Highlights Report

A Study of K–12 Mathematics and Science Education in the United States

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Introduction

The need for information on the nature and quality of K–12 mathematics and science lessons is particularly acute given the current emphasis on reform. The *Inside the Classroom* study was designed to provide snapshots of what transpires inside the nation's mathematics and science classrooms and the factors that shape that instruction. A more detailed description of the study design and results is included in the full report at www.horizon-research.com/public.htm

Lesson Ratings

Horizon Research, Inc. staff and consultants observed a total of 364 mathematics and science lessons using a structured observation protocol. Each lesson was rated on four components: the lesson design, lesson implementation, mathematics/science content addressed, and classroom culture. Observers rated several indicators within each component area, and then provided an overall "capsule" rating of the lesson, along with a detailed rationale for that rating. The scale observers used to provide an overall assessment of the quality and likely impact of the lessons is divided into the following categories:

Level 1: Ineffective instruction
- a. "passive learning"
- b. "activity for activity's sake"

Level 2: Elements of effective instruction
Level 3: Beginning stages of effective instruction (low, solid, high)
Level 4: Accomplished, effective instruction
Level 5: Exemplary instruction

Detailed descriptions of these levels can be found in the *Inside the Classroom* Observation and Analytic Protocol in Appendix A of the full report. Lessons are broadly categorized in this report as low in quality (1a, 1b, 2); medium in quality (low 3, solid 3), and high in quality (high 3, 4, 5). Based on observers' judgments, only 15 percent of K–12 mathematics and science lessons in the United States would be considered high in quality, 27 percent medium in quality, and 59 percent low in quality. (See Figure 1.) Descriptions of lessons at each of these levels can be found in the appendix to the full report.

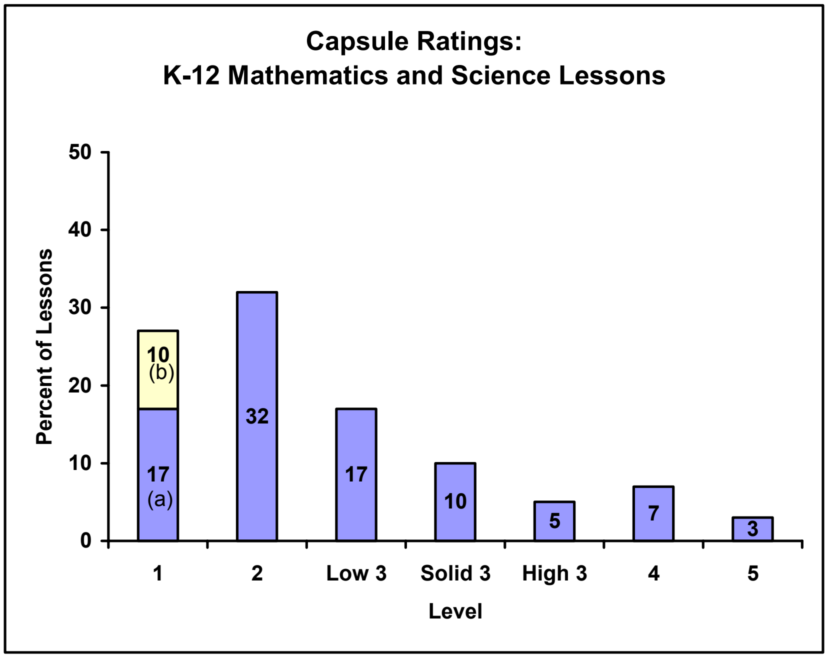

Figure 1

Lessons judged to be low in quality are unlikely to enhance students' understanding of important mathematics/science content or the ability to engage successfully in the processes of science or mathematics. At the other end of the scale, high quality lessons are structured and implemented in a manner which engages students with important mathematics/science concepts; these lessons are very likely to enhance student understanding of these concepts and to develop their capacity to do mathematics/science successfully.

Inside the Classroom observations suggest that mathematics and science lessons in the United States are relatively strong in a number of areas. For instance, a majority of lessons:

- Incorporate content that is both significant and worthwhile;
- Have teachers who appear confident in their ability to teach mathematics and science; and
- Have teachers who provide accurate content information.

At the other end of the spectrum, fewer than 1 in 5 mathematics and science lessons:

- Are strong in intellectual rigor;
- Include teacher questioning that is likely to enhance student conceptual understanding; and
- Provide sense-making appropriate for the needs of the students and the purposes of the lesson.

