10 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).

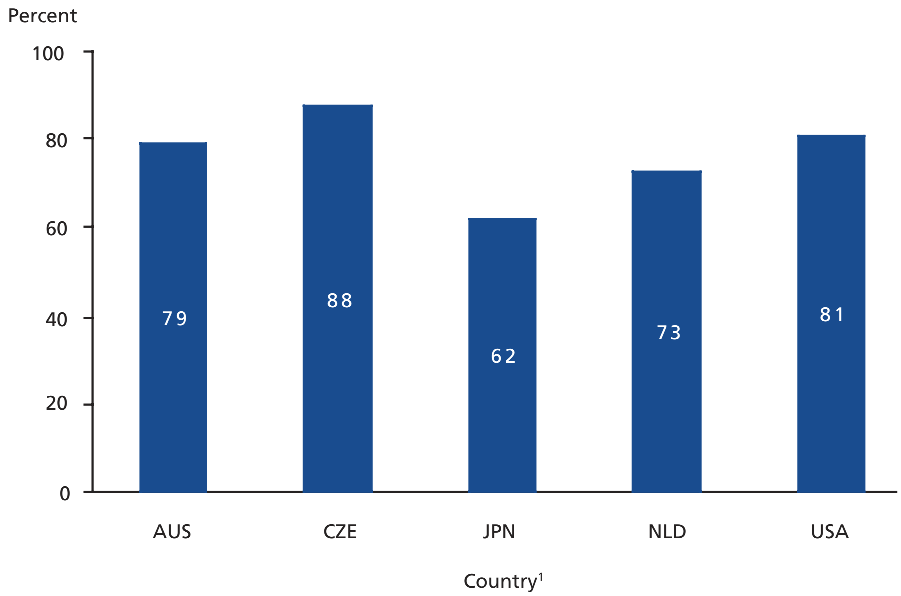
Role of Real-Life Issues in the Lessons

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

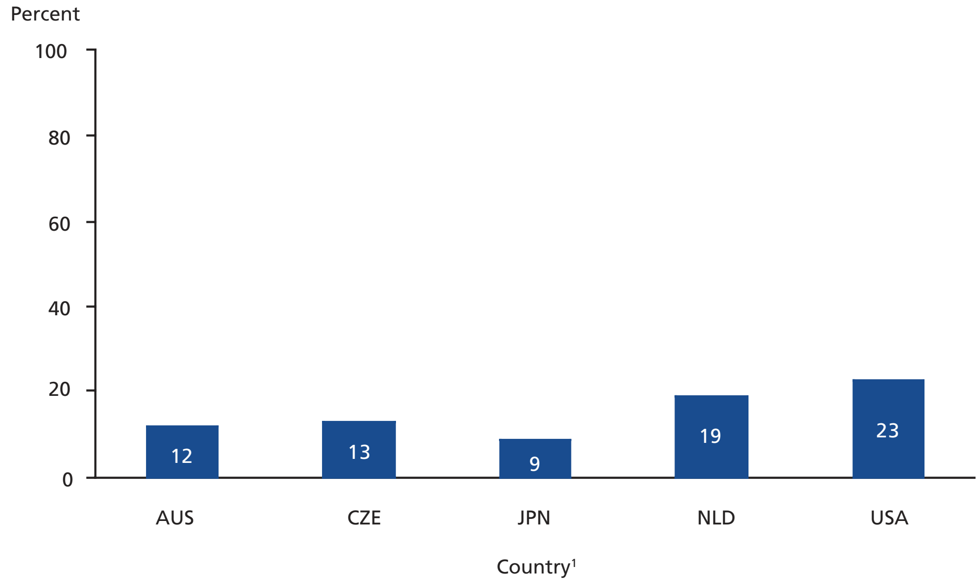


[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: CZE>JPN.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

Figure 10.3 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.

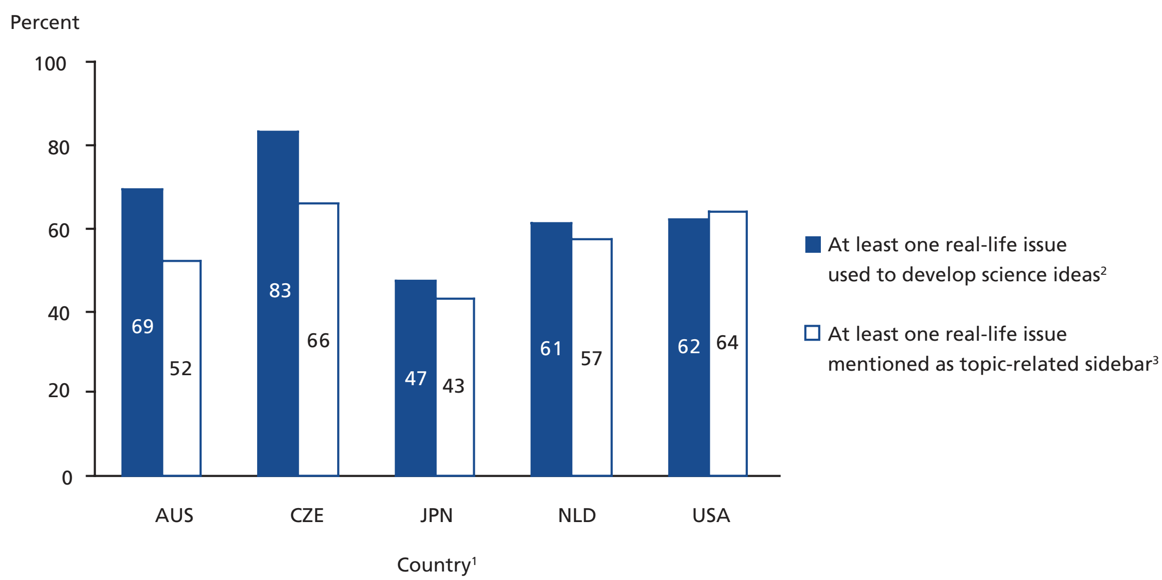
- Teachers in more Czech science lessons used one or more real-life issues to develop science ideas than did teachers in Dutch, Japanese, and U.S. science lessons (figure 10.3).
- Teachers of Czech and Dutch eighth-grade science lessons spent more lesson time, on average, developing science ideas through 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 10.2. Average percentage of science instruction time in eighth-grade science lessons during which real-life issues were raised, by country: 1999



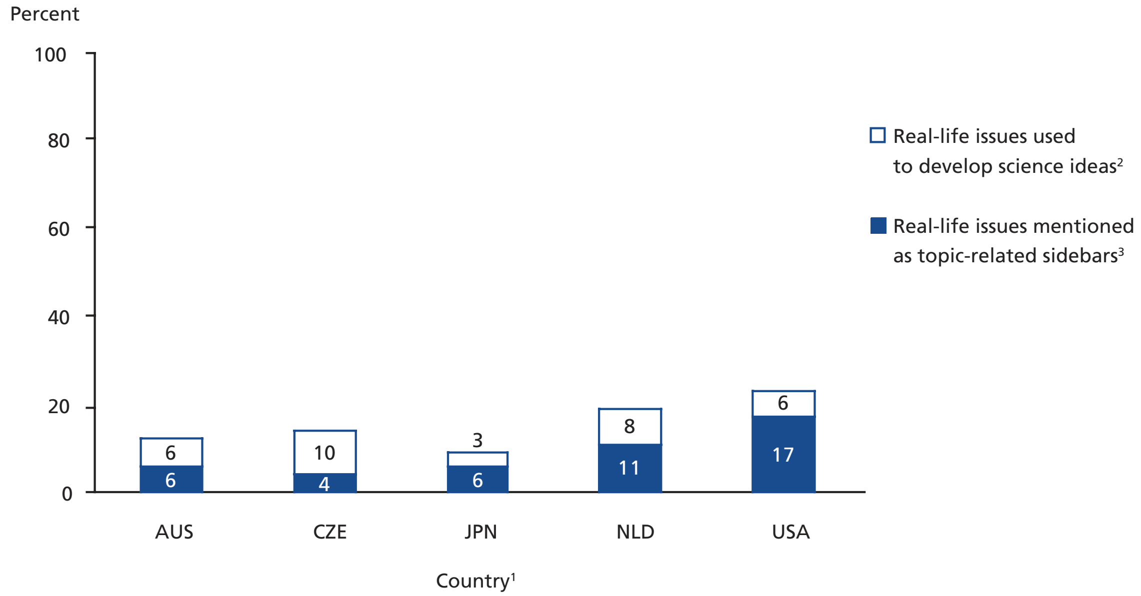
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: No measurable differences detected. Analysis is limited to those portions of the lessons focused on science instruction. See chapter 3, table 3.2 and figure 3.2 for more details.
SOURCE: U.S. Department of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

FIGURE 10.3. 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.

