




# High Quality Mathematics and Science Instruction

Where do we stand?  
How do we move forward?

**Iris R. Weiss**  
**November 7, 2005**


*horizon*  
RESEARCH, INC.

---



Most of our information on mathematics and science instruction nationally comes from teacher surveys:

- National Survey of Science and Mathematics Education
- NAEP
- TIMSS



While self-report data appear to be valid (when there aren't high stakes attached), teachers can't judge the *quality* of their own instruction.



Need to go “Inside the Classroom” and look.

Also need to talk with teachers to find out where the class has been, and where they are going.

# Before the Observation

- Classroom visit is scheduled
- No formal pre-observation interview

# Classroom Observation

- Observers take detailed field notes that will allow them to describe and complete ratings of the lessons

# After the Observation

- Brief teacher interview
  - Characteristics of the students
  - Context of the lesson
  - Learning goals/lesson purpose
  - Teacher's perspective on the lesson and what students got out of it
- Complete Classroom Observation Protocol

# Classroom Observation Protocol

- The Lesson is the Unit of Analysis
- Description and Quality Assessment
- Look at approximately 30 indicators of lesson design, implementation, quality of science/mathematics content, and classroom culture

# Capsule Rating

- Overall assessment of the likelihood the lesson will contribute to students' understanding of the intended content or to develop their capacity to successfully "do" mathematics/science.

# Capsule Rating

Level 1: Ineffective Instruction

Passive "Learning"

Activity for Activity's Sake

Level 2: Elements of Effective Instruction

Level 3: Beginning Stages of Effective Instruction

(3 levels: Low, Solid, High)

Level 4: Accomplished, Effective Instruction

Level 5: Exemplary Instruction

# Abbreviated Classroom Observation Protocol

- The instructional strategies and activities of this lesson provided sufficient pathway(s) for students to build toward understanding of the intended content.
- Content information provided to students by teacher or instructional materials was accurate.
- Students were intellectually engaged with ideas relevant to the focus of the lesson.
- The teacher's questioning strategies likely enhanced the development of students understanding of key concepts connected to this lesson.
- The degree of "sense-making" of mathematics/science content within this lesson was appropriate for the developmental levels/needs of the students and the purposes of the lesson.
- Students were encouraged to use evidence to support their statements.
- Intellectual rigor, constructive criticism, and the challenging of ideas were evident between teacher and students.

# Balloon Travel

- Read the pre-observation interview
- Watch the lesson
- Read the post-observation interview
- Complete the abbreviated observation protocol, including a capsule rating

# Balloon Travel


- After everyone has completed the abbreviated protocol, discuss your comments on the indicators and your overall rating of the quality of the lesson.

# Inside the Classroom Study

- Designed to provide nationally-representative data on the quality of mathematics and science instruction
- Subsample of middle schools in 2000 NSSME
- Elementary and high school in feeder pattern

## Among the Questions Addressed by the *Inside the Classroom Study*:

1. How does mathematics/science instruction “look” in the nation’s classrooms? To what extent are mathematics/science portrayed as inert collections of facts and algorithms, as opposed to dynamic bodies of knowledge continually enriched by conjecture, investigation, analysis, and proof/justification?
2. Are students actively engaged in pursuing questions of interest to them, or simply “going through the motions,” whether they are doing individual “seatwork” or working in groups?

- 
3. To what extent do mathematics and science lessons engage students intellectually with important mathematics and science disciplinary content?
  4. Is teacher-presented information accurate? Do teachers display an understanding of mathematics/science concepts in their dialogue with students?

5. When teachers ask questions, are they posed in a way that is likely to enhance the development of student conceptual understanding?
6. Are adequate time and structure provided for student reflection and sense-making?
7. To what extent is there a climate of respect for students' ideas, questions, and contributions? Are students encouraged to generate ideas, questions, and conjectures?


The observation protocol was adapted from the LSC Classroom Observation Protocol

Used trained observers – Horizon Research, Inc. staff and consultants, most of whom had done classroom observations for the LSC.

Total of 364 lessons observed, K-12 mathematics and science.

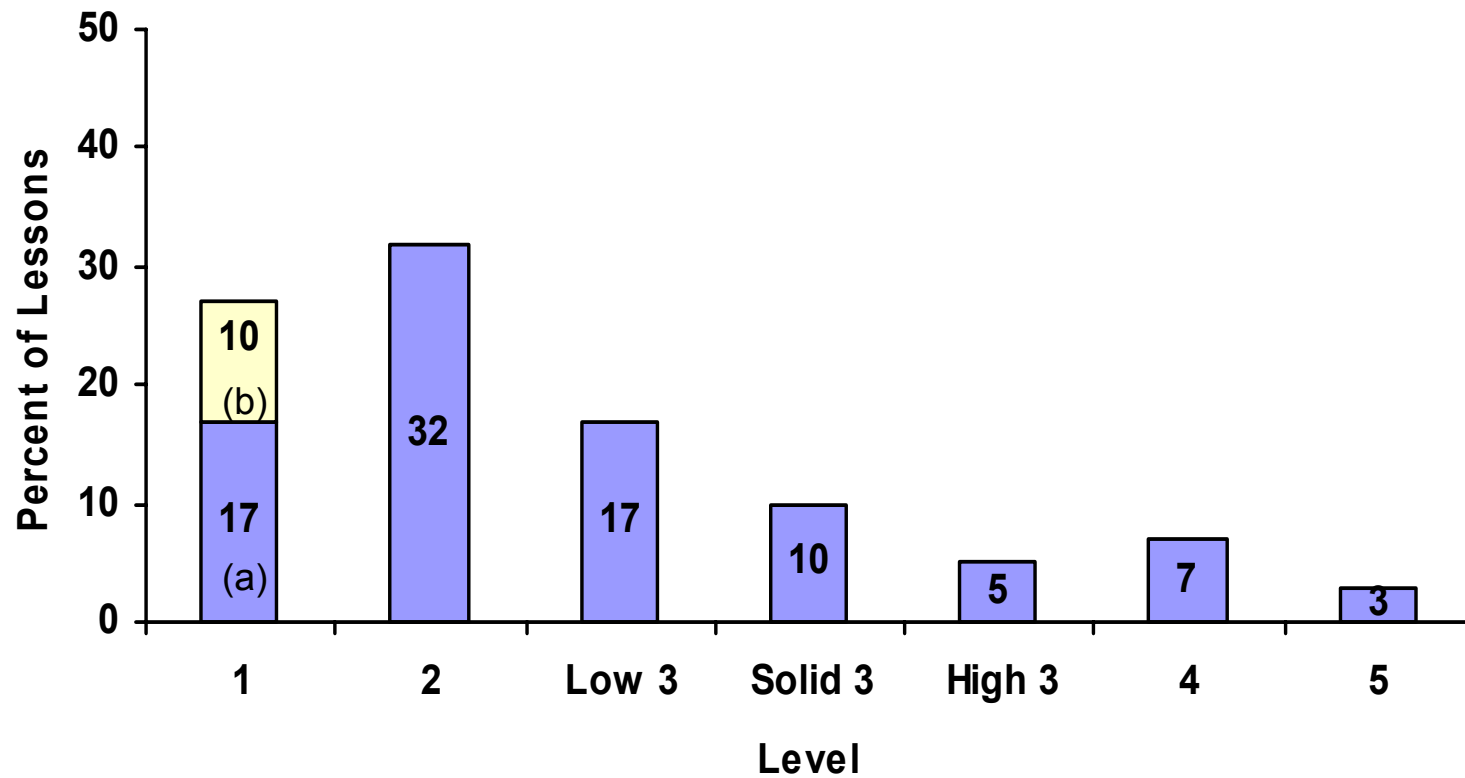
## Researchers

- Took detailed field notes describing what the teachers and students were doing throughout the lesson
- Interviewed the teachers after the lesson
- Completed an Observation and Analytic Protocol



What percent of K–12  
mathematics and science  
lessons would you predict  
were rated as high quality?