Strengths and Weaknesses of Mathematics and Science Lessons

Researchers saw some terrific lessons—classrooms where the students were fully and purposefully engaged in deepening their understanding of important mathematics and science concepts. Some of these lessons were "traditional" in nature, including lectures and worksheets; others were "reform" in nature, involving students in more open inquiries. Observers saw other lessons, some traditional and some reform-oriented, that were far lower in quality, where learning mathematics/science would have been difficult, if not impossible. In an effort to determine which characteristics were most important in determining quality, the authors did an in-depth analysis of lesson descriptions for lessons judged very effective and decidedly ineffective. The factors that seem to distinguish effective lessons from ineffective ones are their ability to:

- Engage students with the mathematics/science content;
- Create an environment conducive to learning;
- Ensure access for all students;
- Use questioning to monitor and promote understanding; and
- Help students make sense of the mathematics/science content.

➢ Engaging Students with the Mathematics/Science Content

One of the most important aspects of effective mathematics and science lessons is content that is both significant and worthwhile, and the majority of lessons do, in fact, include such content. However important content is not enough; high quality lessons invite students to interact purposefully with the content, and represent science and mathematics as dynamic bodies of knowledge generated and enriched by investigation. The following descriptions illustrate how lessons either effectively address, or fail to address, the need to engage students intellectually with the mathematics/science content.

Intellectual Engagement
20 Percent of Lessons

The teacher began an elementary mathematics lesson with a review of the terms for solid geometric shapes. She then asked the class to find a number of shapes. For example: "I spy a shape that has six faces, eight corners, and twelve edges. What solid is it? Can you find an example in the room?" Said the observer: "The children eagerly participated in the game, and had surprisingly little trouble recognizing a rectangular prism, just from the teacher's verbal description."

As a lesson on the skeletal system started, a life size skeleton, named Mr. Bones, was introduced to the 5th grade class. The teacher talked about specific bones of the body, frequently capturing students' attention by telling stories and personal experiences: her husband's broken collar bone, actor Christopher Reeves' spinal cord injury, and her father's arthritis; students shared similar stories about the mailman with carpal tunnel syndrome and a mom with TMJ.

The teacher in a human anatomy and physiology class began a lecture by drawing a diagram of a nerve receptor, connected by a nerve fiber to (eventually) the brain. He explained the concept of a threshold for a receptor, noting that stimuli could be either sub-threshold, threshold, or super-threshold, stressing that only after the threshold is reached does the receptor respond to the stimulus and send a signal to the brain. Using the hand as the point of reference, the teacher differentiated among different stimuli—touch, pressure, poke, punch, hammer, excruciating pain. He gave the example of an instance where if "punch" receptors were stimulated, the brain would not register "touch", only "punch." The students were intrigued with the notion, asking if it worked that way with taste, hearing, and sight.

Lack of Intellectual Engagement
55 Percent of Lessons

For 30 minutes the teacher directed the students in a 1st grade class to complete a test preparation worksheet. The class then went over the answers. The observer noted that "the pace was monotonous and seemed to lose students' attention."

An 8th grade science lesson was designed to give the students a great deal of factual information on Newton's Third Law of Motion. The students copied notes from the blackboard for half of the lesson, and the next half of the lesson was spent with the teacher asking them to recall information from the notes. The observer wrote: "The lesson was designed in a way that allowed the students to be very passive, interacting little with each other or the content. The students spent a great deal of time hurriedly copying the notes; only those students who were called on by the teacher during the review time were required to think about the content, and even that was at the basic level of recalling facts they had just written down."

In a 9th grade teacher's efforts to help his students better understand how to solve equations and inequalities, he asked them to remember and repeat the procedures he had demonstrated in the beginning of the class. The teacher's presentation of the content included questions and comments such as, "There's the variable, what's the opposite?" and "Tell me the steps to do." He did very little to engage students with the content; two students slept through the teacher's entire presentation, and one read a magazine. Other students contributed very little, spending most of the time asking about the particulars of the upcoming assignment.

➢ Creating an Environment Conducive to Learning

A classroom that is both respectful and rigorous is essential in order for students to have an opportunity to learn. In many classrooms, a climate of respect for students' ideas, questions, and contributions prevails, with 45 percent of lessons nationally receiving high ratings on this indicator. Ratings for rigor are much lower, with only 14 percent of lessons nationally having a climate of intellectual rigor, including constructive criticism and the challenging of ideas.

In only 13 percent of lessons is the classroom culture rated as highly respectful and at the same time highly rigorous, encouraging the students to engage in serious learning. The following examples illustrate highly respectful and highly rigorous lessons, as well as lessons that are lacking in respect, in some cases even hostile and demeaning to students; nearly all of these are also very low in rigor. Many other lessons are "cordial" and "pleasant", but lack intellectual rigor.

