Outside interruptions to the lesson occurred in fewer lessons (7 percent) than in Australian and U.S. lessons (42 and 45 percent, respectively; figure 3.3).

Reviewing previously taught material was a prominent feature in Czech lessons, occurring in more lessons (84 percent) and for more lesson time (19 percent) than in the science lessons of the other countries where reliable estimates could be made (tables 3.3 and 3.4). Formal assessment activities (both written and oral) also occurred more frequently in Czech lessons (50 percent of lessons) than in the lessons of the other countries (except in Australia where there were too few lessons to produce reliable estimates; table 3.3). A notable Czech practice observed in the videotaped lessons is the public grading of one or two students at the beginning of a lesson, occurring in a higher percentage of lessons than in all the other countries with reliable estimates (37 percent; figure 11.4). In this practice, the teacher calls a student to the front of the room and asks a series of review questions, probing the student's responses to elicit additional information. At the end of this process, the teacher assigns a grade that is announced so that the entire class can hear it.

Eighth-grade science lessons in the Czech Republic were organized mainly around whole-class activities, with students working independently for 17 percent of science instruction time (figure 3.6). Eighth-graders in the other four countries spent about half of the lesson time on independent activities, on average.

Relatively little instruction time (14 percent) was allocated for practical activities in Czech eighth-grade science lessons compared to lessons in the other countries except the Netherlands (figure 3.5). Independent practical activities accounted for 4 percent of science instruction time, also less than in the other countries (figure 3.7). Whole-class practical activities, such as demonstrations, occurred in 80 percent of the lessons (table 3.5) and accounted for 10 percent of science instruction time (figure 3.7).

Content in Czech Science Lessons

Eighth-grade science lessons in the Czech Republic appear to stand out from lessons in some or all of the other four countries with respect to many aspects of the science content and its organization. All Czech science lessons were focused on learning content (figure 5.2) with more public talk time focused on canonical content knowledge (science facts, concepts, theories, etc.) than science lessons in the other four countries (figure 4.3).

One quarter of Czech science lessons included challenging content (figure 5.11). The level of challenge was also evidenced by attention to laws and theories in 49 percent of lessons (figure 5.12) and by more frequent use of science terms and highly technical science terms than in the lessons of the other countries (figure 5.4). The content in Czech lessons was found to be dense with canonical ideas and science terms. More eighth-grade Czech science lessons had a high number of public canonical ideas (26 percent) compared to science lessons in Japan (7 percent) (figure 5.3).

The content of Czech science lessons, while challenging and dense, did not always appear to be organized to emphasize conceptual connections. Instead of focusing on making connections among experiences, ideas, patterns, and explanations, 72 percent of Czech lessons were found to be organized primarily around facts and definitions (figure 5.5). In addition, 43 percent of Czech lessons presented these facts and definitions as discrete bits of information rather than as sequences of events (9 percent) or algorithms and problem-solving procedures (19 percent; see figure E.1, appendix E).

One half of Czech science lessons were found to be focused on learning content with strong conceptual links, while the other half were found to have weak or no conceptual links (figure 5.7). The percentage of lessons with a high number of public canonical ideas (figure 5.3), the relatively high average number of science terms and highly technical terms in a lesson (figure 5.4), and the percentage of lessons organized primarily as discrete bits of information (43 percent, see appendix E, figure E.1) suggest an emphasis on content coverage rather than coherence. Indeed, half the Czech lessons were characterized by weak conceptual links among ideas presented (figure 5.7). However, the other half of the lessons were found to connect ideas with strong conceptual links, which is a larger percentage of lessons than in the Netherlands (figure 5.7). Other indicators that suggest some content coherence were the use of goal statements in a large percentage of lessons (93 percent of lessons, figure 5.8) and summary statements (35 percent of lessons, figure 5.8). In fact, 33 percent of Czech lessons included both goal and summary statements (figure 5.10). However, the goal statements in Czech lessons were typically limited to naming the topic of study rather than presenting a conceptual organizer for the lesson. For example, 69 percent of science lessons included a goal statement that simply named the topic for the lesson (figures 5.9).

Despite the relatively short amount of instruction time allotted to practical work in Czech eighth-grade science lessons (figure 3.5), 69 percent of Czech lessons included first-hand data (figure 6.1) and 55 percent of lessons included at least one phenomenon for students to observe (figure 6.1). Czech lessons developed all main ideas in the lesson with multiple phenomena in 22 percent of lessons (fewer lessons than in Australia and Japan) and with multiple visual representations in 54 percent of lessons (more lessons than in the Netherlands; figure 6.2). Thirty-three percent of Czech lessons supported each main idea with three types of evidence (first-hand data, phenomena, and visual representations), which was a larger percentage than in the Netherlands (14 percent), but a smaller percentage than in Japan (65 percent; figure 6.3).

Visual representations were more likely to occur in Czech science lessons than first-hand data and phenomena (figure 6.1). Ninety-four percent of Czech lessons used visual representations (figure 6.1), and multiple types of these representations were used in more lessons than in the other four countries (data not shown; chapter 6). Czech science lessons included formulas in more lessons than any of the other countries (data not shown; chapter 6). In addition, 54 percent of Czech lessons presented two or more visual representations to support each main idea (figure 6.2).

Czech science lessons also used real-life issues to support the development of canonical knowledge. Eighty-eight percent of lessons at least mentioned real-life issues (figure 10.1), and 13 percent of public talk time was used to address real-life issues (figure 10.2). In addition, 83 percent of the lessons that mentioned real-life issues also used the real-life issues to support the development of canonical knowledge, more than in the other countries except Australia (figure 10.3). Thus, Czech science lessons not only mentioned real-life situations but also used them to support the development of canonical knowledge.

Student Actions in Czech Science Lessons

Students in the eighth-grade Czech science lessons engaged in doing science work primarily by publicly talking and listening in the whole-class setting. Thirty-three percent of science instruction time was devoted to whole-class discussion, with the teacher asking questions and the students responding (figure 9.1). Students initiated questions themselves in 15 percent of lessons, fewer than in the lessons of the other countries except Japan (figure 11.5). A traditional teacher question/student response pattern characterized the talk in Czech lessons during oral assessments of individual student learning, during review periods, and during some of the time devoted to the development of new content. Although teachers spoke more often than students, as observed in all of the other countries (figure 9.3), 28 percent of utterances by Czech students during public talk were five or more words in length, which is higher than students in three other countries (figure 9.4). In contrast, during independent work (17 percent of instruction time, figure 3.6), Czech students spoke fewer utterances of 5 or more words than students in all the other countries (figure 9.4).

Czech students also participated during whole-class time by coming to the front of the classroom to work publicly. This occurred in 75 percent of the Czech science lessons (more than in the lessons of the other countries), with students typically doing some work on the blackboard, answering teacher questions, or assisting with a practical demonstration (figure 11.4).

During whole-class presentation segments, students were also expected to listen to the teacher or another presenter. Forty-five percent of science instruction time was devoted to such presentations, more than in the lessons of the other countries (figure 9.1). During these presentations, students were responsible for keeping an organized science notebook in more lessons (96 percent) than students in the other four countries (figure 11.1).

Students in the Czech eighth-grade science lessons were observed to spend little time working independently (4 percent of instruction time on independent practical activities and 13 percent of instruction time on independent seatwork activities; figure 3.7). The teacher was more likely to speak to the whole class, directing students as they worked through an independent activity rather than to interact privately with individual students or small groups of students as they worked independently (figures 9.1 and 9.2). During the infrequent private teacher-student interactions (3 percent of lessons, less than in the other countries, figure 9.2), Czech students were less likely to use 5 or more word utterances than students in lessons in all the other countries (figure 9.4). Thus, even during independent activities, Czech students were observed listening to the teacher.

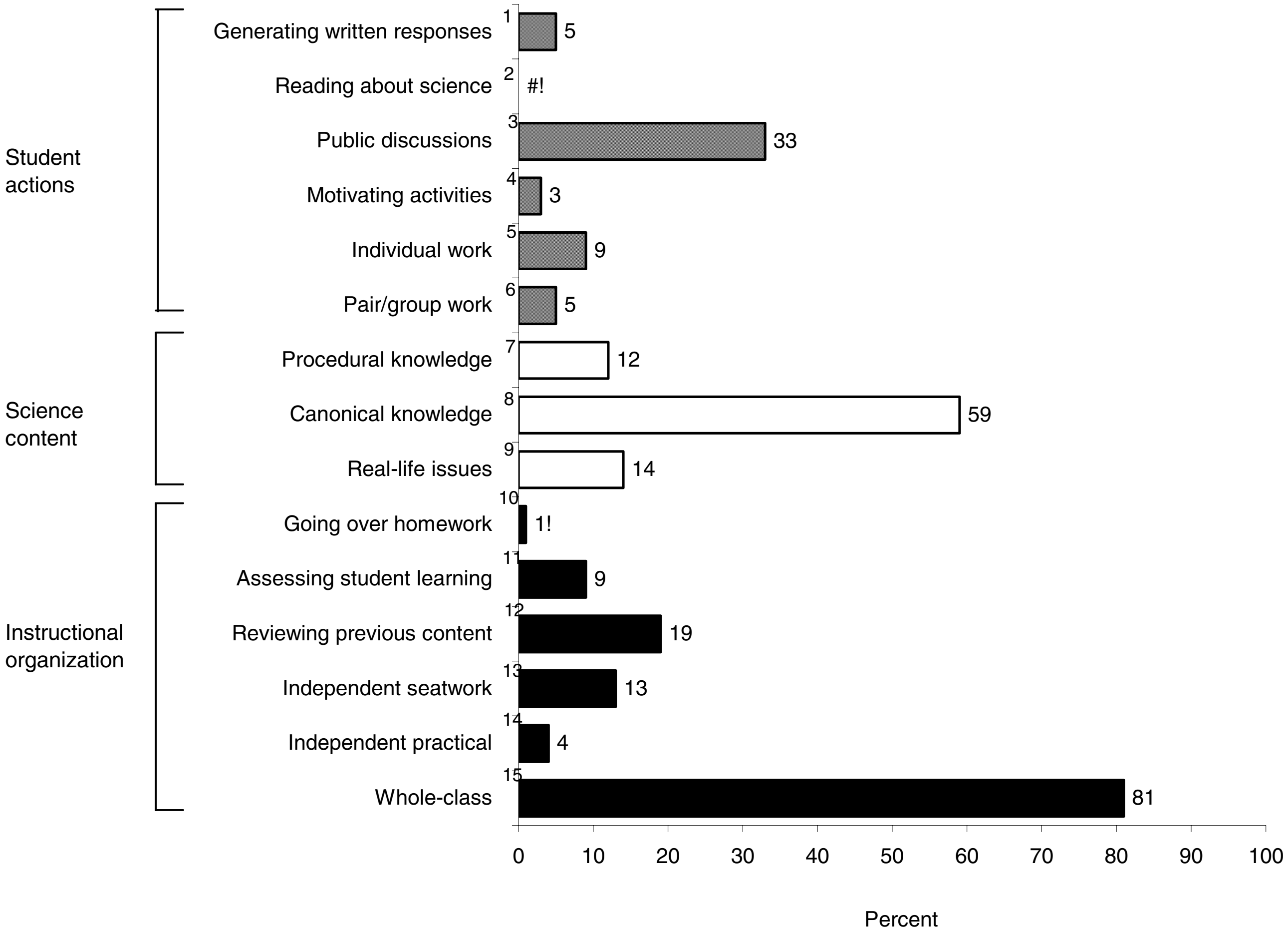
While relatively little time was allotted to practical activities in the Czech science lessons, students were given opportunities to interpret the first-hand data or phenomena that were generated during the lesson, usually through a whole-class practical activity. When students were given the opportunity to conduct experiments on their own, they interpreted data in 20 percent of lessons, which is a smaller percentage than lessons in Australia and Japan (table 7.3). However, when students were engaged in experiments as a whole class, they were asked to interpret data or phenomena in 33 percent of lessons, which is a larger percentage of lessons than in the other countries (figure 7.5)

Context of Czech Science Lessons

Ninety-five percent of the eighth-grade science lessons were taught by Czech teachers who reported having an undergraduate or graduate major area of study in a science field (table 2.1). In addition, 100 percent of the lessons were taught by Czech teachers who reported attaining a graduate degree (figure 2.1). Czech teachers reported on questionnaires that they had been teaching science longer than the teachers in the other four countries (table 2.2).

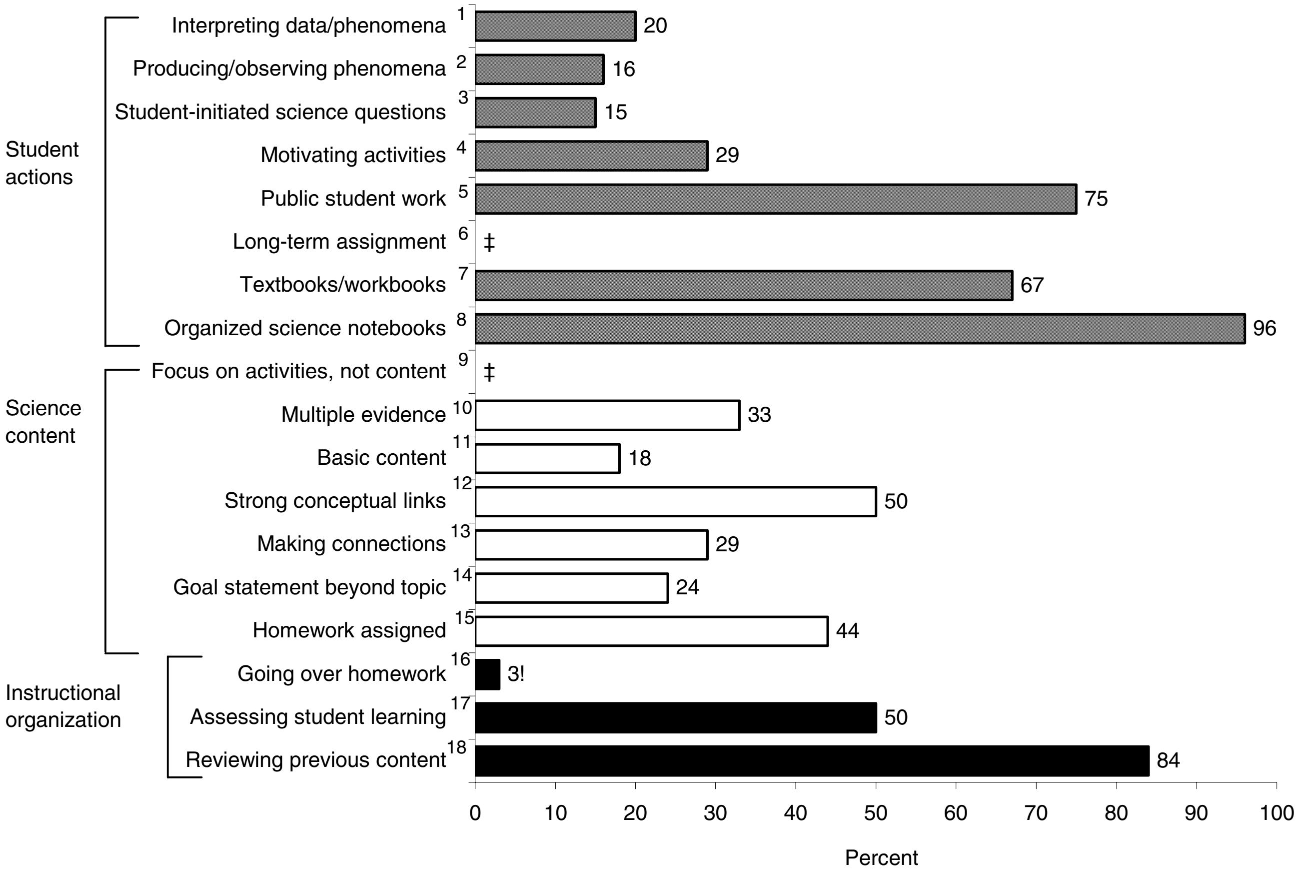
In describing their main goals for the videotaped lesson, teachers in more Czech lessons named students' knowledge about specific science information than teachers of science lessons in the other four countries (table 2.6). These self-reports appear to be consistent with the strong focus on science content in the Czech science lessons—teachers have science majors and state their goals in terms of informational science content knowledge.

Figure 12.1. Average percentage of science instruction time in Czech eighth-grade science lessons devoted to student actions, science content, and instructional organization: 1999



#Rounds to zero.
!Interpret data with caution. Estimate is unstable.
[1] Generating written responses during independent work: See figure 9.5.
[2] Reading about science: See figure 9.8.
[3] Public discussions: See figure 9.1.
[4] Motivating activities: See figure 10.6.
[5] Individual work: See figure 8.2.
[6] Pair/group work: See figure 8.2.
[7] Procedural and experimental knowledge: See figure 4.7.
[8] Canonical knowledge: See figure 4.3.
[9] Real-life issues during public talk: See figure 4.5.
[10] Going over homework: See table 3.3.
[11] Assessing student learning: See table 3.3.
[12] Reviewing previous content: See table 3.3.
[13] Independent seatwork activities: See figure 3.7.
[14] Independent practical activities: See figure 3.7.
[15] Whole-class work: See figure 3.6.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Figure 12.2. Percentage of eighth-grade science lessons in the Czech Republic devoted to instructional organization, science content, and student actions: 1999



!Interpret data with caution. Estimate is unstable.

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

[1] Interpreting data/phenomena related to independent practical work: See table 7.3.

[2] Producing/observing phenomena during independent practical work: See table 7.2.

[3] Student-initiated science questions: See figure 11.5.

[4] Motivating activities: See figure 10.5.

[5] Public student work: See figure 11.4.

[6] Self-pacing on long-term assignment: See figure 11.10.

[7] Textbooks/workbooks: See figure 11.2.

[8] Organized science notebooks: See figure 11.1.

[9] Focus on activities, not content: See figure 5.7.

[10] Multiple evidence supporting all main ideas: See figure 6.3.

[11] Basic content: See figure 5.11.

[12] Learning content with strong conceptual links: See figure 5.7.

[13] Making connections: See figure 5.5.

[14] Goal statement beyond topic: See figure 5.9.

[15] Homework assigned for future lessons: See figure 11.7.

[16] Going over homework: See table 3.3.

[17] Assessing student learning: See table 3.3.

[18] Reviewing previous content: See table 3.3.

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

Eighth-Grade Science Teaching in the Netherlands: Learning Science Independently

The Dutch approach to eighth-grade science teaching appears unique among the five countries (see figures 12.3 and 12.4). The differences between Dutch lessons and lessons in the other four countries involve features related to all three of the categories of lesson characteristics—instructional organization, science content, and students' actions. In brief, much of the instruction Dutch science teachers provide appears to be in support of independent, self-directed student learning. Dutch students are presented with long-term schedules of assignments around which their science learning is organized. They are expected to check their own work and to keep well-organized science notebooks. Lessons are used as opportunities to go over homework, work on homework (read science text and complete seatwork activities), and ask questions of the teacher that students could not work out on their own. Because much of this learning activity takes place in a way that the camera cannot capture, a video study cannot fully represent Dutch science lessons. For example, the video study did not analyze the textbooks and worksheets that students used during their independent work. However, despite this limitation, it is possible to compose a useful, if only partial, portrait of the Dutch pattern of eighth-grade science teaching.

Instructional Organization of Dutch Science Lessons

Observations of the videotaped lessons showed that more time was spent on non-instructional issues (e.g., attendance, school announcements, explanations about the videographer's presence in the classroom) in Dutch eighth-grade science lessons than in Czech and Japanese science lessons (Figure 3.2). In addition, more time was spent on science organizational work than lessons in the Czech Republic (figure 3.2). Dutch lessons were interrupted by outside sources in 16 percent of cases (figure 3.3). On average, 91 percent of lesson time remained available for science instruction, a smaller percentage than in the science lessons of the Czech Republic and Japan (figure 3.2).

Dutch science lessons were found to be distinct from lessons in the other countries in terms of their use of instruction time for going over homework together. Forty-five percent of Dutch lessons allotted time for going over homework, a larger percentage than in the other countries with reliable estimates (table 3.3), accounting for 12 percent of science instruction time on average (table 3.4).

Activities in the eighth-grade science lessons in the Netherlands focused on independent and seatwork activities (i.e., reading and writing tasks not connected to a practical activity such as an experiment). Students were involved in working independently for about half of the science instruction time (figure 3.6). Independent seatwork activities occurred in 77 percent of Dutch science lessons (table 3.5) and took up 28 percent of science instruction time, on average, more than in lessons in the Czech Republic and Japan (figure 3.7). Independent practical activities during science lessons were found to be less common in the Netherlands, occurring in 30 percent of lessons (table 3.5) and receiving 19 percent of total instruction time (less than in Australia and Japan but more than in the Czech Republic, figure 3.7).

Content in Dutch Science Lessons

The textbook or workbook determined the content organization of 65 percent of eighth-grade Dutch science lessons (figure 5.1). For example, when a class went over homework, they followed the list of questions in the textbook, discussing them one by one. Similarly, when students worked on independent reading and writing tasks, they often followed the textbook (figure 11.2). Some of the features of the science content organization in the lessons may be a reflection of the way content is organized in Dutch textbooks.

Dutch science lessons had fewer indicators of lesson coherence than some of the other countries, at least as investigated in this study. The textbook organization and students' freedom to work through a series of assignments at their own pace in around half of the science lessons (figure 11.10; see "student actions" section below) may at least partially explain the observation that 65 percent of Dutch lessons were characterized by weak conceptual links among ideas (figure 5.7). In addition, 73 percent of Dutch lessons organized content around facts and definitions rather than making connections among experiences, ideas, patterns, and explanations (figure 5.5). Most of the science lessons that focused on facts and definitions were organized around discrete bits of information rather than as problem-solving algorithms or sequences of events (see figure E.1, appendix E). Fewer Dutch lessons were found to have strong conceptual links among ideas (27 percent) compared to Australian, Czech, and Japanese lessons (58, 50, and 70 percent, respectively; figure 5.7). In addition, although teachers of Dutch science lessons used goal statements in 83 percent of the lessons (figure 5.8), the goal statements were found to simply name pages to be covered or the topic to be addressed in 54 percent of the lessons (figure 5.9). Summary statements occurred in 6 percent of Dutch lessons and in 11 to 41 percent of the lessons in the other countries (figure 5.8).

Coherence was also less evident in relationship to independent practical activities in Dutch science lessons. Based on observations, the set-up discussion for these activities focused more often on procedures than on both procedures and ideas (figure 7.1) and discussion of the results or conclusions at the end of a practical activity occurred in just 3 percent of the lessons (figure 7.3). Set-up talk that focused on ideas and procedures was observed in fewer Dutch lessons than in lessons in the other countries except the Czech Republic (figure 7.1), and follow-up discussion that focused on a main conclusion occurred in too few lessons to calculate reliable estimates (figure 7.3).

The content in Dutch eighth-grade science lessons was not found to be as dense, as challenging, or as focused on canonical science knowledge as the Czech lessons. Sixteen percent of Dutch lessons presented a high number of publicly developed canonical ideas (figure 5.3), and 47 percent of the lessons were judged to address all basic and no challenging content (figure 5.11), with 13 percent of lessons addressing mostly challenging content (figure 5.11). Dutch lessons focused on canonical knowledge during 33 percent of public talk time compared to 59 percent in Czech lessons (figure 4.3).

