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

May 2003

Horizon Research, Inc.
326 Cloister Court
Chapel Hill, NC 27514

www.horizon-research.com

Iris R. Weiss
Joan D. Pasley
P. Sean Smith
Eric R. Banilower
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Looking Inside the Classroom

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Highlights Report

A condensed version of this report—*Highlights Report, Looking Inside the Classroom: A Study of K–12 Mathematics and Science Education in the United States*—is available on the web at www.horizon-research.com

Executive Summary

The major purpose of the *Inside the Classroom* study is to provide the education research and policy communities with snapshots of mathematics and science education as they exist in classrooms in a variety of contexts in the United States. These snapshots include both the instruction that takes place and the factors that shape that instruction. Horizon Research, Inc. (HRI) staff and consultants conducted observations and interviews for the study during the period November 2000–April 2002.

For *Inside the Classroom*, the study coordinators adapted the classroom observation instrument originally developed by HRI as part of the core evaluation of National Science Foundation's Local Systemic Change initiative. The instrument is designed to assess the quality of the design and implementation of mathematics and science lessons. In addition, an interview protocol was developed to use with observed teachers in order to gather data on the factors that shape 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.

For *Inside the Classroom*, 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 largely comparable to districts and schools in the nation generally. The observed teachers and classrooms were also largely comparable to those in the nation as a whole in terms of teacher backgrounds, instructional objectives, and instructional activities.

Ratings of the Quality of Mathematics and Science Lessons

The *Inside the Classroom* study employed an overall quality rating scale for lessons, ranging from "ineffective instruction" to "exemplary instruction." Using observers' ratings on this scale, lessons were broadly categorized as low, medium, and high quality. Fifteen percent of mathematics and science lessons nationally are estimated to be high in quality; 27 percent medium in quality; and 59 percent low in quality.

The classroom observation protocol also called for ratings on four lesson components: the lesson design, lesson implementation, mathematics/science content addressed; and classroom culture. Within each component area, observers rated several indicators, and then provided an overall rating with a detailed rationale.

Lesson designs were rated between 1 and 5, with 1 representing "not at all reflective of best practice," and 5 representing "extremely reflective of best practice. Based on the *Inside the Classroom* observations, most mathematics and science lessons in the nation would be rated a 2 or 3 out of 5 for the overall quality of their designs. Across all lessons, the strongest elements of lesson design are the contribution of available resources to accomplishing the purposes of instruction, and the careful planning and organization of lessons. The weakest elements of lesson design are the adequacy of time and structure provided for sense-making, and the adequacy of time and structure provided for lesson wrap-up.

Overall judgments of the quality of implementation of lessons were provided on a 1 to 5 scale analogous to the lesson design scale. The modal rating of lessons nationally would be 2 out of 5. The strongest element of lesson implementation is the confidence of the teacher in her/his ability to teach mathematics/science. The weakest element of lesson implementation is teacher questioning in terms of likelihood to enhance development of students' understanding.

The quality of mathematics/science content addressed in lessons was also rated on a 1 to 5 scale, where a 1 represents "not at all reflective of current standards" and a 5 represents "extremely reflective of current standards." Nationally, the modal rating of the content addressed in lessons would be 2 out of 5. The mathematics/science content of lessons is typically accurate, significant, and worthwhile. Lessons are relatively weak in their portrayal of mathematics or science as a dynamic body of knowledge. Similarly, lessons tend to fall short in the degree of sense-making of the mathematics/science content provided.

Classroom culture was rated on a 1 to 5 scale, but with a different meaning. On this scale, a 1 indicates a culture that "interferes with learning" and a 5 indicates a culture that "facilitates learning." Nationally, most lessons would receive a 2 or 3 rating for classroom culture. Among the strongest elements of culture are the climate of respect for students' ideas, questions, and contributions; and the encouragement and valuing of active participation of all students. Classroom culture is weakest in terms of evidence of intellectual rigor, constructive criticism, and challenging of ideas.

Strengths and Weaknesses of Mathematics and Science Lessons

An important aspect of the *Inside the Classroom* study was identification of characteristics that appear to be most important in determining lesson quality. Key factors that seem to distinguish lessons judged to be high in quality from those judged to be low in quality are their ability to: engage students with the mathematics/science content; create an environment conducive to learning; ensure that all students have access to the lesson; and help students make sense of the mathematics/science content.

Although the majority of lessons address important mathematics/science content, high quality lessons are differentiated by the proactive strategies employed to engage students with that content. For example, high quality lessons often invite students into purposeful interaction with the content through experience of phenomena, real-world examples, or other engaging learning contexts.

A common characteristic of high quality lessons is the portrayal of mathematics or science as a dynamic discipline, with some established conventions, methods, and principles, but also a commitment to ongoing enrichment of understanding through conjecture, investigation, theorizing, and application. In contrast, most lessons, and in particular lessons or components of lessons intended to provide review for high stakes tests, portray mathematics and science as static bodies of factual knowledge and procedures.

Lessons judged to be high in quality are distinguished from those judged to be low in quality in that they gear the learning goals and instructional activities of lessons to the developmental levels of the students, building on students' level of understanding to move them forward in their thinking. In doing so, high quality lessons generally provide multiple pathways for students to engage with the content and increase their grasp of targeted concepts. The use of multiple pathways can allow students with different background knowledge or learning styles to engage successfully with the content, and provide opportunities for all students to draw conceptual connections among related phenomena and representations.

Mathematics and science lessons in general tend to provide environments of respect for students' ideas, questions, and contributions. They are far less likely to provide environments characterized by intellectual rigor, constructive criticism, and challenging of ideas. Lessons providing environments high in both respectfulness and rigor are found in both mathematics and science across grade levels, but are relatively uncommon (13 percent of lessons nationally).

Another distinctive feature of lessons that are judged to be high in quality is that they ensure access to opportunities to learn for all students. Generally, but not universally, mathematics and science lessons encourage active participation of all students. Lessons that are rated low on this characteristic (29 percent nationally) may not invite active participation of students at all, or may favor participation of some students and discriminate against the participation of others.

There appears to be a pattern of differential quality of instruction across types of communities, in classes with varying proportions of minority students, and in classes of varying ability levels. Lessons in rural schools are less likely to receive high ratings on a number of key indicators than are lessons in schools in suburban and urban communities. Similarly, lessons in classes that are "majority minority" score lower on these indicators than do lessons in other classes. Finally, mathematics and science lessons in classes that teachers categorize as comprised of "low ability" students, and those with "middle ability" students, are less likely to receive high ratings than are lessons in classes categorized as either "high ability" or "heterogeneous in ability."

A key facet of lessons judged to be high in quality is that they help students make sense of mathematics/science content by connecting the activities of the lessons with important learning goals. A primary means to encourage sense-making in mathematics and science lessons is teacher questioning. High quality lessons frequently include questioning used effectively to find out what students already know or do not know about a concept addressed, to provoke deeper thinking, and to monitor emerging understanding of new ideas. These questioning techniques often include probing students for elaboration, explanation, justification, or generation of new questions or conjectures. Questioning in low quality lessons tends to evoke only yes/no or "fill-in-the-blank" responses from students. These questioning techniques elicit, at best, factual or procedural information and do not promote conceptual engagement or understanding of ideas. Questions in low quality lessons are, in some cases, both asked and answered by the teacher. Nationally, two-thirds of lessons would receive low ratings for the indicator "teacher's questioning enhanced development of student understanding/problem solving."

Effective questioning is not the only means of helping students make sense of mathematics/science concepts. In some lessons, relevant and accessible examples given in lectures help students connect concepts to experiences as a way to enhance understanding. Purposeful and thought-provoking teacher demonstrations or student activities, coupled with discussion or writing about observations and ideas, can also be used to promote sense-making.

Lessons judged to be low in quality often lack sufficient opportunities for sense-making. Prevalent across grade levels in mathematics and science are lessons in which students experience phenomena, conduct investigations, work problems or exercises, or attend to presented information, but never have a chance to distinguish important concepts from supporting details or to connect new information to existing knowledge.

Influences on Mathematics and Science Lesson Content and Instruction

In interviews, teachers were queried about factors that may have influenced the content and instruction used in the observed lesson. State/district curriculum standards are the most frequently cited influences on lesson content, with more than 7 out of 10 lessons nationally being influenced by these documents. Teachers also report that textbooks/programs designated for the class and state/district accountability systems influence content selection, with each being a factor in nearly 5 out of 10 mathematics and science lessons. Other potential influences are less frequently reported by teachers, including their own knowledge and beliefs (roughly 3 in 10 lessons), the characteristics of the students in the particular class (fewer than 2 out of 10 lessons), and teachers' colleagues (1 in 10 lessons). Teachers rarely report that school boards, district administrators, principals, parents/community, professional development activities, teacher evaluation systems, or national standards influence their selection of content.

While teachers report that the content of most mathematics and science lessons is guided by external factors such as state and/or district curriculum standards or frameworks, these policy documents seem to have much less of an influence on instructional strategies. Instead, teachers indicate that they have a great deal of latitude in selecting the strategies they use in their mathematics and science lessons. In 9 out of 10 lessons, the teacher's own knowledge, beliefs, and prior experiences (e.g., as mathematics/science learners or in their pre-service/in-service preparation) influence their instruction. For example, some teachers believe that hands-on activities are particularly effective. Other teachers believe that effective instruction requires the use of lecture and other "traditional" strategies. Some teachers believe that repetition is necessary for learning, and incorporate frequent review into their instruction. Other teachers believe that multiple strategies need to be used in order to accommodate the varied learning styles of their students. All of these beliefs influence teachers' selection of instructional strategies.

According to teachers, the textbook/program designated for use in their classes is influential in the selection of instructional strategies in roughly 7 out of 10 lessons, but the nature of that influence varies from closely following the textbook plan for instruction, to modifying the textbook plan, to simply using the textbook as a resource. Teachers also report that instructional strategies in 5 out of 10 mathematics/science lessons are influenced by the characteristics of students in their classes, as they attempt to gear their instruction to the ability levels and needs of the group.

Instruction in roughly 3 out of 10 mathematics/science lessons is influenced by teachers' professional development, including both formal courses and staff development activities, and in 2 out of 10 lessons by their work with colleagues at their schools. Other potential influences on instruction are less frequently cited, including principals, school boards and superintendents, state/district curriculum documents and accountability systems, and parents/community. Surprisingly, given the age of many schools in the United States, and the budget problems in many school systems, instruction in fewer than 1 in 10 lessons is reportedly influenced by constraints in the physical environment.

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.

CHAPTER ONE
Background

Introduction

In 1976, in order to get a better idea of the status of science, mathematics, and social studies education in the United States, the National Science Foundation (NSF) commissioned three large studies. These included: (1) a major review of the science, mathematics, and social studies education research literature, coordinated by Stanley Helgeson at The Ohio State University; (2) a national survey of teachers, principals, district, and state personnel, directed by Iris Weiss, then at the Research Triangle Institute; and (3) intensive case studies in 11 districts, coordinated by Robert Stake and Jack Easley at the University of Illinois. The results of these three studies, collectively known as “the NSF needs assessment,” were disseminated widely and used extensively in program decision making. Follow-up national surveys of science and mathematics education were conducted in 1985–86, 1993, and 2000. Information provided by respondents included teacher and student demographics, teacher background and beliefs, instructional materials, and classroom practices. A number of reports and research syntheses using these data have been produced since the late 1970s.