High Respect, High Rigor
13 Percent of Lessons

An observer described the classroom culture in a 3rd grade mathematics class as "phenomenal," noting that "at any given point there was an extraordinary amount of excitement, and the content was new and rigorously-taught for this bunch of students." During the introductory discussion, the teacher allowed students the opportunity to challenge one another's answers by asking questions such as "Is this correct?" and "Does anyone have a different idea?" After the discussion, the students worked in pairs on plotting. When they had completed the assignment, students came up and placed pictures on the overhead version of the grid and the teacher encouraged other pairs to comment on the correctness of the placement. The observer noted that, "The teacher and students were respectful of each other's thoughts. Discussions were lively and included multiple students' perspectives."

The researcher reported that all of the students in a high school biology class were involved throughout the lesson, and it was clear that all of them were expected to contribute. "The students worked together in groups, discussing and challenging each other's ideas. The teacher also challenged students to back up their ideas with evidence from the lab (e.g., 'How do you know?' and 'What happened [when you tested it]?'). The classroom atmosphere was rigorous, but friendly."

Low Respect, Low Rigor
26 Percent of Lessons

The researcher reported that she had never seen a class with a poorer classroom culture than this 3rd grade class. "The teacher's main classroom management strategy was to chastise the class repeatedly, 'pockets on your seat, eyes up, lips zipped.' She allocated 'points' for each table behaving as she had requested, and recorded these table points on the board….To ensure that the students were able to follow the instructions, she called on individual students to repeat each instruction as it was given. For example, 'While I am handing out the construction paper, please finish writing. When you get the construction paper, write your name on one side; that will be the back… Where do you need to write your name?' She would then call on individual students, and each one would parrot, 'on the back.'

The observer of a 9th grade Pre-Algebra class reported that comments like "Stop talking," "Settle down," and "Am I disturbing you or something?" were used to interact with students throughout the lesson. "The teacher focused less on participation and more on control….There was no rigor and no opportunities for trying to talk about or make sense of any ideas. …The teacher did not seem to trust the students to do the computations in their heads—at four times during the lesson he told them to use the calculators and not to trust their own thinking."

➢ Ensuring Access for All Students

A critical aspect of the teacher's role is to ensure that students are in fact accessing the mathematics/science content, and that no students are slipping between the cracks. Researchers rated the extent to which observed lessons encouraged active participation of all students. They described cases where some students were "left out" of the lesson, as well as cases where the teacher was particularly successful at engaging learners with differing needs.

Across the nation, 29 percent of lessons would be rated low in terms of encouraging active participation of all students. The following are examples of lessons from both ends of the spectrum, where teachers adjusted, or failed to adjust, their instruction for the differing needs of the students.[1]

Access for All Students
47 Percent of Lessons

A researcher indicated that a student in a 2nd grade class was hearing-impaired and wore a special amplification device. The teacher had a microphone/transmitter around her neck, which beamed her voice to the hearing device. Said the observer, "the student participated in the lesson to the same extent as all the others, including being asked the same level of questions by the teacher."

A 3rd grade teacher altered her lesson plan to accommodate the varying levels of her students. She required that all students depict what they had observed in the experiment that they had conducted during the class. The more able students could do this in a six part step-by-step description, with pictures, of the experiment. Other children, who had more difficulty with writing, were allowed to express their understanding through a cartoon or other drawing.

An observer reported that "two non-English speaking students were included fully [in a middle school science lesson], using specially translated notes, translation tools, and lots of contact with the teacher and other members of their group. These students contributed to the making of observations, recording of information, and identification of the rock samples."

Lack of Access for Some Students
29 Percent of Lessons

An observer reported that this 7th grade science teacher "had students she liked and students she didn't like…One boy and one girl were particular favorites. The sole African American boy was treated differently and badly. Any answers he suggested were dismissed with a strong 'No.' even when they were much closer to the correct answer than the suggestions of white students in the class."

A teacher noted that the students in his 7th grade mathematics class varied widely in ability levels, with some students "who can retain information at jet speed" and other students who are "very low functioning." The observer noted that the teacher "made no adjustments in instruction to accommodate the diverse needs of his students. This lesson was designed as a 'one size fits all lesson' without attention to students' levels of mathematics development."

Another observer noted that although the teacher had identified a few students in a high school science class as special education students, "no effort could be observed during the class to engage them in any way different from the techniques used for the general group."

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1 It is also important to note that lessons in rural schools and in "majority-minority" classes were rated lower than lessons in other classes on key indicators such as significant and developmentally appropriate content, respect, rigor, intellectual engagement, and sense-making. Lessons in classes where all students were considered by their teachers to be low or middle ability were also rated lower on key indicators than those in classes that included high ability students, whether in homogeneous or heterogeneous groups.