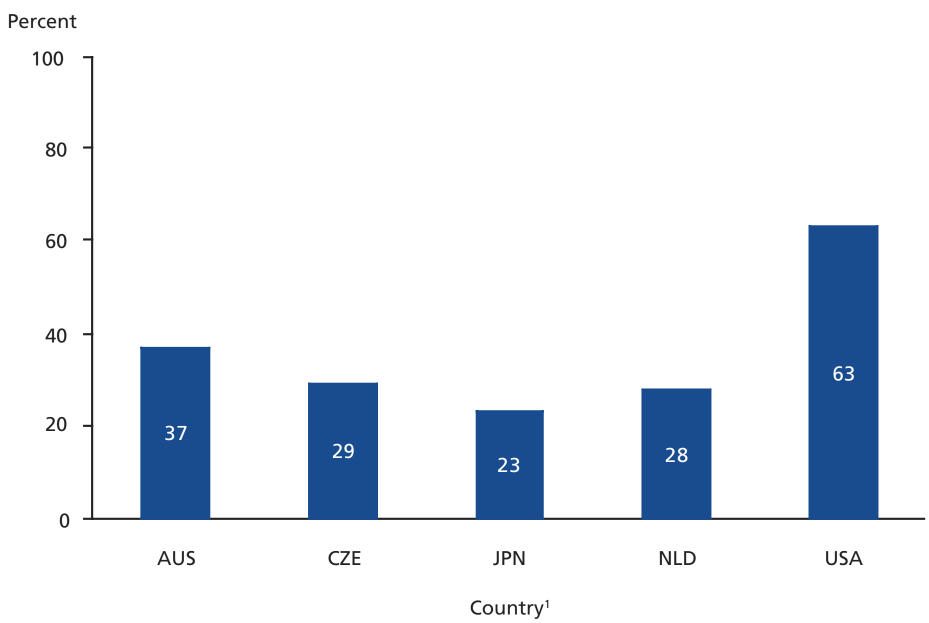
Motivating activities were defined as whole-class or independent activities that include at least one of the following elements:

- o surprising, exciting, and/or dramatic phenomena or demonstrations;
- o dramatic presentations or stories such as personal experience stories and role plays (Video clip example 10.3);
- o 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);
- o presentation and/or use of materials or objects that appeal to students' fascination such as novel gadgets or mysterious substances such as "goop"; and
- o 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 percentages 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.

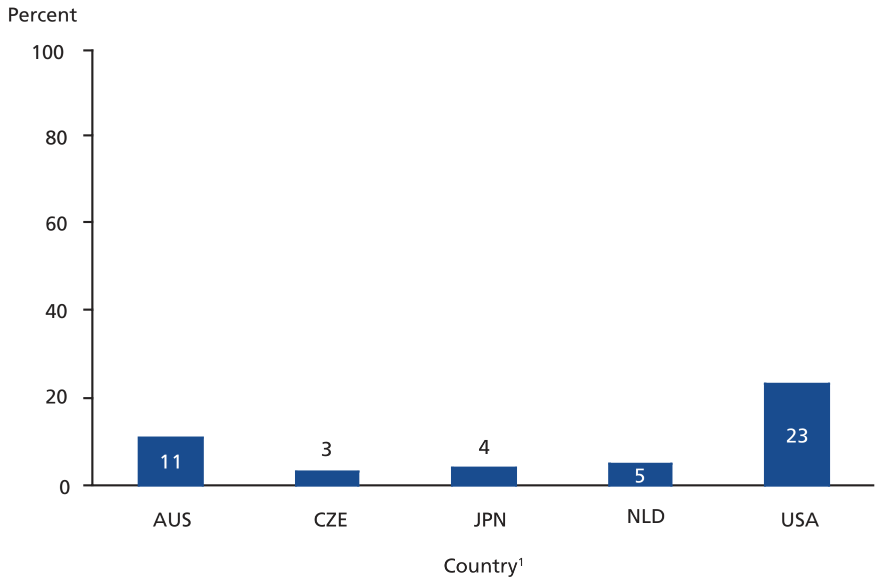
- More eighth-grade science lessons in the United States included potentially motivating activities (figure 10.5), and more instructional time was allocated for these motivating activities, than science lessons in the Czech Republic, Japan, and the Netherlands (figure 10.6).

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



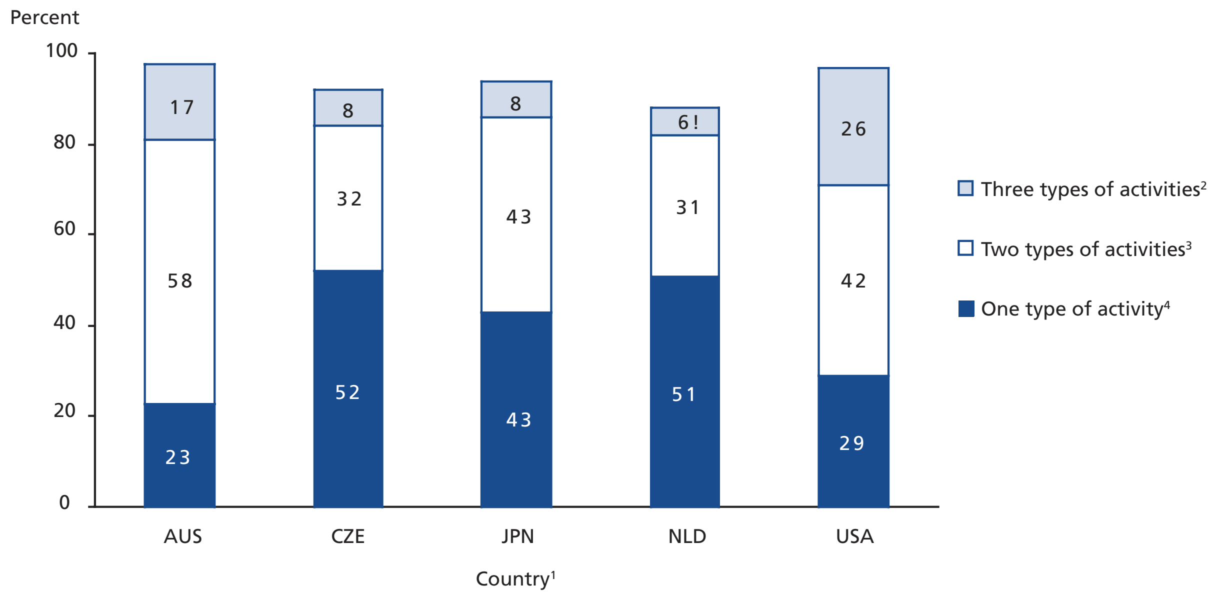
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: USA>CZE, JPN, NLD; AUS>CZE.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

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 10.7. 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.

11

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.

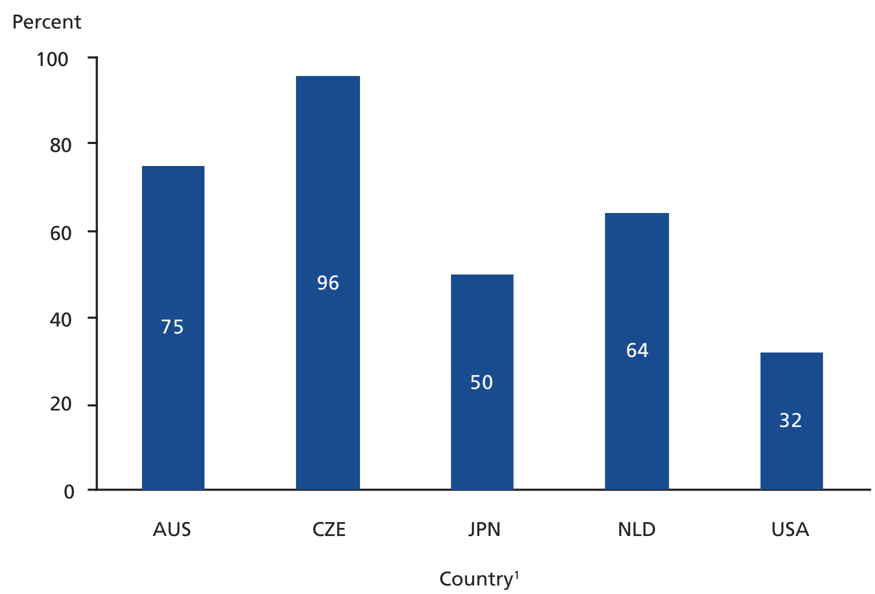
- Students independently started their science lesson by working on routine lesson openers in 26 percent of U.S. eighth-grade science lessons and in 5 percent of Japanese lessons (data not shown).