While survey data are very important, the research and policy communities are interested in learning about classroom practice not only from the perspective of the classroom teacher, but also through the eyes of external observers. Previous research has demonstrated that teachers’ self-report on the *frequency* of reform-oriented instructional practices meet reasonable standards of validity and reliability, but teachers are clearly not in a position to judge the *quality* of their own instruction (Mayer, 1999).

For example, researchers in one study observed 25 teachers who reported reform-oriented practice on a survey questionnaire and found evidence of such practice in all of the classrooms, e.g., an emphasis on mathematical problem-solving, using manipulatives, and making connections to the real world. However, only 4 of the 25 teachers were implementing these practices consistent with the reform vision, where “mathematical tasks were set up to help students grasp and grapple with principled mathematical knowledge that represented *doing* mathematics as conjecturing, problem-solving, and justifying ideas [and where discourse norms] supported attention to principled mathematical knowledge and represented mathematical work as more than computation” (Spillane and Zeuli, 1999, p.19).

The need for information on the nature and quality of K–12 lessons is particularly acute given the current emphasis on mathematics and science education reform, yet there have been no national efforts along these lines since the Stake and Easley case studies of 1976.[1] *Inside the Classroom* was designed to help fill the gap in information on what transpires inside the nation's mathematics and science classrooms.

Purpose of the Study

The major purpose of *Inside the Classroom* is to provide the education research and policy communities with snapshots of mathematics and science education as they exist in classrooms in a variety of contexts in the United States. These snapshots include both the instruction that takes place and the factors that shape that instruction. The study was designed specifically to complement and extend findings from the 2000 National Survey of Science and Mathematics Education, the most recent of the surveys mentioned above.

As part of the core evaluation of NSF's Local Systemic Change Initiative, Horizon Research, Inc. (HRI) field-tested, revised, and demonstrated the reliability of a classroom observation instrument for assessing the quality of the design and implementation of mathematics and science lessons.[2] For *Inside the Classroom*, HRI adapted the observation instrument and developed an interview protocol to use with observed teachers in order to gather data on the factors that shape instruction.

Among the questions addressed by the 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?

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[1] The Third International Mathematics and Science Study (TIMSS) included examination of a national sample of mathematics lessons (videotaped in 1995) and of grade mathematics and science lessons (videotaped in 1999), but both studies were limited to the 8th grade. The mathematics findings are reported in Stigler, et. al., 1999 and Hiebert, et. al., 2003; the science findings have not yet been released.

[2] "Validity and Reliability Information for the LSC Classroom Observation Protocol." Horizon Research, Inc., Chapel Hill, NC, 2003.

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?

8. To what extent does each of the following factors shape teachers' decisions about curriculum and pedagogy:
   - Teacher beliefs about how students learn;
   - Student characteristics;
   - School and district administration; and
   - School, district, and state policies regarding curriculum, textbook adoption, testing, and professional development.

CHAPTER TWO
Data Collection and Analysis

Introduction

The *Inside the Classroom* study involved selecting a sample of lessons to be representative of all mathematics and science lessons in the United States; developing instruments to use in observing classrooms and interviewing teachers; training researchers in the use of those instruments; and collecting and analyzing the data. Information about these aspects of the study design and implementation is presented in the following sections.

Sample Selection

In designing this study, HRI was able to draw upon the nationally representative sample of schools that had been selected for the 2000 National Survey of Science and Mathematics Education. The target population for the National Survey school sample included all regular public and private schools in the 50 states and the District of Columbia; the only schools excluded were vocational technical schools, schools offering alternative, special, or adult education only, and pre-school/ kindergarten schools.

Using the Quality Education Data, Inc. database, HRI's sampling subcontractor (Westat) constructed a sampling frame for the National Survey of Science and Mathematics Education based upon all eligible records, creating strata based on grade span, census geographic region, and type of community. To ensure that the sample would represent the variation among schools in socioeconomic status, each stratum was sorted by the Orshansky percentile, which reflects the proportion of students whose family incomes are below the poverty line. Schools were then selected with probability proportional to size.

For *Inside the Classroom*, HRI selected a subset of 40 middle schools from the schools that participated in the 2000 National Survey of Science and Mathematics Education; at the same time, a replacement for each sampled school was designated in the event of refusal. To ensure that the 40 sites would be as representative of the nation as possible, HRI used systematic sampling with implicit stratification. The National Survey sample of middle schools was sorted by region (Northeast, South, Midwest, West), state, Orshansky percentile, and school size. Once the list of middle schools was sorted in this manner, a random starting point was chosen and every n^{th} one was selected so that every school had an equal probability of being included in the *Inside the Classroom* sample. When a middle school agreed to participate, HRI identified the elementary schools and high school(s) in the same feeder pattern and randomly sampled one of each. Thus, each site consisted of three schools—one elementary, one middle, and one high school.[3]

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 science teachers and two mathematics teachers was to be observed in each school. The total sample was projected to be 480 teachers/lessons in 120 schools in 40 districts throughout the United States, evenly divided between mathematics and science and evenly distributed among the elementary, middle, and high school levels.

Data collection began in November 2000. Despite generous incentives and efforts to minimize both the burden and obtrusiveness of the study, HRI encountered some resistance in securing cooperation of the sampled sites. When roughly half of the project observations had been completed, HRI 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 2000 National Survey schools and hand-picked a sub-group of 14 sites (in addition to ones that were already in progress) 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 in April 2002 having visited 31 sites. To reach this number, HRI contacted 86 sites. The disposition of sites is shown in Table 1. In each instance where a site refused, a replacement was chosen with similar demographic characteristics. Three of the 31 sites were sites of convenience. Of these, 2 were selected specifically to ensure adequate representation of large urban schools.

Table 1
Disposition of Contacted Sites

	Number of Sites
Contacted	86
Observed	31
Declined to participate	46
Did not respond	9

3 Among the sites visited, there were five exceptions to this arrangement. In one, two elementary schools were included at the site: a K–2 school and a school containing only grades 3–5. At two sites, the high school declined to participate. In a fourth instance, the single grade K–8 school in a district was included as both an elementary and a middle school. In the fifth site, science was not included in the elementary curriculum so two additional teachers were observed at the middle school level.

Distribution of Observed Sites

Tables 2 and 3 show the grade level, urbanicity, and student demographics of the visited schools. For comparison purposes, data for all schools in the nation are included as well.[4] The majority of schools visited are classified as suburban, with the remainder about equally divided between urban and rural schools.[5] The sampled schools appear to slightly over-represent suburban schools and under-represent rural ones. In addition, large high schools appear to be over-represented. Otherwise, study schools on the whole are quite comparable to schools in the nation in terms of demographic characteristics, including race/ethnicity and percent of students qualifying for free/reduced lunch. (See Table 3.)

Table 2
Urbanicity of Schools

	Percent of Schools		
	Urban[†]	**Suburban**	**Rural**
Overall			
Observed	22	61	17
Nation	24	45	30
Elementary			
Observed	19	63	19
Nation	27	45	29
Middle			
Observed	20	67	13
Nation	22	50	28
High			
Observed	25	57	18
Nation	18	44	38

[†] Here, and throughout this report, "urban" includes both large and mid-size cities.

[4] Data for the study schools and all schools in the nation are tabulations of data from the National Center for Education Statistics' (NCES's) Common Core of Data. NCES has a fourth category of school level called "other." Of the 92 study schools, 2 (2 percent) fell in this category. Nationally, 8 percent of schools are classified as "other."

[5] While all schools at a site were part of the same district, schools within a district may vary in their urbanicity classification.

Table 3
School Size and Student Demographics

	Mean School Size	Mean Percent of Students					
		Free/Reduced-Price Lunch	American Indian/ Alaskan Native	Asian	Black	Hispanic	White
Overall							
Observed	797	40	1	4	23	11	61
Nation	513	41	2	3	16	15	64
Elementary							
Observed	472	46	0	3	27	11	58
Nation	440	45	2	3	16	16	63
Middle							
Observed	702	43	1	4	22	11	62
Nation	602	40	2	3	15	14	66
High							
Observed	1,288	29	0	4	21	13	62
Nation	742	30	2	3	13	12	70

Figure 1 shows the geographic distribution of observed sites superimposed on the population in the United States (darker shading corresponds to greater population). As expected, the *Inside the Classroom* sites are concentrated in the most populous states.

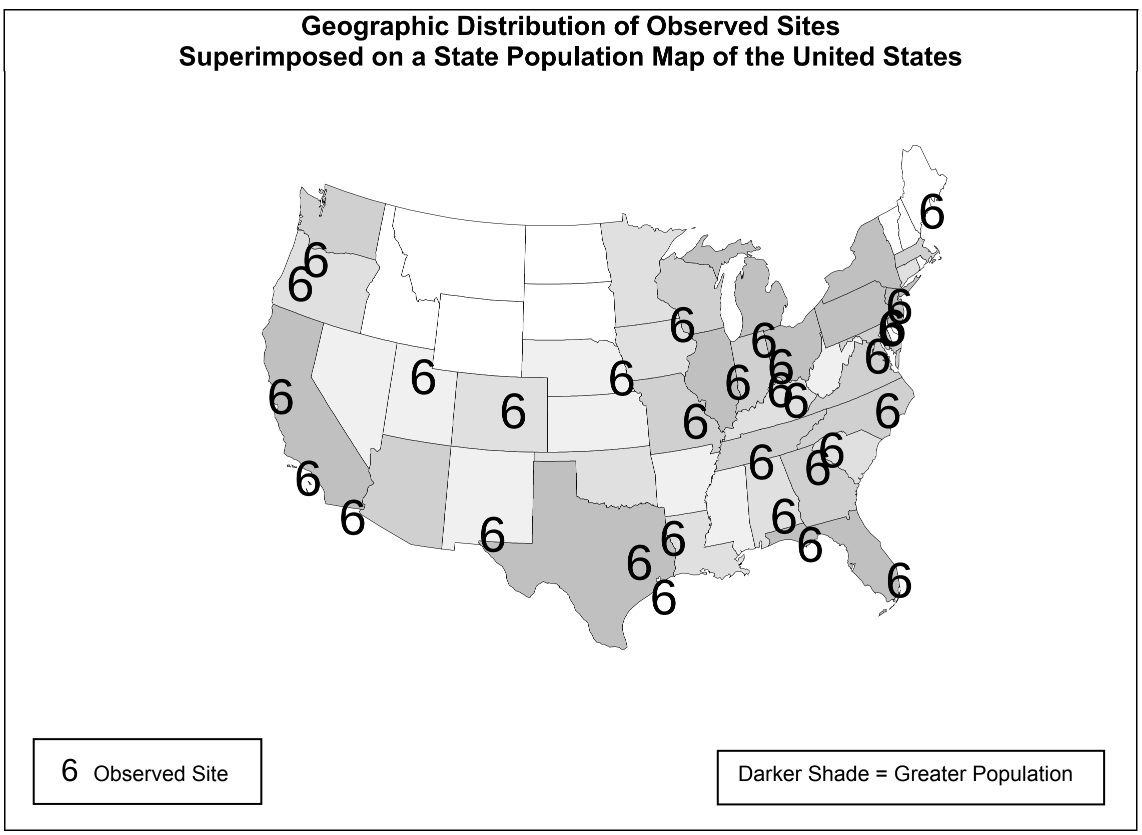


Figure 1

Characteristics of Observed Teachers

Tables 4 and 5 show demographic characteristics of the 364 observed mathematics and science teachers, respectively, with national data from the *Report of the 2000 National Survey of Science and Mathematics Education* (Weiss, et. al., 2001) presented alongside for comparison. In mathematics, teachers observed for the study are representative of teachers in the nation, with two exceptions. African-American elementary teachers and high school teachers with a Master's degree are over-represented in the sample of observed mathematics teachers.