Dutch science lessons were not found to support main ideas with evidence as much as lessons in some of the other countries. Among the findings, fewer Dutch lessons included at least one instance of first-hand data or phenomena than Japanese lessons (figures 6.1). In addition, fewer

Dutch science lessons than Australian and Japanese science lessons developed all main ideas with multiple data sets or multiple phenomena (figure 6.2). In addition, main ideas in Dutch lessons were supported by multiple visual representations less frequently than in Czech and Japanese lessons (figure 6.2). Regarding the types of visual representations used, Dutch lessons were found to use diagrams in fewer lessons than in Japan, and used formulas in fewer lessons than in the Czech Republic (see figure E.2, appendix E).

Overall, the content of Dutch eighth-grade science lessons was found to be less challenging and dense than science lessons in the Czech Republic, and less coherent and less supported by connections between data/phenomena and ideas than science lessons in Australia and Japan. Dutch science lessons were found to present content most often as facts and definitions, similar to what was observed in Czech lessons but different from how science lessons were conducted in Australia and Japan (figure 5.5). Australia, the Czech Republic, and Japan all had more lessons that were coherent with strong conceptual links among ideas compared to the Netherlands (figure 5.7). A feature of Dutch science content that distinguishes it from all of the other countries except the United States was its organization around the textbook and/or workbook (figure 5.1).

Student Actions in Dutch Science Lessons

Eighth-graders in Dutch science lessons were often observed to be engaged in carrying out tasks independently and were expected to take responsibility for their own learning of science content in a number of ways. Thus, the emphasis in the Dutch curriculum guidelines on fostering independent learning was enacted, at least to some extent, in the Dutch lessons (Dutch Ministry of Education, Culture and Science 1998).

Homework-related activities were evident in Dutch science lessons. Homework was assigned in 66 percent of the Dutch science lessons, more than in lessons in the Czech Republic and Japan (figure 11.7). Forty-five percent of Dutch lessons allocated time for going over homework completed by the students prior to the lesson, a higher percentage of lessons than in the other countries with reliable estimates (figure 11.9). Dutch students had the opportunity to work on their homework assignments during class in 52 percent of science lessons, more than in the Czech Republic and Japan (figure 11.9). Twenty-seven percent of lessons engaged students in both of these homework-related activities, compared to 7 percent of U.S. lessons, with too few observed cases to be reported in the other countries (figure 11.9).

Students in eighth-grade Dutch science lessons spent more time on seatwork than practical independent activities (28 and 19 percent, respectively; figure 3.7). During independent seatwork activities, Dutch students typically worked individually (figure 8.3). However, this individual work appeared to be collaborative, with students talking to each other a great deal as they worked (table 8.1). Students used textbooks in 90 percent of the lessons, more than in the lessons of the other countries (figure 11.2). Students were observed to independently read text that went beyond simply reading a description of a task or question for 19 percent of instruction time, more than in Australian lessons (figure 9.7). In contrast with the other countries except the United States, Dutch students generated sentence-length written responses for longer average proportions of instructional time (36 percent) than they selected answers (6 percent) during independent work (figure 9.5).

Dutch students were observed to be held responsible for their own independent learning from independent activities in several ways. In 52 percent of Dutch science lessons, students had a long-term schedule of assignments to complete (figure 11.10), thus requiring them to pace their own work over a period of several days or weeks. Students were also responsible for using an answer book to check their answers as they worked. This was almost exclusively a Dutch practice, occurring in 37 percent of Dutch lessons and in too few lessons to report in the other countries (data not shown; chapter 11). In 64 percent of Dutch lessons, students were expected to keep their work organized in a special science notebook (figure 11.1).

Although independent practical activities occurred in fewer Dutch science lessons than in Australian and Japanese lessons**,** Dutch students engaged in such activities in 30 percent of the lessons (table 3.5), accounting for 19 percent of science instruction time on average (figure 3.7). Several indicators suggest that Dutch students were also expected to take responsibility for their own learning during these activities. For example, the teacher's set-up talk for the practical activities focused on procedures rather than both procedures and ideas (figure 7.1), and there was typically no post-laboratory discussion to help students interpret the findings (figure 7.3).

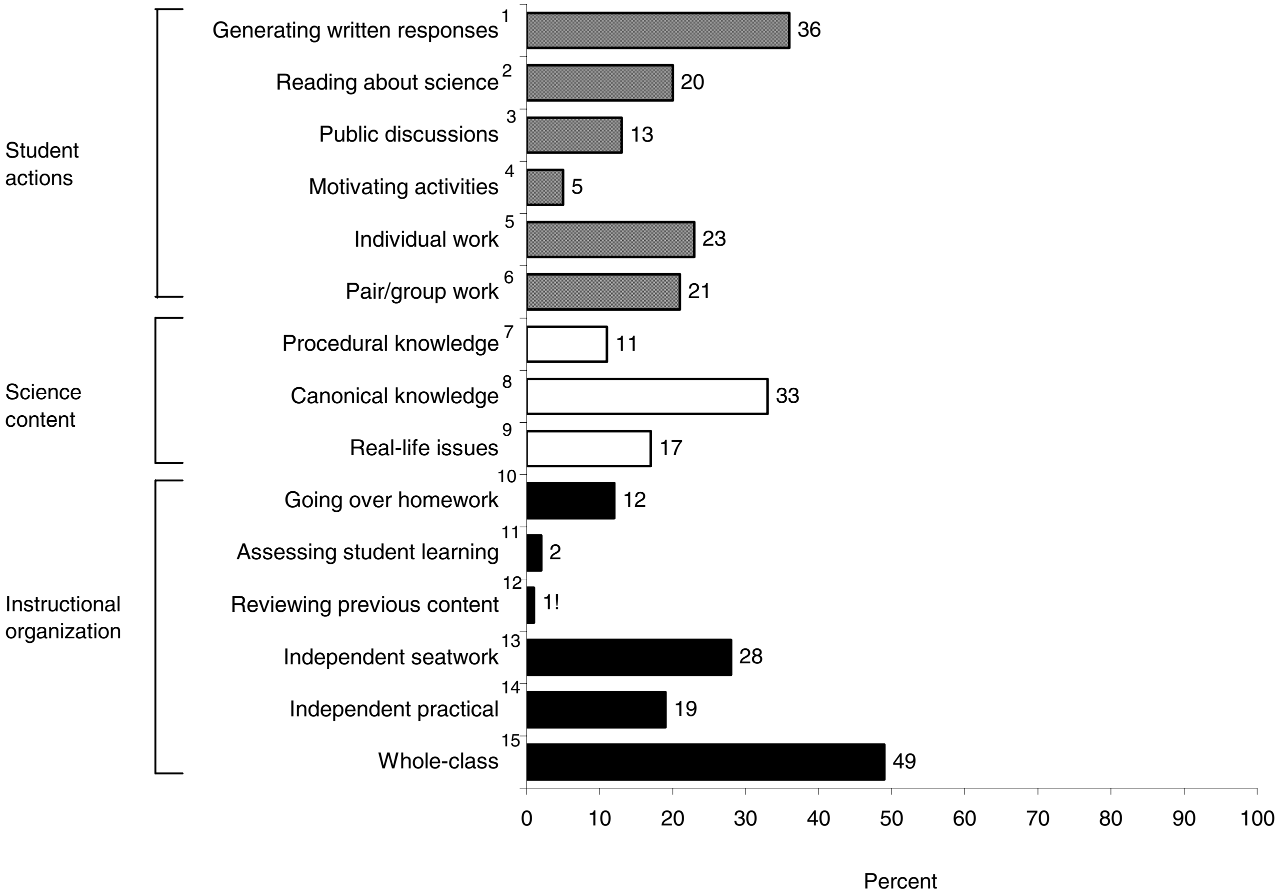
Whole-class activities included a focus on Dutch students' independent work. For example, the class reviewed homework assignments together in 45 percent of the science lessons, more than in the lessons of the other countries where reliable estimates could be made (figure 11.9).

Students took responsibility for their own learning during whole-class discussions by initiating content questions about things that they did not understand or wanted to know more about. This occurred in 64 percent of the Dutch science lessons, with Dutch students asking more questions per lesson (4 questions, on average) than students in the Czech Republic and Japan (figures 11.5 and 11.6).

Context of Dutch Science Lessons

Ninety-nine percent of Dutch eighth-grade science lessons were taught by teachers who identified science as their major area of postsecondary study, more than in Australia and the United States (table 2.1). Furthermore, 39 percent of lessons were taught by Dutch science teachers who reported attaining a graduate degree (figure 2.1). Supporting lesson observations of the prominent role of the textbook (figures 5.1 and 11.2), teachers in 74 percent of the Dutch lessons reported that a mandated textbook influenced the content of their lessons (table 2.7).

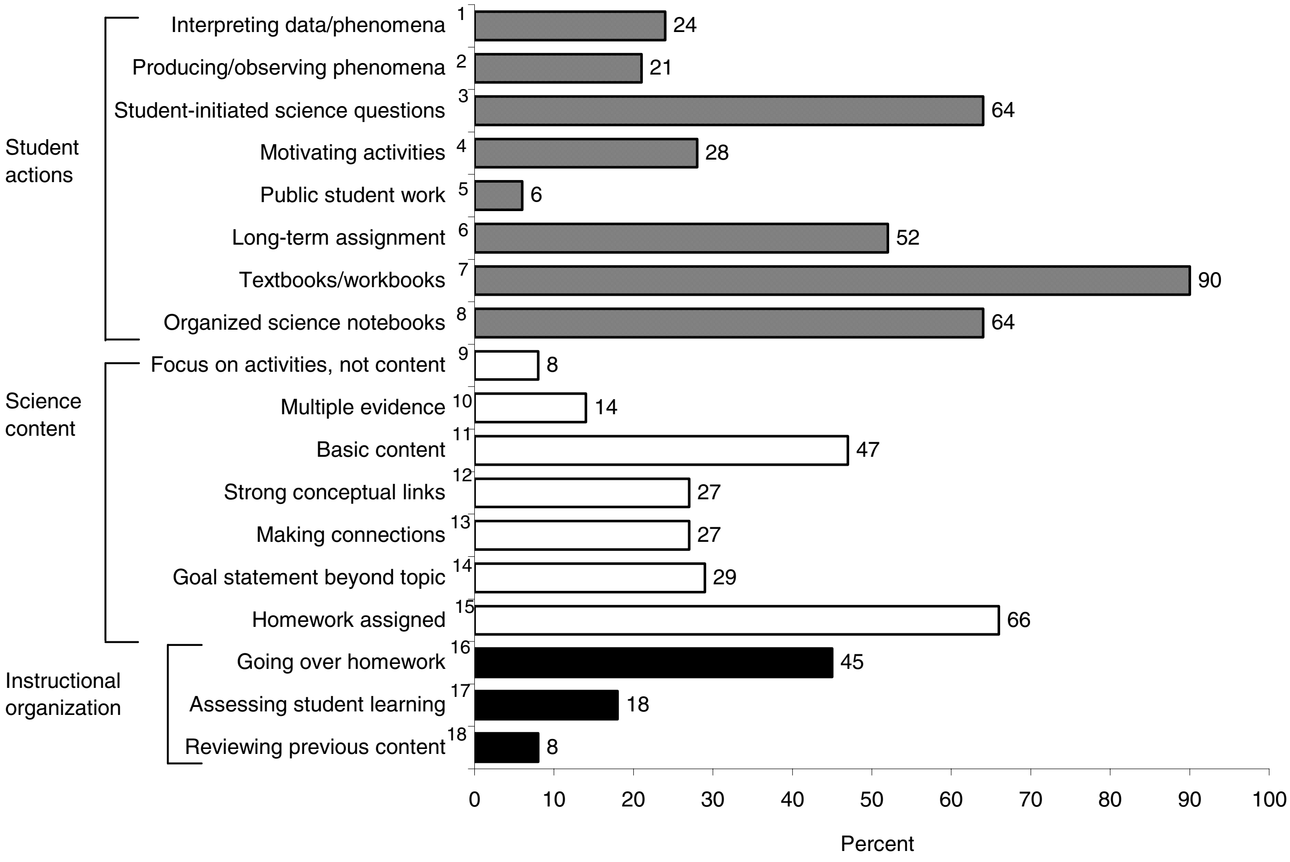
Figure 12.3. Average percentage of science instruction time in Dutch eighth-grade science lessons devoted to student actions, science content, and instructional organization: 1999



[1] Generating written responses during independent work: See figure 9.5.
[2] Reading about science: See figure 9.8.
[3] Public discussions: See figure 9.1.
[4] Motivating activities: See figure 10.6.
[5] Individual work: See figure 8.2.
[6] Pair/group work: See figure 8.2.
[7] Procedural and experimental knowledge: See figure 4.7.
[8] Canonical knowledge: See figure 4.3.
[9] Real-life issues during public talk: See figure 4.5.
[10] Going over homework: See table 3.3.
[11] Assessing student learning: See table 3.3.
[12] Reviewing previous content: See table 3.3.
[13] Independent seatwork activities: See figure 3.7.
[14] Independent practical activities: See figure 3.7.
[15] Whole-class work: See figure 3.6.

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

Figure 12.4. Percentage of eighth-grade science lessons in the Netherlands devoted to instructional organization, science content, and student actions: 1999



[1] Interpreting data/phenomena related to independent practical work: See table 7.3.
[2] Producing/observing phenomena during independent practical work: See table 7.2.
[3] Student-initiated science questions: See figure 11.5.
[4] Motivating activities: See figure 10.5.
[5] Public student work: See figure 11.4.
[6] Self-pacing on long-term assignment: See figure 11.10.
[7] Textbooks/workbooks: See figure 11.2.
[8] Organized science notebooks: See figure 11.1.
[9] Focus on activities, not content: See figure 5.7.
[10] Multiple evidence supporting all main ideas: See figure 6.3.
[11] Basic content: See figure 5.11.
[12] Learning content with strong conceptual links: See figure 5.7.
[13] Making connections: See figure 5.5.
[14] Goal statement beyond topic: See figure 5.9.
[15] Homework assigned for future lessons: See figure 11.7.
[16] Going over homework: See table 3.3.
[17] Assessing student learning: See table 3.3.
[18] Reviewing previous content: See table 3.3.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Eighth-Grade Science Teaching in Japan: Making Connections Between Ideas and Evidence

Japanese eighth-grade science lessons also appear to have a distinctive pattern that set them apart from lessons in the other countries except Australia (see figures 12.5 and 12.6). Eighth-grade science lessons in both Japan and Australia emphasized a few ideas by making connections among experiences, ideas, patterns, and explanations, and data or phenomena to support the ideas being presented. Japanese eighth-graders generated data and phenomena while carrying out practical activities independently. Characteristic features of Japanese lessons are described in this section. Ways in which science lessons in Australia were similar and different from Japan are highlighted in the following section.

Instructional Organization of Japanese Science Lessons

Japanese science lessons kept lesson time focused largely on instruction (figure 3.2). The amount of time spent on administrative purposes during lessons was less than in the other countries except the Czech Republic (other purposes; see table 3.4). While both Japanese and Australian science lessons devoted about one-third of science instruction time for independent work on practical activities (figure 3.7), Japanese lessons provided less time for science organizational work (e.g., gathering and putting away materials) than Australian lessons (figure 3.2). Thus, Japanese science lessons engaged students in hands-on work with materials without spending as much time getting organized as in Australian lessons.

Japanese eighth-grade science lessons focused 93 percent of lesson time on the development of new content (table 3.4). In fact, 67 percent of Japanese lessons were devoted solely to developing new content, with no review of content introduced in prior lessons (figure 3.4).

In contrast with the Czech focus on whole-class work, Japanese eighth-grade science lessons engaged students in working on independent activities for 49 percent of science instruction time on average (figure 3.6). In contrast with the Czech and Dutch focus on seatwork activities, Japanese lessons allocated more time for practical activities, with 43 percent of science instruction time devoted to either independent or whole-class practical activities (figure 3.5). This was found to be more than in the lessons of the other countries except Australia.

Content in Japanese Science Lessons

The content of Japanese science lessons was found to be less challenging, less dense, and less theoretical than Czech eighth-grade science lessons (figures 5.11, 5.3, and 5.12, respectively). Sixty-five percent of Japanese lessons were judged to contain mostly basic content, while 7 percent were categorized as having a high number of canonical ideas that were presented publicly to the class and 15 percent addressed ideas at a theoretical level (figures 5.11, 5.3, and 5.12, respectively). Canonical knowledge (e.g., science facts, ideas, and concepts) and procedural and experimental knowledge were both present during public talk time in Japanese science lessons (44 and 25 percent of public talk time, respectively; figures 4.3 and 4.7, respectively). There was less public talk time about canonical knowledge during Japanese science lessons than in Czech lessons, but there was more public talk time spent on procedural and experimental knowledge compared to lessons in the other four countries (figures 4.3 and 4.7, respectively).

Rather than presenting a high number of challenging and theoretical ideas, Japanese lessons emphasized coherent, conceptual development of a few ideas, using data and phenomena generated during practical work to support the building of main ideas.[12] The conceptual focus of Japanese science lessons was reflected in the large percentage of lessons that were organized primarily to make connections among ideas, evidence, and experiences rather than presenting facts and definitions (72 percent; figure 5.5). This occurred more often than in the lessons of the other countries except Australia. Fifty-seven percent of Japanese lessons made connections through an inquiry approach, using data to build ideas inductively (figure 5.6). Goal and summary statements that focused on questions and main ideas rather than simply stating a topic contributed to the coherence of Japanese science lessons (figures 5.9, 5.10).

The lesson coherence and conceptual, inquiry approach were also evident in the ways that the Japanese science teachers guided students' independent work on practical activities. In eighth-grade Japanese science lessons, students were often informed of the main question or conceptual idea they were to explore through practical activities before they began the work (figure 7.2). This occurred more frequently (49 percent of lessons) than in the lessons of the other countries except Australia. After independent practical activities, 55 percent of Japanese lessons typically included a discussion of the observations made, data obtained, or possible conclusions, which led to the development of one big idea or conclusion in 34 percent of the lessons (figure 7.3). Within country comparisons show that independent practical activities in Japanese science lessons were more likely to be followed by a discussion that led to one big idea than any of the other options explored in this study (e.g., no discussion, discussion of results only, and discussion of multiple conclusions; figure 7.3).

Observations that the Japanese practice of supporting main ideas in the lesson with evidence, often from multiple sources, were also found to be consistent with the inductive, inquiry approach and focus on in-depth, evidence-based treatment of a few ideas. For example, 65 percent of Japanese science lessons supported all the main ideas with first-hand data, phenomena, and visual representations, more than in the other four countries (figure 6.3). Thus, Japanese eighth-graders had opportunities to link main ideas with different sources of evidence, suggesting an in-depth treatment of ideas.

While data and phenomena (and to a somewhat lesser extent visual representations) played important roles in developing main ideas in Japanese science lessons, real-life issues were used less often compared to Czech science lessons (figures 4.4 and 10.1). While teachers of 61 percent of Japanese eighth-grade science lessons mentioned at least one real-life issue during public talk time (figure 4.4), 6 percent of public talk time was spent on real-life issues, less than in the other countries except Australia (figure 4.5). Furthermore, real-life issues were used to support and develop science ideas (rather than as interesting sidebars) in fewer Japanese science lessons than

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[12] The observed focus on the conceptual development of a few ideas in eighth-grade Japanese science lessons is consistent with the approach observed in eighth-grade Japanese mathematics lessons. See Hiebert et al. (2003) for details.

in Australian and Czech lessons (figure 10.3), and for less instruction time on average (3 percent) compared to Czech and Dutch lessons (10 and 8 percent, respectively; figure 10.4).

The results suggest that, in contrast to Czech science lessons where many challenging canonical ideas were presented but with limited support based on data and phenomena, Japanese science lessons explored a few ideas in depth, developing main ideas with multiple sources of evidence, especially first-hand data and phenomena. Furthermore, the results suggest that the content of Japanese science lessons was organized to support the making of connections between ideas and evidence, and was presented coherently with strong conceptual connections.

Student Actions in Japanese Science Lessons

Students in Japanese science lessons were frequently observed to carry out practical activities independently, occurring in 67 percent of lessons and accounting for 34 percent of instruction time on average (table 3.5 and figure 3.7, respectively). Students worked in pairs/groups for most of the time spent in independent practical activities (33 percent, figure 8.3). Before, during, and after these activities, Japanese students were expected to carry out several inquiry actions. Students collected and recorded data in 59 percent of science lessons, more than in the lessons of the other countries except Australia (table 7.3). Japanese eighth-graders were sometimes asked to make predictions and/or give reasons for their predictions (23 percent of lessons, table 7.3). They organized and manipulated data into graphs, charts, or other formats in 37 percent of lessons, which is more often than in Dutch lessons (table 7.3). However, the science teacher or textbook usually provided the format structure for students to organize the data. Japanese students were also observed to interpret data from their independent practical activities (43 percent of lessons, table 7.3).

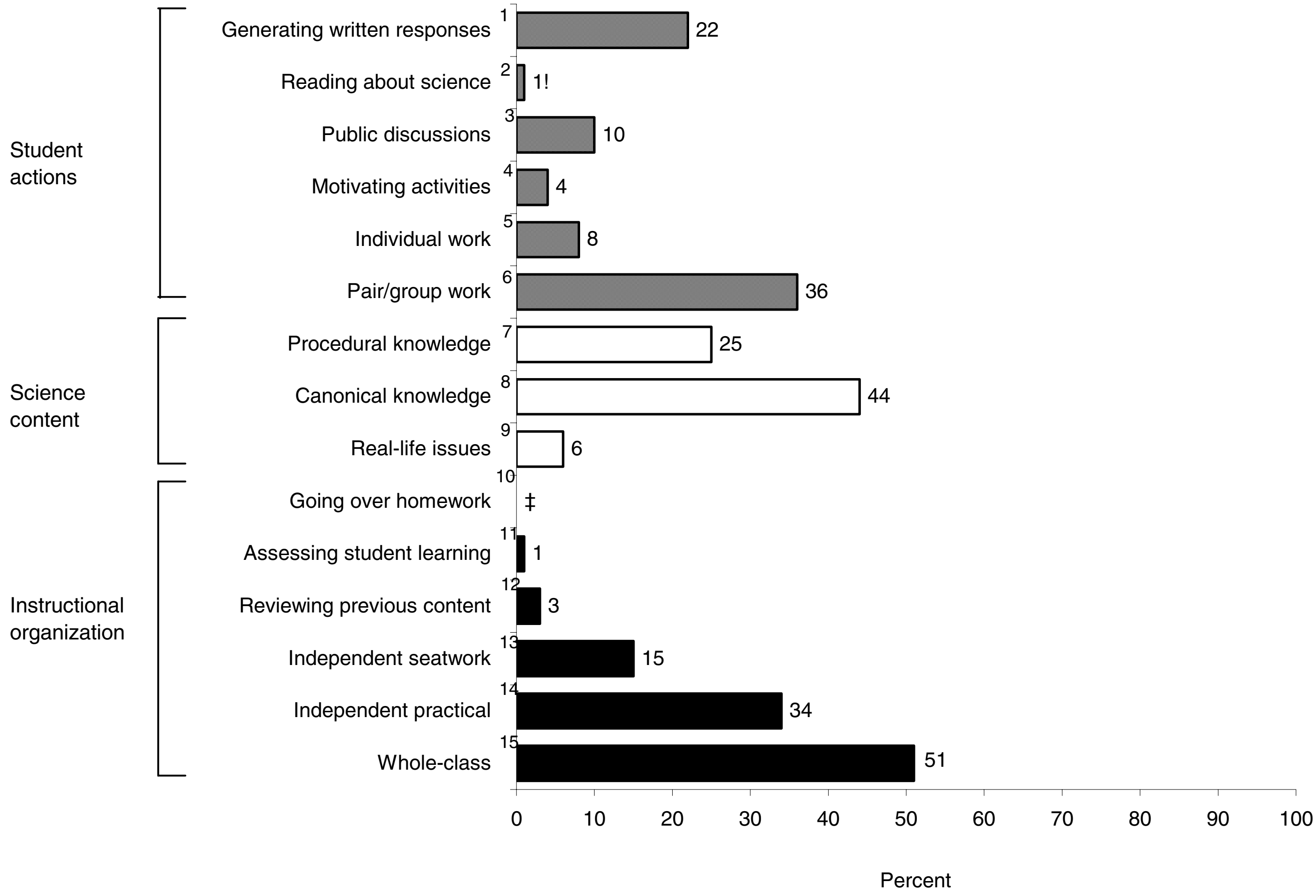
During whole-class time, Japanese students had additional but limited opportunities to carry out inquiry actions in relationship to whole-class practical activities such as teacher demonstrations (figure 7.7). Students made predictions about the whole-class practical activities in 11 percent of Japanese science lessons and interpreted data generated from these whole-class activities in 11 percent of lessons (figure 7.5).