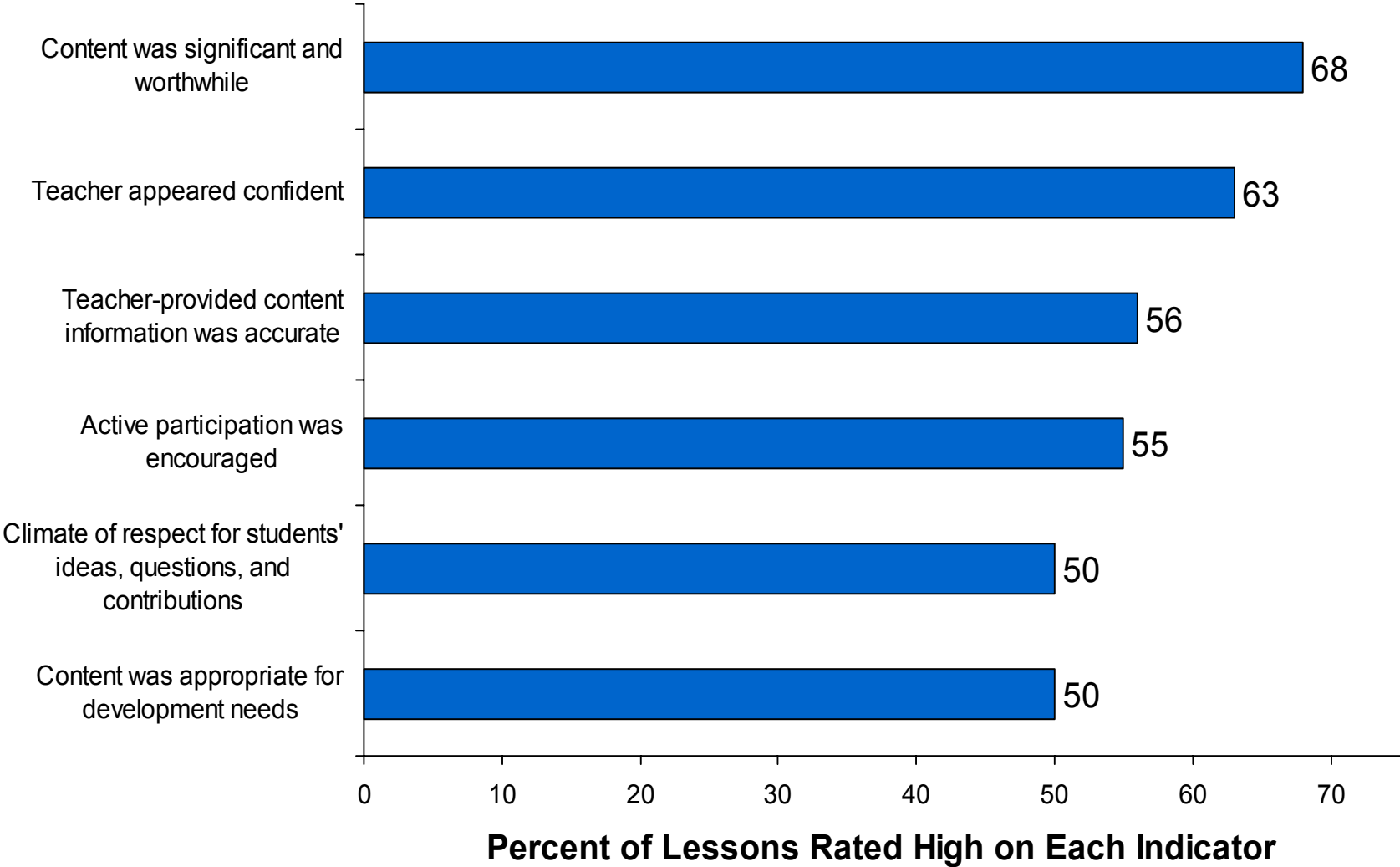
# Capsule Ratings: K-12 Mathematics and Science Lessons