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



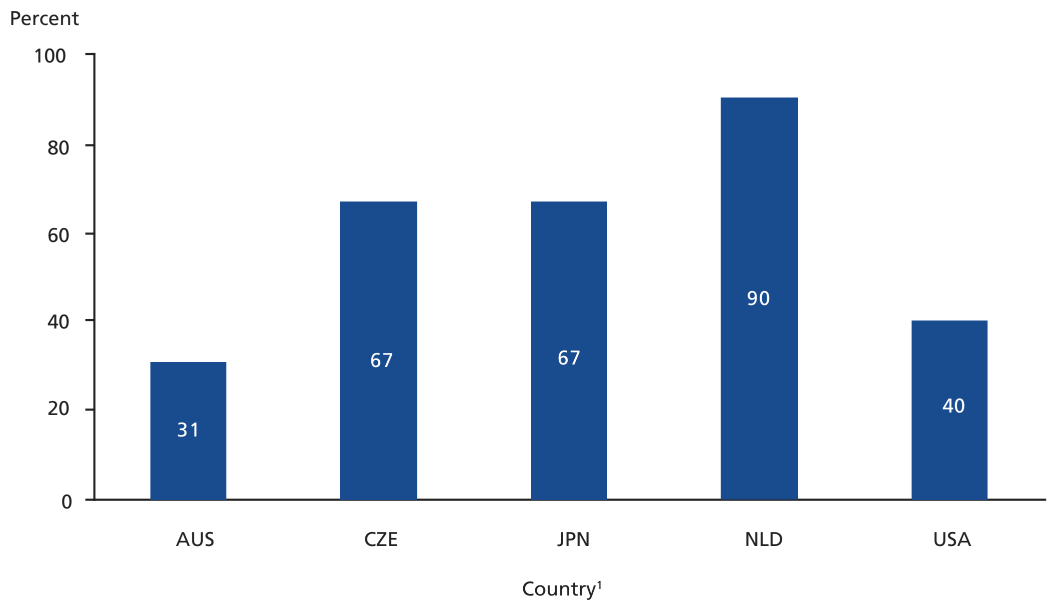
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: CZE>AUS, JPN, NLD, USA; AUS>JPN, USA; NLD>USA.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

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



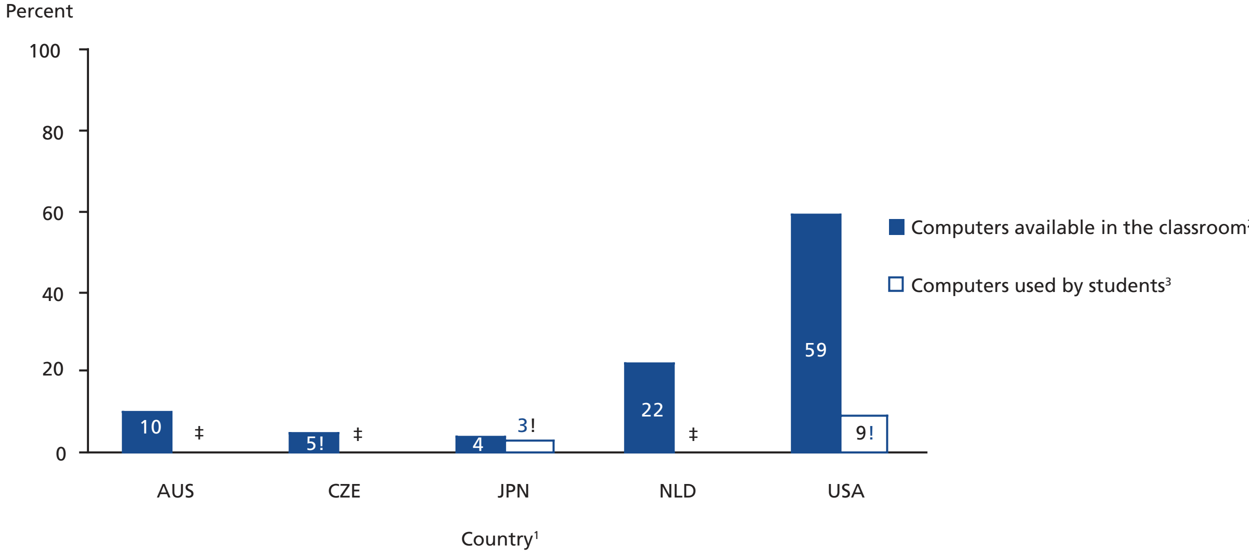
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: NLD>AUS, CZE, JPN, USA; CZE, JPN>AUS, USA.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

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



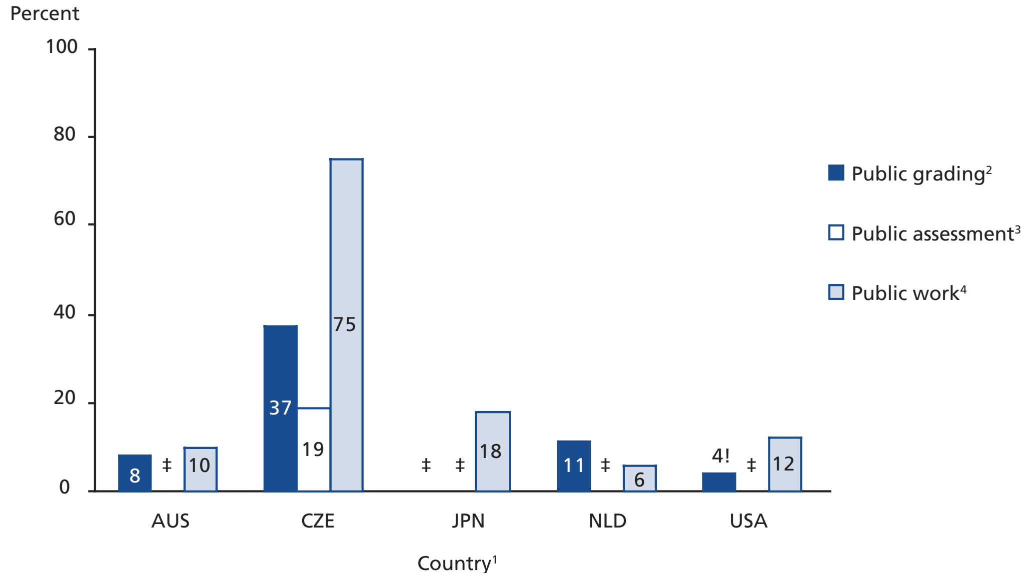
‡Reporting standards not met. Too few cases to be reported.
! Interpret data with caution. Estimate is unstable.
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
[2] Computers available in the classroom: USA>AUS, CZE, JPN, NLD; NLD>CZE, JPN.
[3] Computers used 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.

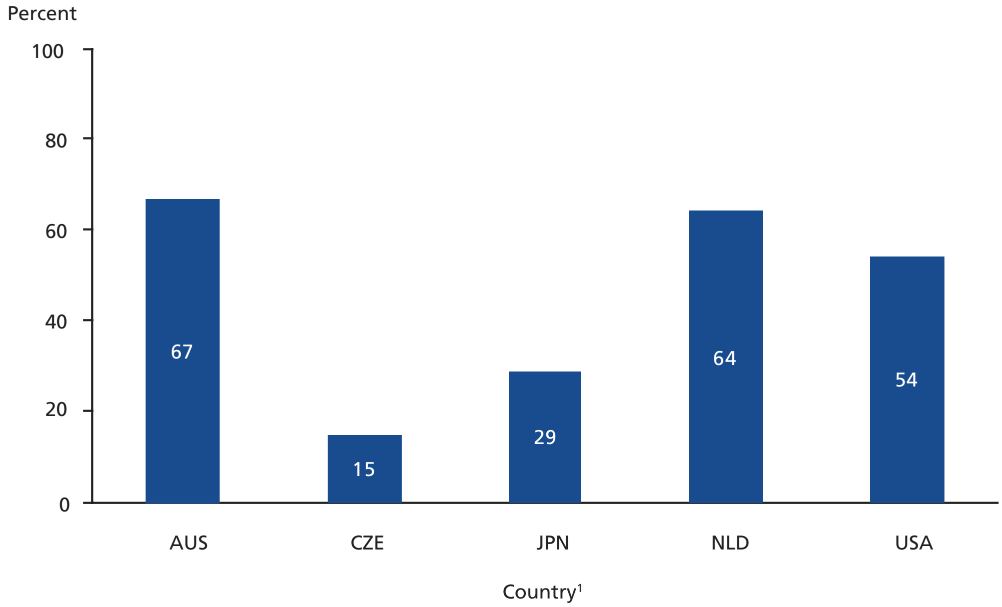
- Students made presentations in 4 to 9 percent of eighth-grade science lessons (data not shown).

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).

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.

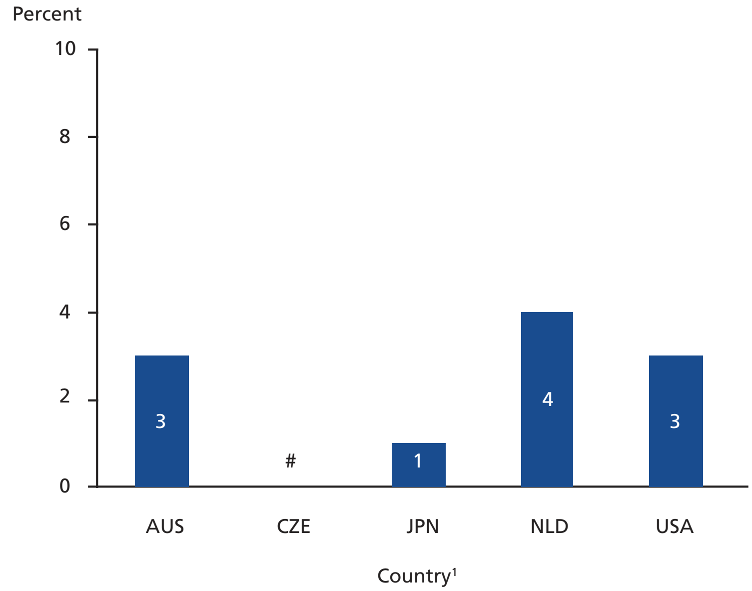
- In Australian, Dutch, and U.S. eighth-grade science lessons, students initiated a greater number of science questions, on average, than in Czech and Japanese lessons (figure 11.6).
- Although Czech lessons included more instruction time for public talk and discussions than the other four countries (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 11.6. 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.

