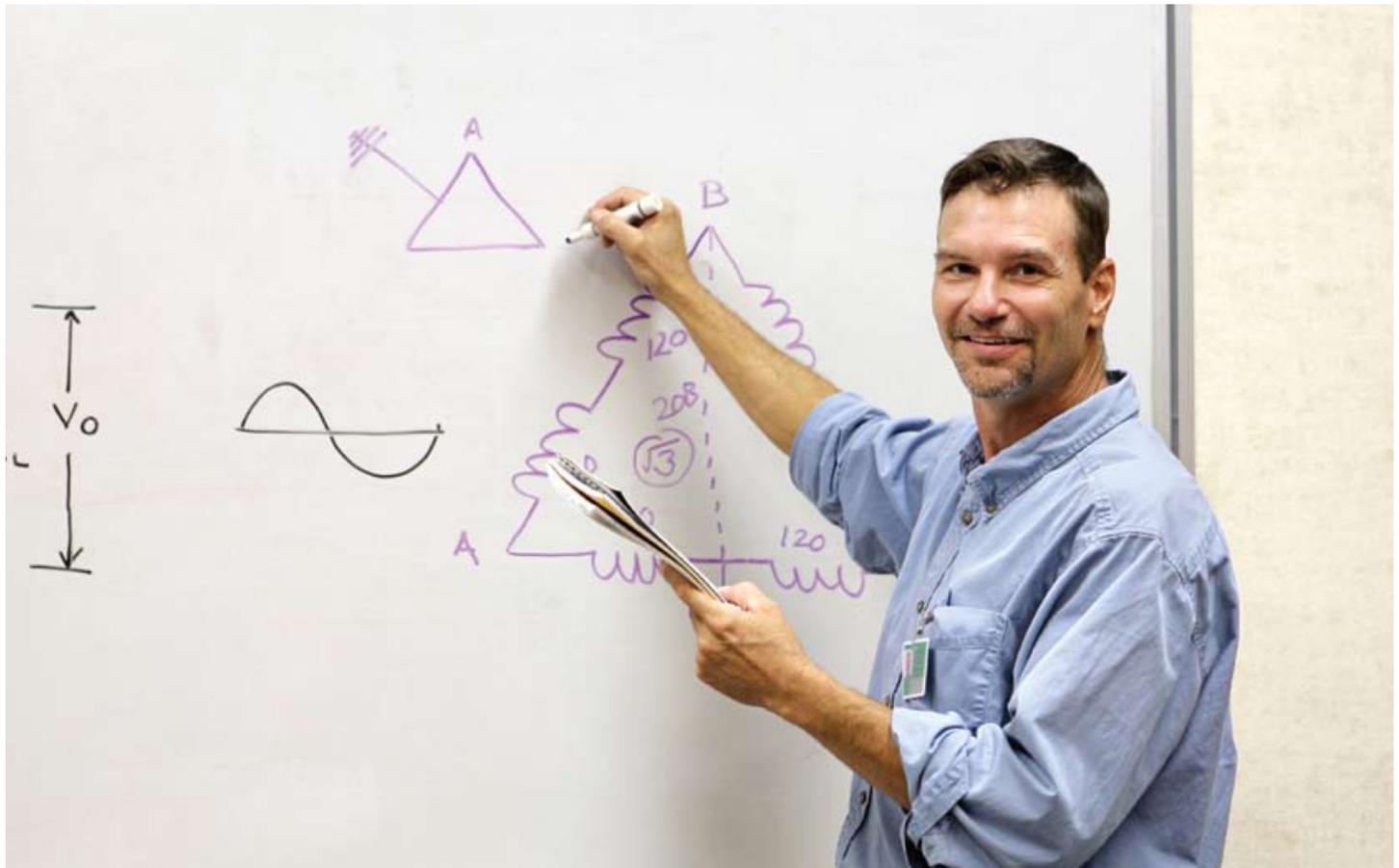


# Implications for



# Math and science Instruction

From the TIMSS 1999 Video Study

By Kathleen Roth and Karen B. Givvin

## PREVIEW

**The TIMSS 1999 Video Study revealed key differences between the United States and other higher-achieving countries in mathematics and science instruction.**

**Countries with high scores in mathematics focused on building connections among mathematical ideas, facts, and procedures.**

**Strong content development—the lesson story line—and connecting concepts and activities typified the most successful countries science programs.**

**M**edia headlines often announce that U.S. students don't shine in international comparisons in mathematics and science. But seldom does any one focus on the specifics of how instruction differs among countries and how U.S. educators can alter their practices to improve student achievement. Examining key findings from the Third International Mathematics and Science Study (TIMSS) 1999 Video Study provides important insights into ways to improve teaching and increase learning in mathematics and science.