In science, males are slightly over-represented among teachers observed at the middle and high school level. At the elementary level, observed science teachers are more likely than those in the nation to have a Master's degree. In general, however, the sample of observed science teachers is quite similar to the national population of science teachers.

Table 4
Characteristics of the Mathematics Teaching Force, by Grade Range

	Percent of Teachers					
	Grades K–5		Grades 6–8		Grades 9–12	
	Observed	National†	Observed	National†	Observed	National
Sex						
Male	6	7	21	28	49	45
Female	94	93	79	72	51	55
Race						
White	79	89	82	84	94	90
Black or African-American	15	3	10	10	2	4
Hispanic or Latino	6	5	4	4	2	2
Asian	0	0	0	1	0	1
American Indian or Alaskan Native	0	0	0	0	0	0
Native Hawaiian or Other Pacific Islander	0	0	0	0	0	0
Other	0	2	4	2	2	1
Age						
≤ 30 Years	24	20	26	24	12	16
31–40 Years	15	21	24	23	22	24
41–50 Years	33	30	33	27	24	29
51 + Years	28	28	17	26	41	30
Experience						
0–2 Years	21	18	22	19	8	13
3–5 Years	13	13	16	13	6	15
6–10 Years	15	15	20	13	22	14
11–20 Years	29	25	24	25	24	24
≥ 21 Years	23	29	18	30	39	34
Master's Degree						
Yes	42	42	41	43	69	51
No	58	58	59	57	31	49

† Data for K–5 and 6–8 teachers are special tabulations from the 2000 National Survey of Science and Mathematics Education, since the technical report categorizes teachers as K–4, 5–8, and 9–12.

Table 5
Characteristics of the Science Teaching Force, by Grade Range

	Percent of Teachers					
	Grades K–5		Grades 6–8		Grades 9–12	
	Observed	National†	Observed	National†	Observed	National
Sex						
Male	5	10	38	29	63	50
Female	95	90	62	71	38	50
Race						
White	85	87	87	85	85	88
Black or African-American	7	5	9	6	8	4
Hispanic or Latino	2	3	0	4	0	2
Asian	2	1	0	1	4	1
American Indian or Alaskan Native	0	0	0	0	0	0
Native Hawaiian or Other Pacific Islander	0	0	0	0	0	0
Other	2	3	4	5	2	3
Age						
≤ 30 Years	27	20	26	19	20	20
31–40 Years	7	19	26	26	24	23
41–50 Years	39	33	28	28	28	29
51 + Years	27	27	21	27	28	28
Experience						
0–2 Years	17	15	24	17	23	16
3–5 Years	15	15	13	15	17	16
6–10 Years	10	16	16	17	15	18
11–20 Years	22	27	22	24	23	21
≥ 21 Years	37	27	24	27	23	29
Master's Degree						
Yes	54	42	59	47	52	57
No	46	58	41	53	48	43

† Data for K–5 and 6–8 teachers are special tabulations from the 2000 National Survey of Science and Mathematics Education, since the technical report categorizes teachers as K–4, 5–8, and 9–12.

Distribution of Observed Classes

As noted earlier, teachers at sampled schools were selected randomly from among all teachers of mathematics and science in the school. Using class schedules for each of the selected teachers, an observation schedule was constructed for each site, a process that necessitated choosing classes based on constraints such as: (1) scheduling observers at one school for an entire day; and (2) limiting the observation period to three days at any site. Scheduling observations for elementary science proved especially challenging due to the relative infrequency with which the subject is taught in grades K–5.

Mathematics observations in grades K–8 were fairly evenly distributed among the grades. (See Table 6.) At the high school level, sampled classes generally follow patterns of course offerings in the United States; e.g., Review Mathematics classes were least likely to be observed and also least likely to be offered at the high school level (Weiss, et al, 2001).

Table 6
Mathematics Classes Observed

	Percent of Classes
Grades K–5	**(N=57)**
Kindergarten	11
1st Grade	16
2nd Grade	21
3rd Grade	14
4th Grade	16
5th Grade	12
Other (multi-grade) Elementary Mathematics	11
Grades 6–8	**(N=66)**
6th Grade, Regular	30
6th Grade, Accelerated	2
7th Grade, Regular	29
7th Grade, Accelerated	6
8th Grade, Regular	9
8th Grade, Enriched	12
Algebra 1, 7th or 8th Grade	5
Other Mathematics	8
Grades 9–12	**(N=61)**
Review Mathematics (e.g., Basic Math, Review Math)	3
Informal Mathematics (e.g., Pre-Algebra, Applied Math)	7
Formal Math Level 1 (e.g., Algebra I)	30
Formal Math Level 2 (e.g., Geometry)	16
Formal Math Level 3 (e.g., Algebra II)	18
Formal Math Level 4 (e.g., Algebra III, Pre-Calculus)	20
Formal Math Level 5 (e.g., Calculus, AP Calculus)	5
Probability and Statistics	2

With the exception of over-representation at the 3rd grade, science classes observed at the elementary level were well distributed among the grades. (See Table 7.) At the middle school level, General Science classes were the most likely to be observed and also the most likely to be taught in the United States. Observations at the high school level also generally mirror the prevalence of science course offerings in the nation (Weiss, et. al., 2001).

Table 7
Science Classes Observed

	Percent of Classes
Grades K–5	**(N=55)**
Kindergarten	9
1st Grade	13
2nd Grade	15
3rd Grade	25
4th Grade	18
5th Grade	11
Other (multi-grade) Elementary Science	9
Grades 6–8	**(N=64)**
General Science	75
Life Science	13
Earth Science	6
Physical Science	5
Integrated Science	2
Grades 9–12	**(N=61)**
1st Year Biology	21
2nd Year Biology (Advanced, AP)	11
1st Year Chemistry	15
2nd Year Chemistry (Advanced, AP)	3
1st Year Physical Science/Physics	25
Oceanography/Marine Science	2
1st Year Earth Science	7
Environmental Science	10
General/Coordinated/Integrated Science	7

Instrumentation for Observations and Interviews

As noted earlier, the *Inside the Classroom* study included data collected from both classroom observations and teacher interviews. Researchers were asked to take detailed field notes during the observations, including describing what the teacher and students were doing throughout the lesson, and recording the time various activities began and ended. They were asked to pay particular attention to certain aspects of the instruction, describing them in detail and including verbatim accounts of what transpired in these areas if possible. The selected focus areas included: the significance, accuracy, and developmental appropriateness of the mathematics/science content; the extent of intellectual engagement on the part of the students; the nature of the teacher questions and student responses; whether the lesson included appropriate sense-making/closure; and the extent to which the classroom culture encouraged all students to participate in the lesson.

The Teacher Interview

Following the observation, at a time convenient to the teacher such as a planning period or immediately after school, the researcher interviewed the teacher about the lesson using a fairly structured interview protocol. Researchers were asked to tape the interviews (with the approval of the teacher) for later transcription. (A copy of the Teacher Interview Protocol is included in Appendix A.)

Teachers were asked about the learning goals of the lesson (and the unit); the characteristics of the students in the class; and the instructional materials that were used to structure the lesson. They were also asked how well prepared they felt to teach the topic and to use the particular instructional strategies employed in the lesson. Finally, teachers were asked about the context in which they teach, and how that context influences how and what they teach, using the observed lesson as an example.

The Observation and Analytic Protocol

Researchers used their observation and interview field notes to complete a three-part "Observation and Analytic Protocol" which was then submitted to the HRI study coordinators. (A copy of the protocol is included in Appendix A.) Part One of the protocol focused on describing the instruction and assessing the quality of the observed lesson. Along with some basic descriptive information (e.g., subject, course title, and grade of the class), the researcher was asked to document the purpose of the lesson as described by the teacher, and how the class time was spent, including the number of minutes spent on instructional activities as opposed to "housekeeping," interruptions, and the like; and the percent of instructional time spent as a whole class, in pairs/small group work, and in individual work.

The majority of researcher effort was devoted to describing and assessing the quality of the observed lessons in each of four component areas: the lesson design; its implementation; the mathematics/science content; and the classroom culture. In each case, the researcher first rated the extent to which the lesson exhibited each of a number of characteristics of high quality instruction. For example, in the case of mathematics/science content, the observer rated the extent to which the content was significant and worthwhile; and the extent to which teacher-presented information was accurate; among other indicators.

After rating the individual indicators in a component area, the researcher was asked to provide a "synthesis rating" on a five-point scale, where 5 indicated the lesson was extremely reflective of current standards for mathematics/science education. The researcher was then asked to provide a brief description of the nature and quality of that particular component of the lesson, and to provide the rationale for the synthesis rating and evidence to support it, including examples/quotes illustrating the ratings of particular "focus indicators."

Following the ratings of the individual components of the lesson, the researcher was asked to consider the likely impact of the lesson as a whole on students' understanding of mathematics/science. Since the impact of a single lesson would be expected to be quite limited, researchers were asked to judge whether the lesson was likely to move students forward in each of a number of areas, to have a negative impact, or to have a neutral or mixed effect.

Areas of Potential Lesson Impact on Students

- Understanding of the discipline as a dynamic body of knowledge generated and enriched by investigation
- Understanding of important mathematics/science content
- Capacity to carry out their own inquiries
- Ability to generalize their learning to other contexts
- Self-confidence in doing mathematics/science
- Interest in/appreciation for the discipline

The final rating for each lesson was the overall "capsule rating," ranging from Level 1, "Ineffective Instruction," to Level 5, "Exemplary Instruction," based on the researcher's judgment of how likely the lesson was to enhance most students' understanding of the discipline and to develop their capacity to successfully "do" mathematics/science.

The researcher was then asked to provide a 1–2 page summary of the lesson and its quality, describing what happened in the lesson, and including enough rich detail that readers would get "a sense of having been there." Among the elements to be included were:

- Where the lesson fit in with the overall unit;
- The focus of the lesson;
- Instructional materials used;
- A synopsis of the structure and flow of the lesson;
- The nature and quality of lesson activities;
- The roles of the teacher and students in the intellectual work of the lesson; and
- The reasoning behind the capsule rating.

The second part of the Observation and Analytic Protocol asked the researcher to use the information provided in the teacher interview to document the extent to which each of a number of factors influenced the observed lesson. Within the policy domain, researchers used the teacher-provided information to document the extent to which state and district curriculum standards/frameworks; state and district science or mathematics tests/accountability systems; and the textbook/program designated for the class influenced the selection of topics, instructional materials, and/or pedagogy used in the lesson. In the area of support infrastructure, potential influences included the principal; parents/community; school board and district administration; teachers; and their professional development activities. The researcher also had the opportunity to document the influence of factors that were not specified in the interview protocol, but might have been mentioned by the teacher, e.g., national standards documents, school/district scheduling policies, and teacher evaluation systems.

This section of the protocol also asked the researchers to document the teacher's description of the students in the class, including the general ability level; the number for whom English is not their first language; and the number with learning disabilities and other special needs; and to describe how the student characteristics (cognitive abilities, learning styles, prior knowledge, attitudes towards mathematics/science, student absenteeism, and the like) may have influenced the selection of topics, instructional materials, and pedagogy for this lesson. A comparable section focused on the teacher, asking the researcher to use the interview data to describe how the teacher's background knowledge, skills, and attitudes may have influenced the lesson design. Also included in Part Two was the researcher's description of the physical environment of the classroom, including the size and "feel" of the room, the state of repair of the classroom facilities, and the availability of needed equipment and supplies.