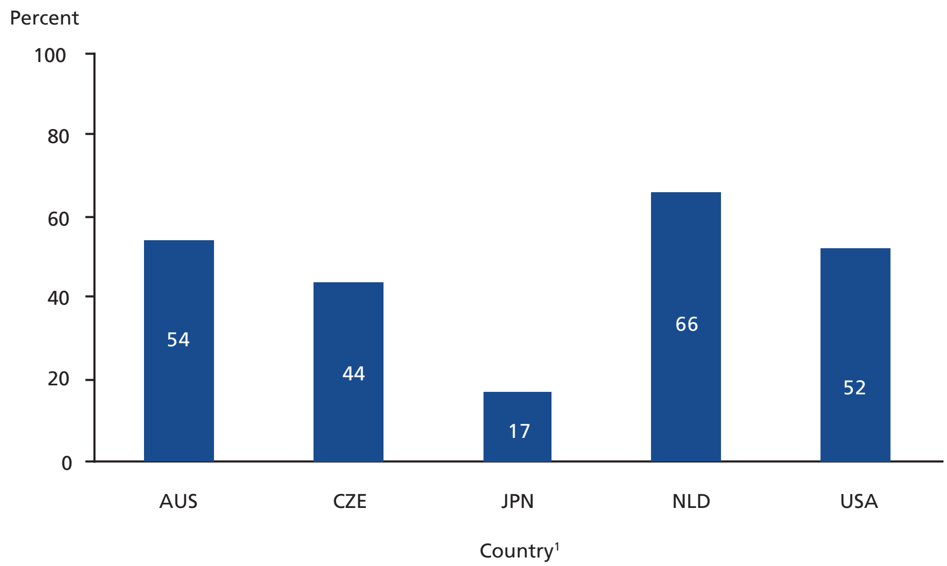
What Responsibilities Do Students Have Outside the Lesson?

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

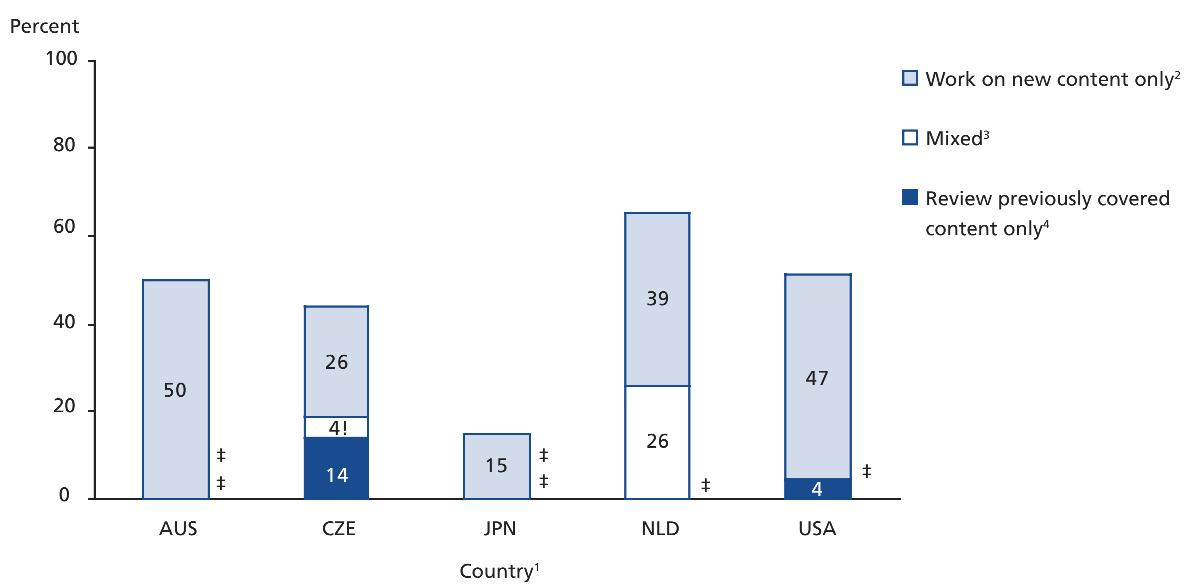
- Homework was assigned for future lessons in fewer Japanese eighth-grade science lessons compared to lessons in the other four countries, and in more Dutch lessons than in Czech lessons (figure 11.7).
- Homework assignments in more of the Czech lessons required students only to review previously covered 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).

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



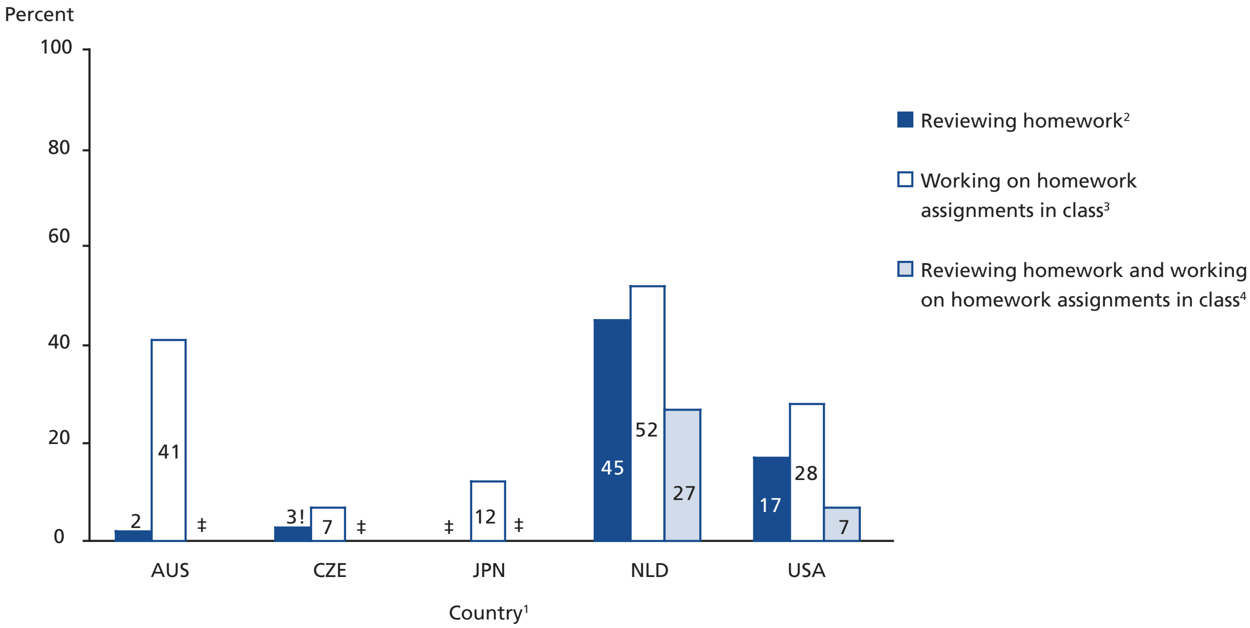
[1] AUS=Australia; CZE=Czech Republic; JPN=Japan; NLD=Netherlands; and USA=United States.
NOTE: AUS, CZE, NLD, USA>JPN; NLD>CZE.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics and Science Study (TIMSS), Video Study, 1999.

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

- 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).

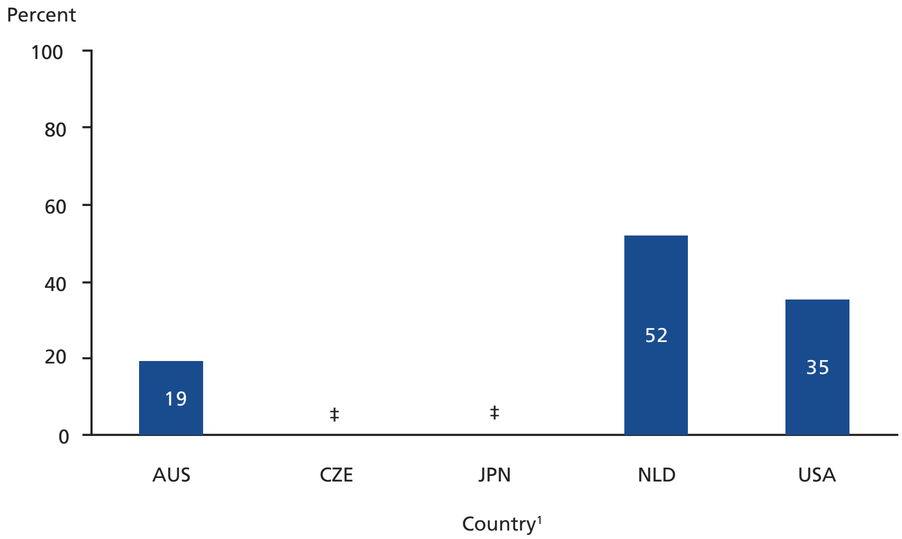
Self-Pacing and Checking Long-Term Assignments

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).

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.

- 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).

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.

12 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.