➢ Questioning to Develop Understanding

The kinds of questions teachers ask are key in determining the extent to which lessons are likely to help students learn important mathematics and science concepts. Teachers can use questioning to monitor student understanding of new ideas and to encourage students to think more deeply, however this kind of effective questioning is relatively rare in the nation's mathematics and science classes. More often, we saw questioning that was unlikely to deepen students' understanding, including teachers asking a series of questions too rapidly, and teachers asking questions focused only on a correct answer without checks for fuller understanding. Below are examples of lessons from both ends of the spectrum -- those that included effective questioning, and those that were lacking in this regard.

High-Level Questioning
16 Percent of Lessons

The observer reported that an 8th grade mathematics class was a very nice illustration of an interactive lecture, where the instructor asked for examples and justifications from the students as a means of assessing their understanding. "For example, when generating examples of tessellations around the room one student proposed the border of the bulletin board that was made of circles.

Student: 'How about the border?'
Students: 'No… that won't work.' (several students talk at once and reject this contribution)
Teacher: 'Why won't it work? Can the circle ever work?'

The discussion became focused on why the circle did not create a pattern that fit the definition of a tessellation. While the student who suggested the circle had been focusing more on patterns, the disagreement helped him redirect his analysis back to the definition of tessellations presented earlier."

As the students in a 10th grade science class were examining the results of their experiment, the teacher asked questions that pushed them to examine their results further and to provide evidence for their conclusions. Examples of questions asked by the teacher are: "How could we test if there is still sugar in the reservoir?" "Why didn't it [the iodine indicator] reach equilibrium?" and "How do you know?"

Inadequate Questioning
66 Percent of Lessons

Said the observer of a Kindergarten science lesson, "The teacher's questioning was fast-paced and primarily low level." For example:

Teacher: "Do leaves all look the same? What is different about them?"
Student: "Veins."
Teacher: "What else?"
Students: "Shape."
Teacher: "What do some trees have and others don't?"
After a few incorrect guesses, a student said, "Pine cones."
Teacher: "What else?"
Student: "Fruit."

The researcher reported that the teacher's questions in a 6th grade mathematics lesson were low-level, "micro-questions." "As she worked the long division problem 4,879,000 divided by 0.39 on the board, she called on students, by name, to give her each number to write down. When the 'brought down part' was 99 and a student had told her that 39 would go into 99 two times and another student had told her that 39 times 2 is 78 (which she wrote down), she asked a third student, 'What is 9 minus 8?' The student answered, '21' (i.e., she did the complete subtraction, 99 minus 78). The teacher responded, '9 minus 8 is 21? You know that's not right!' When the student said, 'I just did the whole thing,' the teacher responded, 'you should answer the question that I ask—what is 9 minus 8?'"

➢ Helping Students Make Sense of the Mathematics/Science Content

A teacher's effectiveness in providing explanations at appropriate junctures as the lesson unfolds often determines students' opportunities to learn. It is important that lessons engage students in doing the intellectual work, with the teacher helping to ensure that they are, in fact, making sense of the key concepts being addressed. Although researchers observed some lessons where students were helped to make sense of the content and see connections among mathematics/science ideas, overall, most lessons lack adequate sense-making. Only 16 percent of lessons in the nation would receive high ratings in this area. Below are examples of lessons that emphasized sense-making and those that were unlikely to help students make sense of the mathematics/science content.

Appropriate Sense-Making
16 Percent of Lessons

The purpose of a 2nd grade mathematics lesson was to allow students to demonstrate understanding of place value—ones, tens, and hundreds, and to practice with thousands place. The lesson emphasized numbers containing a zero, since this was something students found difficult. As the class worked on the various tasks, students would look at each group's response and indicate their agreement with thumbs up or down. The teacher encouraged students to question each other if there was an answer they didn't understand or didn't agree with. If a group did not represent the number correctly, the teacher would probe with questions to see if they could identify their error. She also asked students to respond to discrepancies that appeared among the groups' solutions. During wrap-up at the end of the lesson, the teacher emphasized, "When we write numbers, the digits have to be in the right spot. Remember that the zeros are important, too."

Students in a high school chemistry class had been working on properties of compounds and elements. The observed lesson built upon that knowledge, focusing on compound formation. There were three main components to the lesson: (1) a quick review of the previous lesson's concepts; (2) a lecture/discussion on the new material; and (3) a question/answer review of the new material. The lesson included time for sense-making during the lecture portion of the class (the teacher asked questions throughout to ensure comprehension), and a wrap up question/answer segment at the end.

Inadequate Sense-Making
66 Percent of Lessons

The teacher guided a 3rd grade class through the completion of a science worksheet by telling them to turn to specific pages in their textbook and look for the answers. She asked one student to read an answer from the book, then wrote it on an overhead transparency copy of their worksheet. The observer reported the following conversation as an example:

Teacher: "Let's look at lesson two. Turn to page E16. Fill in the blank. Look on the page. Matter is made of…what?"
Student 1: "Atoms."
Teacher: "Adding heat changes a solid to a what?"
Student 2: "Liquid."
Teacher: "Good. Now read number three."