As in the other countries, students in eighth-grade science lessons in Japan spoke much less frequently than their teachers during public talk (figure 9.3). However, students in Japanese lessons spoke even less during public talk than students in some of the other countries. For example, they participated in discussions for less instruction time, on average, than students in the lessons of the other countries except the Netherlands (figure 9.1). In addition, they spoke a smaller percentage of words during public talk than Czech and Dutch students (figure 9.3), and they spoke a smaller percentage of utterances that were 5 words or longer compared to students in eighth-grade Czech science lessons (figures 9.4). Japanese students initiated substantive, content-related questions in 29 percent of science lessons, with one question per lesson, on average (less than in Australian and Dutch lessons, figures 11.5 and 11.6, respectively).

Context of Japanese Science Lessons

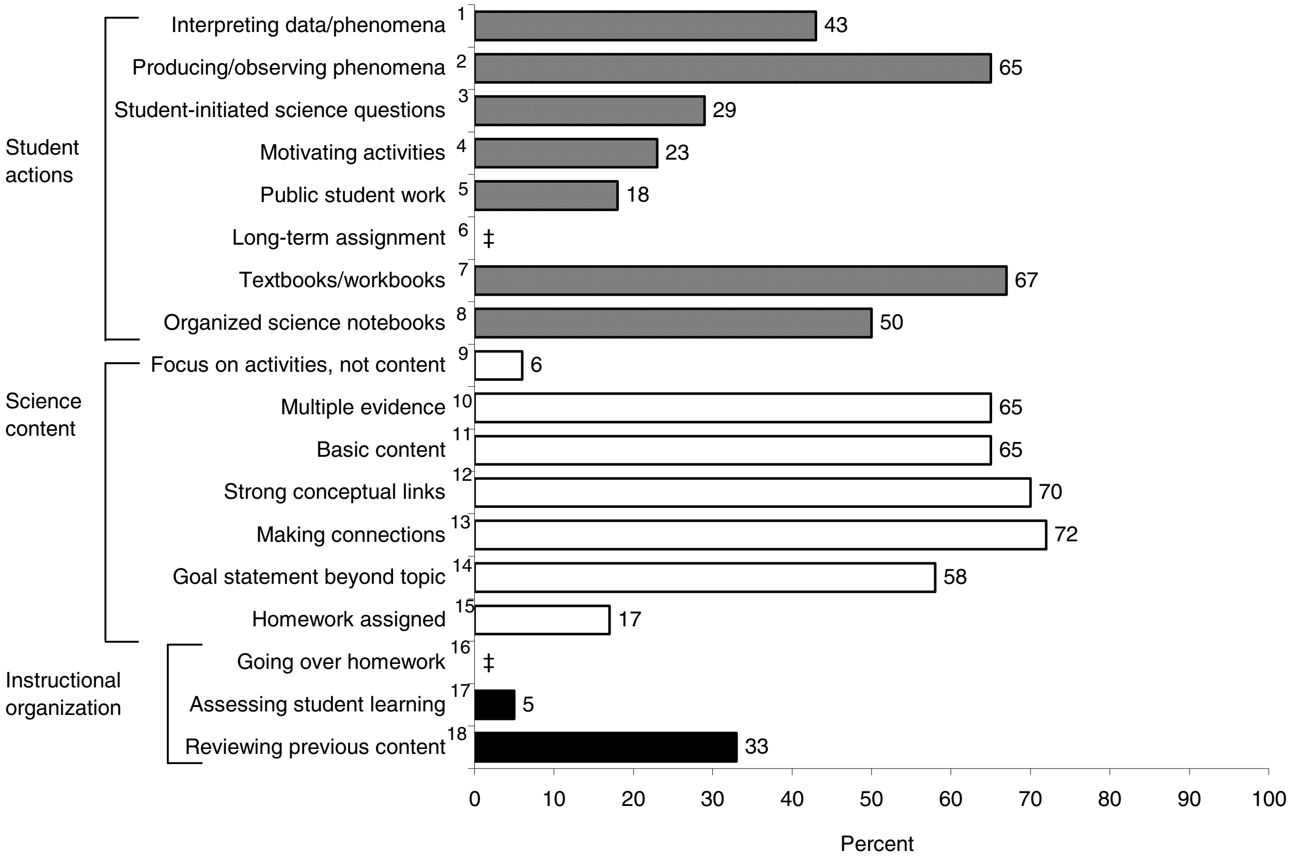
All of the Japanese eighth-grade science lessons were taught by teachers who reported having a major in a science field (table 2.1), and 92 percent of lessons were taught by teachers who held undergraduate degrees (figure 2.1). Teachers in Japanese lessons reported spending more time planning for the videotaped lesson (135 minutes, on average) than teachers of lessons in the other four countries, and they generally reported spending more time planning for lessons (92 minutes per lesson, on average) than their counterparts in the other countries except for the United States (figure 2.5). Consistent with their observed teaching practices, teachers in 70 percent of Japanese science lessons identified lesson goals that focused on understanding science ideas (table 2.6).

Figure 12.5. Average percentage of science instruction time in Japanese eighth-grade science lessons devoted to student actions, science content, and instructional organization: 1999



!Interpret data with caution. Estimate is unstable.
‡Reporting standards not met. Too few cases to be reported.
[1] Generating written responses during independent work: See figure 9.5.
[2] Reading about science: See figure 9.8.
[3] Public discussions: See figure 9.1.
[4] Motivating activities: See figure 10.6.
[5] Individual work: See figure 8.2.
[6] Pair/group work: See figure 8.2.
[7] Procedural and experimental knowledge: See figure 4.7.
[8] Canonical knowledge: See figure 4.3.
[9] Real-life issues during public talk: See figure 4.5.
[10] Going over homework: See table 3.3.
[11] Assessing student learning: See table 3.3.
[12] Reviewing previous content: See table 3.3.
[13] Independent seatwork activities: See figure 3.7.
[14] Independent practical activities: See figure 3.7.
[15] Whole-class work: See figure 3.6
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Figure 12.6. Percentage of eighth-grade science lessons in Japan devoted to instructional organization, science content, and student actions: 1999



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

[1] Interpreting data/phenomena related to independent practical work: See table 7.3.

[2] Producing/observing phenomena during independent practical work: See table 7.2.

[3] Student-initiated science questions: See figure 11.5.

[4] Motivating activities: See figure 10.5.

[5] Public student work: See figure 11.4.

[6] Self-pacing on long-term assignment: See figure 11.10.

[7] Textbooks/workbooks: See figure 11.2.

[8] Organized science notebooks: See figure 11.1.

[9] Focus on activities, not content: See figure 5.7.

[10] Multiple evidence supporting all main ideas: See figure 6.3.

[11] Basic content: See figure 5.11.

[12] Learning content with strong conceptual links: See figure 5.7.

[13] Making connections: See figure 5.5.

[14] Goal statement beyond topic: See figure 5.9.

[15] Homework assigned for future lessons: See figure 11.7.

[16] Going over homework: See table 3.3.

[17] Assessing student learning: See table 3.3.

[18] Reviewing previous content: See table 3.3.

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

Eighth-Grade Science Teaching in Australia: Making Connections Between Main Ideas, Evidence, and Real-Life Issues

The Australian pattern of eighth-grade science teaching appears to be in many ways similar to the Japanese pattern, at least as investigated through this study. Nonetheless, the differences between Australian and Japanese science lessons, in addition to differences from lessons in the other countries, suggest an Australian pattern of science teaching (see figures 12.7 and 12.8). The similarities and differences between Australian and Japanese lessons will be highlighted in this description of the Australian approach to science teaching.

Instructional Organization of Australian Science Lessons

In contrast with science lessons in both the Czech Republic and Japan, Australian eighth-grade science lessons allocated less time for science instruction (91 percent of lesson time, figure 3.2) and more time for organizational work (7 percent of lesson time, figure 3.2). Forty-two percent of lessons were observed to be interrupted by outside sources compared to 7 percent of lessons in the Czech Republic and too few cases in Japan to calculate reliable estimates (figure 3.3). Like Japanese science lessons, eighth-grade Australian lessons focused primarily on developing new content during science instruction time (85 percent of lesson time) with less focus on review (8 percent of lesson time) and other lesson purposes, such as assessment or going over homework (7 percent of lesson time; table 3.4).

In addition, Australian students worked independently for 52 percent of science instruction time on average, which was not significantly different compared to 49 percent of instruction time in Japanese lessons (figure 3.6). Moreover, Australian eighth-graders observed or participated in practical activities during 42 percent of science instruction time, which again was not significantly different compared to an average of 43 percent in Japanese science lessons (figure 3.5).

Content in Australian Science Lessons

Eleven percent of Australian eighth-grade science lessons were found to contain a high number of public canonical science ideas (figure 5.3), and 57 percent of the lessons were judged to address basic rather than challenging content (figure 5.11). In addition, evidence in the form of first-hand data and phenomena played a role in the development of main ideas in Australian lessons. For example, 56 percent of Australian science lessons linked each main idea in the lesson to two or more instances of first-hand data, and 45 percent of lessons supported each main idea with two or more phenomena (figure 6.2). This practice occurred more frequently than in the lessons of other countries except Japan.

Compared to Japanese science lessons, Australian lessons used some types of evidence less frequently. For example, more Japanese lessons used at least one visual representation compared to Australian lessons (figure 6.1). In particular, Australian science lessons were less likely than Japanese lessons to include the use of diagrams (see figure E.2, appendix E). Furthermore, Australian lessons were less likely than Japanese lessons to include three different types of evidence in a single lesson (first-hand data, phenomena, and visual representations; figure 6.3).

Like Japanese science lessons, Australian lessons had several features that indicated coherent content development. Fifty-eight percent of lessons developed science content primarily through making connections among data, patterns, and/or explanations; that is, evidence was used to build a case for a new idea (figure 5.5). As in Japanese science lessons, making connections among ideas, facts, and evidence in Australian lessons was most often accomplished through an inquiry/inductive approach (43 percent of lessons; figure 5.6). In addition, students' work on independent practical activities was linked to the development of ideas. For example, independent practical activities were set up with a focus on ideas as well as procedures in 44 percent of Australian science lessons (figure 7.1). Before starting to work, students knew the question or conceptual issue to be explored in 33 percent of the lessons (figure 7.2). Another indicator of coherence was the use of goal statements that included the main idea presented as a research question or a known outcome (see figure 5.9). This practice occurred in 55 percent of Australian science lessons which is a larger percentage of lessons than observed in all the other countries except Japan (58 percent). After an independent practical activity, results or conclusions were discussed in 50 percent of the lessons (figure 7.3).

A key content difference between Australian and Japanese eighth-grade science lessons was the use of real-life issues to develop science ideas. While no measurable differences were found between the two countries regarding the percentage of lessons that addressed at least one real-life issue (79 percent of Australian lessons and 62 percent of Japanese lessons; figure 10.1) or the percentage of science instruction time spent on real-life issues during the entire instruction time (12 and 9 percent, respectively; figure 10.2), lessons in these two countries differed in how the real-life issues were used. Instead of simply mentioning real-life issues as interesting stories or contexts related to the topic at hand, a larger percentage of Australian lessons (69 percent) used at least one real-life example to develop science ideas compared to Japanese lessons (47 percent; figure 10.3). Thus, using real-life issues was another way in which ideas were supported by evidence in Australian lessons.

The content in Australian science lessons also differed from Japanese lessons in the percentage of public talk time focused on procedural and experimental talk. Although science lessons in both countries engaged eighth-graders in carrying out independent practical activities in a large percentage of lessons (74 percent in Australia and 67 percent in Japan, table 3.5), there was less public talk time focused on procedural talk in Australian lessons than in Japanese lessons (17 and 25 percent, respectively; figure 4.7).

In sum, science content in both Australian and Japanese lessons focused on a few science ideas, emphasized making connections through inductive inquiry, and supported ideas with data and phenomena. The Australian lessons contrasted with the Japanese in giving more attention to supporting and developing ideas with the use of real-life issues and giving less attention to the use of visual representations to support ideas. In addition, eighth-grade science lessons in Australia devoted less public talk time to procedural and experimental issues.

Student Actions in Australian Science Lessons

Australian students in the eighth-grade science lessons were often involved in carrying out independent practical activities while working in small groups to generate data to support the development of science ideas. Independent practical activities occurred in 74 percent of the Australian eighth-grade science lessons (table 3.5). Students typically worked on these practical activities in small groups (figure 8.2).

Students in eighth-grade Australian science lessons were asked to complete several inquiry actions in relationship to the independent practical activities. They made predictions before carrying out their independent practical activities in 11 percent of lessons (table 7.3), and they collected and recorded data in 62 percent of lessons, which was a larger percentage of lessons than in the other countries except Japan (table 7.3). Australian students manipulated data into graphs or charts in 36 percent of the lessons; however, as in Japan, the teacher or the textbook usually provided the form for the students to use in organizing the data (table 7.3). Australian students interpreted data relevant to their independent practical work in 56 percent of the science lessons, more than in the Czech Republic and the Netherlands (table 7.3).

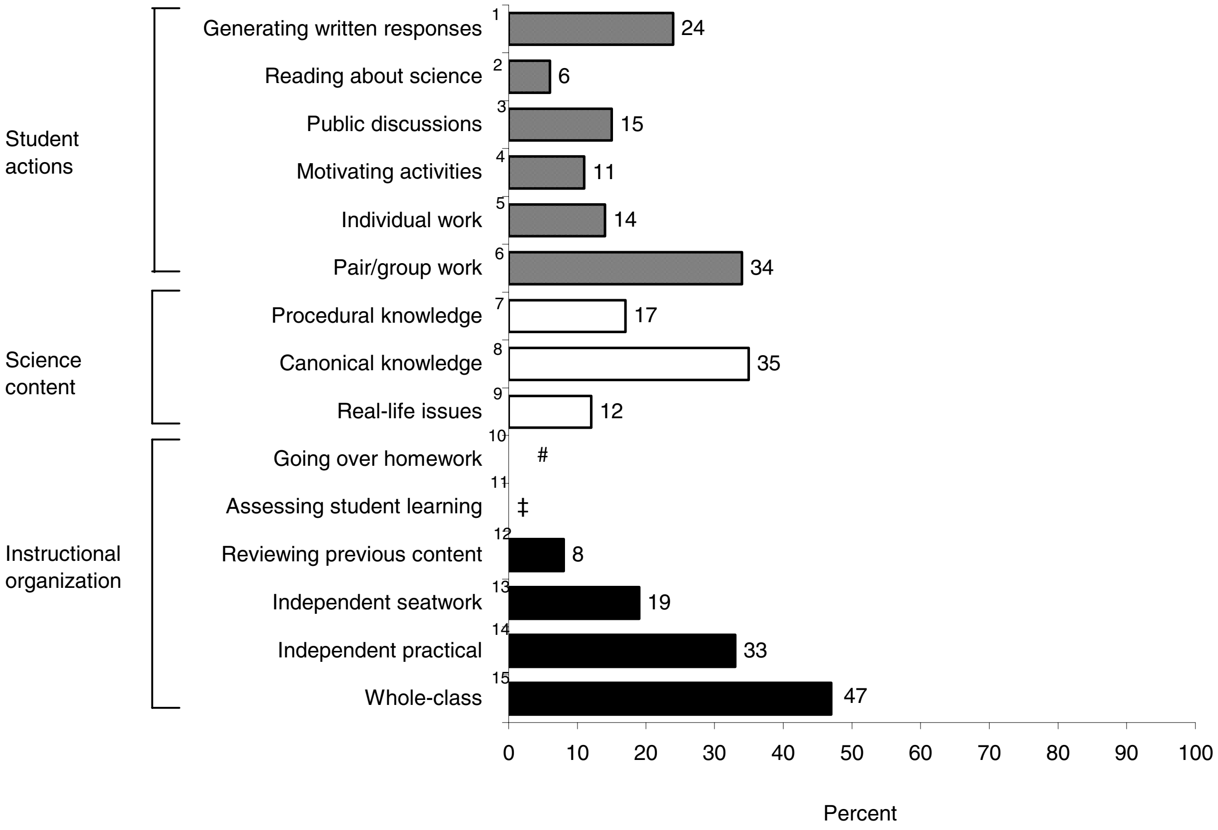
Students in Australian science lessons spent 47 percent of science instruction time participating in whole-class activities (figure 3.6). In some ways, Australian students appeared to be more actively involved during whole-class activities than Japanese students. For example, Australian students engaged in discussions led by the teacher for 15 percent of instruction time on average compared to 10 percent of instruction time in Japanese lessons (figure 9.1). Australian students were also more likely than Japanese students to raise content-related questions during whole-class discussions. In 67 percent of the science lessons, Australian students raised content questions, asking three questions per lesson, on average (figures 11.5 and 11.6). Australian students kept organized science notebooks in 75 percent of the science lessons compared to 50 percent of lessons in Japan (figure 11.1). Finally, Australian students were more often assigned homework than Japanese students (54 and 17 percent, respectively; figure 11.7) and were often given the opportunity to work on their homework during class (41 percent of lessons; figure 11.9).

Australian science lessons also stood out from Japanese lessons in their inclusion of activities likely to engage students' interests. Already noted was the more frequent use of real-life issues to develop science content in Australian science lessons (figure 10.3). While potentially motivating activities occurred in a higher percentage of U.S. science lessons than in all the other countries except Australia, 37 percent of the Australian lessons incorporated potentially motivating activities (figure 10.5), accounting for 11 percent of instruction time on average (figure 10.6).

Context of Australian Science Lessons

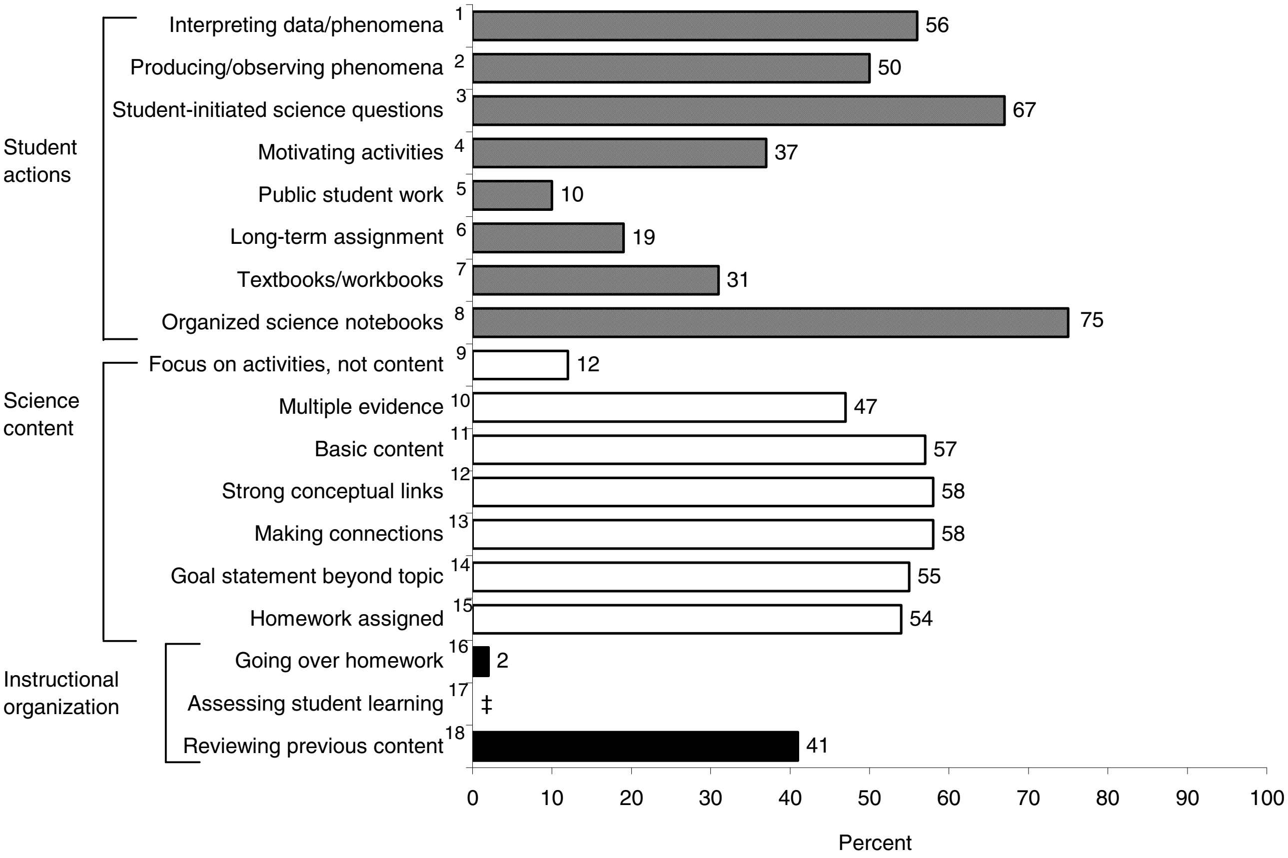
Eighty-seven percent of Australian eighth-grade science lessons were taught by teachers who identified a graduate or undergraduate major in a science field (table 2.1), and 85 percent of lessons were taught by teachers who reported attaining an undergraduate degree and 11 percent a graduate degree (figure 2.1). Consistent with the observed focus on using data to build ideas, science teachers in 51 percent of the lessons described understanding science ideas as the main goal for the videotaped lesson (table 2.6).

Figure 12.7. Average percentage of science instruction time in Australian eighth-grade science lessons devoted to student actions, science content, and instructional organization: 1999



#Rounds to zero.
‡Reporting standards not met. Too few cases to be reported.
[1] Generating written responses during independent work: See figure 9.5.
[2] Reading about science: See figure 9.8.
[3] Public discussions: See figure 9.1.
[4] Motivating activities: See figure 10.6.
[5] Individual work: See figure 8.2.
[6] Pair/group work: See figure 8.2.
[7] Procedural and experimental knowledge: See figure 4.7.
[8] Canonical knowledge: See figure 4.3.
[9] Real-life issues during public talk: See figure 4.5.
[10] Going over homework: See table 3.3.
[11] Assessing student learning: See table 3.3.
[12] Reviewing previous content: See table 3.3.
[13] Independent seatwork activities: See figure 3.7.
[14] Independent practical activities: See figure 3.7.
[15] Whole-class work: See figure 3.6.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Figure 12.8. Percentage of eighth-grade science lessons in Australia devoted to instructional organization, science content, and student actions: 1999



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

[1] Interpreting data/phenomena related to independent practical work: See table 7.3.