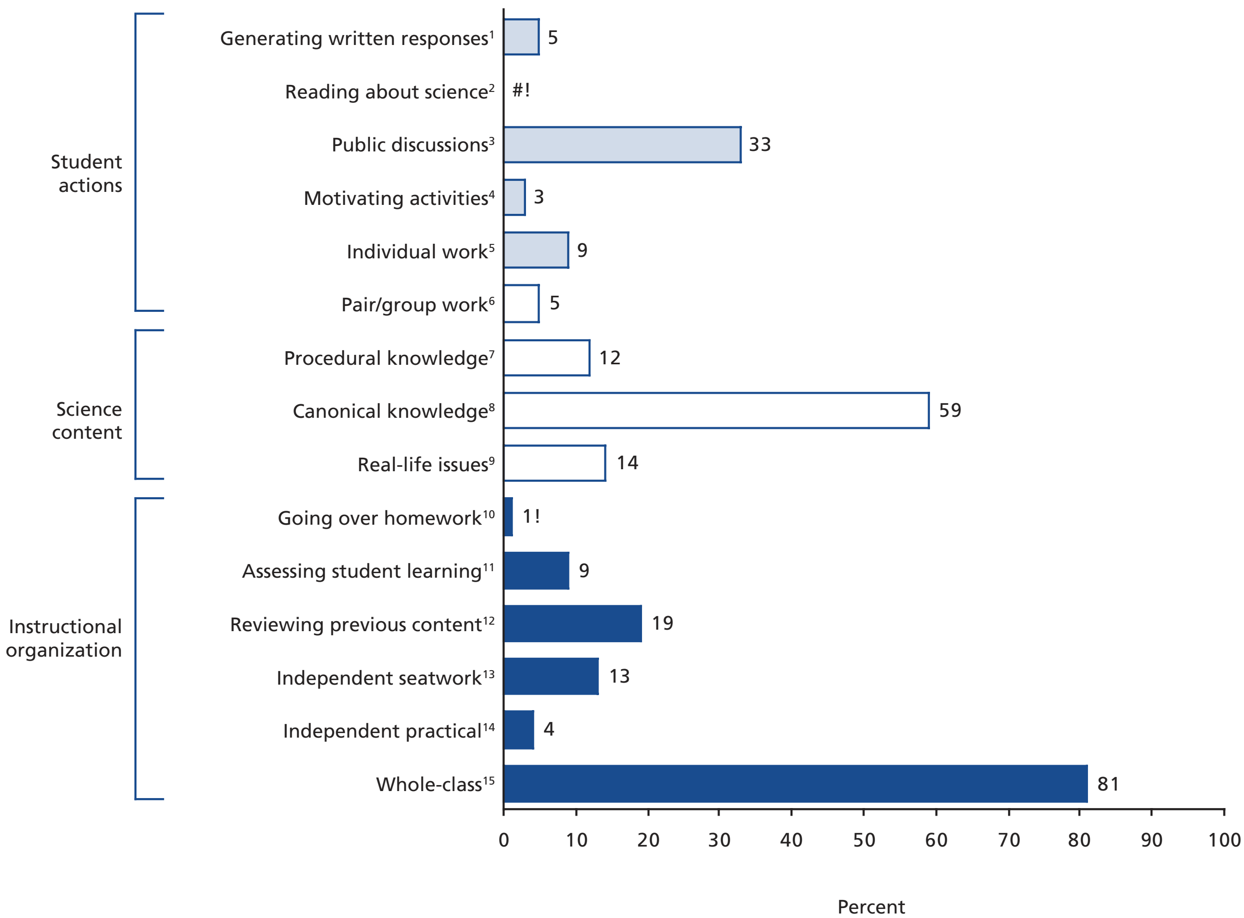
While relatively little time was allotted to practical activities in the Czech science lessons, students were given opportunities to interpret the first-hand data or phenomena that were generated during the lesson, usually through a whole-class practical activity. When students were given the opportunity 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).

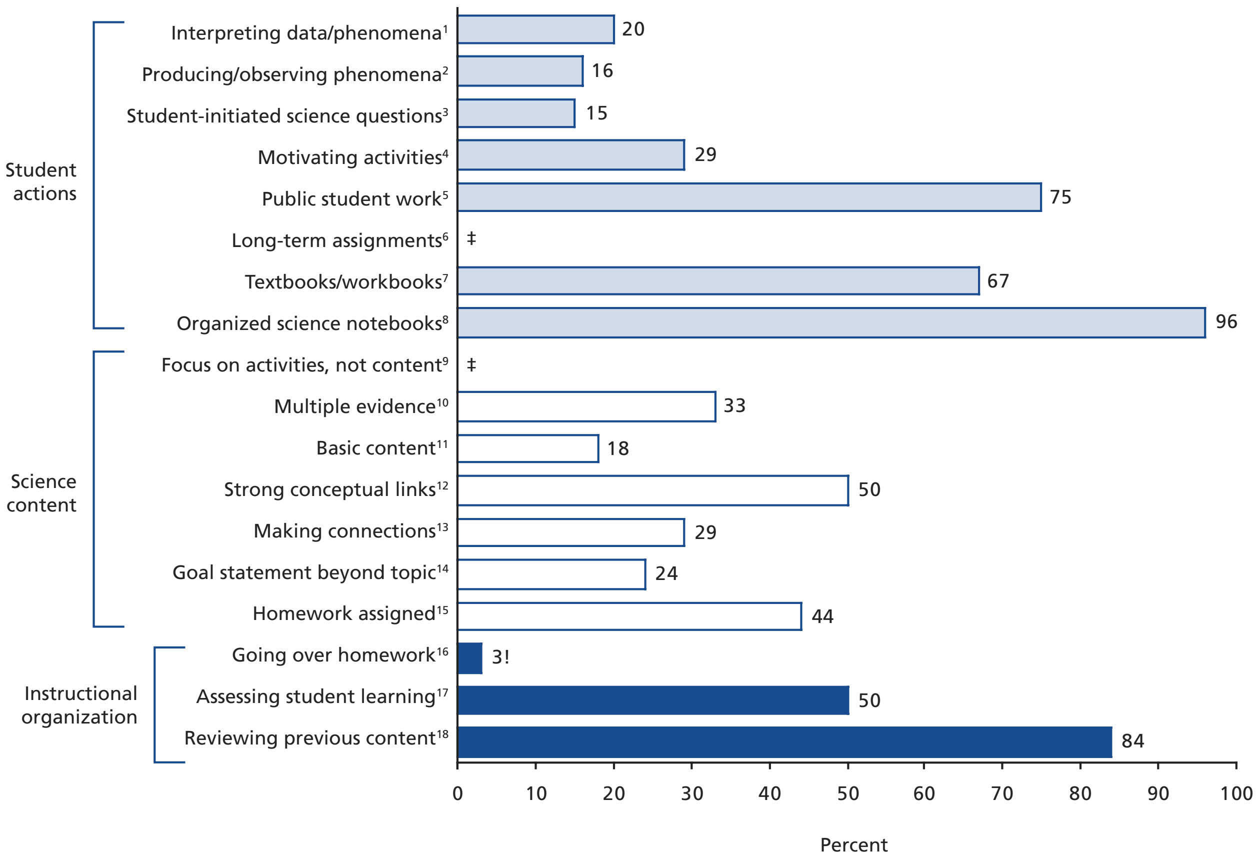
In describing their main goals for the videotaped lesson, teachers in more Czech lessons named students' knowledge about specific science information than teachers of science lessons in the other four countries (table 2.6). These self-reports appear to be consistent with the strong focus on science content in the Czech science lessons—teachers have science majors and state their goals in terms of informational science content knowledge.

FIGURE 12.1. Percentage of eighth-grade science lessons in the Czech Republic devoted to instructional organization, science content, and student actions: 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).