At the completion of the worksheet, the teacher then went over the questions and answers to summarize the content in the lesson. The students were instructed to keep their worksheets for the next lesson.

The student in this Algebra class who put the equation $6x + 7 = -14y$ into standard form on the board explained that she first subtracted 6x from both sides getting $7 = -14y - 6x$, which in standard form is: $-6x - 14y = 7$. Some students seemed confused, and asked the teacher if that was right. The teacher said it was, then solved it a different way, by first moving the y-term, getting the answer $6x + 14y = -7$. As she began solving it this way, some students seemed fixed on first moving the 6x—they didn't understand that either way was correct. The teacher concluded "So you can have two different answers." The observer noted that the teacher never mentioned that these two answers are mathematically equivalent.

Major Influences on Content and Instruction

The previous section provided snapshots of lessons in K–12 mathematics and science classes throughout the United States. This chapter examines some of the reasons the lessons were designed as they were.

In planning mathematics and science lessons, teachers are influenced by a multitude of factors that work together to impact what content is taught, how it is taught, and the materials selected to engage students with the content. These factors may include curriculum standards/frameworks; accountability systems; teachers' familiarity with specific content and pedagogy; teacher perceptions of the needs of the students; and teacher perceptions of the views of the principal, parents, and other key stakeholders.

Following the *Inside the Classroom* observations, extended interviews were conducted with teachers to determine what led them to select the content in the lesson, and why they chose the pedagogy and the materials used in the lesson. The ultimate goal of the interviews was to determine which factors have the greatest influence on the design of the lessons students experience each day in mathematics and science instruction in the United States. The factors that were determined to be most important in selection of either content, instructional strategies, or both, are shown in Figure 2.

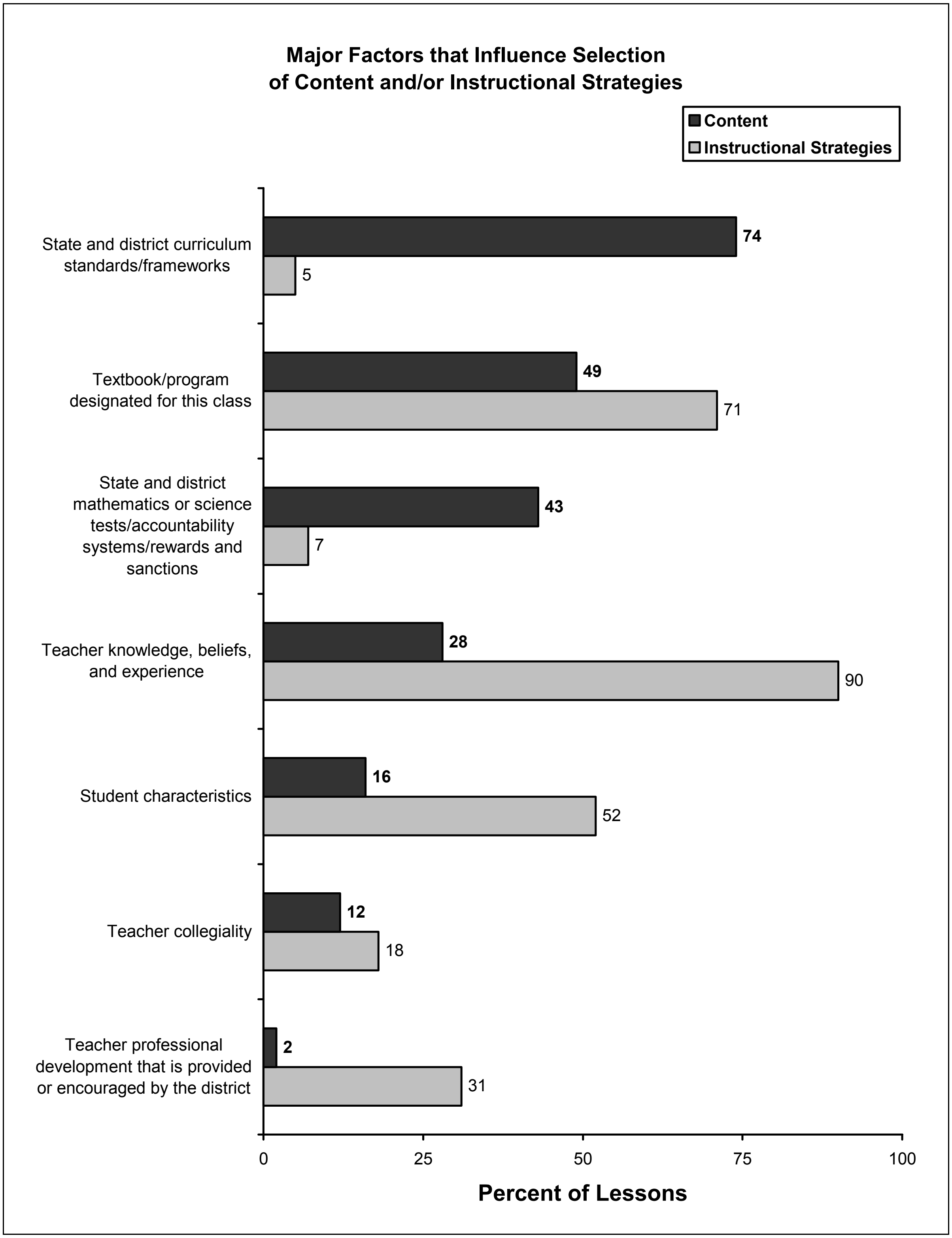
Major Factors that Influence Selection
of Content and/or Instructional Strategies
Content
Instructional Strategies
State and district curriculum standards/frameworks
74
5
Textbook/program designated for this class
49
71
State and district mathematics or science tests/accountability systems/rewards and sanctions
43
7
Teacher knowledge, beliefs, and experience
28
90
Student characteristics
16
52
Teacher collegiality
12
18
Teacher professional development that is provided or encouraged by the district
2
31
0
25
50
75
100
Percent of Lessons