The final section in Part Two of the protocol asked the researcher to consider how the various influences interacted, and to highlight those that were most salient in determining why the observed lesson was taught and how it was designed. Finally, Part Three asked the researcher to "put it all together," and to provide any additional information they wished to share that had not been requested in the protocol.

Researcher Training

Classroom observations were conducted by HRI staff along with a number of consultants selected for their knowledge of mathematics/science education and their expertise in conducting classroom observations. As noted earlier, the observation protocol used in this study was adapted from one developed by HRI for the evaluation of NSF's Local Systemic Change Initiative, and in most cases, the researchers had training and experience using that protocol in conducting classroom observations.

To ensure that all observers had a complete understanding of the purposes and procedures of the study, each researcher participated in a two-day training session conducted by the study coordinators. The research questions guiding the observations and interviews were reviewed, and the data collection instruments were introduced, along with an annotated guide to the Observation and Analytic Protocol that provided detailed definitions of the terms used in the protocol. Researchers then watched a series of videotaped mathematics and science lessons and read simulated interview transcripts, completed protocols and discussed their ratings. By the end of the training there was substantial agreement on ratings and on how to use the protocol to communicate the results of their observations and interviews.

Researchers were asked to send their first completed protocols to HRI as soon as possible after their first site visit. Two of the study coordinators reviewed the protocols—one looked at all of the mathematics protocols and the other at all of the science protocols—to ensure that the protocols were completed correctly, that the lessons were described in sufficient detail, and that the lesson ratings were consistent with the researcher's narrative descriptions. These initial protocols and others submitted throughout the study were returned to the researchers for additional detail and/or clarification as needed.

Data Collection

Once a school agreed to participate in the study, HRI identified a local contact to carry out the following tasks:

- Construct a list of mathematics and science teachers in the school;
- Serve as a liaison between sampled teachers and HRI;
- Help HRI plan an observation schedule for the school; and
- Troubleshoot any scheduling problems that arose while observers were on site.

In return, the local contact received a stipend of $200.

Observers typically spent three days on site, one day each at the elementary, middle, and high school. Each sampled teacher was observed for one class period. Later in the day, the observer interviewed the teacher using a structured protocol. In return for their participation, schools received a voucher for $200 ($50 per observed teacher) worth of mathematics and science materials.

Approximately one week after the observation, each teacher was mailed an abbreviated form of the questionnaire used in the 2000 National Survey of Science and Mathematics Education (Appendix A), allowing comparisons between results based on the observed sample and those based on the survey sample. Seventy-seven percent of observed teachers returned this questionnaire.

Data Analysis

Data from the completed Observation and Analytic Protocol were entered into a database for analysis. The following sections describe how the study team looked for patterns in the qualitative data, and the use of weighting procedures to ensure that the *Inside the Classroom* findings would be representative of mathematics and science classes throughout the United States.

Analysis of 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 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.

Weighting of Quantitative 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.

Representativeness of the Classroom Data

As noted earlier, the 2000 National Survey of Science and Mathematics Education collected data from a large, nationally-representative sample of science and mathematics teachers. Teachers observed as part of *Inside the Classroom* completed a slightly shorter version of the questionnaire used in the National Survey, making possible a set of comparisons on the items that both groups answered.

Factor analysis of instructional practice items common to both the 2000 National Survey of Science and Mathematics Education and *Inside the Classroom* questionnaires was used to create a number of composite variables, which have the advantage of being more reliable than individual items. (Definitions of all composite variables and a description of how composite scores were computed are included in Appendix B.)

Data in Table 8 indicate that national estimates based on observed teachers are strikingly similar to those based on the National Survey in terms of the emphasis teachers give to different types of instructional objectives.

Table 8
Mean Scores on Composite Variables Related to Instructional Objectives in Mathematics and Science

	Estimates Based on:			
	Observed		National	
	Mean	S.D.	Mean	S.D.
Mathematics Objectives				
Mathematics Reasoning	89	12.7	90	12.6
Basic Mathematics Skills	72	20.2	72	21.6
Nature of Mathematics	55	17.3	57	19.9
Science Objectives				
Science Content	82	12.5	80	15.2
Nature of Science	54	21.7	56	22.0

As can be seen in Table 9, there were no substantial differences in estimates of instructional activities in mathematics. In science, national estimates based on the observed teachers are slightly higher than those based on the National Survey with regard to use of laboratory activities; all other estimates were equivalent to each other.

Table 9
Mean Scores on Composite Variables Related to Instructional Activities in Mathematics and Science

	Estimates Based on:			
	Observed		National	
	Mean	S.D.	Mean	S.D.
Mathematics				
Use of Traditional Practices	73	16.8	73	17.1
Use of Strategies to Develop Students' Ability to Communicate Ideas	73	15.5	73	14.3
Use of Calculators/Computers for Investigation	30	18.7	29	19.3
Science				
Use of Strategies to Develop Students' Ability to Communicate Ideas	72	13.5	70	15.8
Use of Laboratory Activities	71	17.4	65	17.7
Use of Traditional Practices	55	20.8	55	21.2
Use of Computers	19	17.4	16	16.7

Finally, an item on the questionnaire asked teachers to indicate the types of activities included in the lesson they taught just prior to completing the survey. Responses are shown in Tables 10 and 11. In mathematics, data from observed teachers appear to overestimate the frequency of small group work, while underestimating the occurrence of students reading about mathematics. In science, data from observed teachers overestimate the frequency of students doing hands-on/laboratory activities. In the vast majority of instructional activities, however, estimates based on the observed teachers and on the National Survey are essentially the same.

Table 10
Activities Occurring in the Most Recent Mathematics Lesson

	Estimates of Percent of Classes Based on:	
	Observed	National
Discussion	89	90
Students completing textbook/worksheet problems	78	79
Lecture	74	77
Students working in small groups	69	53
Students doing hands-on/manipulative activities	57	49
Students using calculators	34	34
Students reading about mathematics	12	20
Test or quiz	9	14
Students using computers	9	5
Students using technologies	6	2

Table 11
Activities Occurring in the Most Recent Science Lesson

	Estimates of Percent of Classes Based on:	
	Observed	**National**
Discussion	87	86
Lecture	67	62
Students working in small groups	59	55
Students doing hands-on/laboratory activities	63	54
Students completing textbook/worksheet problems	53	48
Students reading about science	36	38
Students using calculators	7	9
Test or quiz	7	9
Students using technologies	12	7
Students using computers	10	6

The fact that weighted estimates of the frequency of classroom practices based on *Inside the Classroom* data are generally equivalent to those based on the National Survey sample lends support to the idea that estimates of quality based on the observation data are an accurate depiction of what happens in the nation's mathematics and science classes.

CHAPTER THREE
Characteristics of Mathematics and Science Lessons

Introduction

Inside the Classroom researchers documented the observed lessons along a number of dimensions, including how much of the lesson time was devoted to instruction as opposed to housekeeping and interruptions; and how much instructional time was spent in whole class, small group, and individual work. They also described in detail the content addressed in these lessons. These data are presented below, weighted to represent all K–12 mathematics and science lessons in the United States.

Content Areas Addressed

Narrative descriptions were used to categorize the mathematics/science content addressed in each lesson. In mathematics, topics from NCTM's *Principles and Standards for School Mathematics* (2000) were used to classify lessons. In science, lessons were grouped in terms of the major content areas included in the *National Science Education Standards* (NRC, 1996).

Table 12 shows the percentage of mathematics lessons in the nation focusing on particular content areas. Eight in ten lessons have a focus on a single one of these areas, ranging from 72 percent of middle school lessons to 93 percent of lessons in grades 9–12. Number and operations is by far the most common topic in the elementary and middle grades. At the high school level, Algebra is a focus of half of all mathematics lessons. The percentage of lessons categorized as having a focus on problem solving (in most cases in combination with another topic) varied from 3 percent of lessons in grades 9–12 to 15 percent of lessons in elementary schools.

Table 12
Content Focus of Observed Lessons: Mathematics

	Percent of Lessons			
	Overall	**Grades K–5**	**Grades 6–8**	**Grades 9–12**
Lessons with a single content focus	80	78	72	93
Lessons with more than one focus	20	22	28	7
Lessons including a focus on:				
Number and Operations	53	74	53	5
Algebra	20	4	21	55
Geometry	17	11	29	20
Problem Solving	11	15	11	3
Data Analysis and Probability	10	11	9	6
Communication	6	10	4	0
Measurement	5	7	6	0
Trigonometric Functions	3	0	2	13
Reasoning and Proofing	2	2	3	0
Calculus	1	0	0	5
Representations	0	0	0	1
Connections	0	0	0	0

As in mathematics, the vast majority of science lessons have a single content focus. (See Table 13.) The prevalence of life and physical science lessons at the high school level mirrors patterns of course offerings reported in the 2000 National Survey of Science and Mathematics Education, where three-quarters of courses are classified as either life or physical science. The percentage of lessons with a focus on science inquiry (typically in combination with another topic) varies from 2 percent of lessons in grades 9–12 to 15 percent of lessons in elementary schools.

Table 13
Content Focus of Observed Lessons: Science

	Percent of Lessons			
	Overall	**Grades K–5**	**Grades 6–8**	**Grades 9–12**
Lessons with a single content focus	86	87	84	88
Lessons with more than one focus	14	13	16	12
Lessons including a focus on:				
Life Science	41	41	37	45
Physical Science	34	29	37	44
Earth and Space Science	21	24	27	8
Science as Inquiry	11	15	9	2
Science in Personal and Social Perspectives	6	5	8	7
History and Nature of Science	2	2	0	4
Science and Technology	2	2	0	3

Percentage of Time Spent on Instruction

In addition to the content addressed, lesson descriptions included the amount of time spent on instructional and non-instructional activities. Non-instructional activities included such things as taking roll, distributing papers not related to the observed lesson, and interruptions (e.g., loudspeaker announcements).

As can be seen in Table 14, based on *Inside the Classroom* observations, across all mathematics and science lessons, 7 percent of class time is spent on non-instructional activities. Over a 180-day school year, this equates to approximately 2½ weeks of instruction, somewhat lower than the 3½ weeks estimated from teacher self-reports in the 2000 National Survey of Science and Mathematics Education.

The percentage of non-instructional time increases with grade range. In mathematics, 5 percent of class time is spent on non-instructional matters in the elementary grades, rising to 13 percent in grades 9–12, which equates to approximately 4½ lost weeks of instruction at the high school level. In science, the percentage of non-instructional time increases from 4 percent at the elementary level to 11 percent at the high school level.

Table 14
Class Time Spent on
Instructional and Non-Instructional Activities

	Mean Percent of Class Time	
	Instructional	**Non-Instructional**
All Mathematics and Science Lessons	**93**	**7**
All Mathematics Lessons	**92**	**8**
Grades K–5	95	5
Grades 6–8	93	7
Grades 9–12	87	13
All Science Lessons	**94**	**6**
Grades K–5	96	4
Grades 6–8	93	7
Grades 9–12	89	11

How Students Are Grouped for Instruction

Whole-class instruction accounts for almost two-thirds of instructional time in mathematics and science lessons, with the remaining one-third divided fairly evenly between students working individually and students working in small groups. (See Table 15.) In mathematics, students are likely to spend quite a bit more time working individually than in pairs or small groups, especially at the high school level. Overall, students also spend a greater proportion of class time working individually in mathematics lessons than they do in science lessons. Similar results were found when science and mathematics teachers described their lessons as part of the 2000 National Survey of Science and Mathematics Education.