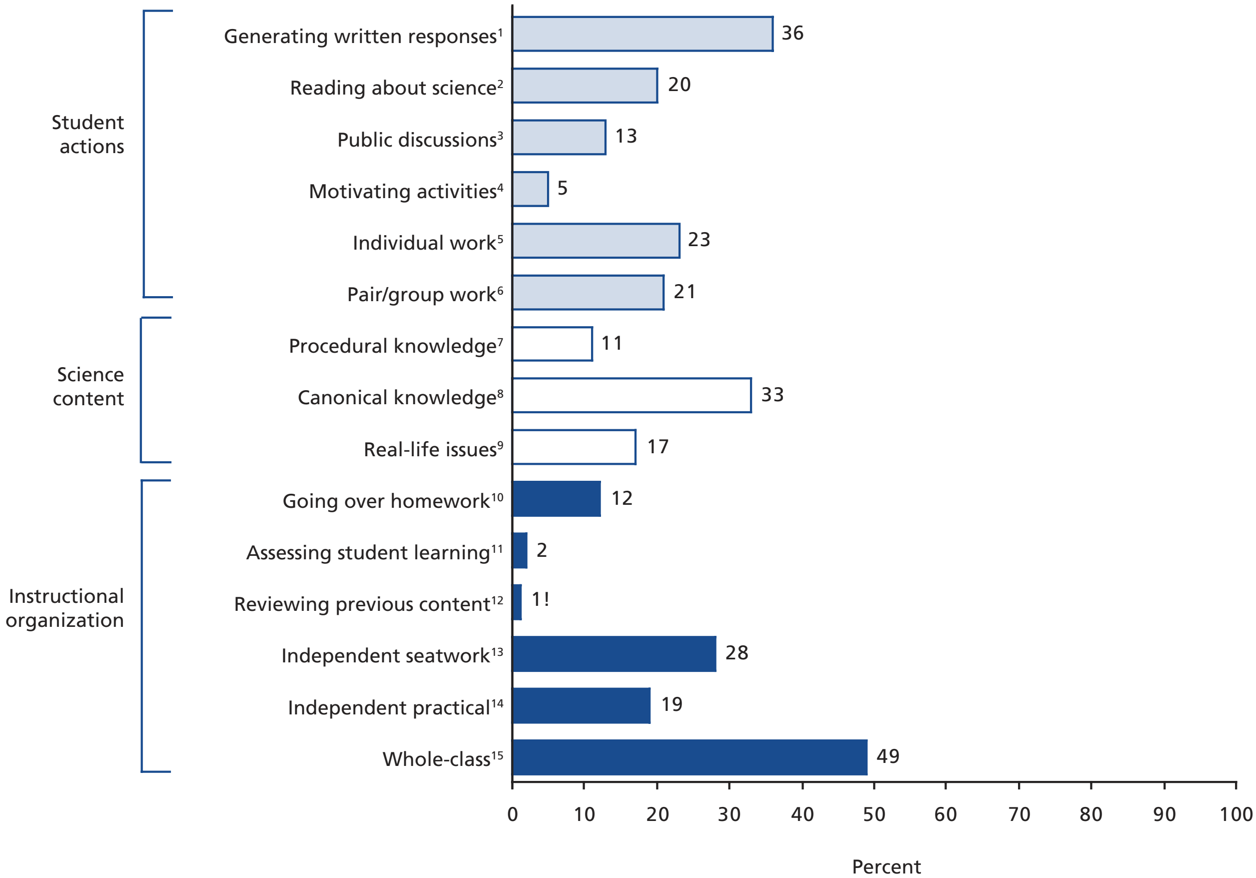
Whole-class activities included a focus on Dutch students' independent work. For example, the class reviewed homework assignments together in 45 percent of the science lessons, more than in the lessons of the other countries where reliable estimates could be made (figure 11.9).

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

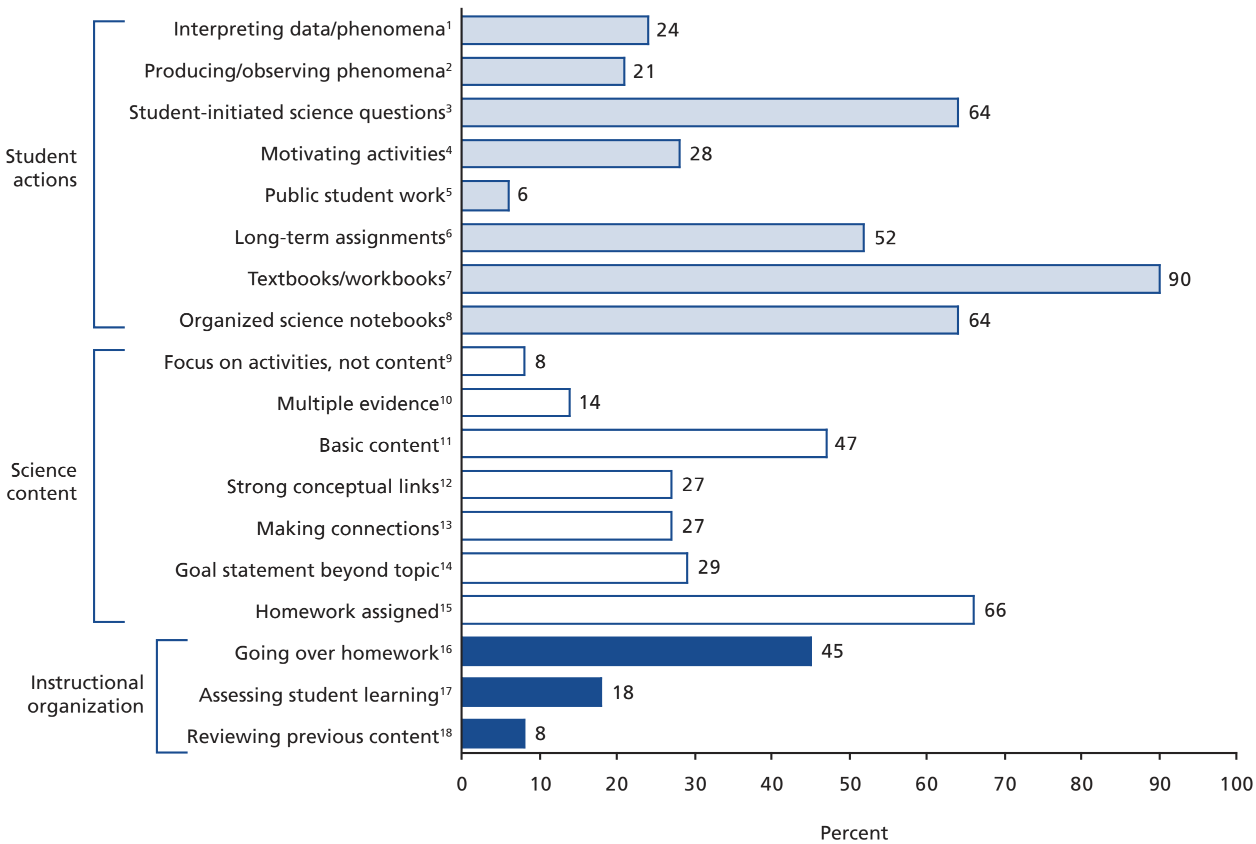
Ninety-nine percent of Dutch eighth-grade science lessons were taught by teachers who identified science as their major area of postsecondary study, more than in Australia and the United States (table 2.1). Furthermore, 39 percent of lessons were taught by Dutch science teachers who reported attaining 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 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).

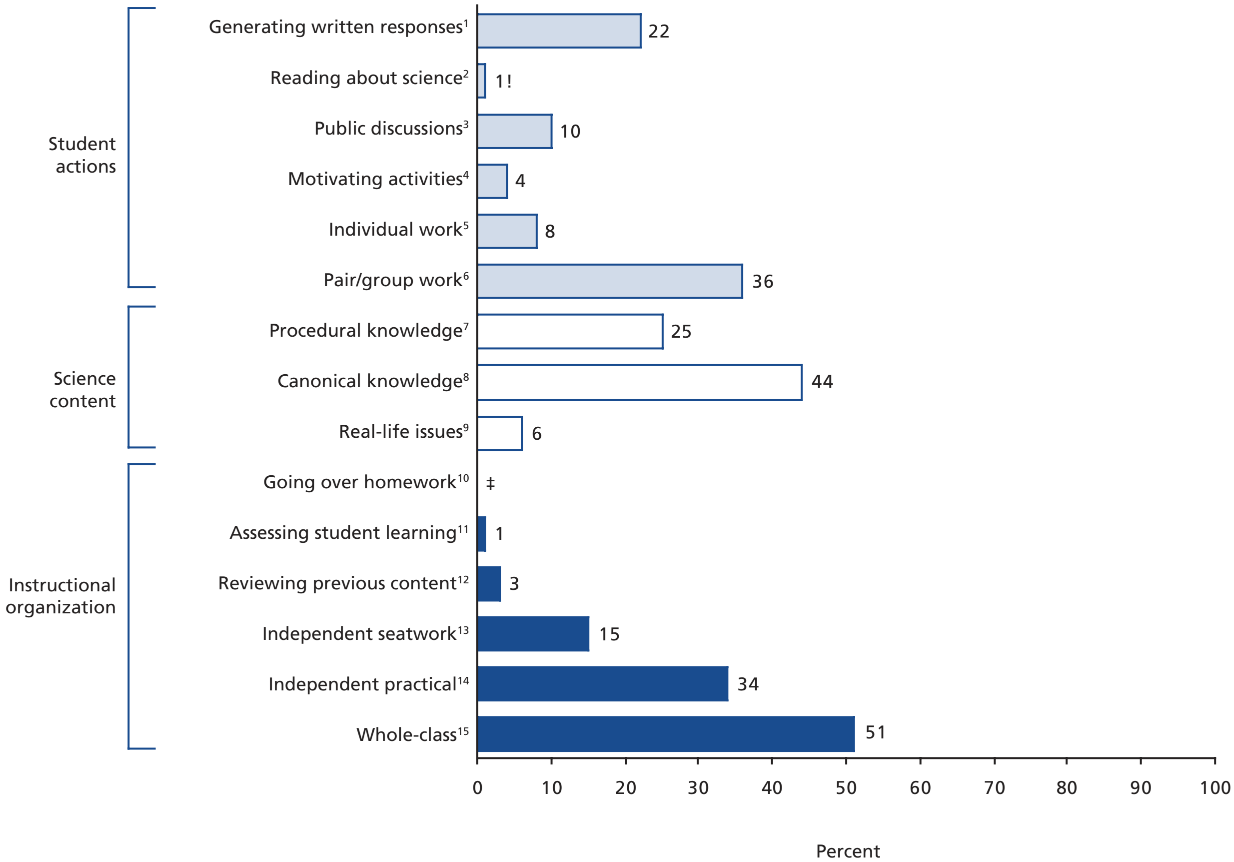
During whole-class time, Japanese students had additional but limited opportunities to carry out inquiry actions in relationship to whole-class practical activities such as teacher demonstrations (figure 7.7). Students made predictions about the whole-class practical activities in 11 percent of Japanese 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