The study collected videotapes of eighth-grade mathematics and science lessons in the United States and in countries that outperformed the United States on the TIMSS assessments. A random sample of 100 science lessons and 50–140 mathematics lessons was videotaped in each country across a school year.

The video study examined:

- Mathematics teaching practices in the United States and five countries (Australia, the Czech Republic, Japan, the Netherlands, and Switzerland) and Hong Kong, which achieved higher scores than the United States.
- Science teaching practices in the United States and four higher-achieving countries (Australia, the Czech Republic, Japan, and the Netherlands).

The study provided detailed pictures of typical mathematics and science teaching practices (Hiebert, et al., 2003; Roth, et al., 2006). The results suggest ways to improve mathematics and science teaching in U.S. schools—especially how problems are presented in mathematics lessons and the role content plays in science lessons.

## Building a Coherent Content Storyline

- Identify one main learning goal
- Communicate the purpose with goal statements and focus questions
- Select activities and content representations that are matched to the learning goal
- Link science content ideas and activities
- Highlight important ideas and links among them
- Sequence key ideas and activities appropriately
- Summarize and synthesize important ideas

Following are key results—two from the mathematics video study and two from the science video study—that have important implications for improving mathematics and science teaching in U.S. schools.

### Making Connections in Mathematics

**Mathematics Key Result #1: Teachers in all countries studied spent the majority of lesson time solving problems.** Those problems usually focused students' attention on using procedures, rather than making connections. Teachers in all the higher-achieving countries except Japan presented a high percentage of problems that required students only to use a memorized procedure or algorithm to solve the problem. (See figure 1.)

Students in all countries except Japan had fewer opportunities to work on "making connections" problems that required them to construct relationships among ideas, facts, and procedures and to engage in mathematical reasoning, such as conjecturing, generalizing, and verifying.

The finding that teachers in high-achieving countries and the United States emphasize procedures problems appears to fly in the face of recommendations that students spend more time learning concepts. For example, the National Council of Teachers of Mathematics (2000) standards call for less reliance on procedural problems and more emphasis on problems that require student reasoning.

From this finding, we can conclude that the United States is no different from higher-achieving countries in the kinds of problems that teachers present to students. The key to understanding U.S. students' lower performance in mathematics must lie elsewhere—this brings us to the second key result for mathematics.

**Mathematics Key Result #2: Teachers in higher-achieving countries implement making connections problems differently from teachers in the United States.** What happens after a making connections problem is presented and students begin to work on it? In all higher-achieving countries except Australia, teachers often implemented such problems by following through on the rich potential implied within the problem statements. Students grappled with the problems, making links across ideas and concepts, generalizing, and conjecturing. In other words, teachers did not reduce and simplify the problems. In contrast, U.S. teachers turned making connections problems into using procedures problems, almost never keeping them at a higher level of cognitive demand. (See figure 2.)

### Implications for Mathematics Instruction

These results suggest that U.S. teachers should make the most of rich, making connections problems and let students struggle, rather than step in

to simplify so that students can come up with the right answer. This will require a change in culture, because U.S. students are used to being given hints to the answers, rather than being required to reason. It will also require teachers to acquire more-sophisticated knowledge of mathematics so that they can facilitate the process of making connections.

Principals can support this process by:

- Giving teachers opportunities to increase their mathematical content knowledge
- Giving teachers opportunities to observe other teachers challenging students to think about mathematics and analyze those teachers' mathematics instruction
- Encouraging teachers to break the pattern of simplifying problems; requiring students to do the cognitive work in making connections problems
- Providing professional development opportunities that strengthen teachers' content and pedagogical knowledge in the context of studying instructional practice (their own and others') over time
- Reinforcing to teachers, parents, and students the idea that students should struggle with important mathematics.

### Finding a Pattern in Science

The science portion of the TIMSS Video Study revealed two major differences between the higher-achieving countries and the United States:

- Each of the higher-achieving countries had a distinct core pattern of science teaching. In contrast, U.S. lessons were characterized by variety.
- Although each country had its own approach, the higher-achieving countries all engaged students with

core science concepts and ideas. Their science lessons focused on content. In the United States, content played a less central role and sometimes no role at all; instead, lessons focused on engaging students in a variety of activities.