[2] Producing/observing phenomena during independent practical work: See table 7.2.

[3] Student-initiated science questions: See figure 11.5.

[4] Motivating activities: See figure 10.5.

[5] Public student work: See figure 11.4.

[6] Self-pacing on long-term assignment: See figure 11.10.

[7] Textbooks/workbooks: See figure 11.2.

[8] Organized science notebooks: See figure 11.1.

[9] Focus on activities, not content: See figure 5.7.

[10] Multiple evidence supporting all main ideas: See figure 6.3.

[11] Basic content: See figure 5.11.

[12] Learning content with strong conceptual links: See figure 5.7.

[13] Making connections: See figure 5.5.

[14] Goal statement beyond topic: See figure 5.9.

[15] Homework assigned for future lessons: See figure 11.7.

[16] Going over homework: See table 3.3.

[17] Assessing student learning: See table 3.3.

[18] Reviewing previous content: See table 3.3.

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

Eighth-Grade Science Teaching in the United States: Variety of Activities

Eighth-grade science lessons in the United States were found to provide students with a wide variety of opportunities to learn science, including many of the features of science teaching seen in the other four countries (see figures 12.9 and 12.10). U.S. lessons differed from the other countries with reliable estimates on two lesson features investigated in this study: 26 percent of U.S. science lessons included a beginning-of-the-lesson routine called lesson openers (data not shown; chapter 11) and 59 percent had computers available in the classroom (figure 11.3). Instead of distinct U.S. lesson features, the data suggest that U.S. eighth-grade science lessons are characterized by the inclusion of many different organizational, content, and student action features.

Instructional Organization of U.S. Science Lessons

The instructional organization of U.S. eighth-grade science lessons was characterized by variety—variety of lesson purposes and types of activities. Perhaps because of the need for transitions among these various purposes and activities, 6 percent of U.S. science instruction time was spent on science organization purposes, more than in the Czech Republic (2 percent, figure 3.2). Despite this attention to organizational issues, 92 percent of U.S. lesson time focused on science instruction (figure 3.2).

Three main lesson purposes characterized U.S. eighth-grade science lessons, and the time spent on each of these purposes fell between what was found for the other countries. In U.S. science lessons, 79 percent of lesson time on average was spent developing new content, while reviewing previous content accounted for 8 percent of lesson time and going over homework was allocated 3 percent of lesson time (table 3.4).

Rather than emphasizing one or two types of activity structures as in the other countries, U.S. eighth-grade science lessons were characterized by variety. As a result, time spent on each of the main activity types often fell somewhere between two or more of the other countries. For example, science lessons in the United States devoted 26 percent of instruction time for all practical activities, less than in Australian and Japanese lessons but more than in Czech lessons (figure 3.5). Time spent in U.S. science lessons on independent practical activities (22 percent), such as creating and observing phenomena or building models, was more than in Czech lessons (figure 3.7). In terms of whole-class seatwork activities, including presentations and discussions, U.S. lessons allowed more time (50 percent) than Australian lessons but less time than Czech lessons (figure 3.7). Independent seatwork activities, such as answering questions in writing or filling in worksheets, accounted for 23 percent of instruction time on average (figure 3.7). Thus, the data indicates that instruction time in U.S. lessons was distributed among different activity structures.

Content in U.S. Science Lessons

In some ways, the science content of U.S. lessons was not that different from the other countries except the Czech Republic. Forty-eight percent of U.S. science lessons were judged to include mostly basic content while 19 percent of lessons were found to include mostly challenging content (figure 5.11). Moreover, 17 percent of U.S. science lessons were judged to have a high density of canonical ideas (e.g., science facts, concepts, and theories; figure 5.3). Eighth-grade science lessons in the U.S. used science terms and highly technical science terms less often than Czech lessons but more often than Dutch lessons (figure 5.4).

Different types of evidence were also present in U.S. science lessons. First-hand data and visual representations were incorporated into 70 and 78 percent of U.S. science lessons, respectively (figure 6.1). In addition, at least one real-life issue or example was included in 81 percent of U.S. science lessons (figure 10.1).

Nonetheless, in a variety of ways, content was treated differently in U.S. eighth-grade science lessons compared to lessons in the other countries. First, science lessons in the United States focused less on science content compared to some of the other countries. For example, 74 percent of U.S. lessons were focused on learning science content compared to 100 percent of lessons in the Czech Republic; in the other 27 percent of U.S. lessons, the focus was primarily on students carrying out activities rather than using activities to develop science ideas (figure 5.7). In addition, 31 percent of public talk time in U.S. lessons focused on canonical knowledge compared to 59 percent in Czech lessons and 44 percent in Japanese lessons (figure 4.3).

In terms of content coherence, fewer U.S. eighth-grade science lessons were found to have strong conceptual links among ideas compared to Australian and Japanese lessons (figure 5.7). In addition, teachers of 66 percent of the U.S. eighth-grade science lessons organized content primarily around facts and definitions rather than through making connections among ideas, patterns, and experiences (figure 5.5). In U.S. lessons, these facts and definitions were organized as either discrete, unconnected bits of knowledge (30 percent of lessons) or as algorithms and techniques (33 percent of lessons; figure E.1, appendix E). Other indicators of content coherence in U.S. science lessons were the limited use of goal and summary statements. Sixteen percent of U.S. lessons included goal statements that went beyond simply naming the page number or topic of the lesson compared to 43 percent of lessons in Australia and 58 percent in Japan (figure 5.9). Summary statements of any kind were present in 11 percent of U.S. lessons compared to 35 percent of Czech lessons and 41 percent of Japanese lessons (figure 5.8).

The U.S. science lessons also appear to stand out among the countries in the use of different types of evidence to support the development of science ideas. For example, U.S. eighth-grade science lessons included phenomena in fewer lessons (43 percent) than in both Australian and Japanese lessons (70 and 77 percent, respectively; figure 6.1). In addition, real-life issues were used as interesting sidebars for more instruction time in U.S. lessons (17 percent) than they were used to support and develop science content ideas (6 percent; figure 10.4). This stands in contrast with the Czech Republic, where more time was spent on using real-life issues to support the development of ideas. Diagrams and graphic organizers are two types of visual representations that were each used in around half of the U.S. science lessons (figure E.2, appendix E). However, diagrams were used more frequently in Czech and Japanese science lessons (78 and 80 percent, respectively). Both formulas and 3-dimensional models were used less frequently in U.S. lessons compared to lessons in the Czech Republic (figure E.2, appendix E).

The eighth-grade science lessons in the United States also stand out from other countries in the relatively infrequent use of multiple instances of evidence (data, phenomena, and visual representations) to support and develop ideas. For example, each main idea was supported by multiple sets of data or by multiple phenomena in fewer U.S. lessons (26 and 18 percent, respectively) than in Australian and Japanese lessons (figure 6.2). Fewer U.S. lessons developed all the main ideas in the lesson with more than one phenomenon (18 percent) or one set of first-hand data (26 percent) than in Australia (45 percent and 56 percent, respectively) and Japan (55 percent and 67 percent, respectively; figure 6.2). Eighteen percent of U.S. lessons supported each of the main ideas in the lesson with three different types of evidence (first-hand data, phenomena, and visual representations) compared to 47 percent of Australian lessons and 65 percent of Japanese lessons (figure 6.3).

Thus, several indicators suggest that science content was less central in U.S. lessons compared to the other countries. Less time was spent on canonical science knowledge, and over a quarter of the U.S. science lessons focused primarily on activities rather than content development. While a variety of sources of evidence were presented in the lessons, these various pieces of content were often not found to be woven together to create coherent lessons that connected ideas and evidence. Ideas were presented as isolated facts and definitions in U.S. science lessons rather than as connected knowledge. Data and phenomena were not present in U.S. science lessons as often as in Australian and Japanese lessons. Real-life issues were mentioned but not used to support science ideas as often as in lessons in the Czech Republic. Finally, main ideas were supported by multiple sets of data or multiple phenomena less often than in Australian and Japanese lessons.

Student Actions in U.S. Science Lessons

As with lesson organization and content, student actions in U.S. eighth-grade science lessons came in a variety of forms and often fell somewhere between what was found in the other countries in terms of frequency or duration. Certain activities occurred in U.S. science lessons more frequently than in one country and less frequently than in another. In other cases, U.S. science lessons were not found to differ measurably from the lessons of the other countries, but the lessons of the other countries differed from each other. However, U.S. science lessons stood out from three of the other countries in terms of the balance among the three main activity structures that involve students' active participation and in terms of activities that are likely to engage students' interest and involvement.

In terms of the three main activity structures that engaged students in actively doing science work, students in U.S. science lessons were observed to carry out independent seatwork activities for 23 percent of science instruction time (figure 3.7), worked on independent practical activities for 22 percent of science instruction time (figure 3.7), and participated in whole-class discussions for 19 percent of science instruction time, on average (figure 9.1). There were no differences in the amount of time students in U.S. science lessons spent on each of these three activity types, whereas in all the other countries one activity type stood out as more likely to occur than another. For example, more time was allocated to public discussions than to either independent practical or independent seatwork activities within Czech science lessons. In Australia and Japan, more time was focused on independent practical activities than o3 seatwork activities or public discussions. In Japan and the Netherlands, more time was focused on independent seatwork activities than public discussions.

During independent practical activities, students in the U.S. eighth-grade science lessons engaged in some of the same inquiry actions that occurred in lessons in the other countries. U.S. eighth-graders independently collected and recorded data in more lessons (31 percent) than in the Czech Republic and in fewer lessons than in Australia and Japan (table 7.3). Predictions about the independent practical activities occurred in 8 percent of U.S. lessons, and interpreting data occurred in 33 percent of U.S. lessons (table 7.3).

During independent work, U.S. students spent 22 percent of instructional time working on written tasks where they were expected to generate text of at least a phrase or sentence (figure 9.5). This occurred in 56 percent of the science lessons, more than in the Czech Republic (data not shown; chapter 9). Writing that involved filling-in-the-blanks or selecting answers accounted for 12 percent of instructional time in U.S. lessons, and taking notes accounted for 1 percent of instructional time, less than in the Czech Republic and Japan (figure 9.5). Students in U.S. lessons worked on homework assignments during independent work in 28 percent of lessons, which is a larger average percentage than in Czech lessons (figure 11.9).

A distinctive feature of student actions in the United States is the routine lesson opener. As students entered the classroom, they were sometimes observed to immediately begin work on an assignment displayed on the blackboard or overhead projection. This occurred in 26 percent of U.S. lessons and in 5 percent of Japanese lessons, with too few observations in the lessons of the other three countries to calculate reliable estimates (data not shown; chapter 11).

During whole-class activities, U.S. students participated in some type of discussion in 87 percent of science lessons (data not shown; chapter 9) and for 19 percent of science instruction time on average, which was more than in Japanese lessons and less than in Czech lessons (figure 9.1). During these discussions, U.S. students initiated substantive, content-related questions in 54 percent of the lessons (figure 11.5), asking an average of 3 questions per lesson (more than in the Czech Republic and Japan; figure 11.6).

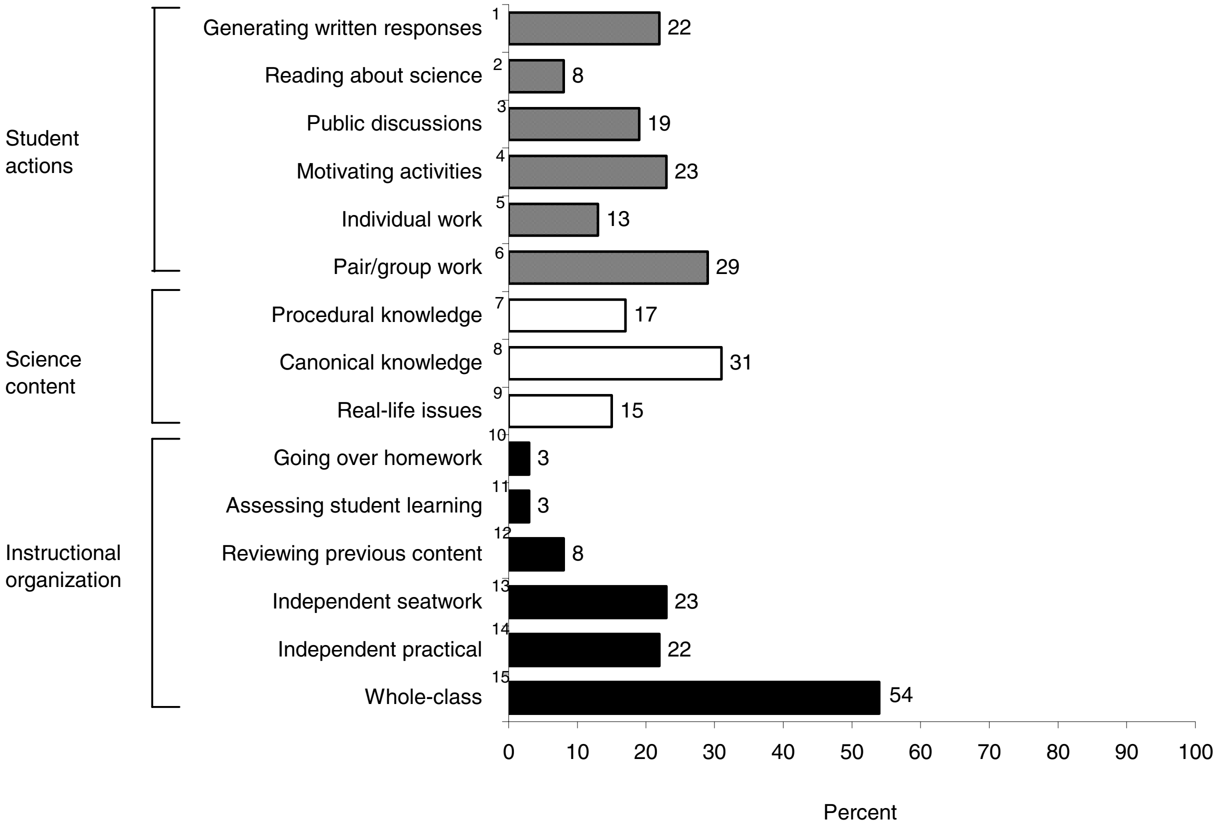
Another distinctive feature of U.S. science lessons was the inclusion of a variety of activities that may potentially engage students' interest in doing science. These included the use of hands-on independent practical activities, real-life issues, and motivating activities. U.S. lessons included more time for independent practical activities than Czech lessons (figure 3.7), and included at least one real-life issue in 81 percent of lessons (figure 10.1), accounting for 23 percent of science instruction time (figure 10.2).

Motivating activities in U.S. eighth-grade science lessons appeared to be designed to engage students' interest and involvement in ways other than independent practical work and real-life issues. These motivating activities in U.S. science lessons included such things as games, puzzles, role plays, simulations, competitions, humor, physical activities, visits outside the classroom, use of the creative arts, and surprising or dramatic phenomena. U.S. science lessons stood out from lessons in the other countries except Australia on their inclusion of potentially motivating activities in 63 percent of lessons (figure 10.5). Twenty-three percent of U.S. eighth-grade science instruction time was spent on these motivating activities, again more than in the lessons of all the other countries except Australia (figure 10.6). Finally, more U.S. lessons included all three types of potentially engaging activities—independent practical, real-life, and motivating activities— compared to lessons in the other countries except Australia (figure 10.7).

Context of U.S. Science Lessons

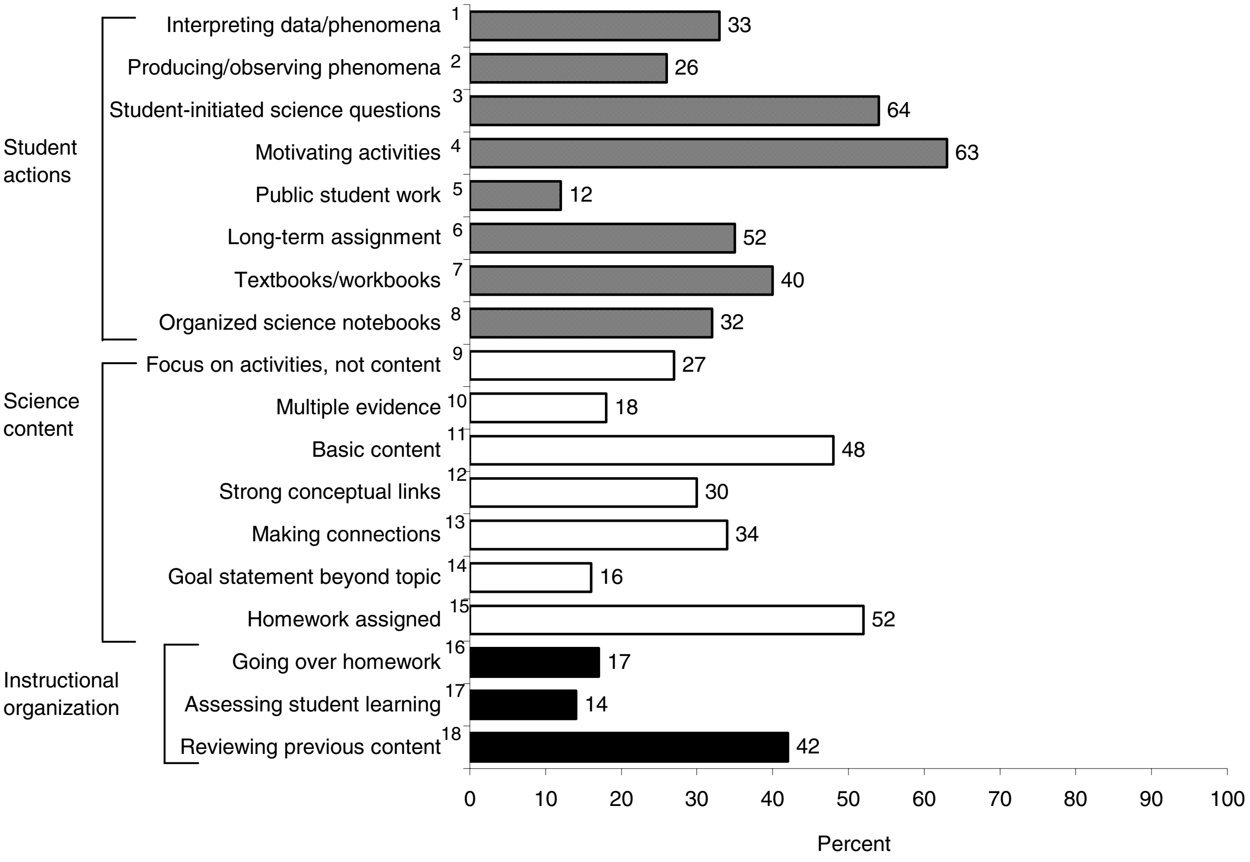
Fewer teachers who taught U.S. science lessons reported having an undergraduate and/or graduate science major (64 percent) than in the other four countries (table 2.1), but teachers of more U.S. lessons stated they had attained graduate degrees (39 percent) than teachers of Australian and Japanese lessons (figure 2.1). Consistent with the prominence of students doing activities in the videotaped lessons, the teachers' goals for the lessons focused more often on understanding science ideas than Czech lessons but less often compared to Australian and Japanese lessons (table 2.6).

Figure 12.9. Average percentage of science instruction time in U.S. eighth-grade science lessons devoted to student actions, science content, and instructional organization: 1999



[1] Generating written responses during independent work: See figure 9.5.
[2] Reading about science: See figure 9.8.
[3] Public discussions: See figure 9.1.
[4] Motivating activities: See figure 10.6.
[5] Individual work: See figure 8.2.
[6] Pair/group work: See figure 8.2.
[7] Procedural and experimental knowledge: See figure 4.7.
[8] Canonical knowledge: See figure 4.3.
[9] Real-life issues during public talk: See figure 4.5.
[10] Going over homework: See table 3.3.
[11] Assessing student learning: See table 3.3.
[12] Reviewing previous content: See table 3.3.
[13] Independent seatwork activities: See figure 3.7.
[14] Independent practical activities: See figure 3.7.
[15] Whole-class work: See figure 3.6.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Figure 12.10. Percentage of eighth-grade science lessons in the United States devoted to instructional organization, science content, and student actions: 1999



[1] Interpreting data/phenomena related to independent practical work: See table 7.3.
[2] Producing/observing phenomena during independent practical work: See table 7.2.
[3] Student-initiated science questions: See figure 11.5.
[4] Motivating activities: See figure 10.5.
[5] Public student work: See figure 11.4.
[6] Self-pacing on long-term assignment: See figure 11.10.
[7] Textbooks/workbooks: See figure 11.2.
[8] Organized science notebooks: See figure 11.1.
[9] Focus on activities, not content: See figure 5.7.
[10] Multiple evidence supporting all main ideas: See figure 6.3.
[11] Basic content: See figure 5.11.
[12] Learning content with strong conceptual links: See figure 5.7.
[13] Making connections: See figure 5.5.
[14] Goal statement beyond topic: See figure 5.9.
[15] Homework assigned for future lessons: See figure 11.7.
[16] Going over homework: See table 3.3.
[17] Assessing student learning: See table 3.3.
[18] Reviewing previous content: See table 3.3.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Do the Higher-Achieving Countries Share Any Commonalities?

The last of the three broad questions addressed in this chapter is whether the four countries that, until recently, outperformed the United States in science share any commonalities to teaching eighth-grade science lessons. Inspection of the core country approaches in the preceding chapters suggests that there are two related elements that may characterize lessons in the four relatively higher-achieving countries: Australia, the Czech Republic, Japan, and the Netherlands.

First, in each of the four higher-achieving countries, the core instructional approach appeared to hold students to high science content standards defined in various ways. Second, in each country, the means to achieve these content standards appeared to be a consistent, commonly shared strategy across teachers for organizing the content and engaging students in doing science work.

In the Czech Republic, students were expected to learn many ideas and technical terms, about challenging and often theoretical content. Students were expected to display their mastery of this knowledge publicly. They were regularly called upon to do science work in front of their peers, sometimes working problems on the board and explaining their thinking, and other times being quizzed on a set of questions after which the teacher’s evaluation of their performance was publicly announced to the class and recorded in a grade book. Consistent with these high expectations for students, teachers in 59 percent of Czech lessons described their learning goals for the videotaped lessons in terms of specific science information that they wanted their students to learn (more than teachers in all of the other countries; table 2.6). Representing science content as a body of knowledge with its own specific terminology appeared to be the centerpiece of Czech lessons, and the science content was presented to students by the teacher. The content standards appeared high in terms of the level of challenge and the density of the science content, and the central pedagogical strategy was public teacher presentations and teacher questioning of students.

High content standards and expectations for student learning in Australia and Japan were manifested in a different way. Instead of presenting students with dense, challenging, and theoretical content, as in the Czech Republic, Australian and Japanese eighth-grade science lessons presented students with the potentially demanding task of connecting multiple sources of evidence to build a limited set of ideas. Thus, the science content in the lessons of these two countries appeared to focus on building evidence-based understandings of science content. Teachers’ goals for the videotaped lessons in these two countries reflected this emphasis, focusing most often on the understanding of science ideas (more than teachers of lessons in most of the other countries; table 2.6). Students were expected to know the question that they would explore during an independent practical activity, to carry out the manipulations needed to generate data and phenomena, to organize and manipulate data, and to interpret the data. In Australia, science lessons appeared to place added emphasis on making connections between ideas and real-life issues. Representing science as a way of thinking from evidence to ideas appeared to be the primary focus in Australian and Japanese lessons, and the content was delivered to students via the teacher and data. Thus, in both Australia and Japan, the content standards of the lessons appeared high in terms of understanding relationships among ideas and evidence, and the central pedagogical approach appears to have been gathering and analyzing data during independent practical activities to develop understandings of key ideas in an inquiry/inductive mode. While in the case of Japan one might be tempted to connect the apparently high content standards to the existence of a national curriculum, Australia has no national curriculum; rather, the Australian states and territories have independent authority over curricular matters.