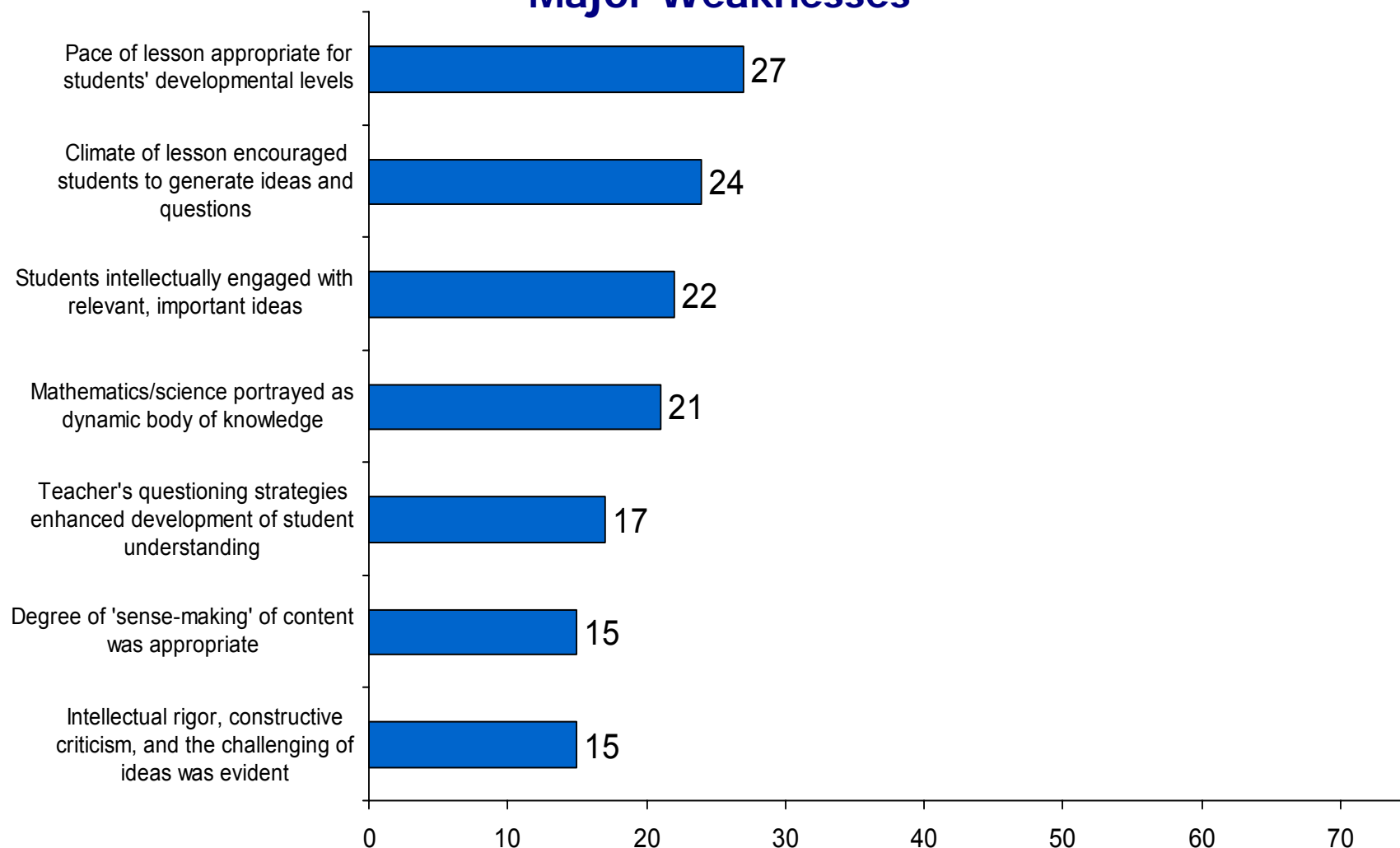


**We saw well-designed lessons  
that were “reform-oriented,”  
“traditional,” and a blend of  
the two.**

# Inside the Classroom National Observation Study Relative Strengths




# Inside the Classroom National Observation Study Major Weaknesses



Percent of Lessons Rated High on Each Indicator

# Key Elements of High Quality Mathematics/Science Instruction

- 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.