Table 15
Class Arrangements

	Mean Percent of Instructional Time†		
	Whole Class	**Pairs/ Small Groups**	**Individuals**
All Mathematics and Science Lessons	**62**	**17**	**21**
All Mathematics Lessons	**59**	**15**	**27**
Grades K–5	57	16	27
Grades 6–8	60	15	25
Grades 9–12	61	12	27
All Science Lessons	**65**	**20**	**15**
Grades K–5	65	23	12
Grades 6–8	64	18	18
Grades 9–12	65	16	19

† Time spent on non-instructional activities is not included in these percentages.

CHAPTER FOUR
Ratings of Lesson Quality

Introduction

The vision of effective mathematics and science education that guided this study considers the primary goals of mathematics and science education to be (1) helping students learn important mathematics and science concepts; and (2) deepening their abilities to successfully engage in the processes of mathematics and science. To achieve these goals, not only do lessons need to provide students opportunities to learn, but teachers also need to be very clear about the purposes of each lesson in relation to the specific concepts being addressed, in order to help guide students in their learning.

Note that while the goal of instruction in all cases needs to be understanding, in our view, understanding can be developed through well-designed lectures, well-designed hands-on activities, well-designed paper-and-pencil tasks, or any of a myriad of other strategies. The key is that the activities be designed to be purposeful, accessible, and engaging to students, with a clear and consistent focus on student learning of important mathematics and science concepts.

The Observation and Analytic Protocol developed for the *Inside the Classroom* study was designed to assess the quality of lessons in relation to this vision of effective mathematics and science instruction. In addition to rating specific components of the lessons, such as the accuracy of the mathematics/science content and the quality of the teachers' questioning, observers rated the likely impact of each lesson on students and provided an overall "capsule rating" of the lesson.

This chapter presents data based on the observed classrooms, weighted to represent all grade K–12 mathematics and science lessons in the United States. Data broken down by subject and grade range, again weighted to provide national estimates, are included in Appendices C–H.

Overall Ratings of Lesson Quality

As can be seen in Table 16, based on observers' judgments, only about a third of lessons nationally are likely to have a positive impact on student understanding of mathematics/science concepts, and 16 percent are likely to have a negative effect on their understanding; the remaining lessons would likely have no effect, or both positive and negative effects. Lessons are as likely to have a negative impact on students' interest in and/or appreciation for mathematics/science as they are a positive impact, with roughly a third of lessons in each category.

Table 16
Likely Impacts of Mathematics and Science Lessons†

	Percent of Lessons		
	Negative Effect	Mixed or Neutral Effect	Positive Effect
Students' understanding of important mathematics/science concepts	16	50	34
Students' interest in and/or appreciation for the discipline	27	41	32
Students' self-confidence in doing mathematics/science	20	50	30
Students' ability to apply or generalize skills and concepts to other areas of mathematics/science, other disciplines, and/or real-life situations	15	58	27
Students' understanding of mathematics/science as a dynamic body of knowledge generated and enriched by investigation	31	45	25
Students' capacity to carry out their own inquiries	21	55	24

† Data are reported by subject and grade range in Appendices C–H.

The scale observers used to provide an overall assessment of the quality and likely impact of the lesson 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. 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).

Lessons judged to be low in quality are unlikely to enhance students' understanding of important mathematics/science content or provide them with abilities to engage successfully in the process of science or mathematics. While low quality lessons fall down in numerous areas, their overarching downfall tends to be the students' lack of engagement with important mathematics or science. Examples of low quality lessons include:

- A primary grade science lesson in which students drew their favorite animal, but never focused on science concepts;

- A mathematics class where students spent most of the time playing a mathematics-related game with no attention to the mathematics concepts implicit in the game;

- A science lesson that attempted to teach a 3rd grade class about buoyancy, clearly not developmentally appropriate for these students;

- A mathematics lesson in which the primary focus was on learning algorithms instead of on the meaning of concepts represented by the algorithms; and

- A science class where students followed the steps through laboratory procedures, but did not seem to understand why they were doing what they were doing.

At the other end of the scale, high quality lessons are structured and implemented in a manner which engages students with important mathematics or science concepts and are very likely to enhance their understanding of these concepts and to develop their capacity to do mathematics/science successfully. Regardless of the pedagogy (e.g., investigations, teacher presentations, discussions with each other or the teacher, reading), high quality lessons provide opportunities for students to interact purposefully with science/mathematics content and are focused on the overall learning goals of the concept. Examples of high quality lessons include:

- A lively discussion in a science class focused on interpreting and identifying trends in data collected in lab the previous day;

- A middle school mathematics lesson where small groups of students developed strategies to find the volume of irregularly shaped objects and shared them with the rest of the class; and

- A lecture where high school students were engaged in learning about how nerve receptors are differentiated to distinguish levels of pain.

In the middle, are lessons that are purposeful and include some elements of effective practice, but also include substantial weaknesses that limit the potential impact for students. The specific areas where "middle quality" lessons fall down varies widely and could be related to the content that is the focus of the lesson, how the lesson is designed and implemented, and/or the classroom culture. Examples include:

- A small group exploration that was short-circuited by the teacher, who told the students what they should find;

- A lesson in which the needs of a subgroup of students were not addressed;

- A lesson where students were ridiculed for asking questions, which interfered with the implementation of a well-designed learning activity; and

- A discussion that involved high-quality ideas, but was too fast-paced for many of the students.

As can be seen in Figure 2, 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 of medium quality, and 59 percent low in quality. Descriptions of lessons at each of these levels can be found in the subject-specific Appendices C–H.

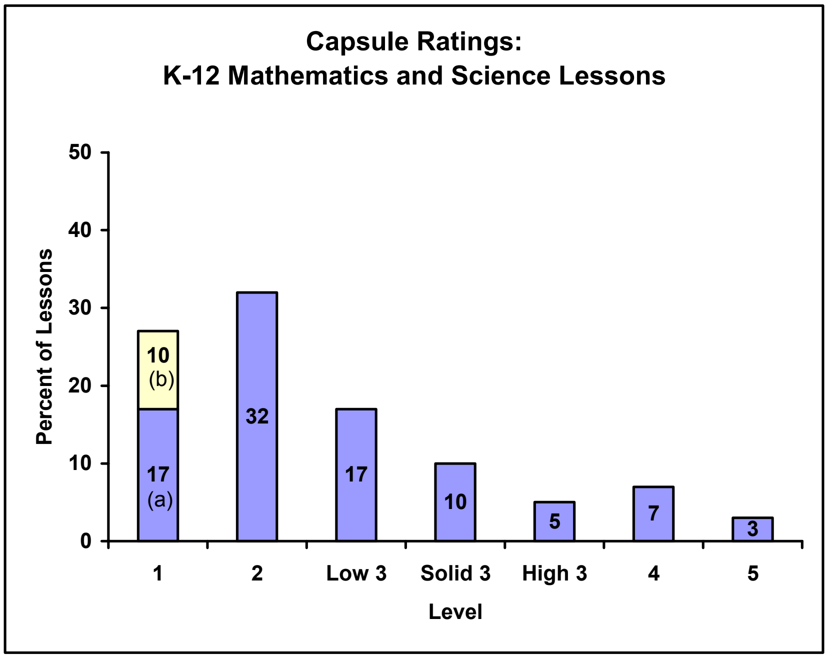


Figure 2

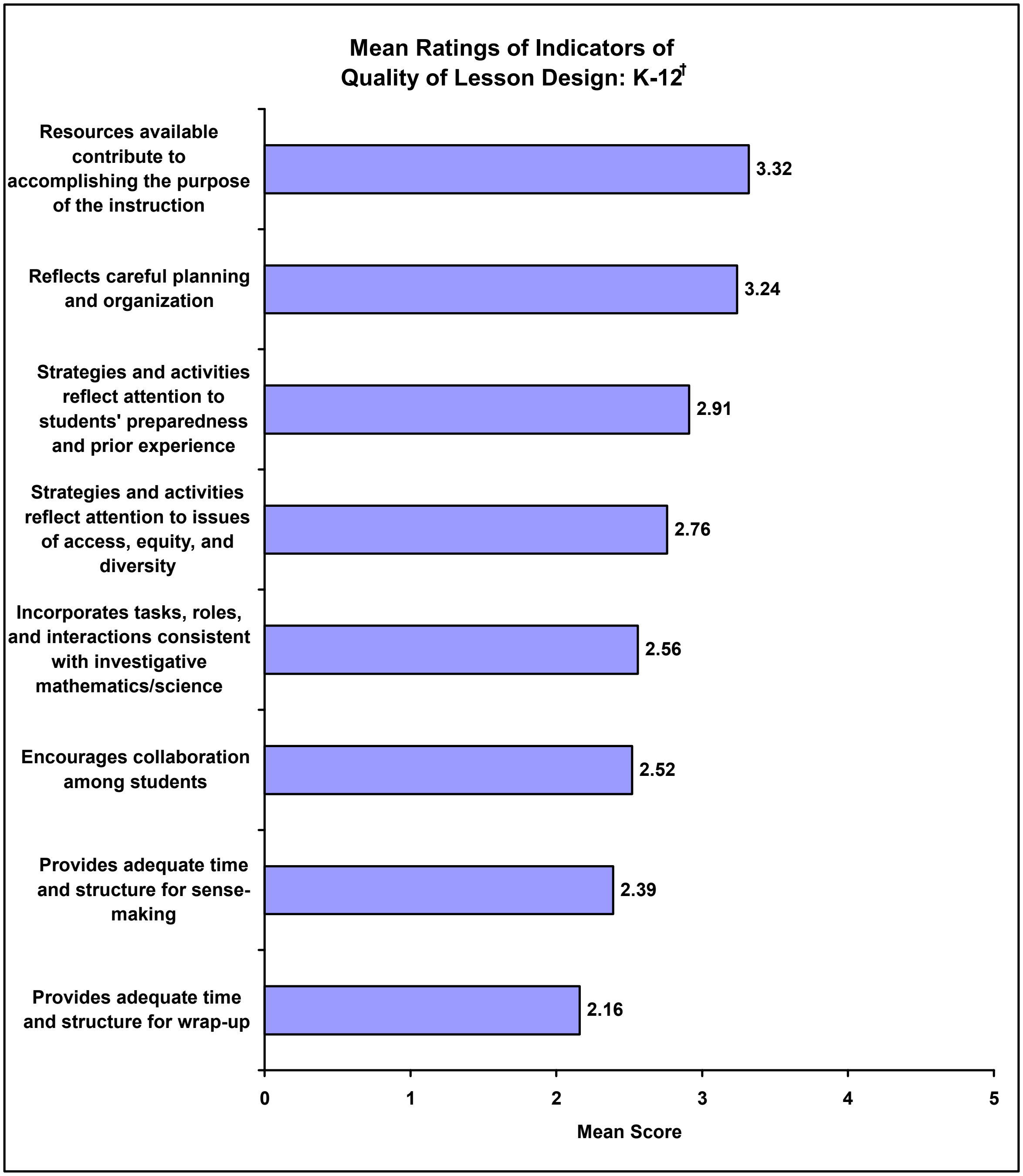
Ratings of Lesson Components

As noted earlier, *Inside the Classroom* observers assessed the quality of four components of each lesson: (1) the lesson design, (2) the lesson implementation, (3) the mathematics/science content addressed, and (4) the classroom culture. They rated specific indicators in each area, then assigned an overall rating to that component, providing a detailed rationale for their judgment.