Figure 2

➢ Selection of Mathematics/Science Content

The most frequently cited influences on lesson content are state/district curriculum standards, followed by the textbook/program designated for the class, and then state/district accountability systems.

Influence of Curriculum Standards
State and district curriculum standards have a substantial influence on the selection of content, providing teachers a road map for what to teach in roughly 3 out of 4 mathematics/science lessons nationally.

> *[The state's course of study is] very important because we align everything and, therefore, you're always conscious of the state requirements, and once you align everything, you know that you're going in the right direction and the children are getting everything that they pretty much need during the course of the year.* (3rd grade mathematics teacher)

> *As far as the state, we are teaching to the curriculum. If it says we have to teach it in the 7th grade, you teach it. There's a set of goals; there's a set of objectives, and you teach it…We are driven by the state objectives…You teach to the objectives.* (7th grade mathematics teacher)

> *In other words, the state standards will determine what chapters we teach and don't teach.* (High Schools Honors Chemistry teacher)

Influence of Textbook/Curriculum Programs
After state and district standards, the next most common influence on content appears to be textbook/curriculum programs, typically selected at the district level, with 1 in 2 teachers nationally reporting that the textbook has an influence on the content they select for their lessons.

> *That's exactly where we are…as far as chapter-wise…because I pretty much go in order, or in the sequence of the book, because it's pretty much a good order for the kids to learn the concepts.* (Kindergarten mathematics teacher)

> *[The fact that the topic was in the designated text] was an important factor. Sometimes I may pull a resource to enhance, to add to it, but I really do try to go with the topics in the book.* (8th grade science teacher)

> *I looked through the book, and I think the progression of the book is sound. So, quite frankly, I'm just following the progression of the book to an ultimate final exam.* (High School Geometry teacher)

Influence of Accountability Systems

The content selection for nearly 1 in 2 lessons nationally is influenced by an accountability system related to student achievement.

> *We are teaching right to that [state assessment] and that's not how I prefer to do it, but it's the way we are geared right now.* (4th grade science teacher)

> *I definitely wouldn't be doing that unit if it weren't for the benchmark test coming up.* (8th grade Pre-Algebra teacher)

> *I don't like to be driven by a test, but it was important. I feel compelled to teach it if they're going to be tested on it, because I don't want them to get on the test and say "I don't know this; what in the world is this?" I think that would be the worst disservice I could do them.* (8th grade science teacher)

- **Selection of Instructional Strategies**

A sense of autonomy in choosing how to implement lessons is reflected in teachers' identification of factors that have the greatest influence on their selection of pedagogy. The factors examined in this study that appear to have the greatest influence on instructional strategies are the teachers' background, knowledge, and experience, and their beliefs—about the subject, about effective pedagogy, and about their students.

Influence of Teacher Knowledge, Beliefs, and Experience

In marked contrast to the "external" influences on lesson content, teachers have a great deal of latitude in choosing the instructional strategies to use in helping students learn the mathematics/science content. Teachers' background, knowledge, and experience influence the selection of instructional strategies in 9 out of 10 mathematics/science lessons.