In the Dutch eighth-grade science lessons, students were held accountable for learning much of the science content independently. The content discussed publicly appeared to be no different than in the other countries (except the Czech Republic) in terms of the level of challenge and difficulty. However, Dutch students were expected to learn this content independently, taking responsibility for their own science content learning in a number of ways. A main source of their learning was the textbook, and they were frequently expected to learn content by reading the text and generating written responses (not just selecting answers) to questions in the text. Less frequently, they were expected to learn independently by carrying out practical activities, receiving little conceptual guidance from the teacher either before or after the activity. Across both seatwork and practical independent activities, students were responsible for monitoring their own progress on a long-term series of homework assignments that cut across several days or weeks, keeping organized science notebooks, and checking their own work. During whole-class interactions, they raised science content questions to support their understanding. The science content knowledge was made accessible to students by the teacher and the textbook. In the Dutch context, content standards appeared high in terms of students' responsibility for their own independent learning, and the core instructional approach focused on independent seatwork activities such as reading and writing. Further analysis of Dutch textbooks, which was beyond the scope of this study, may reveal additional information about the challenge and coherence of science content that Dutch eighth-graders encounter.

These two common features of science teaching shared by the higher-achieving countries—high content standards and a core instructional approach—can be considered only as possible hypotheses useful for explaining the science achievement of students in these four countries. A study designed to pose these questions would have to be conducted to effectively investigate these observations.

- In light of these hypotheses, it is interesting to note that in the United States, the only relatively lower-achieving country in this study, eighth-grade science lessons did not appear to share these two features, at least as investigated in this study. Instead of a core instructional approach, U.S. eighth-grade science lessons can be characterized as taking a variety of instructional approaches, involving students in multiple types of activities (discussion, independent practical activities, independent seatwork activities, and motivating activities) without emphasizing any one or two. In addition, the multiple types of activities were not found to be well connected to the development of science ideas, with at least one quarter of the lessons having little content development. When content was developed in U.S. science lessons, it was most often presented primarily as discrete bits of information or algorithms with weak or no conceptual links among ideas and activities. U.S. eighth-graders were more often engaged in potentially motivating activities than students in the other countries, but did not appear to be held to high content standards in any of the ways observed in the other four countries. That being said, it must also be kept in mind that a different set of analyses or using different data collection methods may lead to alternative hypotheses or conclusions.

Summary

The results of the TIMSS 1999 Video Study Science suggest characteristic patterns of eighth-grade science teaching in each of the participating countries and are suggestive of the potentially important role of content and a core instructional approach in student learning and achievement. Each of the countries was found to have a characteristic approach to science teaching, providing students with different opportunities to learn science and potentially different visions of what it means to understand science. Science lessons among the five countries varied in their instructional organization features, content features, and the ways in which students were involved in actively doing science work. No single approach appeared to be shared by the four higher-achieving countries in this study. Nonetheless, the data suggest that science lessons in the relatively higher-achieving countries of Australia, the Czech Republic, Japan, and the Netherlands can be characterized by a core instructional approach that includes a relatively consistent instructional and content organization strategy that holds students to some form of high content standards. Science lessons in the United States were also found to have a core instructional approach, but one that appears to focus on a variety of organizational structures, content, and student activities.

Educational Significance

This study identified five varying approaches to science teaching, and illustrates the variety of ways in which students can be actively involved in science learning—from the Dutch practice of students monitoring and pacing their own learning to the Czech routine of students working problems publicly to the Australian pattern of using real-world issues to develop science content ideas to the U.S. routine of lesson opening activities and to the Japanese practice of engaging students in understanding the research questions before starting a practical activity, to mention just a few.

The results also deepen knowledge about the varying ways science content can be addressed in science lessons—the different types of knowledge that may be included (canonical, procedural and experimental, real-life issues, safety, metacognitive, and nature of science), the different types of evidence that can be presented (data, phenomena, visual representations, and real-life issues), and the ways ideas can be developed through the use of evidence. Regarding the use of evidence, the study highlights the distinction between simply including data, phenomena, or visual representations, or mentioning real-life issues versus using these sources of evidence to develop student ideas and stimulate their thinking about science content and methods.

These results can stimulate discussion about science teaching alternatives by opening up a much wider range of options for science teachers to consider. On the other hand, the results can be interpreted as a caution against the temptation to take ideas from each of the different approaches to create science lessons that “do it all.” Although the relatively higher-achieving countries appear to have different approaches to science teaching, they each have evolved a common core approach that tends to give priority to science content over variety of instructional strategies. They do not attempt to “do it all.”

The study also suggests new avenues of research. Although many dimensions of science teaching were investigated, others were not. Would investigating a sequence of lessons rather than a single one reveal new insights and patterns? How can studies explore more closely the connection between science teaching practices and student learning? Would repeating a video survey of science teaching reveal changes in practices over time that may come from national efforts to improve instruction? Would a study limited to one content area, biology for example, reveal important connections between content and pedagogy? Some of these questions can be examined through follow-up studies using the TIMSS 1999 Video Study data; others require new ideas about research design, and the collection of national random samples of lesson videos in the future.

One of the powerful features of a video study is the opportunity to re-use the same data for multiple research studies, as suggested in the previous paragraph. Another strength of a video study is the potential contributions to teacher professional development. Both the data and the analytical tools from the TIMSS 1999 Video Study Science can make contributions to teacher professional development by providing both powerful visual images (the video clips accompanying this report and the 25 public release lessons that will be released separately from this report) and conceptual tools for looking at science lessons.

In chapter 1, four reasons for studying science teaching in different countries were presented—to identify alternatives, to deepen educators’ understanding of teaching and students’ opportunities to learn science, to reveal one’s own practices more clearly, and to stimulate discussion about choices within each country. The success of the study will ultimately be determined by the quality of the discussions it stimulates among science teachers, researchers, scientists, policymakers, and the general public, and the extent to which those discussions remain centered on the ultimate goal of improving students’ opportunities to learn science.

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Appendix A: Sampling, Data Collection and Coding, Reliability, and Statistical Analyses

Information on the technical aspects of the TIMSS 1999 Video Study of eighth-grade science teaching is provided below. More detailed information can be found in the *TIMSS 1999 Video Study Technical Report, Volume 2: Science* (Garnier et al. forthcoming).

Sampling

The sampling objective for the TIMSS 1999 Video Study was to obtain a random, nationally representative sample of eighth-grade science lessons in each participating country.[1] Meeting this objective would enable inferences to be made about the national populations of lessons for the participating countries. In general, the sampling plan for the TIMSS 1999 Video Study followed the standards and procedures agreed to and implemented for the TIMSS 1999 assessments (Martin, Gregory and Stemler 2000). The target population for the study consisted of science lessons for students in the eighth year of formal schooling, which corresponds to eighth grade in the five participating countries. All science courses in which eighth-grade students were enrolled were eligible for selection within the sampled schools.

The national research coordinators were responsible for selecting or reviewing the selection of schools and lessons in their country.[2] Identical instructions for sample selection were provided to all of the national research coordinators. For each country, a sample of at least 100 eighth-grade science classrooms was selected for videotaping. In all cases, countries provided the relevant sampling variables to Westat, so that the school samples could be appropriately weighted.

Most of the participating countries drew separate samples for the Video Study and the TIMSS 1999 assessments. For this and other reasons, the TIMSS 1999 assessment data cannot be directly linked to the video database.[3] Complete details about the sampling process in each country can be found in the technical report (Garnier and Rust forthcoming).

Sample Design

The study made use of a two-stage stratified cluster sampling design. The first stage made use of a systematic probability-proportionate-to-size (PPS) technique to select schools. A PPS sample assigns probabilities of selection to each school proportional to the number of eligible students in the eighth-grade in schools countrywide. Although countries were strongly encouraged to secure the participation of schools selected in the first stage, it was anticipated that a 100 percent participation rate for schools would not be possible in all the countries. Therefore, replacement schools were identified for each originally sampled school, a priori. As each school was

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[1] Australia, the Czech Republic, the Netherlands, and the United States also collected data on eighth-grade mathematics lessons.

[2] In the United States, Westat selected the school sample and LessonLab, Inc., selected the classroom sample.

[3] Australia conducted a separate study that involved testing the science achievement of the videotaped students.

selected, the next school in the sampling frame was designated as a replacement school should the originally sampled school choose not to participate in the study.

The second stage consisted of selecting science classes within schools, and finally lesson selection. One eighth-grade science class per school was sampled. The classes were randomly selected from a list of eligible classes in each participating school. The classroom sampling design was to be an equal probability design with no subsampling of students in the classroom. One lesson from each selected science classroom was videotaped. The videotaping date was determined by a scheduler in each country, and was based on scheduling and operational convenience.

Within the guidelines specified above, each country developed its own sampling strategy. Although countries had to obtain a PPS sample, they were allowed to define strata appropriate for the country.

Exclusions in the TIMSS Video Sample

Countries were not permitted to substitute schools or classrooms in the study. If a school or teacher declined participation, the next school in the sampling frame was designated as a replacement school. Once a school agreed to participate, the science class to be videotaped was randomly selected from a list of all science classes that enrolled eighth-grade students. Schools were not allowed to select alternative classes or teachers to be videotaped. The teacher and all students in the selected class were videotaped after all legal permissions were obtained (if necessary). Students whose parents or legal guardians requested that they not be included in the study were provided alternative instruction during the videotaped class period and did not participate in the lesson.

Response Rates

All of the TIMSS 1999 Video Study countries were required to include at least 100 schools in their initial selection of schools; however, some countries chose to include more for various reasons. The TIMSS 1999 Video Study final sample included 439 eighth-grade science lessons across the five countries. Table A.1 indicates the sample size and participation rate for each country.

Table A.1. Sample size and participation rate for each country in the TIMSS 1999 Video Study

Country	Number of schools in initial sample	Number of eligible schools that participated	Percentage of eligible schools that participated including replacements[1] – unweighted[2]	Percentage of eligible schools that participated including replacements[1] – weighted[3]
Australia	100	87	87	85
Czech Republic	100	88[4]	100	100
Japan	100	95	95	95
Netherlands	98	81	83	81
United States	108	88	82	81

[1] The participation rates including replacement schools are the percentage of all schools (i.e., original and replacements) that participated.

[2] Unweighted participation rates are computed using the actual numbers of schools and reflect the success of the operational aspects of the study (i.e., getting schools to participate).

[3] Weighted participation rates reflect the probability of being selected into the sample and describe the success of the study in terms of the population of schools to be represented.

[4] Twelve 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.

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

The weighted school response rate before replacement is given by the formula:

$$\begin{array}{l}\text{weighted school response}\\ \text{rate before replacement}\end{array} = \frac{\sum_{i \in Y} W_i E_i}{\sum_{i \in (Y \cup N)} W_i E_i},$$

where Y denotes the set of responding original sample schools with grade-eligible students, N denotes the set of eligible non-responding original sample schools, W_i denotes the base weight for school i, $W_i = 1/P_i$, where P_i denotes the school selection probability for school i, and E_i denotes the enrollment size of grade-eligible students, as indicated on the sampling frame.

Data Collection and Coding

Data Collection Procedures

Data for the TIMSS 1999 Video Study of eighth-grade science teaching was collected by the contractor for the study, LessonLab, following a standard set of guidelines and specifications. The designated class was videotaped once, in its entirety, without regard to the particular science topic being taught or type of activity taking place. The only exception was that teachers were not videotaped on days they planned to give a test or examination for the entire class period.

Teachers were asked to do nothing special for the videotape session, and to conduct the class as they had planned. The scheduler and videographer in each country determined on which day the lesson would be filmed.

Two cameras were used during each videotaping. One camera was placed at the back or side of the classroom with the widest angle shot of students and the teacher possible. This camera was used to capture an overall shot of the lesson as it occurred. Information from this camera can be used to verify student activities and the degree to which the entire class is focused on the same or similar activities, for example. The second camera was positioned so that it captured what an attentive student would see. For the most part, the second camera focused on the teacher. The second camera was also used to follow the teacher as s/he helped individual students during independent work periods. All videographers were trained extensively using a videographer's training manual. The training manual detailed every aspect of the videotaping procedure, from needed supplies to camera angles to checklists. Detailed information on the videographer's training manual can be found in the *TIMSS 1999 Video Study Technical Report, Volume I: Mathematics* (the data collection procedures were the same for the mathematics and science components of the video study; Jacobs et al. 2003).

The goal was to sample lessons throughout a regular school year, while accommodating how academic years are organized in each country. Most of the filming took place in 1999. In the Czech Republic filming began in 1998 and ended in 1999, and in Japan filming began in 1999 and ended in 2000. The receipt control system tracked the proportion of lessons that arrived from each country on a monthly basis, to ensure there was not a disproportionate number of tapes collected during any given month.

Questionnaire Data

To help understand and interpret the videotaped lessons, questionnaires were collected from the eighth-grade science teachers of each lesson. The teacher questionnaire was designed to elicit information about the professional background of the teacher, the nature of the science course in which the lesson was filmed, the context and goal of the filmed lesson, and the teacher's perceptions of its typicality. Teacher questionnaire response rates are shown in table A.2.

Table A.2. Teacher questionnaire response rates (unweighted)

Country	Number of teachers videotaped	Number of questionnaires completed	Percent returned
Australia	87	87	100
Czech Republic	88	88	100
Japan	95	95	100
Netherlands	81	79	98
United States	88	84	95

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

The questionnaire was developed in English and consisted of 27 open-ended questions and 32 closed-ended questions. Each country could modify the questionnaire items to make them culturally appropriate. In some cases, questions were deleted from the questionnaires for reasons of sensitivity or appropriateness. Country-specific versions of the questionnaire were reviewed for comparability and accuracy.

The final version of the questionnaire asked science teachers to provide additional information about the videotaped lesson, their background and experience, attitudes, and professional development. The questionnaire included the seven domains listed below:

- contextual information about the videotaped lesson (the content of the lesson, specific goals for student learning, planning for the lesson, and assessment tasks);
- description of the videotaped lesson in the context of a larger unit or sequence of lessons;
- the typicality of the videotaped lesson (teaching methods, student participation, difficulty of the lesson, and effect of the videotaping);
- ideas that guide teaching (teacher's knowledge and personal views of current science teaching);
- educational background, teaching background, and teaching load;
- school characteristics (size, type, how students are admitted, number of teachers of science, and grade levels); and
- attitudes about teaching (attitudes toward work, the students, and science).

Additional details regarding the development of the questionnaire, along with a copy of the U.S. version of the teacher questionnaire, can be found in the technical report (Garnier forthcoming).

Short questionnaires also were distributed to the students in each videotaped lesson; however student data are not presented in this report. More information about the student questionnaire, and a copy of the U.S. version of the student questionnaire, can be found in the technical report detailing the procedures used in the mathematics component of the study (Jacobs et al. 2003, appendix F).

Coding of Questionnaire Items

The teacher questionnaire consisted of both open- and close-ended items. The open-ended items in the teacher questionnaire required development of quantitative codes, a procedure for training coders, and a procedure for calculating inter-coder reliability.

Teachers' responses to open-ended questionnaire items were translated into English by coders who were bilingual in English and the relevant language being used (e.g., Czech). Coding of the open-ended items was then carried out using the English translations.

Separate codes were developed for open-ended items. The codes captured both anticipated responses to the items as well as those not-anticipated but that were provided by teachers. The final set of codes developed for the open-ended teacher questionnaire items reflected the frequency of response, the significance of the code, and the importance of the category for understanding teachers' responses.

Video Data

This section provides information on the development and application of codes to the video data by four project teams. More details about each of these groups and the codes they developed and applied can be found in the technical report (Lemmens, Garnier, and Roth forthcoming).

Science Code Development Team

An international team was assembled to develop codes to apply to the TIMSS 1999 Video Study science data. The team consisted of country associates (bilingual representatives from each country) and was directed by a science education researcher (see appendix B for team members). The Science Code Development Team was responsible for creating and overseeing the coding process, and for managing the international video coding team. The team discussed coding ideas, created code definitions, wrote a coding manual, gathered examples and practice materials, designed a coder training program, trained coders and established reliability, organized quality control measures, consulted on difficult coding decisions, and managed the analyses and write-up of the data.

The Science Code Development Team worked closely with two advisory groups: a group of national research coordinators representing each of the countries in the study, and a steering committee consisting of five North American science education researchers (see appendix B for advisory group members).

International Video Coding Team

Members of the International Video Coding Team represented all of the participating countries (see appendix B for team members). They were fluently bilingual so they could watch the lessons in their original language, and not rely heavily on the English-language transcripts. In almost all cases, coders were born and raised in the country whose lessons they coded.

Coders in the International Video Coding Team applied 174 codes in 11 coding dimensions to each of the videotaped lessons.

Specialist Coding Teams

The majority of codes for which analyses were conducted for in this report were applied to the video data by members of the international video coding team, who were cultural insiders and fluent in the language of the lessons they coded. However, not all of them were experts in science or teaching. Therefore, two specialist coding teams with expertise in the area of science were employed to create and apply special codes regarding the scientific nature of the content and the discourse in the science lessons.

- *Science Content Coding Team.* The Science Content Coding Team was comprised of individuals with expertise in science content and science education (see appendix B for group members). They developed and applied a series of codes to all of the scientific content in the videotaped lessons.

The Science Content Coding Team constructed a comprehensive, detailed, and structured list of the predominant scientific topics covered in eighth-grade in all participating countries. In addition to coding the nature of the scientific topics, the group also coded the types of science knowledge, the level of difficulty of the science content, and the different modes of content development (see chapter 4 for definitions of science content topics and types of science knowledge, and chapter 5 for definitions of level of content difficulty and modes of content development).

- *Text Analysis Team.* The Text Analysis Team used all portions of the science lesson transcripts designated as public interaction to conduct various text analyses (see appendix B for group members). The group utilized specially designed computer software for these quantitative analyses of classroom talk.

  Because of resource limitations, computer-assisted analyses were applied to English translations of lesson transcripts.[4] In the case of the Czech Republic, Japan, and the Netherlands, all lessons were translated from the respective native languages.

Reliability

Questionnaire Coding Reliability

Separate codes for each open-ended item were developed using a four-phase process. First, categories of anticipated responses were developed based on current research in teaching and learning and advice from subject matter specialists. This part of the process helped the code developers (1) form a common interpretation of the question, (2) identify categories that may not be provided in the teachers' responses, and (3) address culturally specific issues, such as the meanings of phrases used in the different countries. Second, categories were further developed based on the responses from the first 10 teacher questionnaires received from each country. Third, codes were created using the categories generated in the preceding two phases considering frequencies of responses, the cultural significance of a code, and the importance of a category in understanding teachers' beliefs and goals. Fourth, the codes were checked for reliability. Using these results, the codes were further revised and then applied to the remainder of the questionnaires.

Coders initially reviewed the codes with the code developers, practiced applying codes to teacher responses from five questionnaires, and then discussed the codes with the code developers to resolve any questions. For each item, two coders independently coded 10 randomly selected

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[4] Transcribers/translators were fluent in both English and their native language, educated at least through eighth-grade in the country whose lessons they translated, and had completed 2-weeks training in the procedures detailed in the TIMSS 1999 Video Study Transcription and Translation Manual (available in Garnier et al. forthcoming). A glossary of terms was developed to help standardize translation within each country.

lessons from each country. All codes applied to the open-ended items had to meet an 85 percent inter-coder reliability, at a minimum. If the 85 percent reliability criterion was not achieved initially, discrepancies were discussed, and necessary modifications were made to the code definition. Reliability was then attempted on a different, randomly selected set of lessons. The reliability procedures were similar to those used in the TIMSS 1995 assessment to code students' responses to the open-ended tasks (Mullis, Jones, and Garden 1996; Mullis and Martin 1998). The analyses of teacher responses included in this report are based on codes that met or exceeded this criterion.

For the five extended-response items describing teachers' educational backgrounds, each lesson was reviewed by the questionnaire coding team. This procedure ensured that each lesson would be reviewed and judged by a team member familiar with that country's educational system. The teams were required to come to consensus on the codes for each lesson, referring to documents describing each country's educational system and consulting with the national research coordinators to resolve any disagreements.

Video Coding Reliability

The members of the Science Content Coding Team each established reliability through consensus coding of all the team members.

Percentage agreement was used to estimate inter-rater reliability and the reliability of codes applied by the International Video Coding Team within and across countries for all variables presented in the report. The procedures were based on those previously used and documented for the TIMSS 1995 Video Study and as described in the literature (Bakeman and Gottman 1997). Percentage agreement allows for consideration of not only whether coders applied the same codes to a specific action or behavior, for example, but also allows for consideration of whether the coders applied the same codes within the same relative period of time during the lesson. That is, the reliability of coding in this study was judged based on two general factors: (1) that the same code was applied and (2) that it was applied during the same relative time segment in the lesson. Thus, it was not deemed appropriate to simply determine that the same codes were applied, but that they were applied to the same point in the lesson (here referred to as time segment) as well.

The calculation of percentage of agreement in this study is defined as the proportion of the number of agreements to the number of agreements and disagreements (Bakeman and Gottman 1997). Table A.3 reports the reliability of applying codes to the video data at two points: at or very near the beginning of applying codes (initial reliability) and at the midpoint of applying codes to the video data (midpoint reliability). Coders established initial reliability on all codes in a coding pass prior to their implementation. After the coders finished coding approximately half of their assigned set of lessons (in most cases about 40-50 lessons), coders established midpoint reliability. The minimum acceptable reliability score for each code (averaging across coders) was 85 percent. Individual coders or coder pairs had to reach at least 80 percent reliability on each code.[5]

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[5] The minimum acceptable reliability score for all codes (across coders and countries) was 85 percent. For coders and countries, the minimum acceptable reliability score was 80 percent. That is, the reliability of an individual coder or

Initial reliability was computed as agreement between coders and a master document. A master document refers to a lesson or part of a lesson coded by consensus by the Science Code Development Team. To create a master, the country associates independently coded the same lesson and then met to compare their coding and discuss disagreements until consensus was achieved. Masters were used to establish initial reliability. This method is considered a rigorous and cost-effective alternative to inter-coder reliability (Bakeman and Gottman 1997).

Midpoint reliability for each of the 11 coding dimensions was computed as agreement between pairs of coders. By halfway through the coding process, coders were considered to be more expert in the code definitions and applications than the Science Code Development Team. Therefore, in general, the most appropriate assessment of their reliability was deemed to be a comparison among coders rather than to a master document. Each midpoint reliability check involved pair coding of five randomly-selected lessons, one from each country. For each coding dimension, or pass, a different set of five lessons was randomly selected. When there were disagreements between pairs of coders, the Science Code Development Team met to resolve the disagreement. Pair-rater agreement was also used to establish initial reliability in some of the later coding passes, but only for those codes for which coders helped to develop coding definitions.

In each of 11 coding dimensions, a minimum of 15 lessons were coded independently by two or more international coding team members: ten lessons used in the initial training and reliability tests and five lessons at midpoint. Because consensus coding was used in the content coding dimensions, all of the lessons were examined by two or more coders for science content codes.

A percentage agreement reliability statistic was computed for each coder by dividing the number of agreements by the sum of agreements and disagreements (Bakeman and Gottman 1997). Average reliability was then calculated across coders and across countries for each code.