Lesson Design

The lesson design (or structure of the observed lesson) generally encompasses the activities, the instructional strategies, the assigned roles, and the resources of the lesson. Indicators in the area of design include the extent to which the lesson reflected careful planning and organization, the extent to which the available resources contributed to accomplishing the purpose of the lesson, and the extent to which strategies and activities reflected attention to issues of access, equity, and diversity. Observers also rated the extent to which students were provided with time and structure for wrap-up and sense-making. "Sense-making" is broadly defined to include time for thought and processing and can occur in a variety of contexts (e.g., individually, small groups, and whole group) and either during an activity or as part of a wrap-up.

As can be seen in Figure 3, the strongest elements of lesson designs are the instructional resources used, and the planning that went into the lessons. Among the weakest elements are the lack of time and structure for sense-making and for wrap-up appropriate for the purposes of the lesson. Based on the *Inside the Classroom* observations, most mathematics and science lessons in the nation would be rated a 2 or 3 out of 5 for the overall quality of their designs. (See Figure 4.)



† Frequency distributions for these indicators are included in Appendix I.

Figure 3

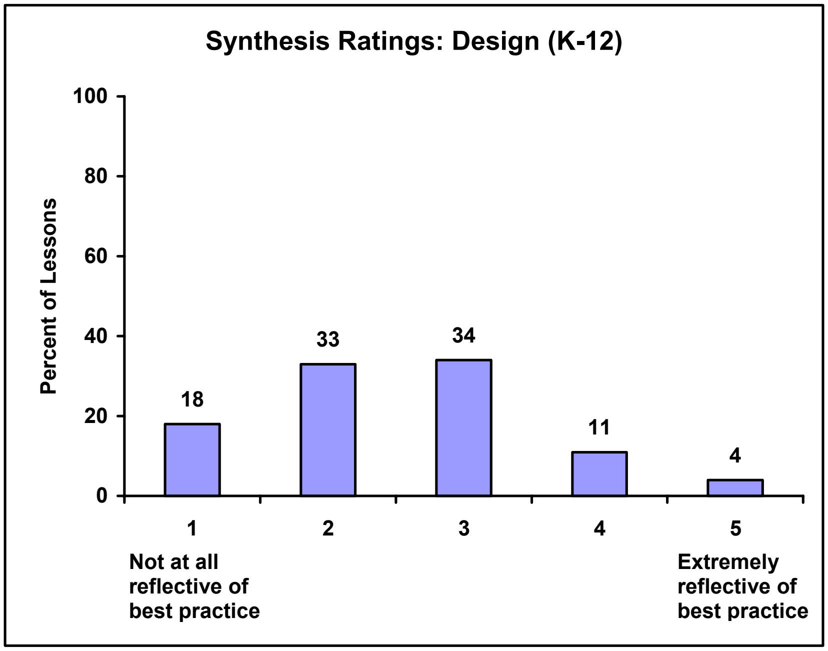
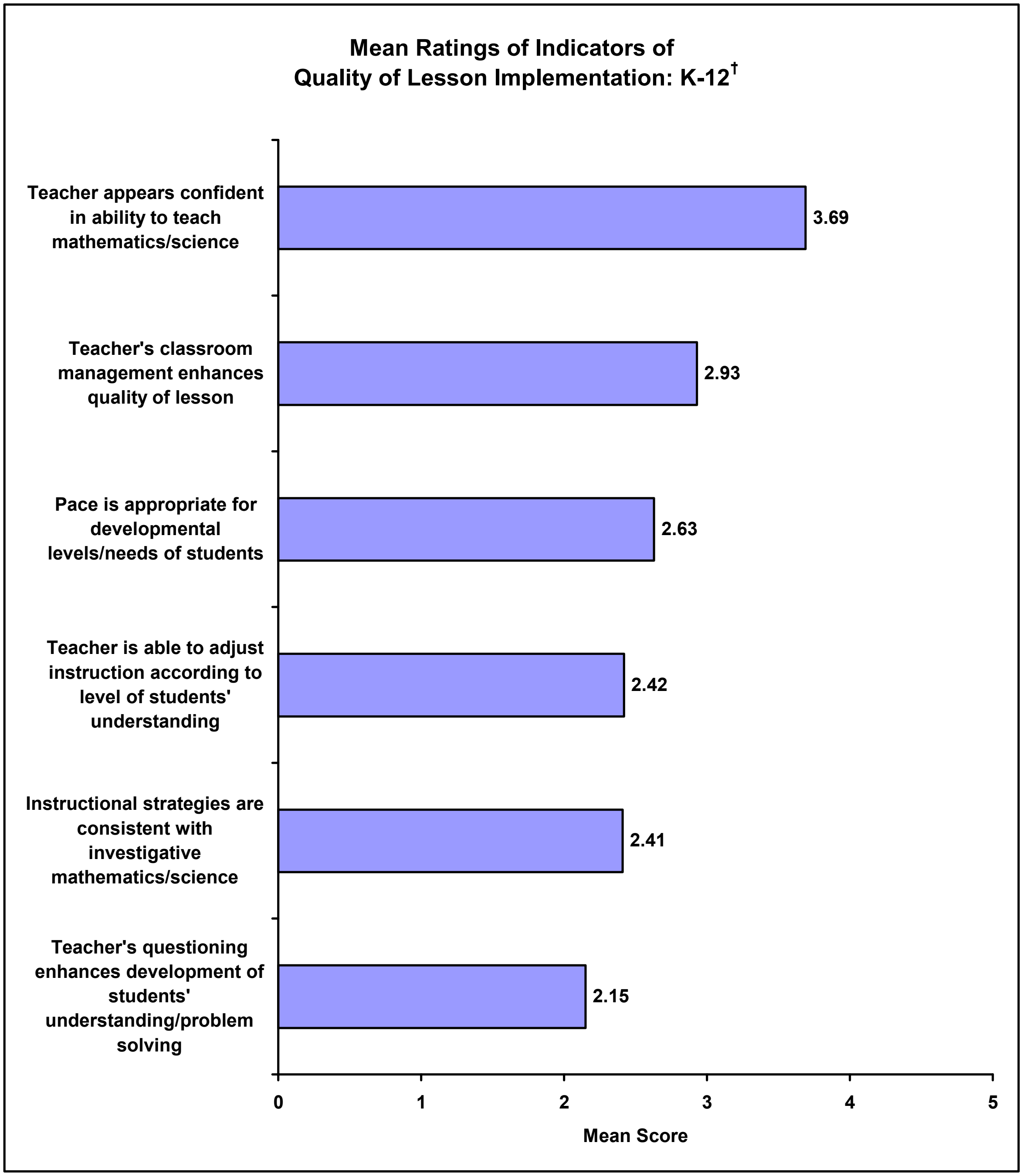


Figure 4

Lesson Implementation

Lesson implementation, the second lesson component assessed by observers, refers to how the teacher carried out the lesson. Indicators in implementation focus on the pace of the lesson, classroom management, teacher questioning, and the teacher's apparent confidence in teaching the subject. Observers also rated the extent to which the teacher's instructional strategies were consistent with investigative mathematics and science.

As can be seen in Figure 5, most teachers appear confident in their ability to teach mathematics and science. At the other end of the scale, teachers' questioning strategies receive generally low ratings overall. Based on *Inside the Classroom* observations, most mathematics and science lessons in the nation are clustered at the low end of the implementation scale, with a modal rating of 2 out of 5. (See Figure 6.)



† Frequency distributions for these indicators are included in Appendix I.

Figure 5

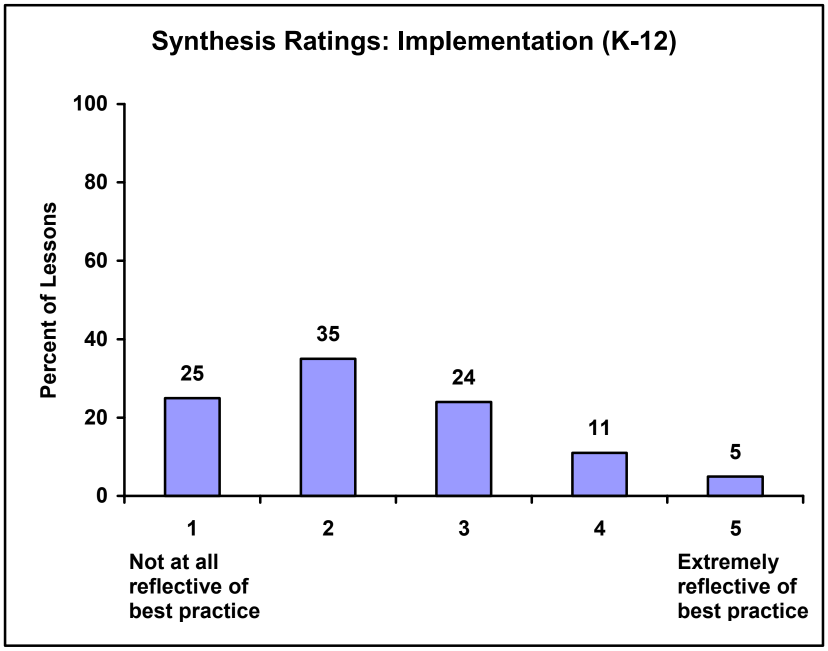
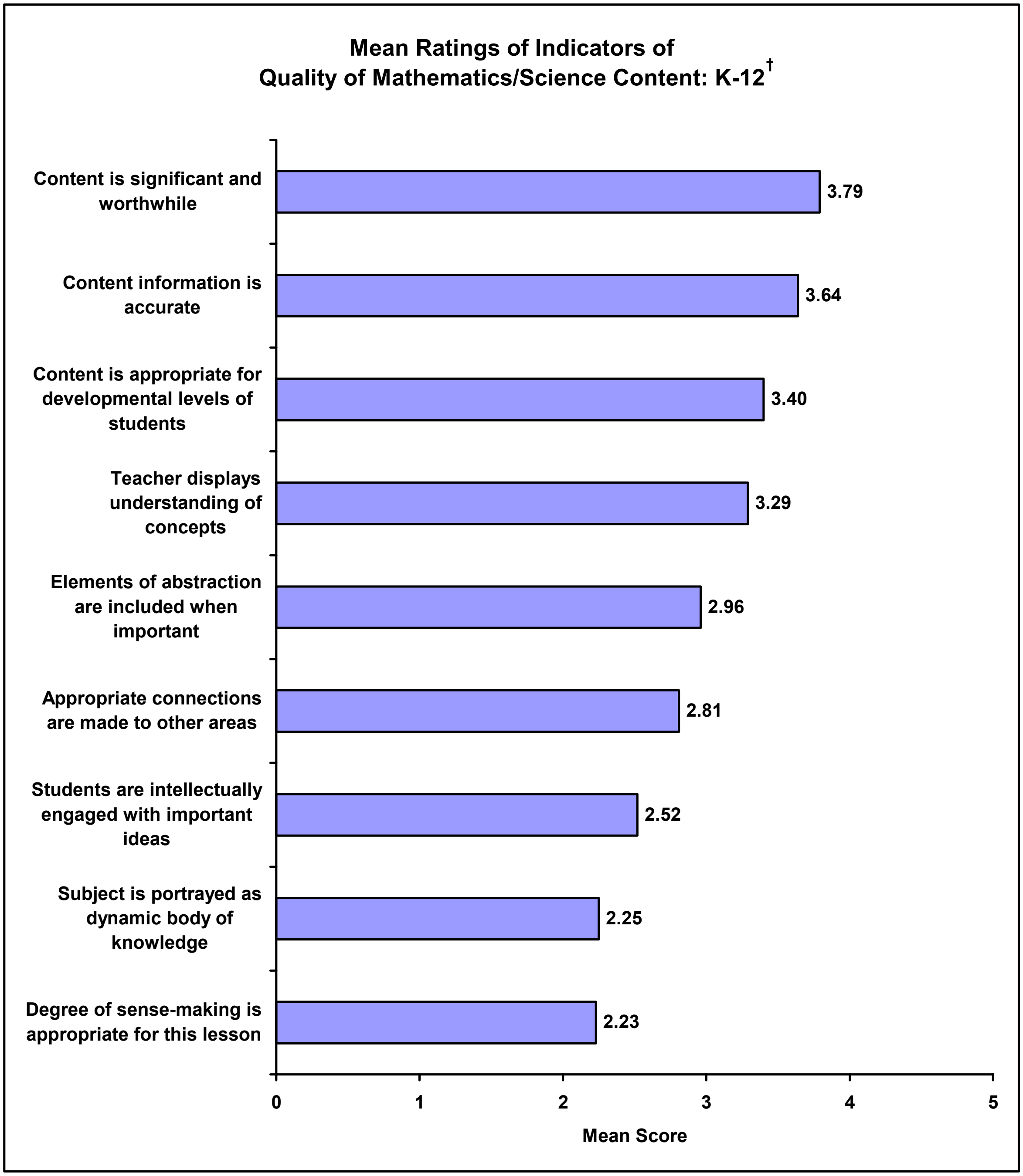