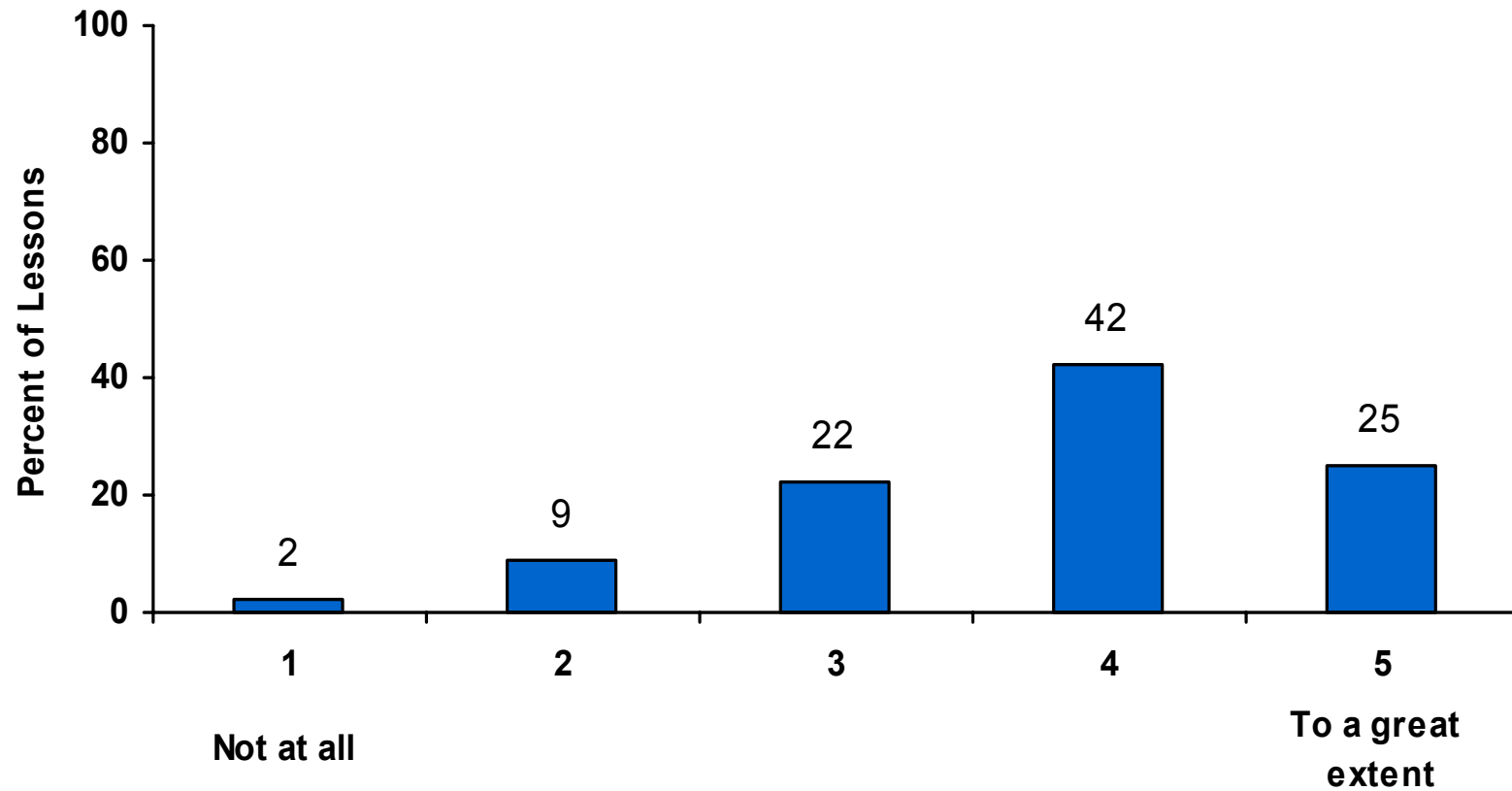


# Engaging Students With Mathematics/Science Content

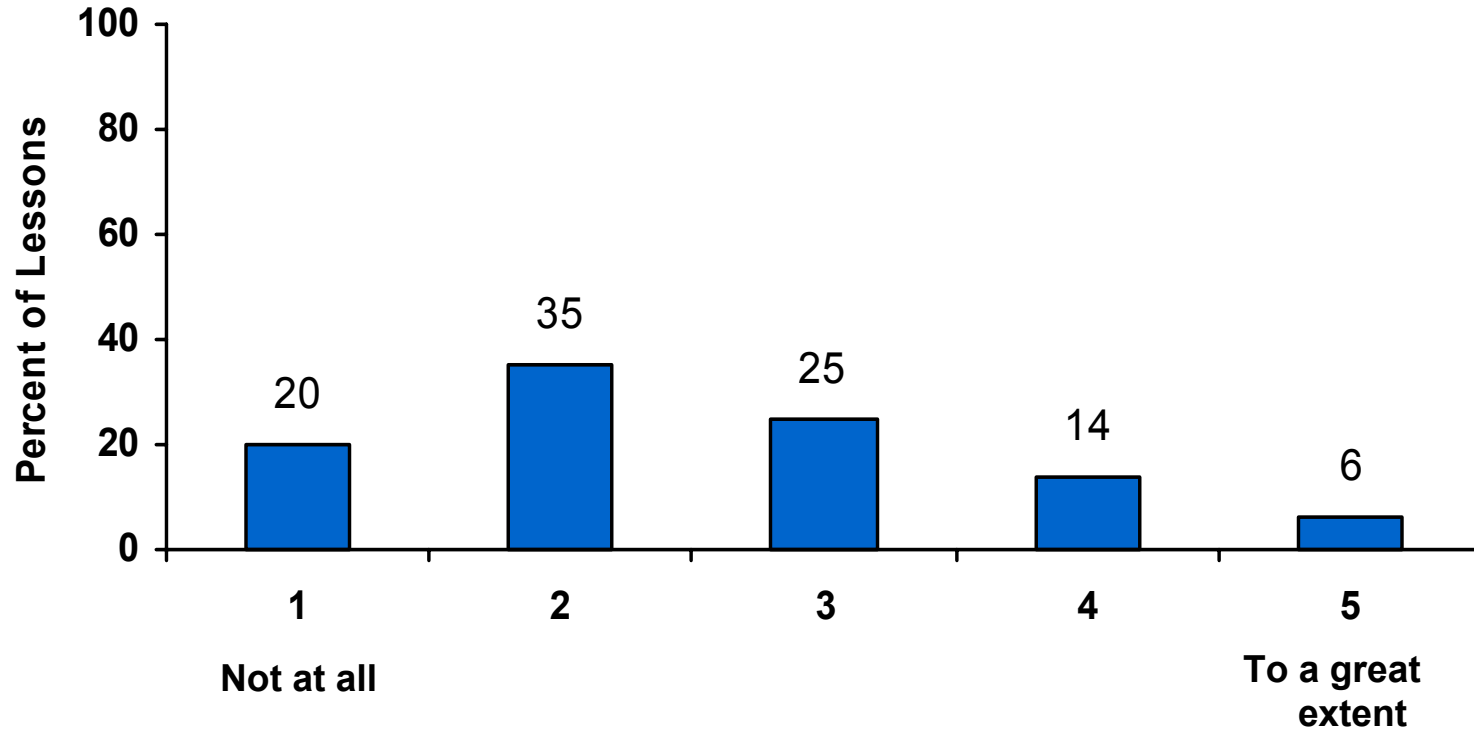
*horizon*  
RESEARCH, INC.

---

## Mathematics/Science Content Is Significant and Worthwhile



## Students Are Intellectually Engaged with Important Ideas Relevant to the Focus of the Lesson



# Many Lessons “Just Started”

- “Turn to page 178 in your book”

or

- “All right now, these pages should be very easy if you’ve been paying attention in class. We talked about all of this stuff.”

# In Contrast:


In a lesson on fractions and as an introduction to percents, the teacher in a 7th grade mathematics class asked three students to come to the front of the class for a demonstration. One student measured the height and arm spread of a second student, while the third student wrote the numbers on the board. The students used these numbers to express the relationships both as a ratio and as a percent.

# Portraying Mathematics/Science as a Dynamic Body of Knowledge Not!!!

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 Contrast:

- A 6th grade science lesson consisted of a teacher-led discussion of the process of sedimentary rock formation. By drawing upon the experiences and prior knowledge of the students, the teacher helped the students devise a model of how sedimentary rock is formed. For example, the teacher asked students, if they broke a vase, what they would need to fix it. The students decided that not only would they need glue, they would also need something to push the pieces together. The teacher then asked the students, "Where might the force come from [to push sand together to make sandstone]?" The teacher probed students until they considered possible sources of the pressure. This lesson emulated the scientific process of using observable data and knowledge of basic scientific principles to create a model of an unobservable process.