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‡Reporting standards not met. Too few cases to be reported.
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[10] Going over homework: See table 3.3.
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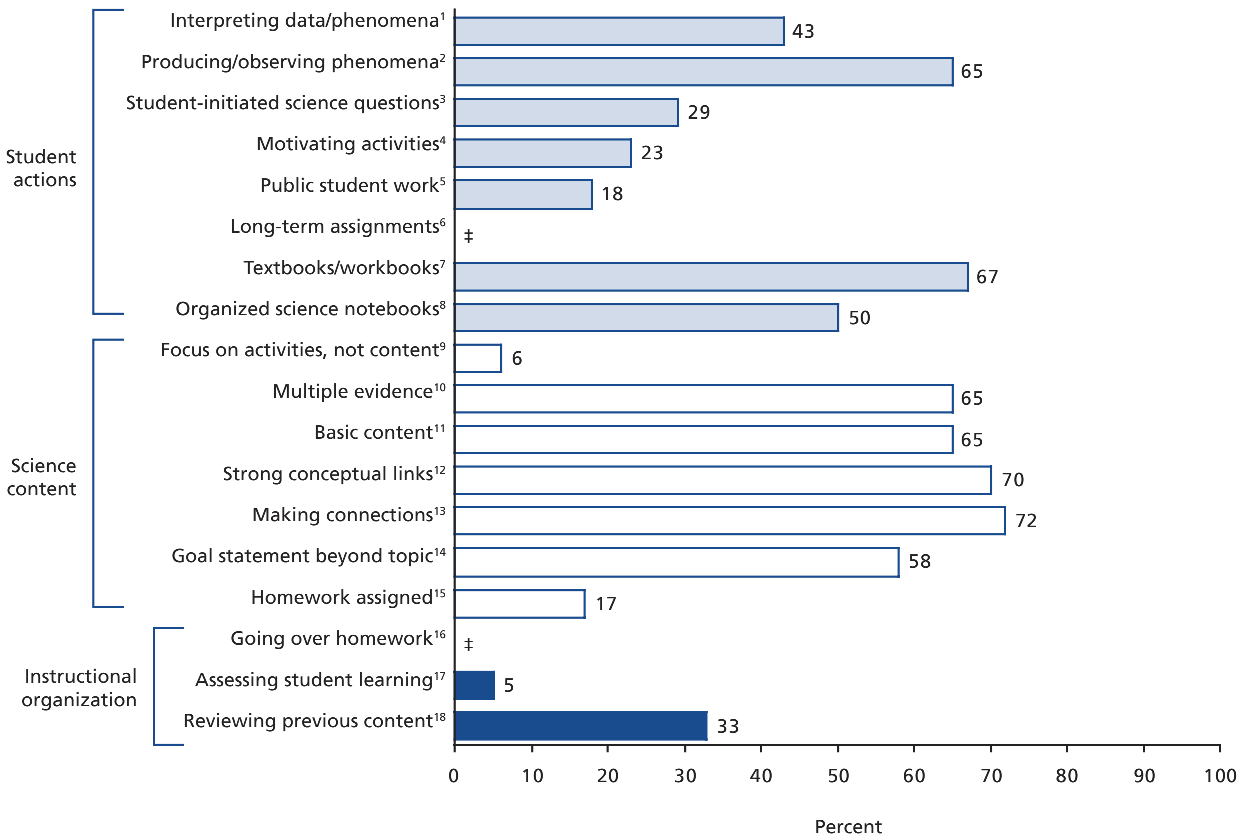
[12] Reviewing previous content: See table 3.3.
[13] Independent seatwork activities: See figure 3.7.
[14] Independent practical activities: See figure 3.7.
[15] Whole-class work: See figure 3.6
SOURCE: U.S. Department of Education, National Center for Education Statistics, Third International Mathematics 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).

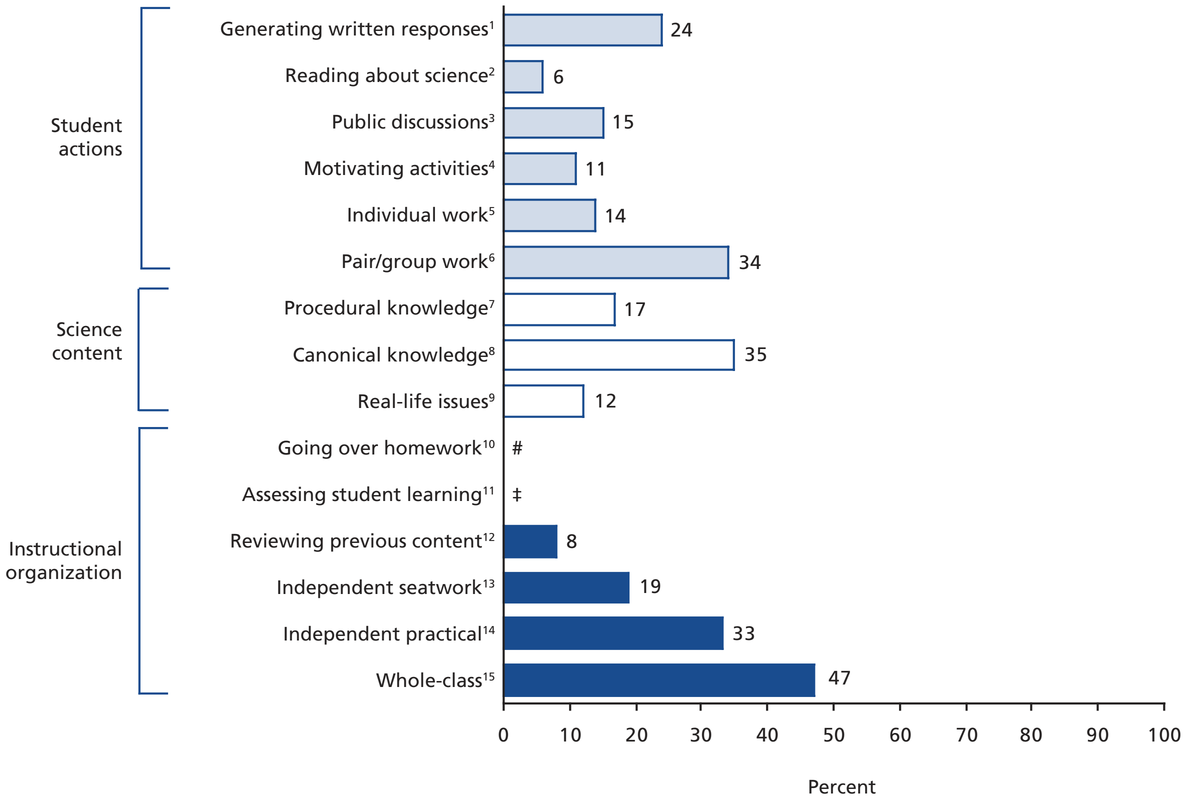
Students in Australian science lessons spent 47 percent of science instruction time participating in whole-class activities (figure 3.6). In some ways, Australian students appeared to be more actively involved during whole-class activities than Japanese students. For example, Australian students engaged 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