Figure 6

Lesson Mathematics/Science Content

Observers assessed the quality of the mathematics/science content of the lessons using a number of indicators. The quality of the content was rated based on its inherent importance in K–12 mathematics/science and its appropriateness for the particular students in the observed class. The extent to which students were engaged with the content and were able to make sense of the content were also assessed. Other indicators included: the extent to which the teacher displayed an understanding of concepts, the accuracy of the content, and the extent to which there were appropriate connections to other disciplines or to real-world contexts.

As can be seen in Figure 7, the mathematics/science content of lessons is typically accurate, significant, and worthwhile. Lessons are less likely to portray mathematics or science as a dynamic body of knowledge. Similarly, lessons tend to fall down in regard to the degree of sense-making of the mathematics/science content. As was the case with quality of implementation, the modal synthesis rating for mathematics/science content nationally is 2 out of 5. (See Figure 8.)



† Frequency distributions for these indicators are included in Appendix I.

Figure 7

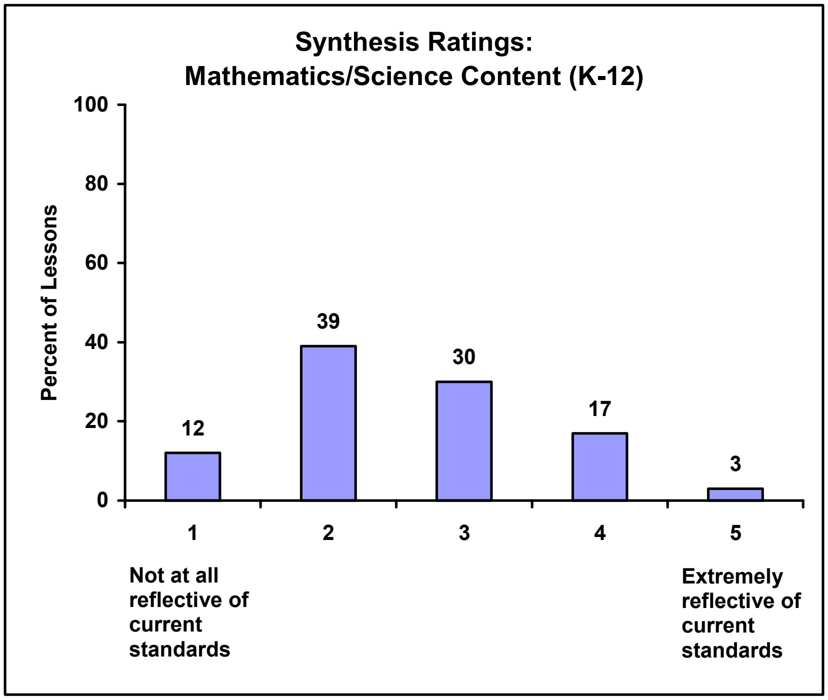
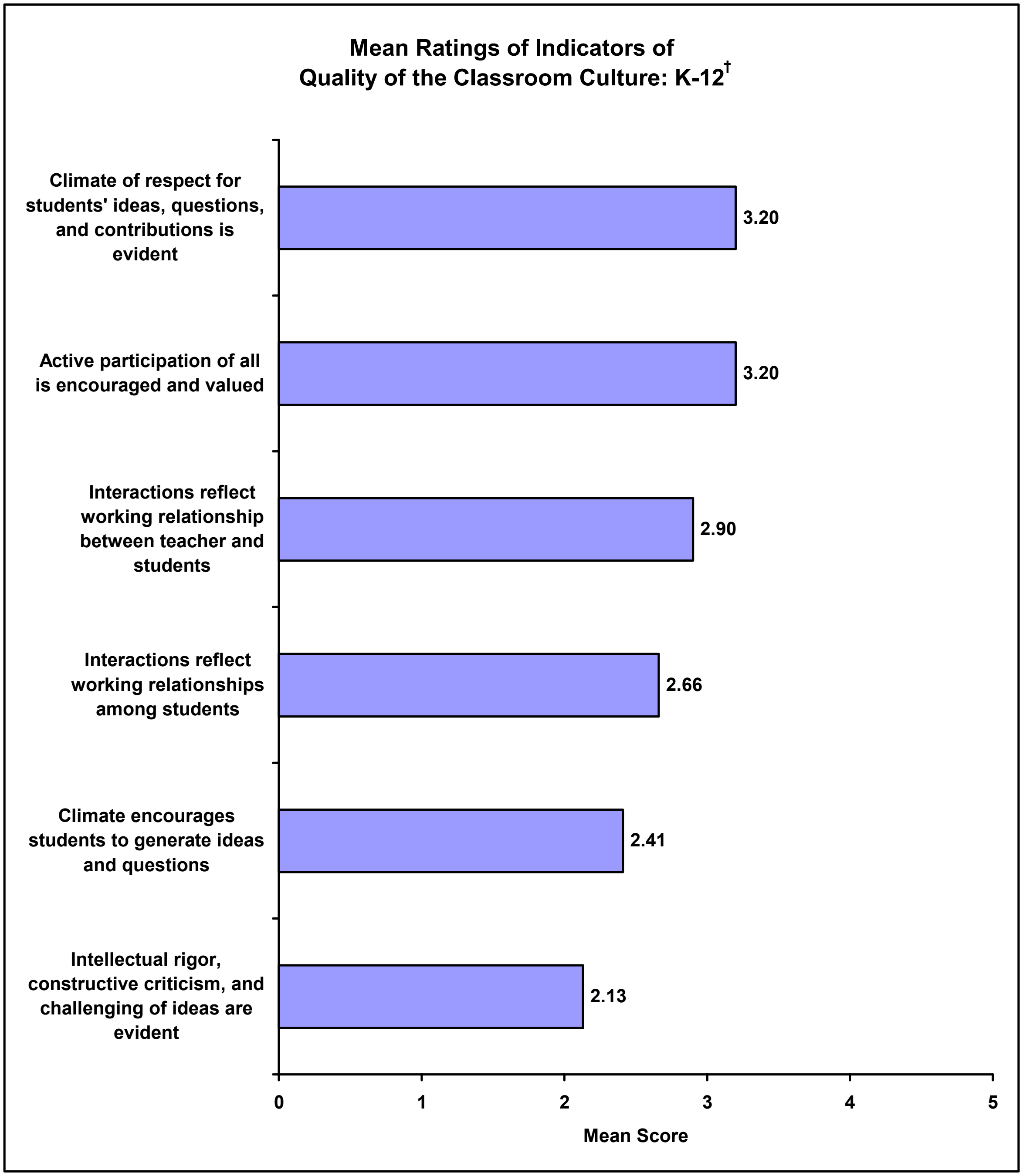


Figure 8

Classroom Culture

Classroom culture, the final component area assessed by observers, includes indicators of the extent and nature of the engagement of students in the class. It focuses not only on the quality of interactions among students and between the students and the teacher, but also on the rigor of the classroom climate. In addition, observers had the opportunity to comment on issues of equity and diversity that may have impacted the culture of the classroom. Sample indicators include the extent to which active participation was encouraged and valued; interactions reflected collaborative working relationships between teacher and students; and intellectual rigor, constructive criticism, and the challenging of ideas were evident.

Mathematics and science lessons are relatively strong in their climate of respect for students' ideas, questions, and contributions; and in the extent to which active participation of all students is encouraged. As a whole, lessons are weaker in the extent to which their climate encourages students to generate ideas and questions; and in the extent of intellectual rigor. (See Figure 9.)



† Frequency distributions for these indicators are included in Appendix I.

Figure 9

The overall rating for classroom culture differs from those for the previous component areas in that observers were asked to rate the extent to which the classroom culture interfered with or facilitated student learning. As can be seen in Figure 10, most lessons nationally would be rated a 2 or 3 out of 5.

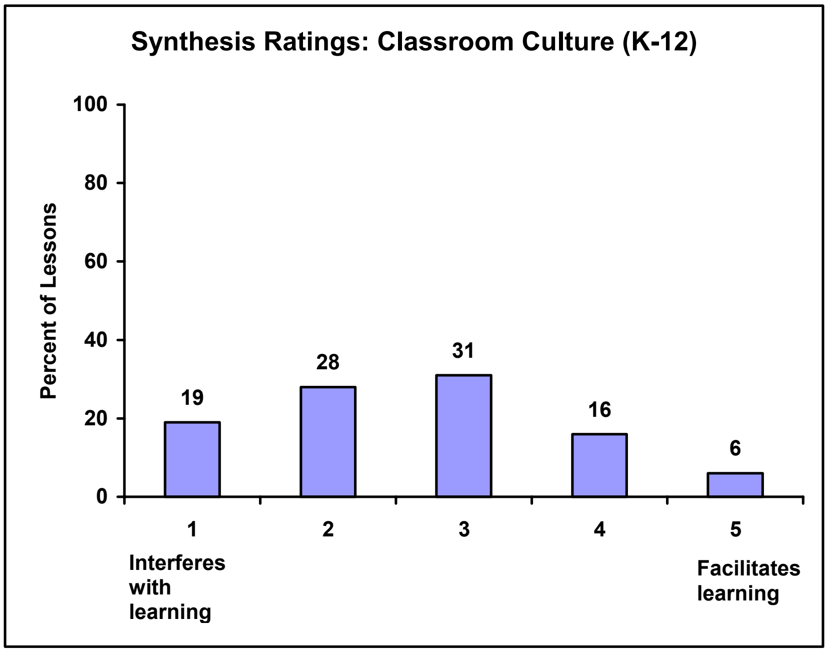


Figure 10

Indicators of High and Low Quality Lessons

As can be seen in Table 17, the vast majority of lessons judged to be effective, and roughly half of the lessons judged ineffective, in helping students learn important mathematics/science content have strengths in a number of areas, including content that is significant and worthwhile; teachers who are confident in their ability to teach mathematics/science; and teachers who provide accurate information. Where most high quality lessons are strong, but almost all low quality lessons fall down, is in such areas as engaging students intellectually with the mathematics/science content; portraying these disciplines as dynamic bodies of knowledge; having a climate that encourages students to generate ideas, questions, conjectures, and propositions; extent of intellectual rigor; teachers' questioning strategies; teachers' abilities to adjust instruction based on students' level of understanding; and the degree of "sense-making" within the lesson.