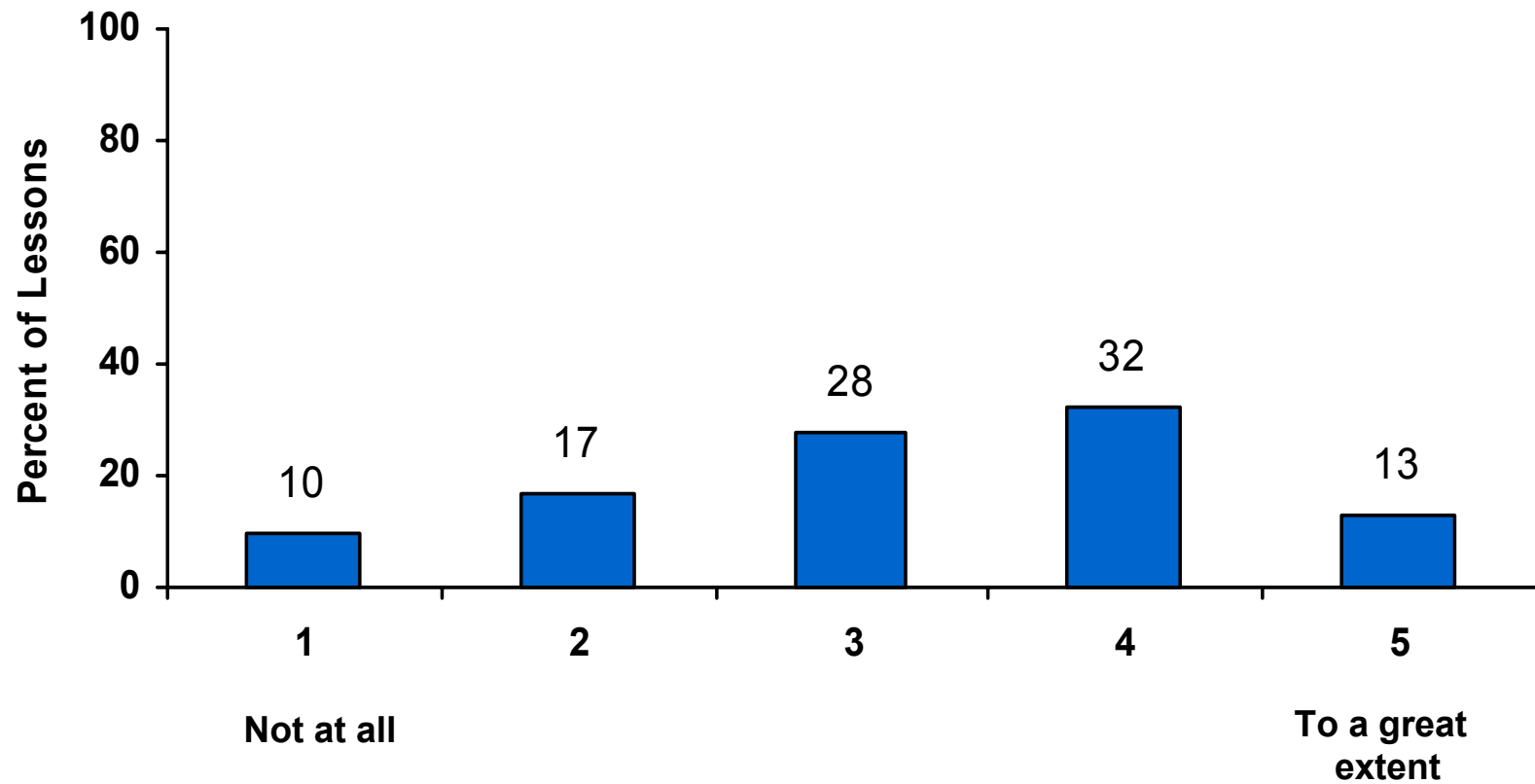


# Creating an Environment Conducive to Learning

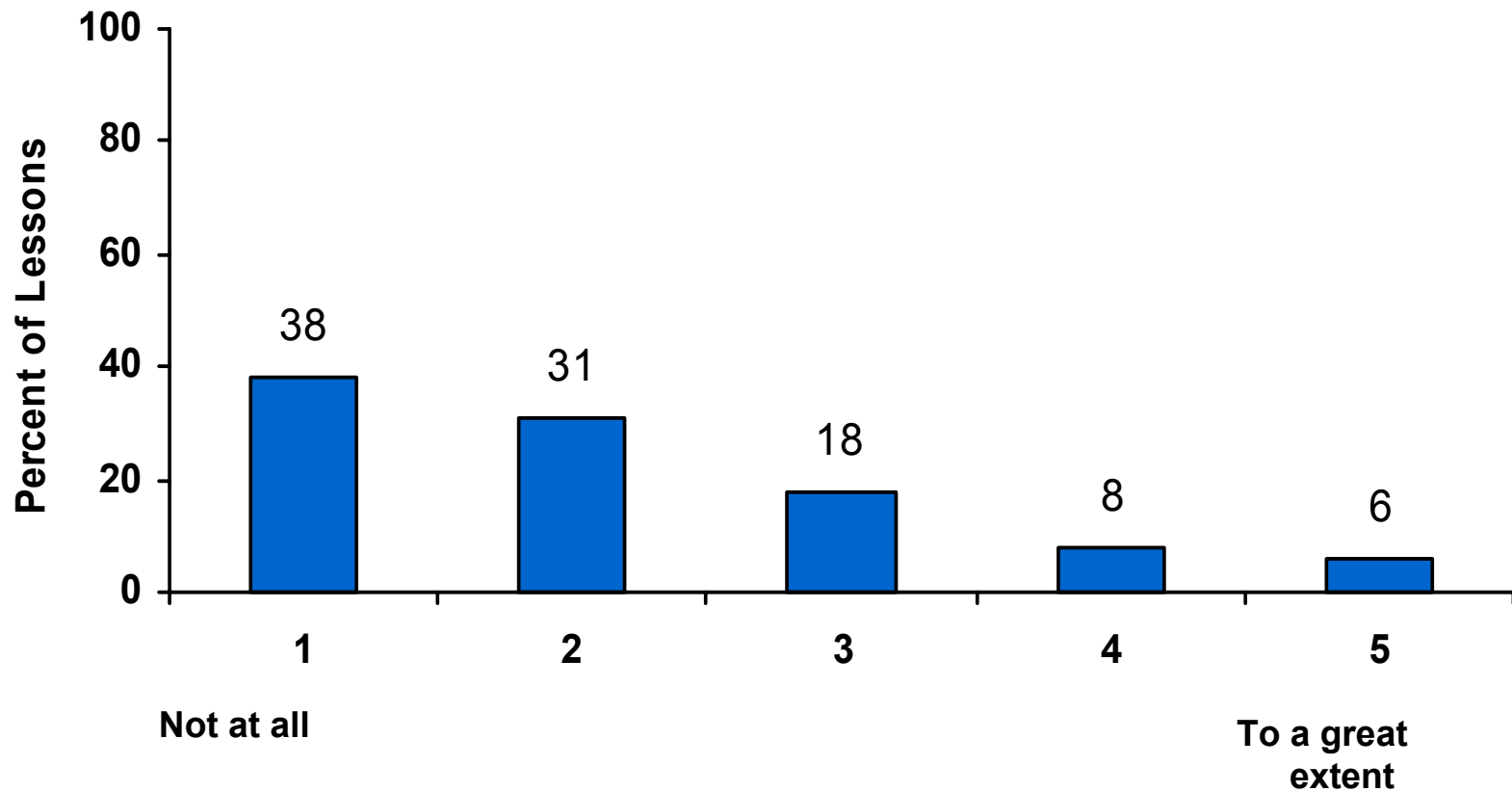
*horizon*  
RESEARCH, INC.

---

# Climate of Respect for Students' Ideas, Questions, and Contributions



## Intellectual Rigor, Constructive Criticism, and Challenging of Ideas Are Evident



# Cross Tabulation of Climate of Respect and Intellectual Rigor

		Percent of Lessons		
		Intellectual Rigor, Constructive Criticism, and Challenging of Ideas Are Evident		
		Low	Medium	High
Climate of Respect for Students' Ideas, Questions, and Contributions	Low	26	1	0
	Medium	24	3	1
	High	17	14	13

# Respectful and Rigorous

A student in a high school geometry class offered an answer that was slightly off-base and confusing to many others in the class. The teacher responded with, "Right idea, let's clean it up a bit." The class remained supportive as students offered suggestions for ways to clean the answer up, building on the first student's answer rather than totally dismissing it.

# Respectful, But Lacking in Rigor

Other lessons could be categorized as respectful, but lacking in rigor. Observers used terms like “pleasant, but not challenging” to describe such lessons.

# Respectful, But Lacking in Rigor


An observer described a 4th grade mathematics lesson where “the teacher was very enthusiastic; she gave lots of verbal encouragement to students as they worked...The culture suffered from a lack of focus on the intellectual content, however. The teacher appeared more intent on the students having a positive experience with mathematics than really engaging with the concepts.”

# Lacking in Respect

Some lessons were judged to be lacking in respect, in some cases even hostile and demeaning to students.

# Lacking in Respect for Students


- The observer noted that the culture in a high school biology classroom was one of an authoritarian teacher and uninspired students. About half the class was entirely disengaged for the entire block period, and several did not even fill out the worksheet during the time allotted. Students remained silent during work time and apologized when they gave a wrong answer. On three different white boards the teacher had written: "If anyone writes with my pens again you will pay the price."