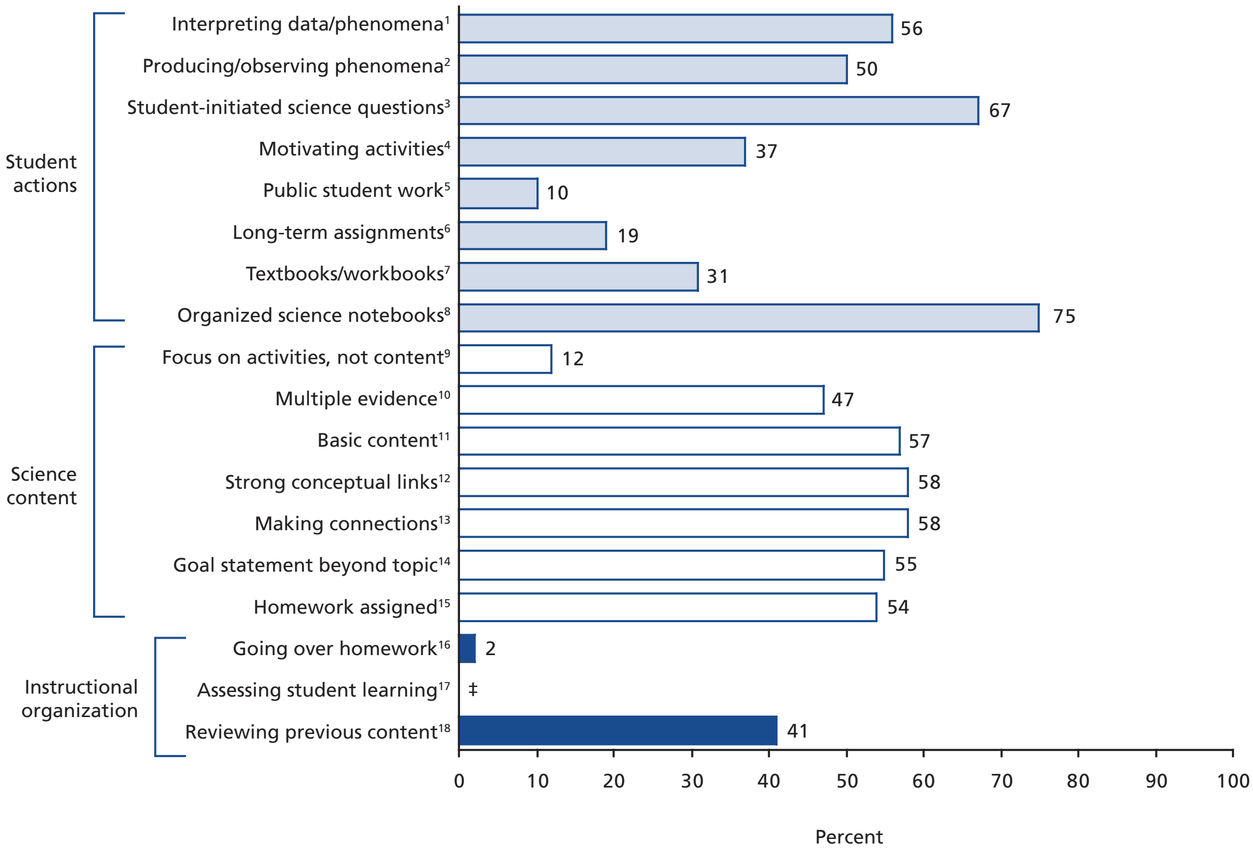
Eighty-seven percent of Australian eighth-grade science lessons were taught by teachers who identified a graduate or undergraduate major in a science field (table 2.1), and 85 percent of lessons were taught by teachers who reported attaining an undergraduate degree and 11 percent a graduate degree (figure 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).

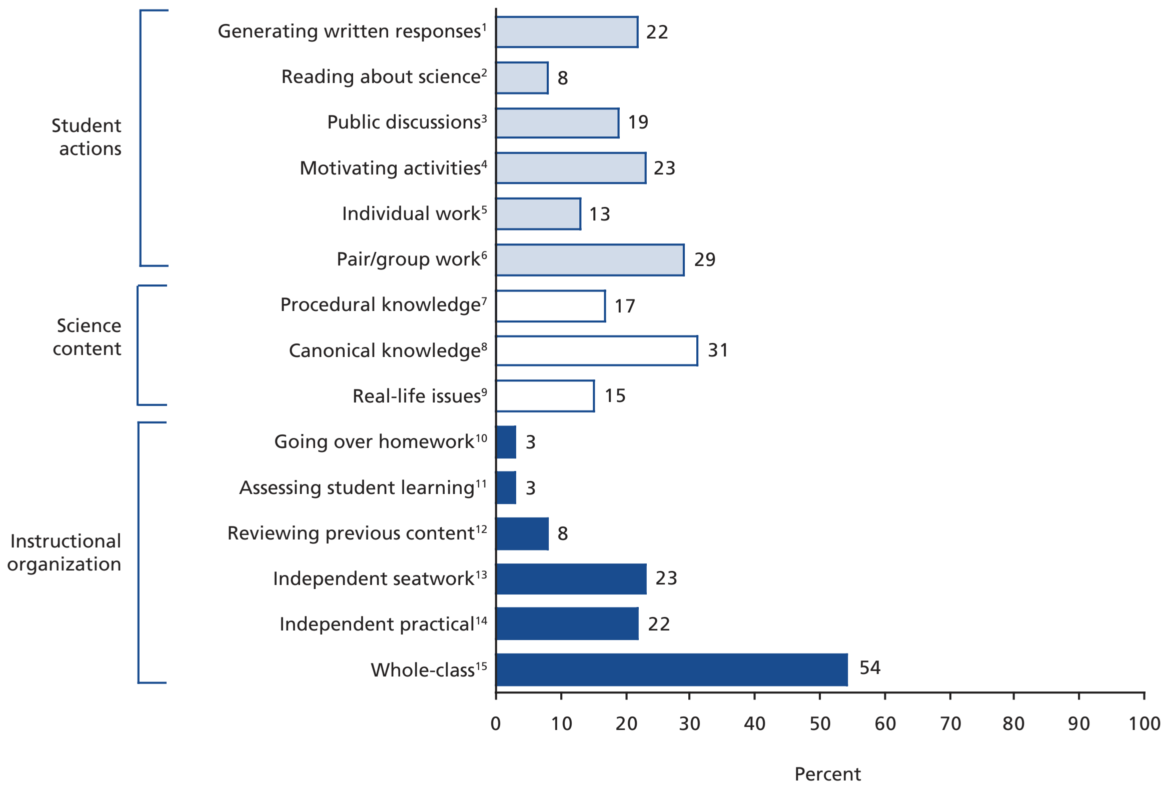
Motivating activities in U.S. eighth-grade science lessons appeared to be designed to engage students' interest and involvement in ways other than independent practical work and real-life issues. These motivating activities in U.S. science lessons included such things as games, puzzles, role plays, simulations, 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

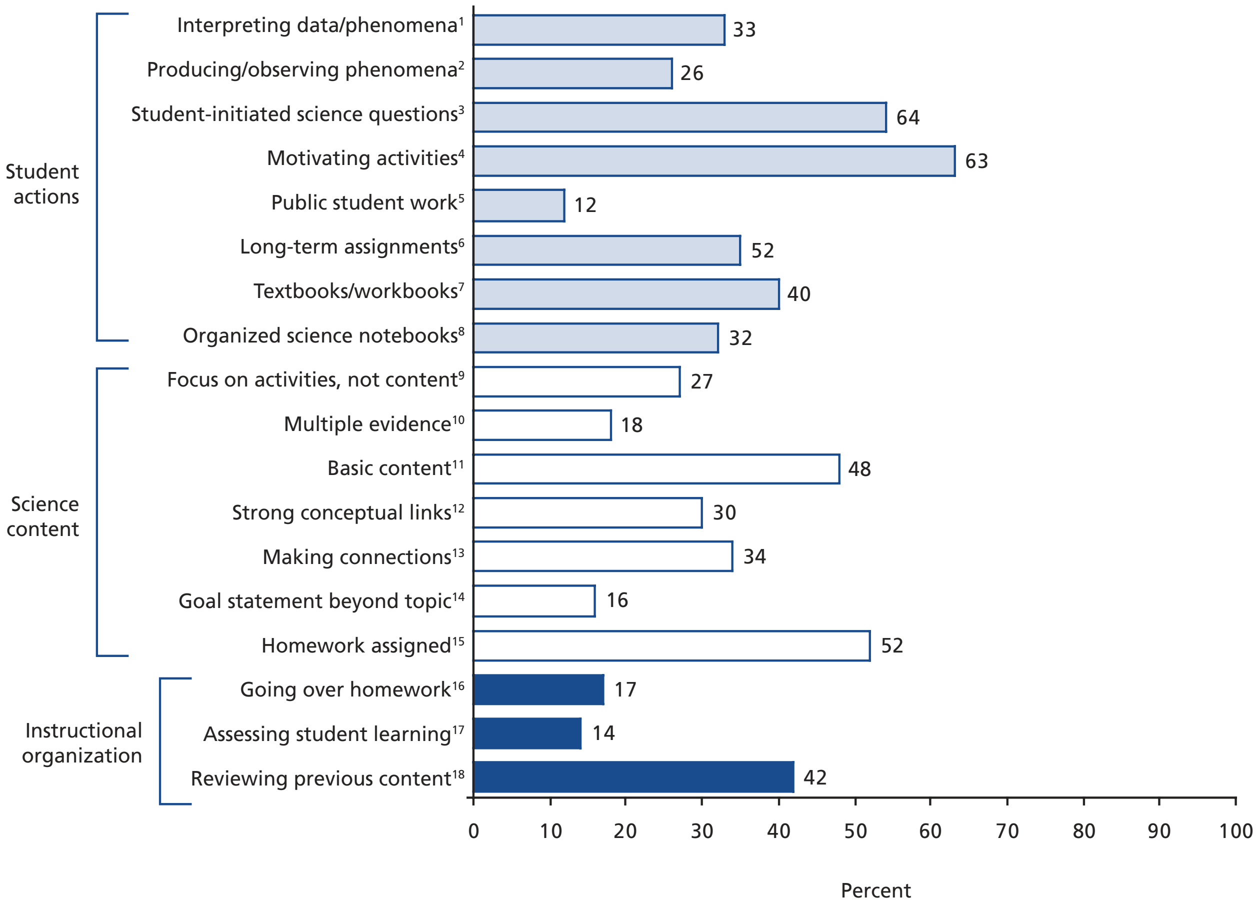
Japanese lessons (figure 2.1). Consistent with the prominence of students doing activities in the videotaped lessons, the teachers' goals for the lessons focused more often on understanding science ideas than Czech lessons but less often compared to Australian and Japanese lessons (table 2.6).

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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