> *What I tell my students is the way that I'm teaching them is the way that someone taught me. The strategies that I use I picked up from teachers that [taught me]. I didn't get them from my college instructors. I didn't get them from observing or anything like that. The way that I teach is because a teacher that I had one time or another taught me that way. The way that they taught me; I learned that way. I'll teach them [that way] because I think they will learn it. I'm the type of person that I have to do something to learn it. You tell me something, you explain something to me, I'll ask you to explain it to me again several times. So I have to do it. I have to actually do it to learn it.* (4th grade science teacher)

I went to the university and they had a constructivist model…We were given lessons and information on discovery and inquiry. So I'm real comfortable with it. It makes a lot of sense to me. (7th grade mathematics teacher)

☙ ❧

I remember my math teacher when I was in school…I still remember the way she taught certain topics…I emulate what she did. (9th grade Pre-Algebra teacher)

☙ ❧

Actually, just trial and error over the years. Trying to get a feel for what works and what does not work. Like I try to tell my students, you can't always be in the lab, you can't always look at the weather, you can't always be outside. I can do what I can in the room, but you have to have lecture. There is some degree of lecture. (10th grade Biology teacher)

Influence of Textbooks/Curriculum Programs

Textbooks are second only to teachers' knowledge, experiences, and beliefs in the frequency of influence on instruction. The majority of teachers (71 percent nationally) rely to some extent on the textbook/curriculum program designated for use in their class in making decisions on how to teach.

I used the book exactly as it is laid out, because it had everything I needed for this topic. (3rd grade science teacher)

☙ ❧

I like just about everything about it [the mathematics program]. I follow the format of the book. (6th grade mathematics teacher)

☙ ❧

I must admit I think that the class is very textbook-oriented. I trust the judgment of textbook writers and textbook selectors to pick out a curriculum within that textbook that's going to be okay…That book has been used for 5–6 years. I'm pretty happy with it. (High School Pre-Calculus teacher)

Influence of Student Characteristics

Teachers often consider the ability levels of the students and their behavior when deciding on instructional strategies. In addition, proficiency with the English language and student absenteeism influence teachers' selection of instructional strategies.

Behavior is not a strong point for most of the groups across the [City] School System at this time. So I try to find lessons that will keep them calm. Usually nothing that will harm anyone. So I try to come up with a safe lesson. (5th grade science teacher)

☙ ❧

I think because I really like this class that I do more hands-on…My other classes weren't allowed out of their seats. (7th grade science teacher)

This group is a lot slower than others. They need to see everything. I have some kids in the other class who can write down what I say. Here, I make sure I have my overheads ready. [Instruction is] stretched out a little bit more and includes a lot more repetition. They need to see everything. (9th grade Physical Science teacher)

Most of them are very self-motivated and we just kind of cut to the chase. We present the material. And if they have a particular problem, we may try to change the approach just a little bit to better the understanding, but it is going to be mostly lecture and examples and question and answer-type stuff. (12th grade AP Calculus teacher)

Implications

Observations conducted for the *Inside the Classroom* study suggest that the nation is very far from the ideal of providing high quality mathematics and science education for all students. The study findings, both the lesson snapshots and teacher reports on what influenced their lesson designs, have implications for the preparation and continuing education of the mathematics/ science teaching force, and for other support provided to teachers.

Teachers need a vision of effective instruction to guide the design and implementation of their lessons. Findings from this study suggest that rather than advocating one type of pedagogy over another, the vision of high quality instruction should emphasize the need for important and developmentally-appropriate mathematics/science learning goals; instructional activities that engage students with the mathematics/science content; a learning environment that is simultaneously supportive of, and challenging to, students; and, vitally, attention to appropriate questioning and helping students make sense of the mathematics/science concepts they are studying.

A number of interventions would likely be helpful to teachers in understanding this overall vision, and in improving instructional practice in their particular contexts. First, teachers need opportunities to analyze a variety of lessons in relation to these key elements of high quality instruction, particularly teacher questioning and sense-making focused on conceptual understanding. For example, starting with group discussions of videos of other teachers' practice, and moving toward examining their own practice, lesson study conducted with skilled, knowledgeable facilitators would provide teachers with helpful learning opportunities in this area.

Second, the support materials accompanying textbooks and other student instructional materials need to provide more targeted assistance for teachers—clearly identifying the key learning goals for each suggested activity; sharing the research on student thinking in each content area; suggesting questions/tasks that teachers can use to monitor student understanding; and outlining the key points to be emphasized in helping students make sense of the mathematics/science concepts.