Codes were dropped from the study if 85 percent reliability could not be achieved. As indicated in table A.3, all codes presented in the report met or exceeded the minimum acceptable reliability standard established for this study.

In cases where coders did not reach the established reliability standard, they were re-trained and re-tested using a new set of lessons. Coders who still could not achieve the reliability standard did not code the given pass. Coders not achieving 85 per cent reliability at midpoint were also re-trained and re-tested. In addition, all previously coded lessons in that dimension were checked by a code development team member and changes made as appropriate. Coders who did not reach the defined standard even after re-training were not permitted to code for that dimension or any future dimensions that depended on knowledge of that dimension.

What counted as an agreement or disagreement depended on the specific nature of each code, and is explained in detail in Lemmens, Garnier, and Roth (forthcoming). Some codes required coders to indicate a time. In these cases, coders' time markings had to fall within a

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the average of all coders within a particular country was occasionally between 80–85 percent. In these cases clarification was provided as necessary, but re-testing for reliability was not deemed appropriate.

predetermined margin of error. This margin of error varied depending on the nature of the code, ranging from 10 seconds to 2 minutes. Rationales for each code's margin of error are provided in Lemmens, Garnier, and Roth (forthcoming).

Exact agreement was required for codes that had categorical coding options. In other words, if a code had four possible coding categories, coders had to select the same coding category as the master. In most cases, coders had to both mark a time (i.e., note the in- and/or out-point of a particular event) and designate a coding category. In these cases, it was first determined whether coders reliably marked the same or nearly the same in- and out-points, within the established margin of error. If reliability could not be established between coders based on marking the in- and out-time of codes, then reliability for the actual coding category was not calculated. In these cases, as explained above, coders were re-trained and re-tested using a different set of lessons.

Percentage agreement was used to estimate inter-rater reliability and the reliability of the codes within and across countries for all the variables presented in this report. Percentage agreement allowed us to take into account the markings of both in- and out-points of the codes applied to the videotaped lessons when computing the reliability for a code. All three marks (i.e., in-point, out-point, and label) were included in the calculation. Percentage agreement was selected to calculate reliability for all codes because most codes included marking times as well as labels.

While initial and midpoint reliability rates are reported, coders were monitored throughout the coding process to avoid reliability decay. If a coder did not meet the minimum reliability standard, additional training was provided until acceptable reliability was achieved. The data reported only include data from coders who were evaluated as reliable.

A variety of additional quality control measures were put in place to ensure accurate coding. These measures included: 1) discussing difficulties in coding reliability lessons with the science code development team and/or other coders, 2) checking the first two lessons coded by each coder, either by a code developer or by another coder, and 3) discussing hard-to-code lessons with code developers and/or other coders.

Table A.3 lists the initial and midpoint reliability scores for each code, averaged across coders.

Table A.3. Initial and midpoint reliability statistics for each science code applied by the International Coding Team, by code: 1999

Code	Initial reliability[1] (percent)	Midpoint reliability[2] (percent)
Lesson structure		
Lesson (LSSN)	96	99
Science instruction (SI)	94	95
Science organization (ORG)	90	90
Non-science (NS)	94	92
Technical difficulties (TD)	96	96
Classroom talk		
Public talk (PUBL)	92	94
Teacher-student interaction (TSI)	95	98
Social structure		
Individual work (AP1)	92	94
Pair work (AP2)	97	97
Group work (AP3)	98	99
Other work (AP4)	95	98
Activity structure		
Copying notes (CN)	93	98
Divided class work (DC)	100	100
Silent reading (IR)	96	96
Whole-class work (PDF)	99	100
Independent seatwork work (WA)	97	95
Independent practical work (WP)	92	91
Whole-class seatwork activities (PD)	100	98
Whole-class practical activities (PPD)	99	98
Purpose		
Administrative purpose (ADM)	99	97
Assessing student learning (AS1)	96	94
Going over assessment (AS2)	94	96
Developing new content (DEV)	95	94
Assigning homework (HW1)	96	96
Going over homework (HW2)	96	95
Review (REV)	98	100
Students coming to the front of class (SCF)	97	94
Homework start in class (HWS)	95	97
Type of homework (HWT)	99	98
Students pace their own work (PAC)	98	99
Independent practical activities		
Writing (LW)	86	86
Diagrams (DD)	87	94
Graphs (GRP)	97	97
Mathematics calculations (MP)	95	98

See notes at end of table.

Table A.3. Initial and midpoint reliability statistics for each science code applied by the International Coding Team, by code: 1999—Continued

Code	Initial reliability[1] (percent)	Midpoint reliability[2] (percent)
Content development		
Density of science ideas (2)	87	94
Making connections/ acquiring information (22)	92	93
Goal statements (2)	100	100
Summary statements (3)	96	100
Focus of lesson (content/activity) (18)	98	100
Textbook use (19)	100	100
First-hand data (8)	98	98
Phenomena (17)	97	98
Visual representations (11)	99	98
Rigor (20)	99	98
Learning environment		
Rooms (RM)	98	100
Computers (C)	97	98
Chalkboards (CB)	99	98
Overhead projectors (OH)	97	94
Adult teaching assistants (TA)	100	100
Video recorders (TC)	90	93

[1] Initial reliability refers to reliability established on a designated set of lessons before coders began work on their assigned lessons.

[2] Midpoint reliability refers to reliability established on a designated set of lessons after coders completed approximately half of their total assigned lessons.

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

Data Reliability

Estimates produced using data from the TIMSS 1999 Video Study are subject to two types of error, sampling and nonsampling errors. Nonsampling errors can be due to errors made in the collection and processing of data. Sampling errors can occur because the data were collected from a sample rather than a complete census of the population.

Nonsampling Errors

Nonsampling error is a term used to describe variations in the estimates that may be caused by population coverage limitations, nonresponse bias, and measurement error, as well as data collection, processing, and reporting procedures. The sources of nonsampling errors are typically problems like unit and item nonresponse, the differences in respondents' interpretations of the meaning of the questions, response differences related to the particular time the survey was conducted, and mistakes in data preparation.

In general, it is difficult to identify and estimate either the amount of nonsampling error or the bias caused by this error. In the TIMSS 1999 Video Study, efforts were made to prevent such errors from occurring and to compensate for them when possible. For example, the design phase entailed a field test that evaluated items as well as the implementation procedures for the survey.

Another potential source of nonsampling error was respondent bias, which occurs when respondents systematically misreport (intentionally or unintentionally) information in a study. One potential source of respondent bias in this survey was social desirability bias. For example, teachers may report that they assign more homework than would be observed through classroom observation. If there were no systematic differences among specific groups under study in their tendency to give socially desirable responses, then comparisons of the different groups will accurately reflect *differences* among groups. In order to minimize bias, all items were subjected to field tests. Readers should be aware that respondent bias may be present in this survey as in any survey. It was not possible to state precisely how such bias may affect the results.

Sampling Errors

Sampling errors occur when the discrepancy between a population characteristic and the sample estimate arises because not all members of the reference population are sampled for the survey. The size of the sample relative to the population and the variability of the population characteristics both influence the magnitude of sampling error. The sample of science classrooms from the 1998–1999 school year was just one of many possible samples that could have been selected. Therefore, estimates produced from the TIMSS 1999 Video Study sample may differ from estimates that would have been produced from other samples. This type of variability is called sampling error because it arises from using a sample of science classrooms in 1998–1999, rather than all science classrooms in that year.

The standard error is a measure of the variability due to sampling when estimating a statistic. Standard errors for estimates presented in this report were computed for each country using the jackknife technique. Standard errors can be used as a measure for the precision expected from a particular sample.

Standard errors for all of the estimates are included in appendix C to this report. These standard errors can be used to produce confidence intervals. There is a 95 percent chance that the true average lies within the range of 1.96 times the standard errors above or below the estimated score. For example, it was estimated that 58.0 percent of U.S. science instruction time was devoted to public talk, and this statistic had a standard error of 4.0. Therefore, it can be stated with 95 percent confidence that the actual percentage of U.S. science instruction time devoted to public talk for the total population in 1998–1999 was between 50.16 and 65.84 percent (1.96 X 4.0= 7.84; confidence interval = 58.0 +/- 7.84).

Data Entry and Cleaning Procedures

Most codes for the TIMSS 1999 Video Study were entered directly into the multimedia database, so that the videotapes and English transcripts could be linked directly with specific codes. The data then were exported either in spreadsheet format for statistical analyses, or in table format for further study by specialist coding groups. In some cases, where the vPrism software was not usable with particular types of coding, codes were entered into an Excel spreadsheet.

Codes from Dimensions 1–7, 9, 10, and 12 were entered directly into a vPrism database. Codes from Dimensions 8 and 11 were entered into an Excel database and the transcripts were analyzed in a custom-made text analysis software program.

A data cleaning process was put in place for both the vPrism and Excel databases. For the vPrism data, coders first recorded their coding decisions in writing onto printed lesson transcripts. Then they entered this information into vPrism. Lastly, coders exported the vPrism data for each lesson and compared it to their markings on the transcripts. In this way, data entry errors were immediately noted and corrected. In addition, errors detected through preliminary data analyses were examined and corrected. For example, coding that was outside of a possible range was detected and extreme outliers on particular codes were studied.

For the Excel data, coders first recorded their coding decisions in writing onto a printed spreadsheet for each lesson. Then they entered this information into Excel. Every tenth lesson was checked for accuracy, and errors were corrected.

Once they were cleaned, all of the data were aggregated to the lesson level, with each coding dimension in a separate datafile. The full sample and replicate weights were then appended to each file. Finally, statistical analyses were run using the weighted data in Wesvar and/or SPSS.

Transcription and Translation

The videotapes of science lessons were digitized and entered into a multimedia database. This made the videotapes available through a network server. All non-English videotapes were transcribed and translated into English. Translation of the videotapes was handled through a team of translators who were hired on the basis of their fluency in both English and in the language of instruction being studies. A science background was also a strong determinant of hire.

Each translator and transcriber participated in a 2-week training period, during which they were instructed in the transcription convention requirements and operation of the specialized vPrism software. Details of the procedure can be found in the TIMSS 1999 Video Study Transcription and Translation Manual, included in appendix A of the *TIMSS 1999 Video Study Technical Report: Volume 1: Mathematics Study* (Jacobs et al. 2003).

Each videotaped lesson was processed and reviewed by two transcribers prior to its final processing and review by the transcription manager. Every audible utterance by the teacher and students was translated into English from the original language. The initial translation of each lesson was reviewed up to three times before its review by a second translator. The second translator made any necessary adjustments to the translation by comparing it to the original videotaped lesson. Each lesson was reviewed in its entirety up to six times (three times per translator). As an additional quality control measure, completed translations were selected at random and checked line-by-line by the transcription manager, with the assistance of a translator.

Weighting

Sampling weights were developed to allow for the computation of statistically sound, nationally representative estimates. Weighting adjusts for various situations such as school nonresponse because data cannot be assumed to be randomly missing. The base weight for each lesson/class selected was the reciprocal of the product of the school selection and classroom selection probabilities. The lesson/class base weights have the following property: had all schools participated, then the sum of these weights across the entire sample within the country would give an unbiased estimate of the total number of lessons in a country (or close to an unbiased estimate when replacement schools were used). In the absence of nonresponse, the lesson/class base weights are a mechanism to provide valid generalizations from the sample to the national population.

To account for nonresponse in cases where a sampled school had one or more eligible classes but none was videotaped, a nonresponse adjustment was created. The idea behind nonresponse adjustments was to compensate for missing data from nonresponding schools by increasing the weights of similar responding schools. To accomplish this, schools were grouped into cells. There were three principles for forming cells: (1) schools within the same cell should be somewhat similar with respect to characteristics that might relate to the phenomena being studied; (2) there were at least six responding schools in each cell; and (3) as many cells could be formed as were reasonable given restraints 1 and 2.

Nonresponse cells were generally based on sampling stratification variables. The final weight for the lesson/class selected from a school was given as the product of the lesson/class base weight, BW_i, and the nonresponse adjustment factor for the cell to which the school belongs, NRF_i:

$$FW_i = BW_i \, x \, NRF_i$$

Variance Estimation Using the Jackknife Technique

Sampling variances were computed for each country using the jackknife technique. This technique takes into account the design used to select the lesson/class samples as well as the effect on sampling variance due to the nonresponse adjustments. Nonresponse adjustments were computed in order to mitigate against any nonresponse bias. However, since these adjustments involved calculating ratios of sample estimates within cells and then applying these ratios to the weights, they also have an impact on the sampling variances of estimates derived from the study. The variance estimates obtained via the jackknife approach reflect this appropriately.

The jackknife technique is described in detail in Wolter (1985) and summarized in Rust (1985) and Rust and Rao (1996). The jackknife technique used in the TIMSS 1999 Video Study is essentially the same as that used in the 1995 and 1999 TIMSS assessment studies, and the TIMSS 1995 Video Study.

Statistical Analyses

Most of the analyses presented in this report are comparisons of means or distributions across five countries for video data and questionnaire data. The TIMSS 1999 Video Study was designed to provide information about and compare science instruction in eighth-grade classrooms. For this reason, the lesson rather than the school, teacher, or student was the unit of analysis in all cases.

Analyses were conducted in two stages. First, means or distributions were compared across all available countries using either one-way ANOVA or Pearson Chi-square procedures. For some continuous data, additional dichotomous variables were created that identified either no occurrence of an event (code = 0) or one or more occurrences of an event (code = 1). Variables coded dichotomously were usually analyzed using ANOVA, with asymptotic approximations.

Next, for each analysis that was significant overall, pairwise comparisons were computed and significance determined by the Bonferroni adjustment. The Bonferroni adjustment was made assuming all combinations of pairwise comparisons. For continuous variables, Student's *t* values were computed on each pairwise contrast. Student's *t* was computed as the difference between the two sample means divided by the standard error of the difference. Determination that a pairwise contrast was statistically significant with $p<.05$ was made by consulting the Bonferroni *t* tables published by Bailey (1977). For categorical variables, the Bonferroni Chi-square tables published in Bailey (1977) were used.

The degrees of freedom were based on the number of replicate weights, which was 50 for each country. Thus, in any comparison between two countries there were 100 replicate weights, which were used as the degrees of freedom.

A significance level criterion of .05 was used for all analyses. All differences discussed in this report met at least this level of significance, unless otherwise stated. Terms such as "less," "more," "greater," "higher," or "lower," for example, are applied only to statistically significant comparisons. The inability to find statistical significance is noted as "no measurable differences detected" or a similar phrase. In this latter case, 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 be due to measurement or sampling error.

All tests were two-tailed. Statistical tests were conducted using unrounded estimates and standard errors, which also were computed for each estimate. Standard errors for estimates shown in figures in the report are provided in appendix C.

The analyses reported here were conducted using data weighted with survey weights, which were calculated specifically for the classrooms in the TIMSS 1999 Video Study (see Rust forthcoming for a more detailed description of weighting procedures).

The coefficient of variation (CV) was calculated for all reported estimates. In cases where the CV was found to be .50 or greater, the estimate was marked as unstable (!) in all tables and figures. Comparisons among unstable estimates are not made in this report. The CV was calculated by dividing the standard error of the estimate by the estimate.

Appendix B:
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Appendix C:
Standard Errors for Estimates Shown in Figures and Tables

Table C.1. Standard errors for estimates shown in figures and tables, by country[1]

Table/Figure	Category	AUS	CZE	JPN	NLD	USA
Figure 2.1	Graduate degree	3.6	0.0	3.7	5.8	6.7
	Undergraduate degree	4.1	‡	3.7	5.8	6.7
	Below undergraduate degree	2.3!	‡	‡	‡	‡
Text	Certified to teach grade 8 or higher	5.7	1.8	0.0	0.2	5.9
Text	Certified to teach lower than grade 8	1.6!	1.8!	0.0	0.2!	5.8!
Table 2.1	Science – Total	3.3	2.3	0.0	1.1	6.5
	Life sciences	6.9	5.4	4.1	5.7	6.9
	Physics	4.7	4.8	4.4	5.8	‡
	Chemistry	4.9	5.2	5.0	6.0	1.8
	Earth sciences	4.6	5.4	3.2	3.3!	2.7
	General science	2.2!	‡	0.0	‡	3.2
	Other than science	3.3	2.3	‡	‡	6.5
Table 2.2	Years teaching					
	Mean	1.2	1.2	0.8	1.3	1.3
	Median	—	—	—	—	—
	Range	—	—	—	—	—
	Years teaching science					
	Mean	1.1	1.1	0.8	1.1	1.3
	Median	—	—	—	—	—
	Range	—	—	—	—	—
Table 2.3	Lessons taught by teachers who took at least one science or science education course	3.3	6.0	5.2	7.4	5.5
	Average number of professional development activities	0.3	0.1	0.1	0.2	0.3
Table 2.4	Classroom management and organization	5.6	2.6	4.3	4.9	4.7
	Cooperative group instruction	6.0	3.2	3.4	5.5	6.2
	Interdisciplinary instruction	4.0	1.7	‡	1.9	6.8
	Science instructional techniques	5.5	4.9	4.9	6.3	7.2
	Standards-based teaching	5.6	—	5.3	3.9	7.2
	Teaching higher-order thinking skills	4.6	‡	‡	4.0	7.0
	Teaching students from different cultural backgrounds	4.0	‡	‡	3.4	5.9
	Teaching students with limited proficiency in their national language	2.4	‡	‡	2.7!	4.8
	Teaching students with special needs	5.5	2.8	2.5	4.0	6.1
	Use of technology	5.9	4.9	5.5	5.4	5.2
	Other professional development activities	6.3	4.5	3.6	5.7	7.2

See notes at end of table.

Table C.1. Standard errors for estimates shown in figures and tables, by country[1]—Continued

Table/Figure	Category	AUS	CZE	JPN	NLD	USA
Table 2.5	All teaching and other school-related activities - Total	1.4	1.1	1.5	1.2	3.0
	Teaching science classes	0.6	0.6	0.3	0.8	1.8
	Teaching other classes	0.4	0.5	0.2	0.8	1.0
	Meeting with other teachers to work on curriculum and planning issues	0.1	0.2	0.2	0.1	0.3
	Work at school related to teaching science	0.6	0.4	0.5	0.5	0.6
	Work at home related to teaching science	0.5	0.4	0.4	0.7	0.8
	Other school-related activities	0.9	1.0	1.2	0.5	1.1
Table 2.6	Performance expectations for science					
	Knowing and understanding science					
	Knowing science information	5.6	5.3	4.5	5.0	5.5
	Understanding scientific ideas	6.3	2.6	5.5	5.9	5.3
	Understanding the nature of science	2.3!	‡	‡	‡	2.1!
	Doing science					
	Carrying out a scientific experiment, project, or activity	2.1!	2.0	3.3	4.1	5.5
	Developing generic thinking skills	‡	‡	1.8!	3.2	2.6!
	Learning laboratory skills	3.7	3.0	3.1	4.2	2.7
	Using scientific inquiry skills	4.1	2.7	2.5	3.9	6.6
	Context of science					
	Awareness of the usefulness of science in life	5.0	3.7	3.2	5.3	5.1
	Collaborative work in groups	‡	‡	‡	3.9	3.7
	Independent work	2.0	‡	1.7!	3.9	3.1
Table 2.7	Cooperative work with other teachers	5.8	2.6	2.7!	7.2	5.4
	Curriculum guidelines	6.2	2.5	4.4	6.7	5.2
	External examinations or standardized tests	—	1.9!	2.3!	2.6	4.4
	Mandated textbook	5.6	5.6	6.3	6.7	6.2
	Teacher's comfort with or interest in the topic	5.0	5.1	3.1	6.7	7.2
	Teacher's assessment of students' interests or needs	6.7	5.8	5.8	6.7	5.9
Figure 2.2	Agree	4.8	4.8	3.5	4.2	5.9
	No opinion	4.1	4.7	5.2	3.3	2.8
	Disagree	2.3	2.6	5.2	2.8	5.3!
Text	Teacher satisfied videotaped lesson achieved goals	3.3	2.9	6.0	4.7	2.4

See notes at end of table.

Table C.1. Standard errors for estimates shown in figures and tables, by country[1]—Continued

Table/Figure	Category	AUS	CZE	JPN	NLD	USA
Text	Teacher not satisfied videotaped lesson achieved goals	3.3	2.9	6.0	4.7	2.4
Figure 2.3	A fair amount or a lot	4.4	4.7	3.5	5.5	4.9
	A little	4.2	5.1	5.5	6.7	4.9
	Not at all	‡	3.2	5.3	5.3	‡
Text	All students required to take science course	3.6	1.9	2.9	0.0	5.1
Text	Students behaved better than usual	5.8	4.0	5.0	4.0	4.4
Text	Students behaved as usual	5.7	5.4	5.5	4.8	5.6
Text	Students behaved worse than usual	2.7!	5.4	2.5	3.9	4.6!
Text	More difficult	1.8!	3.1	3.1	3.6	3.1
Text	About the same	2.5	3.8	3.7	4.3	5.8
Text	Less difficult	1.7	2.2!	2.6	2.4!	5.5
Figure 2.4	Almost always	4.9	5.8	5.0	4.5	5.8
	Often	6.9	5.7	5.0	5.4	6.4
	Sometimes or seldom	5.0	1.9!	3.7	4.7	4.7
Text	Lesson was better than usual	3.7	4.4	4.4	3.0!	2.5!
Text	Lesson was not influenced by camera	6.3	4.5	5.2	4.5	3.1
Text	Lesson was worse than usual	5.3	5.0	3.7	3.6	2.3
Figure 2.5	Videotaped lesson	4.0	6.3	13.5	3.2	5.8
	Similar lessons	1.9	1.9	11.5	1.8	6.1
Text	Videotaped lesson was part of a sequence of lessons	2.6	1.4	0.8	1.3	1.5
Table 2.8	Average number of lessons in unit	1.0	0.7	0.8	2.5	0.8
	Average placement of the videotaped lesson in unit	0.8	0.4	0.7	1.6	0.5
Table 3.1	Mean	1.8	0.2	0.4	0.9	1.6
	Median	—	—	—	—	—
	Range	—	—	—	—	—
	Standard deviation	1.1	0.2	0.3	1.8	2.2
Table 3.2	Mean	1.6	0.2	0.4	0.9	1.5
	Median	—	—	—	—	—
	Range	—	—	—	—	—
	Standard deviation	1.1	0.2	0.2	1.6	2.2
Figure 3.2	Non-science	0.4	0.1	0.2	0.4	0.4
	Science organization	0.8	0.3	0.4	0.7	0.7
	Science organization and non-science	0.8	0.3	0.4	0.7	0.7
	Science instruction	0.8	0.3	0.4	0.7	0.7
Text	Lessons with 3 or more interruptions	6.2	4.7	4.4	6.6	4.1
Figure 3.3	Outside interruptions	6.2	2.8	‡	4.7	6.1
	Non-science segments	6.2	5.4	5.2	5.2	6.3
	Science organization segments	4.3	5.9	4.5	4.2	3.0

See notes at end of table.