# Helping Students Make Sense of the Mathematics/Science Content

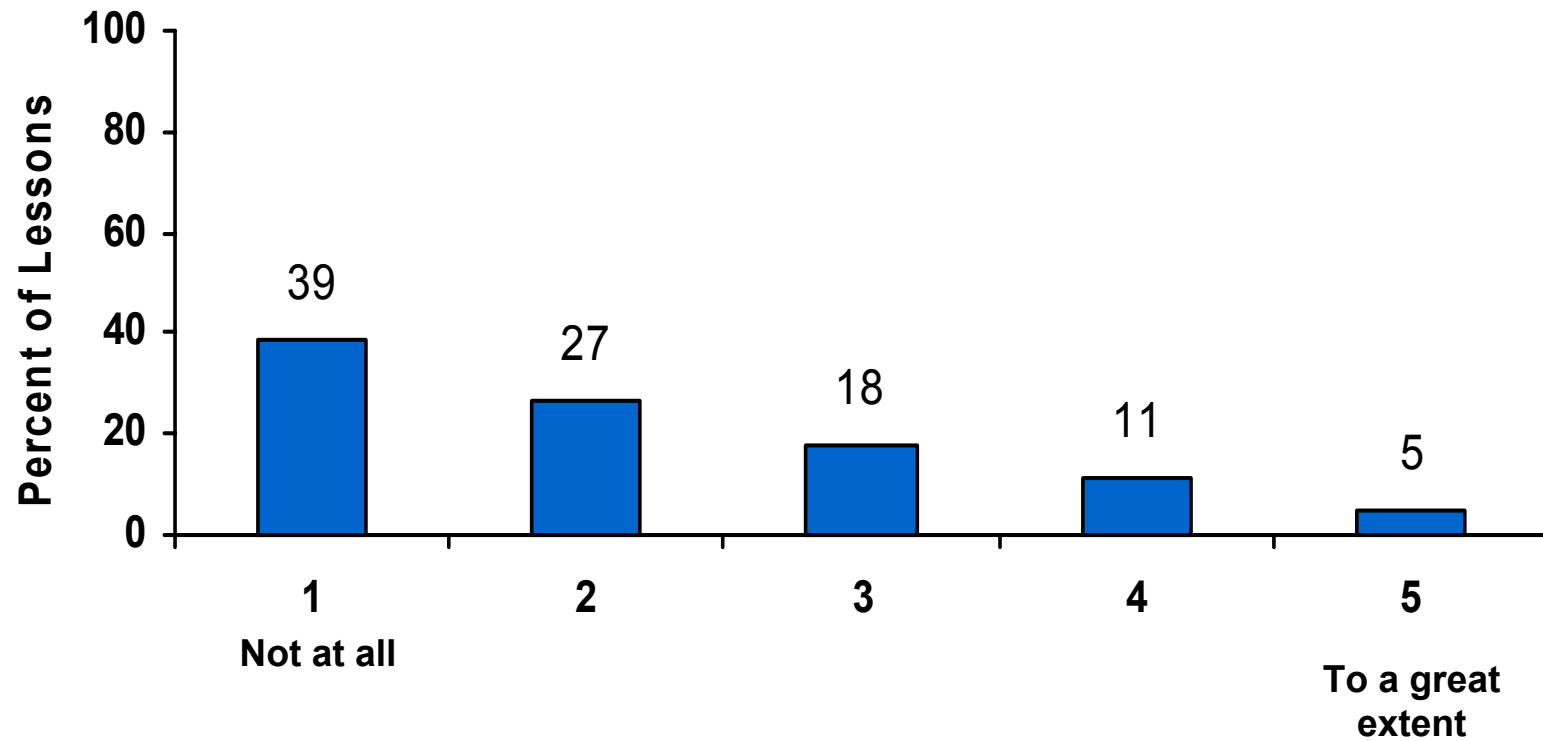
*horizon*  
RESEARCH, INC.

---



Questioning to  
encourage students to  
think more deeply

# Teacher's Questioning Enhanced Development of Student Understanding/Problem Solving



- 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?”

The teacher asked for examples and justifications from the students as a means of assessing their understanding. 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.

# In Contrast,


The observer noted that the entire lesson consisted of a whirlwind of lower level, factual, and procedural questions. For 40 minutes the teacher asked students in this 5th grade class questions about:

- the metric system
- the meaning of base 10
- place value
- multiplication
- division
- fractions
- decimals
- mixed numbers
- improper fractions
- fraction names for 1
- equivalent fractions
- simplifying fractions
- divisibility rules for 2, 3, 5 and 10

- writing numbers in base 5 and 3
- place value in these two bases
- changing mixed numbers to improper fractions
- defining fractions as division
- pulling up real world occupations that use fractions
- comparing fractions using cross multiplication and common denominators
- changing a fraction to a decimal then to a percent

How would you rate the following question and answer session that took place in a 6th grade science lesson on weather and the atmosphere?

- **Teacher:** "The first layer is the what?"
- **Students:** "Troposphere"
- **Teacher:** "How many layers are there?"
- **Students:** "Four"
- **Teacher:** "What happens in the troposphere?"
- **Student:** "It rains"
- **Teacher:** "What happens in that layer?"
- **[Students unsure]**
- **Teacher:** "w, w, w..."
- **Student:** "Water?"
- **Teacher:** "What have we been studying?"
- **Student:** "Weather."
- **Teacher:** "What are four forms of precipitation?"
- **Students:** "Rain, snow, sleet, hail"