Each pattern of science teaching in the higher-achieving countries raises questions for U.S. educators about the role of science content in science teaching. Following are descriptions of each country's core pattern of teaching and approach to science content.

#### Talking to learn challenging content (the Czech Republic).

The Czech science teaching pattern emphasized demonstrating knowledge publicly. Lessons focused on challenging science content that was often conceptual and theoretical and were densely packed with science ideas and technical terms. Teachers held students to high standards for mastering content through public quizzes, reviews, discussions, and other forms of public student work.

**Using practical activities and evidence to develop ideas (Australia and Japan).** The Australian and Japanese patterns focused on engaging students in inquiry and using evidence to develop ideas. Lessons built a carefully developed, coherent content story line in which ideas, evidence, and activities were carefully sequenced and explicitly connected. Teachers developed just one or two science ideas across a lesson, supporting each idea with multiple sources of evidence. They expected students to develop conceptual understanding and to support their ideas and conclusions with evidence.

**Learning science content independently (the Netherlands).** Dutch teachers set high expectations for independent learning of science content. Textbook and homework assignments

usually defined lesson content and organization. Class discussions focused on answering students' questions about independent assignments. The assignments continually engaged students with science content ideas.

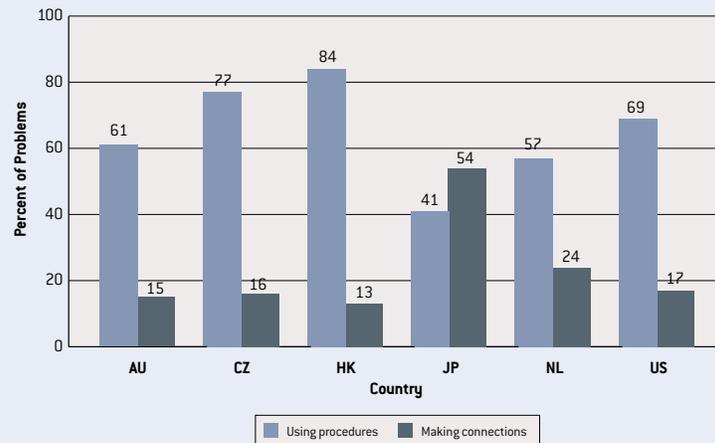
**Doing a variety of activities (the United States).** In contrast, the United States lacked a core pattern

of science teaching. Instead, teaching was characterized by variety. Students worked on many activities, with almost equal emphasis on hands-on activities, independent seat work, and whole-class discussions. (See figure 3.)

In the United States, science content was often secondary to activities. High-interest activities were prominent