Table C.1. Standard errors for estimates shown in figures and tables, by country[1]—Continued

Table/Figure	Category	AUS	CZE	JPN	NLD	USA
Table 3.3	Developing new content	2.8	0.9	0.0	1.1	2.2
	Reviewing previous content	5.2	3.8	5.5	3.5	5.3
	Going over homework	0.5	1.9!	1.5!	6.1	5.5
	Assessing student learning	1.4!	5.5	2.3	3.7	5.6
	Other purposes	0.9	1.4	1.2	0.0	2.8
Text	Time devoted to going over homework	‡	‡	1.9	‡	‡
Table 3.4	Developing new content	3.0	2.3	1.0	2.9	2.4
	Reviewing previous content	2.9	2.0	0.9	0.5!	1.8
	Going over homework	0.0	0.5!	‡	2.5	1.2
	Assessing student learning	‡	1.4	0.2	0.6	0.9
	Other purposes	0.6	0.2	0.2	0.7	1.5
Figure 3.4	Developed new content only	5.2	3.8	5.5	3.5	5.2
	Developed new content and reviewed previous content	4.5	3.9	5.5	3.5	5.4
	Reviewed previous content only	‡	‡	‡	‡	‡
Text	Lessons with practical activities	3.2	4.5	4.1	5.4	4.3
Text	Lessons with seatwork activities	0.5	0.0	0.0	0.0	0.0
Figure 3.5	Practical activities	3.2	4.5	4.1	5.4	4.3
	Seatwork activities	2.7	1.7	3.5	3.9	3.6
Text	Lessons with independent work	0.1	3.0	1.1	4.1	2.4
Text	Lessons with whole-class work	0.5	0.0	0.0	1.6	1.5
Text	Lessons with divided class work	‡	4.2	‡	3.3	1.9
Figure 3.6	Whole-class work	2.7	1.4	2.8	3.9	4.2
	Independent work	2.3	1.5	2.8	4.0	4.1
	Divided class work	‡	0.6	‡	1.5	0.5!
Table 3.5	Whole-class practical activities	4.6	4.4	4.9	6.6	5.3
	Whole-class seatwork activities	0.5	0.0	0.0	1.6	1.5
	Independent practical activities	6.1	4.6	5.5	5.8	6.4
	Independent seatwork activities	3.3	3.2	4.2	5.0	4.3
Figure 3.7	Whole-class practical activities	1.3	1.1	1.0	1.4	0.7
	Whole-class seatwork activities	1.9	1.8	2.7	3.5	3.8
	Independent practical activities	3.0	1.2	3.4	3.9	3.8
	Independent seatwork activities	2.2	1.3	1.7	3.2	2.9
Figure 4.1	Earth science	2.1	‡	2.8	‡	5.3
	Life science	4.5	4.3	3.4	5.4	4.5
	Physics	5.8	4.4	4.6	5.4	5.5
	Chemistry	4.3	4.4	4.6	3.4	4.1
	Other areas	2.9	3.1	‡	4.0	5.4
Figure 4.2	Lessons that addressed canonical knowledge during public talk	2.2	0.0	1.0	4.6	5.5
Figure 4.3	Public talk time devoted to canonical knowledge	2.3	1.9	2.7	3.2	2.8

See notes at end of table.

Table C.1. Standard errors for estimates shown in figures and tables, by country[1]—Continued

Table/Figure	Category	AUS	CZE	JPN	NLD	USA
Figure 4.4	Lessons that incorporated real-life issues during public talk	4.3	3.0	5.8	5.7	5.2
Figure 4.5	Public talk time devoted to real-life issues	4.3	3.0	5.8	5.7	5.2
Figure 4.6	Lessons that addressed procedural and experimental knowledge during public talk	3.9	5.1	2.6	5.9	5.8
Figure 4.7	Public talk time devoted to procedural and experimental knowledge	1.5	1.5	1.9	2.1	2.0
Figure 4.8	Lessons that included classroom safety knowledge during public talk	5.4	4.3	5.6	3.9	5.9
Text	Public talk time devoted to classroom safety knowledge	0.2	0.2	0.5	0.2!	0.5!
Text	Lessons that addressed nature of science knowledge during public talk	1.9	‡	2.7	1.6!	2.9
Text	Public talk time devoted to nature of science knowledge	0.0	‡	0.1!	0.0	0.2!
Text	Lessons that addressed meta-cognitive knowledge during public talk	5.1	4.5	3.8	4.3	5.6
Text	Public talk time devoted to meta-cognitive knowledge	0.3	0.1	0.1!	0.2	0.2
Figure 5.1	Teacher	5.9	5.4	4.3	3.7	3.8
	Textbook/workbook	4.3	5.0	4.6	5.8	7.1
	Worksheet	5.9	‡	5.2	4.8	5.0
	Other source	4.3!	‡	1.8!	‡	3.0
Figure 5.2	Doing activities without the opportunity to learn science content	3.2	‡	2.3	3.1	5.8
	Learning science content	3.2	0.0	2.3	3.1	5.8
Figure 5.3	High number of public canonical ideas	4.7	5.2	2.8	4.8	6.0
Figure 5.4	Science terms	1.3	3.2	1.2	1.6	2.4
	Highly technical science terms	0.9	2.3	0.8	0.7	1.6
Figure 5.5	Making connections	6.2	4.6	4.7	5.3	6.5
	Acquiring facts, definitions, and algorithms	6.2	4.6	4.7	5.3	6.5
Figure 5.6	Making connections through inquiries	6.1	3.6	4.9	4.2	5.7
	Making connections through applications	3.0	3.6	4.1	3.2	3.8
	Making connections through unidentified approaches	‡	‡	‡	3.0!	‡

See notes at end of table.

Table C.1. Standard errors for estimates shown in figures and tables, by country[1]—Continued

Table/Figure	Category	AUS	CZE	JPN	NLD	USA
Figure 5.7	Doing activities with no conceptual links	3.2	‡	2.3	3.1	5.8
	Learning content with weak or no conceptual links	5.7	5.8	5.0	5.6	7.0
	Learning content with strong conceptual links	6.1	5.8	5.3	5.6	5.4
Figure 5.8	Goal statements	2.2	2.7	4.5	5.0	6.1
	Summary statements	5.6	4.4	4.9	3.0!	3.8
Figure 5.9	Goal statement includes main idea presented as a research question	6.2	4.9	4.9	6.0	4.8
	Goal statement includes main idea presented as a known outcome	6.4!	‡	‡	5.9!	‡
	Goal statement includes topic only	5.0	5.0	3.1	5.5	5.4
	Goal statement includes only activity or page number	5.1	‡	2.4	5.7	3.2
Figure 5.10	Both goal and summary statements of any type	5.5	4.5	5.3	3.0!	3.2
	Both goal and summary statements include more than naming a topic	4.9	3.2	5.0	‡	‡
Figure 5.11	Challenging content	4.6!	4.3	2.6	5.0	5.8
	Basic and challenging content	5.1	5.5	4.3	6.6	5.6
	Basic content	5.7	4.2	4.8	6.8	6.4
Figure 5.12	Lessons that publicly presented scientific laws and theories	5.8	4.6	3.4	4.7	5.9
Figure 6.1	First-hand data	3.9	5.6	3.5	6.1	6.6
	Phenomena	1.9	5.7	5.2	5.4	6.2
	Visual representations	4.8	2.5	2.1	5.0	6.6
Text	Lessons that used at least 2 types of visual representations	6.6	4.5	5.3	6.1	6.3
Text	Lessons that used at least 3 types of visual representations	3.1	4.9	4.1	2.7	3.2
Figure 6.2	More than one set of first-hand data	5.9	4.7	4.7	5.1	5.5
	More than one phenomenon	5.5	4.5	5.0	4.3	4.7
	More than one visual representation	6.6	5.6	5.3	5.6	6.7
Figure 6.3	Lessons that supported all main ideas with first-hand data, phenomena, and visual representations	5.1	4.9	5.4	4.0	4.7

See notes at end of table.

Table C.1. Standard errors for estimates shown in figures and tables, by country[1]—Continued

Table/Figure	Category	AUS	CZE	JPN	NLD	USA
Table 7.2	Created models	1.8!	‡	‡	‡	3.2
	Displayed or classified objects	2.7!	‡	‡	‡	4.7!
	Used tools, procedures, and science processes	3.0	1.9!	‡	2.4	1.6
	Conducted an experiment	3.7	‡	‡	2.7!	‡
	Produced or observed phenomena	5.4	4.0	5.4	4.8	5.3
Figure 7.1	No set-up talk	‡	‡	‡	3.1!	2.1!
	Set-up talk about procedures	6.1	2.8	5.2	4.4	4.2
	Set-up talk about procedures and ideas	5.6	4.0	5.5	2.6	5.7
Figure 7.2	Verified knowledge	4.1	3.6	‡	2.1!	5.6
	Followed procedures	4.9	1.8!	3.8	3.1	4.3
	Explored a question	5.0	2.8	5.7	4.4	2.7
Figure 7.3	Main conclusion was discussed	5.0	3.5	5.0	‡	‡
	Several conclusions were discussed	5.2	2.8	3.1	2.1!	5.8
	Observations and data were discussed	4.3	‡	3.5	‡	2.4
	Outcomes were not discussed	5.2	2.0!	3.5	5.4	5.2
Figure 7.4	Methods critiqued or evaluated	4.6	2.2!	3.9	2.0	2.1
	New questions to be investigated discussed	3.3	‡	4.8	‡	‡
Table 7.3	Generated the research question	2.0!	‡	‡	‡	‡
	Designed procedures for investigation	3.7	‡	2.4!	‡	1.9
	Made predictions	3.5	‡	5.0	2.5!	3.1
	Interpreted the data or phenomena	6.1	4.5	5.2	5.1	6.3
	Collected and recorded data	5.5	3.2	5.7	5.6	5.1
	Organized or manipulated data collected independently	3.2	‡	‡	3.4	3.4
	Organized or manipulated collected data guided by teacher or textbook	5.0	1.9!	5.1	3.3	4.5
Figure 7.5	Students made predictions	‡	2.9	3.4	‡	‡
	Students interpreted data or phenomena	4.8	5.6	3.5	4.1	2.6
Text	Students give reasons for predictions	2.4	‡	2.6	‡	‡

See notes at end of table.

Table C.1. Standard errors for estimates shown in figures and tables, by country[1]—Continued

Table/Figure	Category	AUS	CZE	JPN	NLD	USA
Figure 8.1	Individual work	4.8	5.0	4.5	5.7	4.8
	Pair/group work	6.1	5.2	5.0	6.1	6.0
Text	Changing social participation structure	1.6!	1.1!	1.9!	2.1!	1.9!
Figure 8.2	Individual work	2.5	1.0	1.2	3.0	2.5
	Pair/group work	3.0	1.5	3.3	4.0	3.1
Figure 8.3	Individual work during independent practical activities	1.5!	‡	‡	0.4!	‡
	Pair/group work during independent practical activities	3.0	1.2	3.4	3.7	3.6
	Individual work during independent seatwork activities	2.1	1.0	1.1	3.1	2.2
	Pair/group work during independent seatwork activities	1.2	0.7	1.2	1.8!	2.6
Table 8.1	Total	3.0	1.5	3.3	4.0	3.1
	Sitting together	2.9	1.5	3.4	3.7	3.4
	Sharing materials	2.9	1.4	3.4	3.8	3.1
	Talking among students	3.0	1.5	3.3	4.0	3.1
	Working on tasks requiring collaboration	1.3	‡	1.0	‡	2.0
	Assigning roles to group members	1.4	‡	0.7	‡	2.5
	Creating science group products	2.0	0.8	2.4	2.5!	3.0
	Working in all mixed gender groups	0.9!	‡	2.1	‡	1.5
Figure 9.1	Public discussions	1.2	1.5	1.0	2.0	2.3
	Public presentations	2.5	1.4	2.1	2.3	3.3
Figure 9.2	Private teacher-student talk	2.0	0.6	1.7	2.9	2.6
	Private student-peer talk	2.4	0.7	1.1	3.0	2.1
Figure 9.3	Other words	1.2!	0.4	0.1	1.3!	0.7
	Student words	0.6	0.5	1.0	1.4	1.1
	Teacher words	1.0	0.6	0.9	1.7	1.2
Figure 9.4	5+ word student utterances during public talk	1.3	1.1	1.6	1.6	1.3
	5+ word student utterances during private teacher-student talk	1.7	3.4	1.5	2.0	1.9
Figure 9.5	Took notes during whole-class work	0.7	0.6	0.6	0.4	0.4
	Selected answers during independent work	2.3	1.2	2.5	2.2	2.2
	Generated written responses during independent work	3.1	1.2	3.2	4.3	3.3
Text	Time for students to write about science	5.9	11.0	72	9.3	11.0
Text	Lessons in which students were expected to write at least a paragraph	3.5	‡	‡	2.4	4.9

See notes at end of table.

Table C.1. Standard errors for estimates shown in figures and tables, by country[1]—Continued

Table/Figure	Category	AUS	CZE	JPN	NLD	USA
Text	Lessons in which students generated written responses	6.0	5.0	4.9	5.7	5.3
Text	Lessons in which students independently selected answers	5.7	5.1	5.3	4.8	6.4
Text	Lessons in which students took notes	6.2	5.8	5.8	4.1	3.7
Figure 9.6	Graphs	1.5!	‡	3.3	3.7	3.6
	Diagrams	4.6	2.7	3.2	4.9	4.5
	Mathematical calculations	3.5	4.5	3.7	5.7	5.8
Figure 9.7	Reading aloud together	0.1!	0.2!	0.1	0.4!	0.2!
	Reading silently	1.7	0.1!	0.5!	3.7	2.6
Text	Lessons with silent reading tasks	5.1	1.8!	2.8	6.1	4.9
Figure 9.8	Talk about science	2.2	1.6	2.6	2.7	3.2
	Write about science	2.6	1.6	2.9	4.0	3.8
	Read about science	1.7	0.2!	0.5!	3.6	2.6
Text	Time during seatwork activities for students to talk about science	2.6	1.6	1.8	3.2	3.3
Text	Time during seatwork activities for students to write about science	2.2	1.4	1.5	3.1	2.8
Text	Time during seatwork activities for students to read about science	1.5	0.2!	0.2	3.2	2.2
Figure 10.1	Lessons in which at least one real-life issue was raised	4.1	3.0	5.7	5.4	4.3
Figure 10.2	Time during which real-life issues were raised	2.2	1.3	2.1	3.4	4.2
Figure 10.3	At least one real-life issue used to develop science ideas	5.0	3.7	5.9	6.3	5.8
	At least one real-life issue mentioned as topic-related sidebar	6.3	4.7	6.0	6.3	6.0
Figure 10.4	Real-life issues mentioned as topic-related sidebars	1.1	1.1	0.8	1.3	0.9
	Real-life issues used to develop science ideas	1.7	0.8	1.8	3.1	4.2
Figure 10.5	Lessons that had at least one motivating activity	6.0	4.1	4.6	5.7	5.5
Figure 10.6	Time allocated to motivating activities	2.7	0.8	1.6	1.8	4.7
Figure 10.7	Three types of activities	4.1	2.6	2.8	3.2!	5.1
	Two types of activities	5.6	4.6	5.2	6.3	5.8
	One type of activity	4.9	4.6	5.7	6.7	5.3
Text	Lessons with routine lesson openers	1.5!	0.0	2.2	0.0	5.8

See notes at end of table.

Table C.1. Standard errors for estimates shown in figures and tables, by country[1]—Continued

Table/Figure	Category	AUS	CZE	JPN	NLD	USA
Figure 11.1	Lessons in which students created organized science notebooks	4.0	2.0	5.9	5.7	5.3
Figure 11.2	Lessons in which students used textbooks and/or workbooks	5.3	5.5	4.8	3.8	5.8
Figure 11.3	Computers available in the classroom	3.9	2.3!	1.9!	5.3	6.6
	Computers used by students	‡	‡	1.6!	‡	4.7!
Figure 11.4	Public grading	2.3	5.1	‡	3.7	2.3!
	Public assessment	‡	4.2	‡	‡	‡
	Public work	2.9	4.4	4.4	2.4	3.9
Text	Lessons in which students made presentations	2.3	3.6	2.2!	3.3!	3.0
Figure 11.5	Lessons that included at least one student-initiated science question	5.9	3.6	4.3	5.8	7.2
Figure 11.6	Student-initiated science questions per eighth-grade science lesson	33.9	10.8	26.9	109.2	55.5
Text	Lessons in which students generated own research questions	2.0!	0.0	0.0	1.6!	0.0
Text	Lessons in which students designed procedures for investigation	3.7	1.1!	2.4!	1.6!	1.9
Text	Lessons in which students collected data	4.5	5.4	4.6	5.8	6.6
Figure 11.7	Lessons in which the teacher assigned homework for future lessons	5.9	5.4	2.9	6.3	6.6
Figure 11.8	Work on new content only	5.7	5.2	3.5	6.0	6.1
	Mixed	‡	2.4!	‡	5.7	‡
	Review previously covered content only	‡	3.9	‡	‡	1.2
Figure 11.9	Reviewing homework	0.5	1.9!	‡	6.1	5.5
	Working on homework assignments in class	6.3	2.7	3.1	5.6	5.7
	Reviewing homework and working on homework assignments in class	‡	‡	‡	5.2	2.8
Figure 11.10	Students worked at their own pace on long-term assignments	5.0	‡	‡	5.5	4.9
Text	Students expected to check their own work	0.0	0.0	1.1!	6.2	1.1!

See notes at end of table.

Table C.1. Standard errors for estimates shown in figures and tables, by country[1]—Continued

Table/Figure	Category	AUS	CZE	JPN	NLD	USA
Tables E.1-E.5	Earth science					
	Building and breaking of earth's surface	‡	‡	‡	‡	1.3!
	Planets in the solar system	‡	‡	‡	‡	2.4!
	Rocks and soil	‡	‡	‡	‡	2.9
	Weather and climate	‡	‡	2.8	‡	2.3
	Life science					
	Animals	‡	‡	1.8!	‡	‡
	Evolution, speciation, and diversity	‡	‡	‡	‡	2.0!
	Disease	‡	‡	‡	‡	3.1!
	Organs and tissues	2.6!	4.7	3.0	4.5	‡
	Plants and fungi	2.4	‡	‡	‡	‡
	Reproduction	1.8!	‡	‡	1.9!	‡
	Sensing and responding	‡	‡	1.7!	2.0!	‡
	Variation and inheritance	‡	‡	‡	‡	1.7!
	Physics					
	Electricity	4.2	3.0	4.5	1.8!	1.8!
	Energy types, sources, and conversions	4.0	‡	‡	‡	‡
	Fluid behavior	1.7!	1.8!	‡	‡	‡
	Heat and temperature	‡	2.0!	‡	3.1	‡
	Light	2.9	‡	‡	4.0	‡
	Magnetism	‡	‡	1.9!	‡	‡
	Physical changes	‡	2.6	‡	‡	‡
	Physical properties	‡	‡	‡	‡	1.6!
	Sound and vibration	‡	‡	‡	4.7	‡
	Types of forces	3.3	‡	‡	2.3!	‡
	Chemistry					
	Atoms, ions, and molecules	‡	1.7!	‡	‡	3.2!
	Chemical changes	1.6!	2.2!	4.5	2.7!	‡
	Chemical properties	3.3	2.3!	‡	2.2!	1.7!
	Classification of matter	‡	3.5	‡	‡	2.3!
	Other areas					
	Interactions of science, technology, and society	1.9!	2.3	‡	‡	2.1!
	Nature of scientific knowledge	‡	‡	‡	‡	3.4!
	Science and mathematics	‡	2.1!	‡	1.5!	‡

See notes at end of table.

Table C.1. Standard errors for estimates shown in figures and tables, by country[1]—Continued

Table/Figure	Category	AUS	CZE	JPN	NLD	USA
Table E.6	Earth science					
	Making connections	1.5!	‡	2.3	‡	1.9
	Acquiring facts, definitions, and algorithms	‡	‡	‡	‡	5.1
	Life science					
	Making connections	3.9	‡	2.3	‡	‡
	Acquiring facts, definitions, and algorithms	3.8	4.2	2.8	5.4	4.4
	Physics					
	Making connections	5.7	3.9	4.8	3.8	5.1!
	Acquiring facts, definitions, and algorithms	5.2	3.9	2.2	5.4	2.7
	Chemistry					
	Making connections	4.2	3.3	4.9	2.4!	3.1
	Acquiring facts, definitions, and algorithms	1.8	3.4	3.3	2.4!	3.2
	Other areas					
	Making connections	1.7!	‡	‡	3.0!	4.2
	Acquiring facts, definitions, and algorithms	2.4	3.1	‡	2.7	4.8
Figure E.1	Focus on algorithms and techniques	3.6	4.4	3.8	4.5	5.9
	Focus on sequences of events	‡	3.1	‡	‡	‡
	Focus on discrete bits of information	5.7	4.8	3.3	6.1	6.2
	Focus on unidentified approaches	‡	‡	‡	‡	‡
Table E.7	Earth science					
	Challenging or a mix of basic and challenging	‡	‡	‡	‡	3.8
	Basic	1.9!	‡	2.6	‡	4.1
	Life Science					
	Challenging or a mix of basic and challenging	3.2	4.3	3.3	5.5	3.7
	Basic	3.9	2.8	3.0	2.0	3.5!
	Physics					
	Challenging or a mix of basic and challenging	6.1	4.2	3.5	4.7	5.5
	Basic	4.4	2.1	4.5	5.5	2.5
	Chemistry					
	Challenging or a mix of basic and challenging	2.3!	3.9	2.9	‡	3.6
	Basic	3.6	2.4	4.3	2.8	‡

See notes at end of table.

Table C.1. Standard errors for estimates shown in figures and tables, by country[1]—Continued

Table/Figure	Category	AUS	CZE	JPN	NLD	USA
Figure E.2	3-dimensional models	4.8	4.3	2.2	4.6	2.6
	Graphic organizers	5.9	5.9	5.2	6.5	6.6
	Diagrams	6.9	4.3	3.4	6.4	6.4
	Formulas	2.2	4.9	4.5	3.7	4.0
	Other visual representations	3.9	4.4	2.8	3.1	3.7

!Interpret data with caution. Estimate is unstable.

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

—Not available.

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

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

Appendix D:
Definitions of Constructs and Variables Used in Analyses

The definitions of constructs and variables, and, in some cases, the methods by which they are reported, are organized by the chapter in which they first appear. Only those constructs and variables which are not already defined in the chapters are included here.

Chapter 2

Educational Preparation

Teachers were asked about their training in and preparation for teaching science. Since comparisons of degree type are difficult to compare cross-nationally due to differences in the education systems of the participating countries, definitions developed by the Organization for Economic Cooperation and Development (OECD 1997) specifically for international comparative purposes were used to help categorize teachers' educational backgrounds in the questionnaires into three educational levels. This categorization schema is known as the International Standard Classification of Education (ISCED). Teachers' reports of their educational attainment were assigned to three categories. The first level includes upper secondary and post-secondary educational programs that require a minimum of high school completion, matriculation, or a vocational certificate (ISCED levels 3 and 4). Teachers' indications that they hold a degree from a secondary vocational school or a high school diploma fall into this category. This level also includes some college attendance, such as attaining an associate degree, without attaining a bachelor's degree. The second level incorporates postsecondary programs that last at least 3 years and prepare students for entry to graduate programs (ISCED level 5A). The third and highest level covers programs that result in an advanced research qualification or degree and include submission of original research such as a thesis or dissertation (ISCED level 6). This category includes such programs as master's degree and doctoral degree. Any of these three education levels could incorporate teacher training.

Certification to Teach Science

Preparation for teaching eighth-grade science includes certification to teach science as well as having a science content background. To describe teachers' certification backgrounds, teachers were asked to list the subject areas and corresponding grade levels in which they were certified to teach. Each response was divided into two mutually exclusive groups: (1) teacher's certification in science included eighth-grade or (2) teacher's certification in science was not identified for grade level, did not include eighth-grade, or certification was identified in another subject area.