Sometimes teachers  
answer their own  
questions

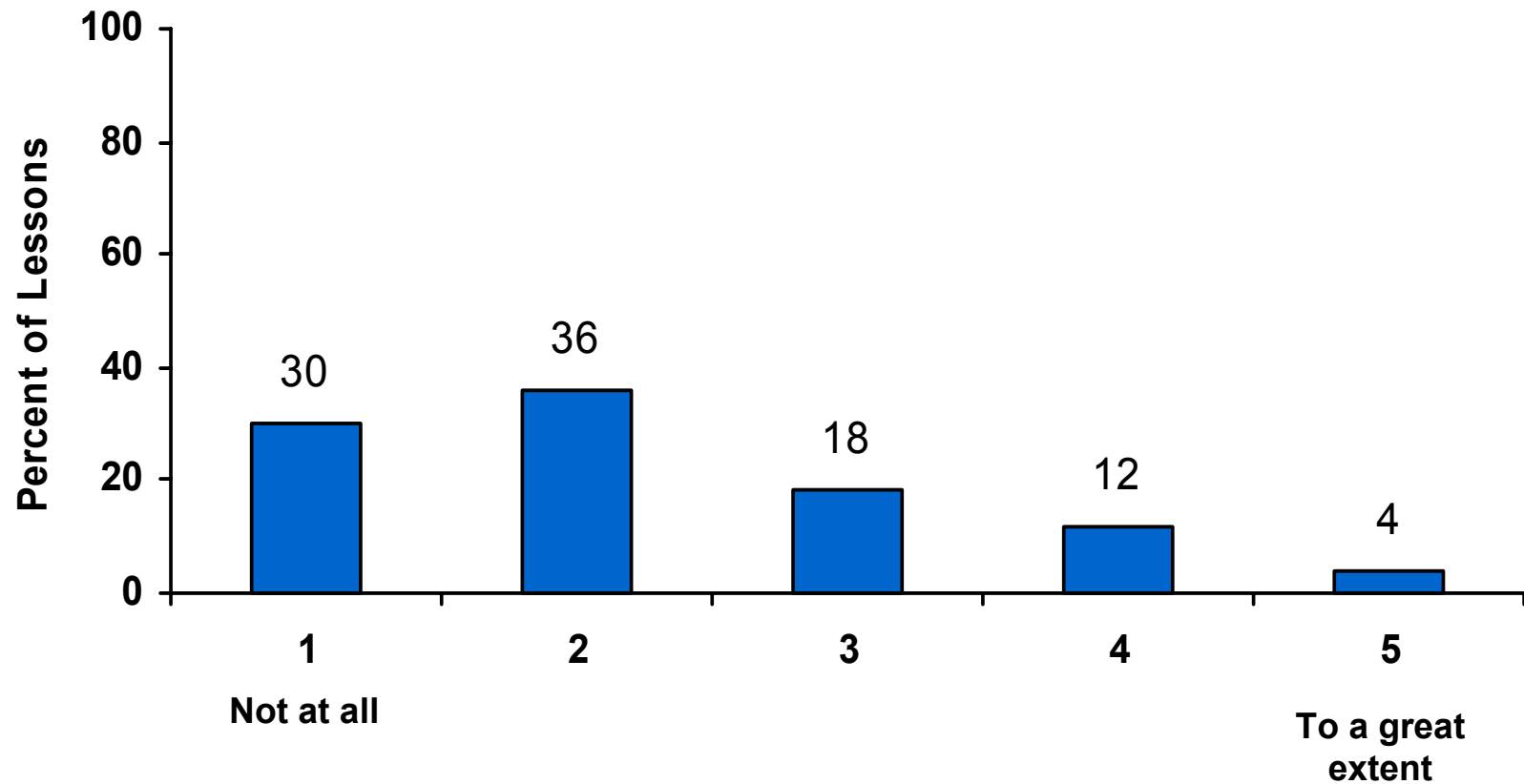
Said the observer of a high school calculus lesson: "The teacher asked for a student's input as to the next step toward the solution, but then disregarded the student's suggestion (which was one correct way to proceed) and went with his own strategy, saying: 'Yes, we can do that. But let's....' So the teacher solved the problem his way, even though he had asked for a student's strategy."



MAJOR Weakness:

Inadequate attention to  
"sense-making"

## Degree of Sense-Making Is Appropriate for This Lesson



The teacher guided a 3rd grade class through the completion of a science worksheet by referring the students to a particular question, telling them to turn to a specific page in their textbook and look for the answer, asking one student volunteer to read the answer from the book, then writing the answer 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.

An observer of a 6th grade class noted that the teacher did not seem to be trying to monitor if students understood what was going on in the lesson. "Her focus throughout the large group discussion was on getting through the sequence of questions she had prepared. The teacher did not seem tuned into whether the 'big ideas' made sense to the kids or not. She seemed pleased that she had answers to her questions and they were the answers she was looking for."

# In Contrast:

The teacher in a high school 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. He spent most of the remainder of the lesson explaining that receptors vary in threshold and, "Your brain recognizes the highest threshold receptor stimulated." The teacher gave the example of caution signs being made of certain colors because the receptors for those stimuli have the lowest threshold, and of an artist using certain colors to create light and draw a person to a particular part of a painting.

- Choice of instructional strategy doesn't appear to be as important as some have suggested.
- The key appears to be providing students an opportunity to engage with important science concepts and ensuring that they in fact make sense of these concepts.

# Local Systemic Change Initiative

- NSF funded the first cohort of Local Systemic Change (LSC) projects in 1995
- A total of 88 projects were funded by 2002
- Projects represent a wide variety of contexts – rural, suburban, urban districts, with widely varying demographics

# Logic Model of LSC Professional Development

Quality of PD Program



Increased Teacher Knowledge/Skills



Improved Classroom Practice



Improved Student Performance

# Local Systemic Change Initiative

- Targeted all teachers in a jurisdiction for professional development (minimum 130 hours)
- Emphasized preparing teachers to implement project-designated mathematics/science instructional materials in their classes
- Promoted efforts to build a supportive environment for improving science, mathematics, and technology instruction

# Core Evaluation Activities

- Interviews with PIs to understand the project approach
- Observations of professional development activities
- Teacher and principal questionnaires
- Classroom observations
- Teacher interviews

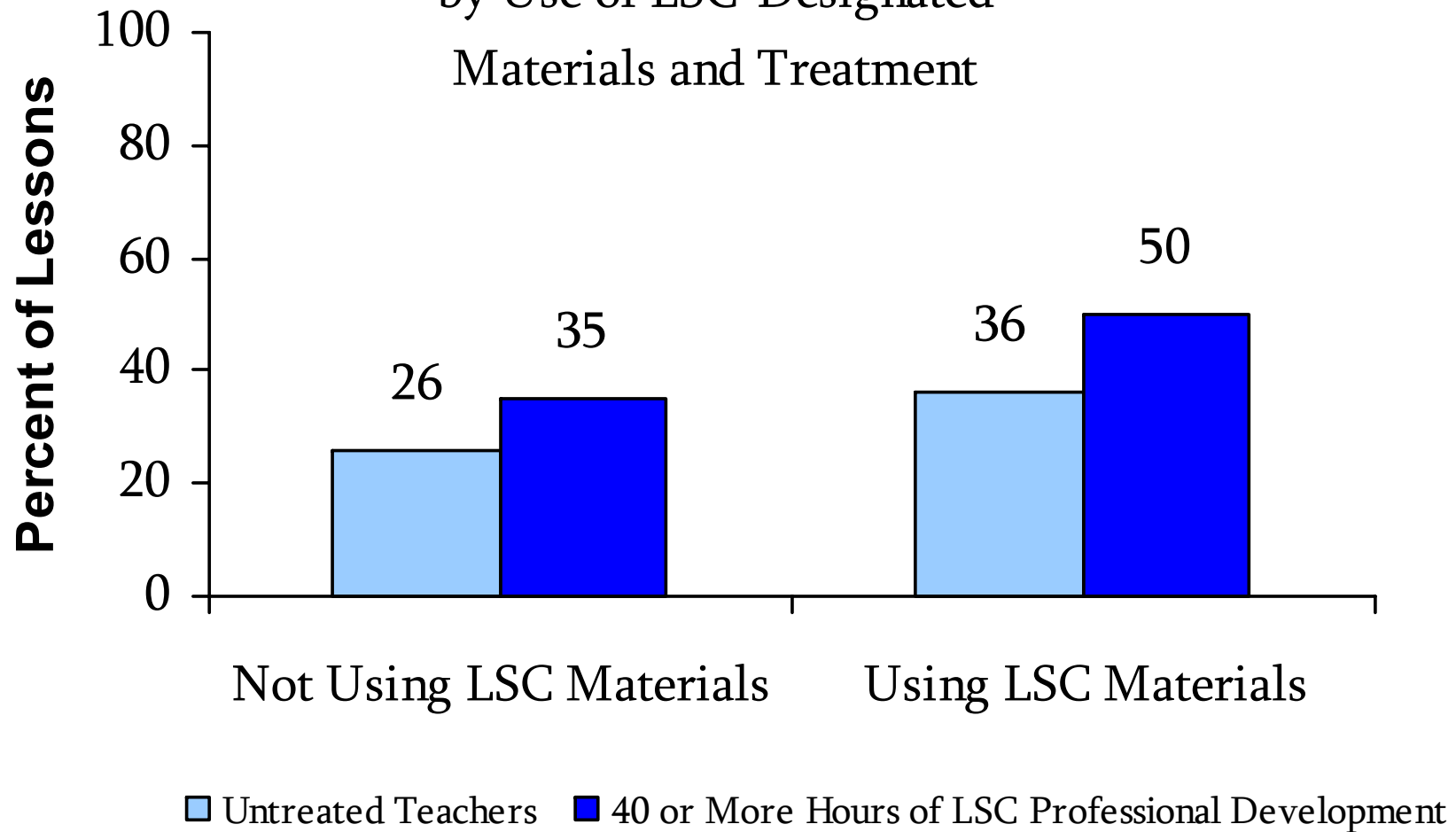
LSC professional development had a positive impact on classroom practice:

- Increased use of designated instructional materials
- Enhanced quality of content presented to students

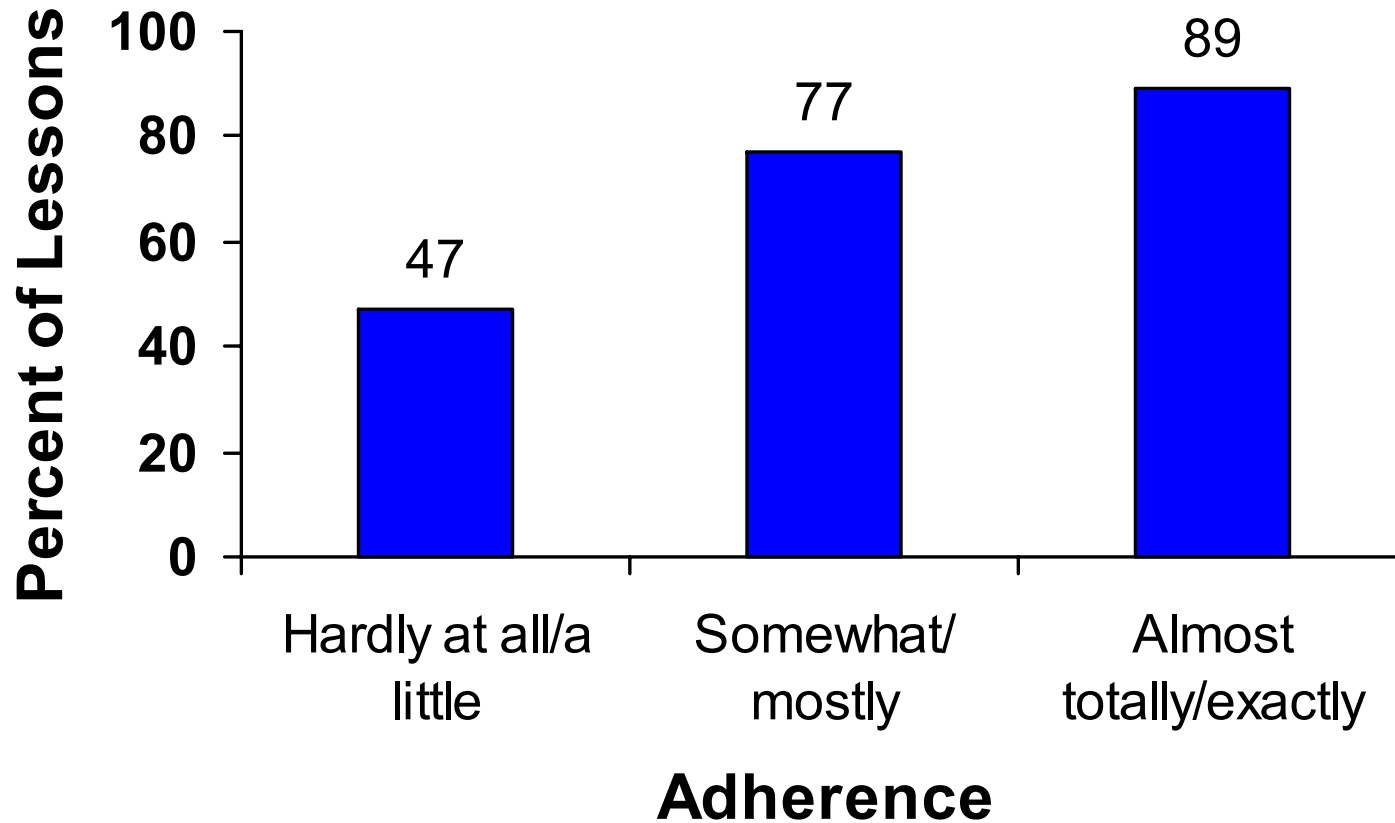
- More frequent use of investigative practices, questioning, and sense-making practices
- A greater likelihood that the classroom culture promoted intellectual rigor and student engagement


# Impact on Classroom Practices

Highly-Rated K-12 Mathematics Lessons,  
by Use of LSC-Designated  
Materials and Treatment



## Highly-Rated Lessons, by Adherence to LSC-Designated Materials





PIs were encouraged to visit classrooms, and reported that teachers were doing the activities without adequate focus on the mathematics.

Theoretical limitation: PIs evaluating their own “work” so they might be biased in a positive direction.

# PI Report: Elementary Mathematics Class

"We could not see any evidence that she [the teacher] understood how the content in the lesson fit into the big picture of the unit. ... She asked questions and her behavior indicated that she was cognizant of student thinking. However we did not see any evidence of a focus on student conceptual development."

# PI Report: Secondary Mathematics Class

"In all three lessons observed, teachers did not demonstrate that they understood the content or how the concepts in the lessons they were teaching fit into the concepts in the unit. They tended to zero in on the minutia of a particular lesson and apparently did not recognize how the lessons fit into the bigger picture of the unit."

# Implications

- Teachers need a vision of effective instruction to guide the design and implementation of their lessons.

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.

- It would be helpful to provide teachers with opportunities to analyze a variety of lessons in relation to these key elements of high quality instruction.

- The support materials accompanying textbooks and other student instructional materials need to provide more targeted assistance for teachers.

- 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; means to ensure that teachers are developing understanding.

- Finally, administrators and policymakers need to ensure that teachers are getting a coherent set of messages
  - Preservice preparation
  - Curriculum
  - Student Assessments
  - Professional Development
  - Teacher Evaluation