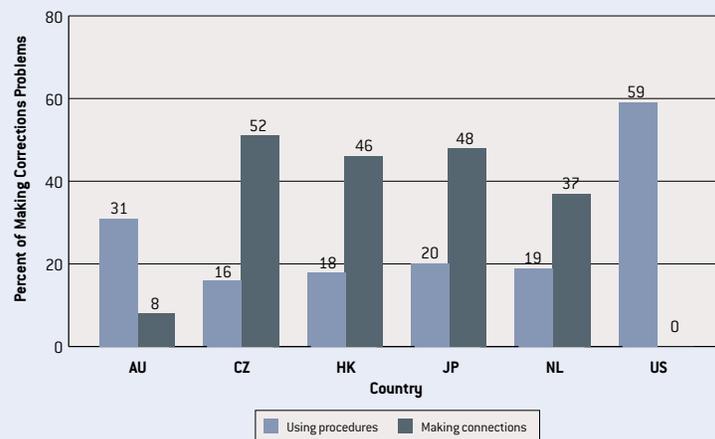
**FIGURE 1**

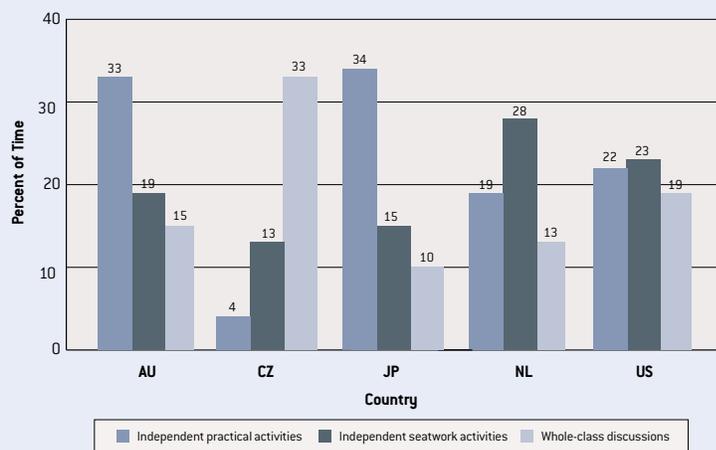
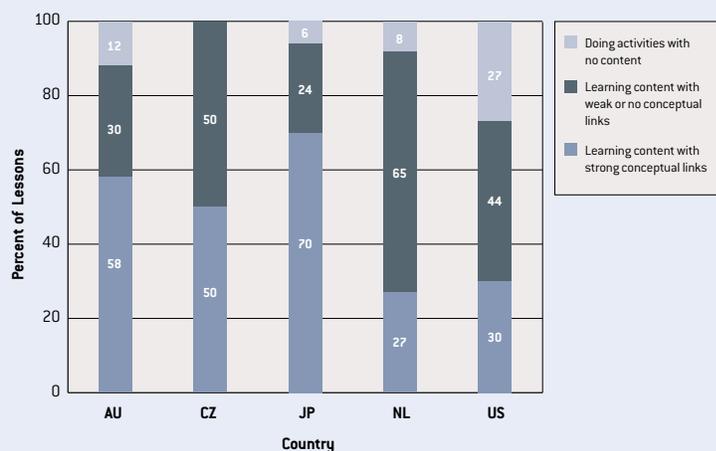
**Average percentage of problems that required students to use procedures or make connections**



**FIGURE 2**

**How "making connections" problems are implemented in the classroom**



**FIGURE 3****Variety of activities****FIGURE 4****Missing links between ideas and activities**

and frequent, but teachers did not typically connect them to the development of science ideas. Science content was usually organized as a collection of discrete facts, definitions and algorithms, rather than a connected set of ideas. A striking finding was that 27% of U.S. lessons did not include *any* science content; instead, students carried out activities without any links to science ideas. (See figure 4.) For example, students spent an entire lesson following a set of procedures to build

rockets, without any consideration given to the science ideas related to the activity.

#### Implications for Improving Science Teaching

Although their teaching approaches were different, each higher-achieving country had a strategy for engaging students with core science concepts and ideas. To strengthen the science content development—the story line—of science lessons in the United

States, teachers must focus more directly on the science ideas in the lessons. During lesson planning, teachers should consider how to set up and follow up each activity to challenge students to think about the science *ideas* that are related to the activity, not just the procedures or the results. Teachers should also review each potential lesson activity to ensure that it matches the lesson's learning goal and advances the content story line.

Principals can support this process by:

- Giving teachers opportunities to increase their science content knowledge
- Giving teachers opportunities to observe other teachers challenging students to think about science content before, during, and after each activity
- Setting aside time for teachers in each grade level to collaborate to develop clear, coherent science content story lines for lessons and units
- Reminding teachers to make science ideas prominent in science lessons, to select activities that match those ideas, and to make explicit links between activities and science ideas
- Providing professional development opportunities that strengthen teachers' content knowledge and pedagogical knowledge in the context of studying instructional practice (their own and others') over time.

#### Rising to the Challenge

The TIMSS 1999 Video Study results challenge U.S. educators to improve instruction to increase student learning in mathematics and science. Principals can use the mathematics and science findings to emphasize the importance of:

- Building connections instead of teaching isolated algorithms and facts in both mathematics and science (e.g., asking making connections problems in mathematics; connecting science ideas to activities)
- Engaging students in challenging mathematical and scientific work (e.g., implementing making connections problems in mathematics; getting students thinking about science ideas before, during, and after each activity)
- Engaging teachers in challenging mathematical and scientific work in the context of collaboratively analyzing and learning from practice (both their own and others'). Videotapes from hundreds of eighth-grade mathematics and science classrooms enable educators to see

how students in different countries experience mathematics and science teaching, to consider alternative ways of teaching, and to rethink ideas about effective instruction. These observations offer promising directions for improving mathematics and science teaching in U.S. schools. **PL**

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