Years Teaching in General and Teaching Science

Teachers were asked to identify how many years they had been teaching in general, and also how many years they had been teaching science (not limited to grade 8).

Professional Development Opportunities

Teachers were asked to describe the science courses and professional development activities they participated in during the two years up to and including the day of videotaping.

Teachers' Learning Goals for Science Lessons

Teachers were asked to identify, in their own words, their main goals for students in the eighth-grade science lessons that were subsequently videotaped. Teachers' responses subsequently were coded to a set of goals based on common themes across the teachers' responses. Teachers could identify more than one goal for a lesson; all goals identified by a teacher were coded. Goals were grouped according to three major expectations: knowing and understanding science (four goals), doing science (six goals), and developing students' attitudes toward science and participating in science (five goals).

Typicality of Planning for the Lesson

Once they agreed to be videotaped, the eighth-grade science teachers could have spent more effort in planning for the videotaped lesson than they normally would have spent for a typical science lesson, although they were asked specifically to do nothing special. To get an indication of the degree to which the videotaped teachers may have put more effort into their lesson planning specifically for the purpose of the study, the teachers were asked to report how many minutes they spent planning for the videotaped lesson and how many minutes they typically spent planning for similar science lessons.

Chapter 3

Lesson Interruptions

Comparing countries on the occasions when science instruction was interrupted is a way of assessing whether lessons maintained a continuous focus on science instruction or provided breaks from the science instruction focus. Interruptions by an outside source, by non-science segments, or by science organization segments were examined. Examples of outside interruptions are announcements over the intercom, telephone calls that require the teacher's attention, fire drills, and visitors from outside the classroom who require the teacher's attention. Non-science segments could occur at the start or end of the lesson without interrupting or providing a break from science instruction, but occurrences of three or more of these events would most likely involve a mid-lesson interruption to science instruction. Time spent on science organization is sometimes needed to move the flow of the science lesson from one activity to another. These organizational periods do not necessarily disrupt the lesson as would outside interruptions or non-science interruptions, but they are more likely to interrupt the lesson flow if they occur multiple times. These three indicators of lesson interruptions are analyzed together in order to describe and compare how countries organize their lessons with a minimum of interruptions.

Whole-Class and Independent Work

Science activities, both practical and non-practical, were observed to take place as a whole class or as an independent student activity. Whole-class work occurs when science instruction and related information are provided to or worked on together by the entire class. In whole-class work, all students are expected to pay attention to the same activity that is led by the teacher, a student, a small group of students, or another source (e.g., videotape, assistant teacher). Independent activities involve students working on their own, either individually or in small groups. At times, science lessons are conducted with part of the class working together under the direction of the teacher and part of the class working independently. For example, the teacher may assign half the class to work on answering questions individually, while she showed the rest of the class a demonstration. In this case, some students worked independently while the other students worked together under the direct supervision of the teacher.

Chapter 5

Science Terms

Science terms were identified by a team of six scientists who reviewed and categorized the words generated by a computer-assisted analysis. Science terms can range from terms commonly used outside the classroom (e.g., energy, force, kidney) to highly technical terms. The use of highly technical science terms is another indicator of the density of content in the eighth-grade science lessons. The list of science words was reviewed by a team of six scientists to identify highly technical science words.

Acquiring Facts, Definitions, and Algorithms

The primary way in which facts, definitions, and algorithms were used to develop science content was identified for each lesson using the following definitions:

- ***Algorithms and techniques:*** Science information is presented primarily through problem solving or procedural tasks that rely on linear reasoning. Problems are straightforward (for example, calculate the volume of a cube) rather than open-ended (for example, determine which kind of water filtration plant would be best for the local community). Teachers first show the students the problem, the steps needed to solve the problem with linear reasoning, and the answer. Students then practice applying the procedures to a similar set of problems.
- ***Sequences of events***: Science information is presented primarily as facts describing processes or stages. For example, a teacher describes how blood travels through the body beginning with the process of blood traveling through the heart and continuing with the process of oxygen being received as blood travels through the lungs. Students also may participate by drawing or labeling diagrams that represent the process of blood flow.
- ***Discrete bits of information***: Science information is presented as isolated and unrelated definitions, facts, processes, and/or procedures. The teacher presents the information as separate and unconnected in an "all about the topic" mode. For example, a teacher may talk

about different elements on the Periodic Table, describing each element and its everyday uses without any conceptual or theoretical organization.

- ***Unidentified approaches:*** The teacher helps students acquire facts, definitions, and algorithms in a way that is not primarily defined as solving problems, describing sequences of events, or presenting discrete bits of information.

Chapter 7

Discussion of Results

Based on observations, four types of public discussion of the outcomes of practical activities were identified:

- ***Discussing observations and data:*** The class publicly shares, compares, and checks observations and data resulting from the practical activities, but does not discuss a possible conclusion or conceptual idea based on those outcomes (📹 Video clip example 7.7).
- ***Discussing several conclusions:*** The class discusses multiple conclusions or ideas related to different parts of the practical activity. However, there is no attempt to identify and connect them to a single conclusion or idea that is supported by the evidence available. For example, one conclusion is drawn about what happens to food when it is mashed and mixed with saliva, and another conclusion is made about what happens to food when it is mixed with gastric juices. But these two conclusions are not linked together to create a big conclusion about the process of digestion involving chemical as well as physical breakdown of food.
- ***Discussing main conclusion:*** The class discusses how the outcomes of the practical activity are connected to and support a single or main conclusion or idea (📹 Video clip example 7.8).
- ***Not discussing outcomes:*** Nothing about the outcomes or results of the independent practical activity is discussed publicly.

Chapter 9

Teacher and Student Words

Computer-assisted analyses were applied to English-language transcripts (Australia and the United States) and translations (Czech Republic, Japan, and the Netherlands) of the eighth-grade science lessons. Analyses based on same-language transcripts allow for comparisons of speech across countries, thought not without potential bias. Transcribers and translators were fluent in English and the language of the countries they translated. A glossary was developed to standardize translation of special terms within each country. All translations were checked for accuracy by a second translator as well as a content expert.

It is important to note that the analyses are based on only those segments of public talk in which the teacher and student(s) could be heard. In cases where many students spoke at once or made remarks out of the range of the microphones, the transcripts noted that something was uttered, but did not include guesses about what was said. Because of instances such as this, estimates of the amount of student talk are likely to be lower than actually occurred.

Chapter 11

Organized Science Notebooks

In some science lessons, students were observed organizing their notes and other science work in a special science notebook. These notebooks became a record of the class activities, including notes as well as work on practical and seatwork activities. In many classes, the record was organized chronologically in a sewn notebook format, and any additional worksheets were pasted into the chronological notebook in the appropriate place. Thus, students created a chronological record, or text, of their experiences in science class. In other cases, loose-leaf, ringed binders were used, with special sections for different types of science class records. In all cases, however, students were responsible for keeping a special, organized science notebook. Loose-leaf, ringed binders used by students to keep their papers from all their different classes or binders that were not used in a systematic way were excluded from the analysis that follows.

Research Questions, Procedures for Investigation, and Data Collection

Activities that could encourage students to take responsibility for their learning were defined as:

- ***Generating research questions***: Students, either individually or in small groups, play a role in developing a research question that they will investigate in an independent practical activity. The students may have complete freedom, such as in the definition of a question for a science fair project, or be constrained to a particular topic area or a set of options provided by the teacher. For example, the teacher may allow students to generate a research question about what promotes mold growth, or the teacher may provide a list of five variables related to mold growth and ask students to pick one variable and generate a research question about it.
- ***Designing procedures for investigation***: Students, either individually or in small groups, play a role in planning the procedures that will be used in an independent practical activity. The students may have complete freedom or be constrained by a set of options or materials provided by the teacher. For example, students are provided with bean seeds and related materials and told to design an investigation to explore the effect of light, different colors of light, temperature, gravity, or soil composition on plant growth.
- ***Collecting data***: Students, either individually or in small groups, collect qualitative or quantitative data during independent or whole-class work through observation of phenomena and/or manipulation of physical objects. For example, students collect quantitative data about their pulse rates before and after exercise, or they generate qualitative descriptions resulting from the heating of different metals.

Appendix E:
Additional Figures and Tables

Content Subcategories

Tables E.1 to E.5 present estimates of the percentage of science lessons that addressed various science content subcategories. These tables provide more detailed information that that contained in figure 4.1 (see chapter 4). The science topics in the lessons were identified using the TIMSS *Guidebook to Examine School Curricula* (McNeely 1997), which provided a common, international frame of reference for talking about science content.

The content subcategories shown in tables E.1 to E.5 specify topics at the level typically used by the classroom teachers in describing the content of the lesson on the questionnaires (e.g., rocks and soil, organs and tissues, electricity, and chemical changes). Although multiple science topics may be included in any science lesson, only the primary science topic for each lesson was identified. The primary topic was defined as the topic that was addressed for the longest amount of science instruction time.

The following topic subcategories included too few cases to calculate reliable estimates in all five countries:

- earth science: atmosphere; beyond the solar system; bodies of water; composition; earth in the solar system; earth's history; evolution of the universe; ice forms; land forms; physical cycles;
- life science: animal behavior; biochemical processes in cells; biochemistry of genetics; biomes and ecosystems; cells; energy handling; habitats and niches; interdependence of life; life cycles; nutrition; other organisms;
- physics: dynamics of motion; explanation of physical changes; kinetic theory; quantum theory and fundamental particles; relativity theory; time, space, and motion; wave phenomena; and
- chemistry: crystals; electrochemistry; energy and chemical change; explanations of chemical changes; macromolecules, nuclear chemistry; organic and biochemical changes; rate of change and equilibriums; subatomic particles.

Tables E.6 and E.7, and figures E.1 and E.2 present estimates referred to in other parts of the report but not shown in a figure or table.

Table E.1. Percentage distribution of Australian eighth-grade science lessons devoted to subordinated categories of earth science, life science, physics, chemistry, and other areas: 1999

Discipline and area	Percent of lessons
Life science	
Organs and tissues	5!
Plants and fungi	5
Reproduction	3!
Physics	
Electricity	10
Energy types, sources, and conversions	10
Fluid behavior	3!
Light	6
Types of forces	8
Chemistry	
Chemical changes	3!
Chemical properties	8
Other areas	
Interactions of science, technology, and society	3!

!Interpret data with caution. Estimate is unstable.

NOTE: Total does not sum to 100 because of data not presented for subcategories without reliable estimates. The following subcategories included too few cases to calculate reliable estimates: earth science: building and breaking of earth's surface; planets in the solar system; rocks and soil; weather and climate; life science: animals; disease; evolution, speciation, and diversity; sensing and responding; variation and inheritance; physics: heat and temperature; magnetism; physical changes; physical properties; sound and vibration; chemistry: atoms, ions, and molecules; classification of matter; other areas: nature of scientific knowledge; science and mathematics.

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

Table E.2. Percentage distribution of Czech eighth-grade science lessons devoted to subordinated categories of earth science, life science, physics, chemistry, and other areas: 1999

Discipline and area	Percent of lessons
Life science	
Organs and tissues	19
Physics	
Electricity	8
Fluid behavior	3!
Heat and temperature	4!
Physical changes	6
Chemistry	
Atoms, ions, and molecules	3!
Chemical changes	4!
Chemical properties	5!
Classification of matter	11
Other areas	
Interactions of science, technology, and society	5
Science and mathematics	4!

!Interpret data with caution. Estimate is unstable.

NOTE: Total does not sum to 100 because of data not presented for subcategories without reliable estimates. The following subcategories included too few cases to calculate reliable estimates: earth science: building and breaking of earth's surface; planets in the solar system; rocks and soil; weather and climate; life science: animals; disease; evolution, speciation, and diversity; plants and fungi; reproduction; sensing and responding; variation and inheritance; physics: energy types, sources, and conversions; light; magnetism; physical properties; sound and vibration; types of forces; other areas: nature of scientific knowledge.

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

Table E.3. Percentage distribution of Japanese eighth-grade science lessons devoted to subordinated categories of earth science, life science, physics, chemistry, and other areas: 1999

Discipline and area	Percent of lessons
Earth science	
Weather and climate	7
Life science	
Animals	3!
Organs and tissues	13
Sensing and responding	3
Physics	
Electricity	28
Magnetism	4!
Chemistry	
Chemical changes	33

!Interpret data with caution. Estimate is unstable.

NOTE: Total does not sum to 100 because of data not presented for subcategories without reliable estimates. The following subcategories included too few cases to calculate reliable estimates: earth science: building and breaking of earth’s surface; planets in the solar system; rocks and soil; life science: disease; evolution, speciation, and diversity; plants and fungi; reproduction; variation and inheritance; physics: energy types, sources, and conversions; fluid behavior; heat and temperature; light; physical changes; physical properties; sound and vibration; types of forces; chemistry: atoms, ions, and molecules; chemical properties; classification of matter; other areas: interactions of science, technology, and society; nature of scientific knowledge; science and mathematics.

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

Table E.4. Percentage distribution of Dutch eighth-grade science lessons devoted to subordinated categories of earth science, life science, physics, chemistry, and other areas: 1999

Discipline and area	Percent of lessons
Life science	
Organs and tissues	16
Reproduction	3!
Sensing and responding	3!
Physics	
Electricity	3!
Heat and temperature	9
Light	10
Sound and vibration	14
Types of forces	4!
Chemistry	
Chemical changes	5!
Chemical properties	4!
Other areas	
Science and mathematics	2!

!Interpret data with caution. Estimate is unstable.

NOTE: Total does not sum to 100 because of data not presented for subcategories without reliable estimates. The following subcategories included too few cases to calculate reliable estimates: earth science: building and breaking of earth's surface; planets in the solar system; rocks and soil; weather and climate; life science: animals; disease; evolution, speciation, and diversity; plants and fungi; variation and inheritance; physics: energy types, sources, and conversions; fluid behavior; magnetism; physical changes; physical properties; chemistry: atoms, ions, and molecules; classification of matter; other areas: interactions of science, technology, and society; nature of scientific knowledge.

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

Table E.5. Percentage distribution of U.S. eighth-grade science lessons devoted to subordinated categories of earth science, life science, physics, chemistry, and other areas: 1999

Discipline and area	Percent of lessons
Earth science	
Building and breaking of earth's surface	2!
Planets in the solar system	4!
Rocks and soil	7
Weather and climate	5
Life science	
Disease	6!
Evolution, speciation, and diversity	3!
Variation and inheritance	3!
Physics	
Electricity	3!
Physical properties	3!
Chemistry	
Atoms, ions, and molecules	5!
Chemical properties	2!
Classification of matter	4!
Other areas	
Interactions of science, technology, and society	4!
Nature of scientific knowledge	6!

!Interpret data with caution. Estimate is unstable.

NOTE: Total does not sum to 100 because of data not presented for subcategories without reliable estimates. The following subcategories included too few cases to calculate reliable estimates: life science: animals; organs and tissues; plants and fungi; reproduction; sensing and responding; physics: energy types, sources, and conversions; fluid behavior; heat and temperature; light; magnetism; physical changes; sound and vibration; types of forces; chemistry: chemical changes; other areas: science and mathematics.

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

Table E.6. Percentage distribution of eighth-grade science lessons that developed content primarily by making connections and by acquiring facts, definitions, and algorithms, by content disciplines and country: 1999

	Country[1]				
Discipline and teaching method	AUS	CZE	JPN	NLD	USA
Earth science					
Making connections[2]	3!	‡	5	‡	5
Acquiring facts, definitions, and algorithms[3]	‡	‡	‡	‡	23
Life science					
Making connections[4]	9	‡	10	‡	‡
Acquiring facts, definitions, and algorithms[5]	15	35	9	30	14
Physics					
Making connections[6]	32	13	31	15	9!
Acquiring facts, definitions, and algorithms[7]	16	16	5	32	8
Chemistry					
Making connections[8]	11	13	27	5!	7
Acquiring facts, definitions, and algorithms[9]	4	11	10	4!	11
Other areas					
Making connections[10]	3!	‡	‡	5!	9
Acquiring facts, definitions, and algorithms[11]	5	9	‡	6	11

!Interpret data with caution. Estimate is unstable.

‡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] Earth science: Making connections: No measurable differences detected.

[3] Earth science: Acquiring facts, definitions, and algorithms: No differences detected.

[4] Life science: Making connections: No measurable differences detected.

[5] Life science: Acquiring facts, definitions, and algorithms: CZE>AUS, JPN, USA; NLD>JPN.

[6] Physics: Making connections: AUS>CZE, USA; JPN>USA.

[7] Physics: Acquiring facts, definitions, and algorithms: NLD>JPN, USA.

[8] Chemistry: Making connections: JPN>NLD, USA.

[9] Chemistry: Acquiring facts, definitions, and algorithms: No measurable differences detected.

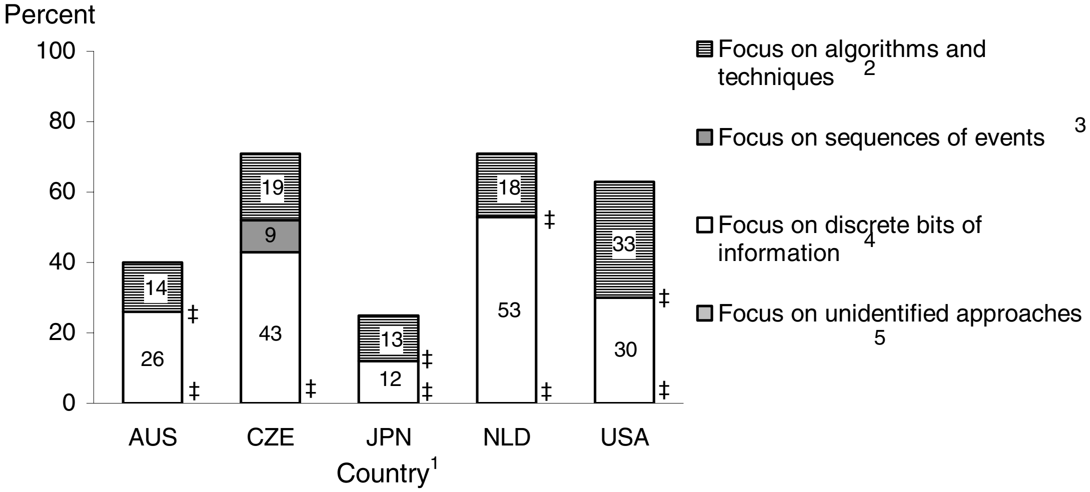
[10] Other areas: Making connections: No measurable differences detected.

[11] Other areas: Acquiring facts, definitions, and algorithms: No measurable differences detected.

NOTE: Totals 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, Video Study, 1999.

Figure E.1. Percentage distribution of eighth-grade science lessons that primarily developed science content by focusing on different approaches to acquiring facts, definitions, and algorithms, 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] Focus on algorithms and techniques: No measurable differences detected.

[3] Focus on sequences of events: No measurable differences detected.

[4] Focus on discrete bits of information: NLD>AUS, JPN; CZE>JPN.

[5] Focus on unidentified approaches: No measurable differences detected.

NOTE: Only those lessons identified as developing science content primarily by acquiring facts, definitions, and algorithms are included in the analysis. See figure 5.5 for the total percentage of lessons that developed content by acquiring facts, definitions, and algorithms.

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

Table E.7. Percentage distribution of eighth-grade science lessons that were judged to include challenging or a mix of basic and challenging content, and basic content, by content topics and country: 1999

	Country[1]				
Discipline and teaching method	AUS	CZE	JPN	NLD	USA
Earth science					
Challenging or a mix of basic and challenging[2]	‡	‡	‡	‡	13
Basic[3]	4!	‡	6	‡	14
Life science					
Challenging or a mix of basic and challenging[4]	9	30	10	27	10
Basic[5]	14	6	9	4	7!
Physics					
Challenging or a mix of basic and challenging[6]	26	24	15	20	11
Basic[7]	22	4	20	26	6
Chemistry					
Challenging or a mix of basic and challenging[8]	4!	18	9	‡	16
Basic[9]	11	6	28	6	‡
Other areas					
Challenging or a mix of basic and challenging[10]	‡	7	‡	‡	‡
Basic[11]	6	‡	‡	10	19

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

!Interpret data with caution. Estimate is unstable.

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

[2] Earth science: Challenging or a mix of challenging and basic: No measurable differences detected.

[3] Earth science: Basic: No measurable differences detected.

[4] Life science: Challenging or a mix of challenging and basic: CZE>AUS, JPN, USA; NLD>JPN.

[5] Life science: Basic: No measurable differences detected.

[6] Physics: Challenging or a mix of challenging and basic: No differences detected.

[7] Physics: Basic: AUS, NLD>CZE, USA; JPN>USA.

[8] Chemistry: Challenging or a mix of challenging and basic: CZE, USA>AUS.

[9] Chemistry: Basic: JPN>AUS, CZE, NLD.

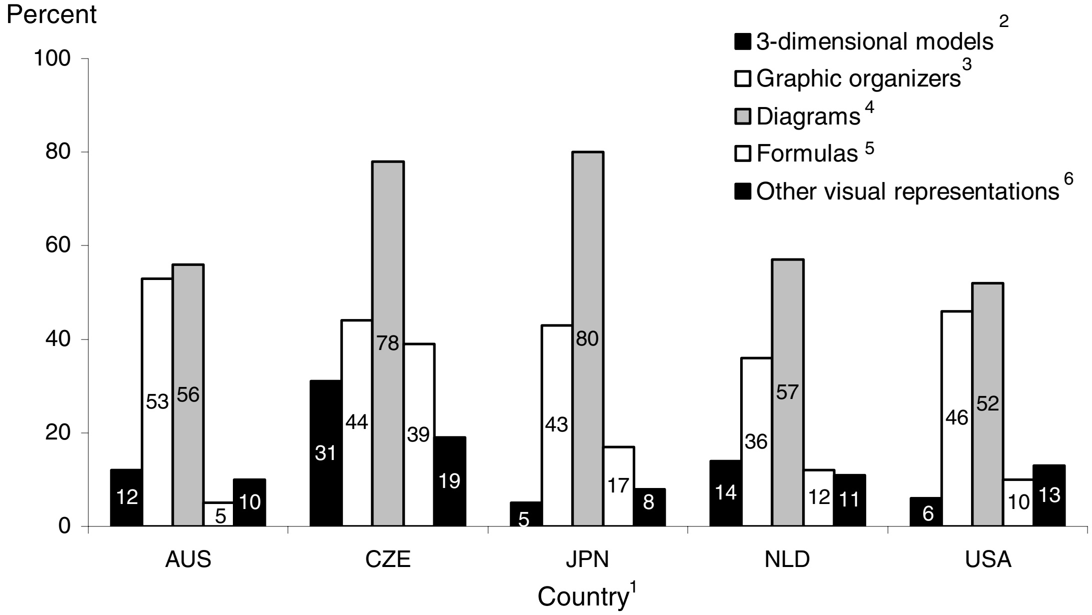
[10] Other areas: Challenging or a mix of challenging and basic: No difference detected.

[11] Other areas: Basic: No measurable differences detected.

NOTE: Totals may not sum to 100 because of rounding and data not reported. 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, Video Study, 1999.

Figure E.2. Percentage of eighth-grade science lessons that incorporated various types of visual representations to support science knowledge, by country: 1999



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

[2] 3-dimensional models: CZE>JPN, USA.

[3] Graphic organizers: No measurable differences detected.

[4] Diagrams: JPN>AUS, NLD, USA; CZE>USA.

[5] Formulas: CZE>AUS, JPN, NLD, USA.

[6] Other visual representations: No measurable differences detected.

NOTE: A lesson may include more than one type of visual representation.

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