Third, workshops and other teacher professional development activities need to themselves reflect the elements of high quality instruction, with clear, explicit learning goals; a supportive but challenging learning environment; and means to ensure that teachers are developing understanding. Without question, teachers need to have sufficient knowledge of the mathematics/science content they are responsible for teaching. However, teacher content knowledge is not sufficient preparation for high quality instruction. Based on the *Inside the Classroom* observations, teachers also need expertise in helping students develop an understanding of that content, including knowing how students typically think about particular concepts; how to determine what a particular student or group of students is thinking about those ideas; and how the available instructional materials (and possibly other examples, investigations, and explanations) can be used to help students deepen their understanding.

Fourth, the apparent inequities in quality of instruction need to be further explored, and if confirmed, steps need to be taken to resolve them. It is essential that all students receive high quality instruction, regardless of the location of their schools or the demographic composition of their classes.

Finally, administrators and policymakers need to ensure that teachers are getting a coherent set of messages. Tests that assess the most important knowledge and skills will have a positive influence on instruction, as will providing opportunities and incentives for teachers to deepen their understanding of the mathematics/science content they are expected to teach, and how to teach it. Only if pre-service preparation, K-12 curriculum, student assessment, professional development, and teacher evaluation policies at the state, district, and school levels are aligned with one another, and in support of the same vision of high quality instruction, can we expect to achieve the goal of excellence and equity for all students.

Appendix: Methodology

For the *Inside the Classroom* study, Horizon Research, Inc. (HRI) staff and consultants conducted observations and interviews during the period November 2000–April 2002. The classroom observation instrument originally developed and validated by HRI as part of the core evaluation of the National Science Foundation's Local Systemic Change initiative was adapted for use in this study. An interview protocol was developed to query observed teachers about influences on their instruction.

The study design involved selecting a sample of schools to be representative of all schools in the United States; gaining school cooperation; selecting the sample of classes to be observed; collecting observation and teacher interview data; and weighting and analyzing the data appropriately to provide estimates for mathematics and science lessons in the nation as a whole.

A subset of 40 middle schools was selected from the sample of schools participating in the 2000 National Survey of Science and Mathematics Education. Systematic sampling with implicit stratification was used to ensure that the 40 sites would be as representative of the nation as possible. When a middle school agreed to participate, the study coordinators identified the elementary schools and high schools in the same feeder pattern and randomly sampled one of each. For classroom observations, a simple random sample was drawn from among the mathematics and science teachers in the sampled school. One class each of two mathematics teachers and two science teachers was to be observed in each school.

HRI encountered some resistance in securing cooperation of the sampled sites. When roughly half of the project observations had been completed, the study coordinators inspected the demographic characteristics of the observed sites to confirm that they were representative of schools in the nation. Noting some gaps, HRI drew a new random sub-sample of middle schools from the national survey schools and hand-picked a sub-group of 14 sites that would round out the sample in terms of demographic characteristics.

Due to time and resource constraints, HRI ended the observation phase of the study having visited 31 sites. The 31 sites and the sampled schools were representative of districts and schools in the nation. The observed teachers and classrooms were also representative of those in the nation in terms of teacher backgrounds, instructional objectives, and instructional activities.

For the analysis of the qualitative data, the research team read the observers' descriptions of the lesson designs to determine factors that distinguished designs judged to be effective from those judged to be ineffective. The same process was followed for each of the remaining component areas (implementation, mathematics/ science content, and classroom culture) and for the final capsule descriptions of entire lessons. In all cases, there was no predetermined coding scheme; themes were developed as they emerged from the data.

As part of completing the observation protocol, field researchers had analyzed the teacher interview data and noted the factors that teachers said had influenced their selection of content, pedagogy, and instructional materials. The research team analyzed the evidence provided by the field researchers for each category, looking for themes in the nature of these influences. For example, teachers often talked about how the characteristics of the students in their classes influenced their instructional strategies. Themes within this category included addressing the needs of low ability, high ability, and heterogeneous groups as well as classes with high levels of absenteeism. It should be noted that it was difficult to separate pedagogy and instructional materials in these analyses. In interviews, teachers often discussed these lesson components as intertwined in their planning. Accordingly, pedagogy and instructional materials were combined into "instruction" in the analysis of these data.

Data from the classroom observations and teacher interviews were weighted in order to yield unbiased estimates of all mathematics and science lessons in the nation. Each sampled teacher was assigned to a cell determined by the subject observed (mathematics vs. science), school urbanicity (rural vs. urban vs. suburban), and sample grade range (K–5 vs. 6–8 vs. 9–12). All sampled teachers in a cell were then given the same weight such that the sum of weights of the sampled teachers equaled the number of teachers in the nation in that cell. These weights were multiplied by the average number of science or mathematics classes taught by teachers in the nation. To avoid underestimating the standard errors used in tests of statistical significance, the weights were normalized, effectively returning the weighted N to the actual sample size.