Table 17
Lessons Rated Strong on Each Indicator, by Lesson Quality

	Percent of Lessons		
	Overall Quality	High Quality	Low Quality
The mathematics/science content is significant and worthwhile	67	99	53
The teacher appears confident in his/her ability to teach mathematics/science	63	99	52
Teacher-provided content information that is accurate	56	91	47
The mathematics/science content is appropriate for the developmental needs of the students in this class	49	90	35
Active participation of all is encouraged and valued	47	85	28
The resources available in this lesson contribute to accomplishing the purposes of the instruction	47	84	30
The design of the lesson reflects careful planning and organization	45	89	23
There is a climate of respect for students' ideas, questions, and contributions	45	88	20
The teacher displays an understanding of mathematics/science concepts (e.g., in his/her dialogue with students)	43	97	23
Interactions reflect collaborative working relationships between teacher and students	37	91	15
Elements of mathematical/science abstraction (e.g., symbolic representations, theory building) are included when it is important to do so	36	85	19
The teacher's classroom management style/strategies enhance the quality of the lesson	34	84	11
The instructional strategies and activities used in this lesson reflect attention to students' experience, preparedness, prior knowledge, and/or learning styles.	32	85	11
Appropriate connections are made to other areas of mathematics/science, to other disciplines, and/or to real-world contexts	30	73	16
Interactions reflect collegial working relationships among students (e.g., students work together, talk with each other about the lesson)	29	71	10
The instructional strategies and activities reflect attention to issues of access, equity, and diversity for students (e.g., cooperative learning, language-appropriate strategies/materials)	28	80	5
The design of the lesson encourages a collaborative approach to learning among the students	27	82	6
The design of the lesson incorporates tasks, roles, and interactions consistent with investigative mathematics/science	26	82	6
The pace of the lesson is appropriate for the developmental levels/needs of the students and the purposes of the lesson	24	78	7
The climate of the lesson encourages students to generate ideas, questions, conjectures, and/or propositions	22	82	5
The instructional strategies are consistent with investigative mathematics/science	21	87	1
Students are intellectually engaged with important ideas relevant to the focus of the lesson	20	84	2
The teacher is able to "read" the students' level of understanding and adjust instruction accordingly	19	79	3
Adequate time and structure are provided for "sense-making"	18	81	1
Mathematics/science is portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification	18	75	3
The teacher's questioning strategies are likely to enhance the development of student conceptual understanding/problem solving (e.g., emphasized higher order questions, appropriately used "wait time," identified prior conceptions and misconceptions)	16	73	1
The degree of "sense-making" of mathematics/science content within this lesson is appropriate for the developmental levels/needs of the students and the purposes of the lesson	15	79	2
Intellectual rigor, constructive criticism, and the challenging of ideas is evident	14	68	1
Adequate time and structure are provided for wrap-up	14	61	3

Chapter Five
Strengths and Weaknesses of Mathematics and Science Lessons

Introduction

As noted in the previous chapter, the quality of the lessons teachers design and enact to help students learn mathematics/science content varies considerably. 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.

These results are presented in the following sections, using excerpts from lesson descriptions to illustrate the findings. All quantitative data provided are weighted to represent all mathematics and science lessons in the United States, grades K–12.

Engaging Students with Mathematics/Science Content

➢ **To be judged effective, lessons need to provide students with opportunities to grapple with important mathematics/science content in meaningful ways.**

Certainly one of the most important aspects of effective mathematics and science lessons, if not the most important, is that they address content that is both significant and worthwhile. Lessons using a multitude of innovative instructional strategies would not be productive unless they were implemented in the service of teaching students important content. Based on the lessons observed in this study, mathematics and science lessons in the United States are relatively strong in this area, with the majority of lessons including significant and worthwhile content. (See Figure 11.)

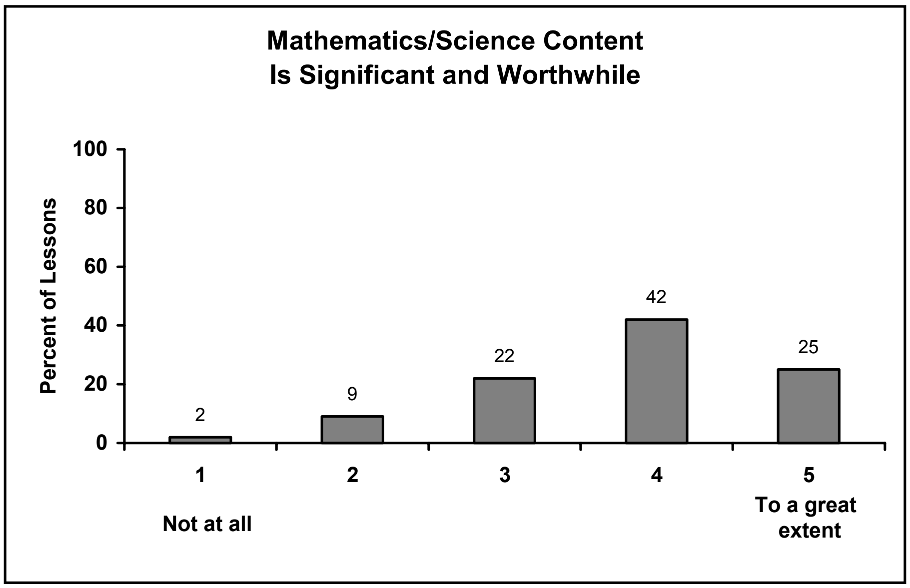


Figure 11

Although lessons generally include important content, most lessons are nevertheless low in overall quality. Clearly, while the inclusion of important content is necessary for high quality science/mathematics lessons, it is not sufficient.

"Inviting" the Learners into Purposeful Interaction with the Mathematics/ Science Content

The hallmark of lessons judged to be effective is that they include meaningful experiences that engage students intellectually with mathematics and science content. These lessons make use of various strategies to interest and engage students and to build on their previous knowledge. Effective lessons often provide multiple pathways that are likely to facilitate learning and include opportunities for sense-making. As can be seen in Figure 12, few lessons in the nation engage students intellectually with important mathematics/science content.

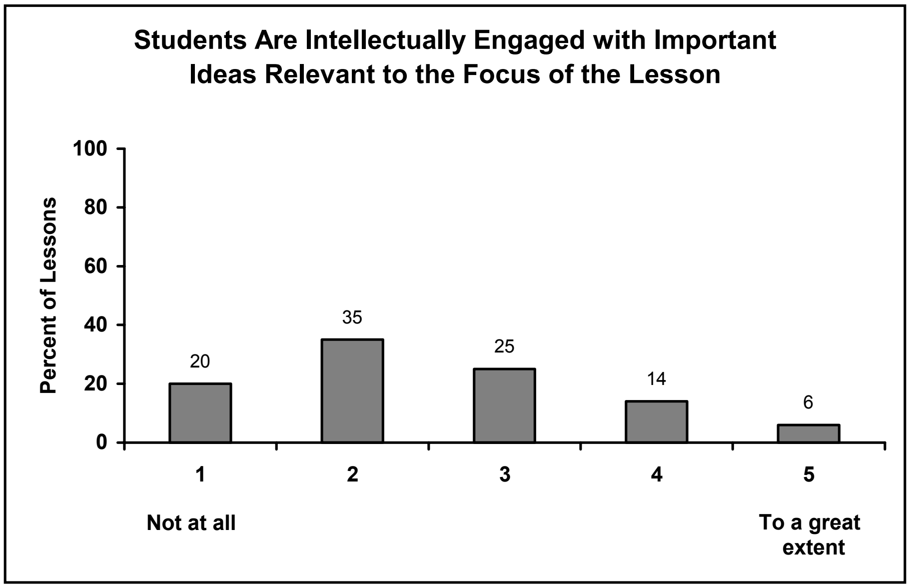


Figure 12

Earlier we noted the importance of lessons being "purposeful" in relation to important learning goals, with teachers having a clear understanding of the purpose of each lesson in terms of those goals. We would argue, further, that *students* also need to see a purpose to the instruction, not necessarily the disciplinary learning goals the teacher has in mind, but some purpose that will motivate their engagement; lessons need to "hook" students by addressing something they have wondered about, or can be induced to wonder about, possibly but not necessarily in a real-world context.[6] The observation protocol used in this study did not specifically ask researchers about the strategies that teachers used to engage students in the lesson, but observers often commented on the presence or absence of this feature in their lesson descriptions. The following sections describe how lessons address, or fail to address, the need to engage students with the mathematics/science content.

- ***Many lessons do not include an element of motivation.***
  Observers noted that many lessons "just started." For example, a teacher began a 3rd grade lesson simply by having the students open their textbooks to the designated chapter, while she handed them a review worksheet. Similarly, a high school lesson began with the teacher distributing a packet of questions and saying, "All right now, these pages should be very easy if you've been paying attention in class. We talked about all of this stuff."

[6] A similar argument was made by Kesidou and Roseman (2002) in their analysis of middle school science programs, citing research support for the idea that "if students are to derive the intended learning benefits from engaging in an activity, their interest in or recognition of the value of the activity needs to be motivated." (p. 530)

"Just starting" is not restricted to review lessons. For example, a high school teacher announced that, "Today we're going to talk about Roman Numeral III.H.," referring to a lengthy outline he had given the students previously. In some cases students did not engage in lessons such as these; in other cases they were attentive, typically with an upcoming test rather than interest in the problem being posed as the apparent motivation.

- ***Some lessons motivate interest by engaging students with phenomena.***
  Lessons that "invite" the learners in sometimes do so by engaging students in first-hand experiences with the concepts or phenomena. For example:

> In a 4th grade science lesson about the basic needs of animals and how different body parts help animals meet these needs, the teacher handed out a tail feather and a magnifying glass to each pair of students, and asked them to examine the feather, pull the barbs apart, and look for the hooks. They then pulled the feather between their fingers, making the barbs stick back together. The teacher then handed out a down feather and they repeated their investigations.
>
> 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.
>
> A high school physics teacher had the students explore static electricity using a Van de Graaf generator, Tesla coil, and fluorescent light tube. The teacher explained how each worked, and used students to demonstrate what happens when electrons are pulled from one source to another.

- ***Other lessons use real-world examples to generate interest.***
  Some teachers, instead of providing students with first-hand experience, invite the students in by using real-world examples to vividly illustrate the concept. The following lesson descriptions illustrate lessons where real-world examples played a large role in student engagement:

> 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 asked students in a 6th grade science class to name different kinds of rocks, based on size, then explained that the Earth's crust is made up of many different-sized rocks. She asked: "Who's been to [a nearby city park]? What's at the bottom of the stream? Have you ever felt squishy stuff between your toes? That's sediment." Students then raised their hands and described their family vacations to different locations with interesting rock formations, and described how the bottom of various lakes felt to them.
>
> A 7th grade mathematics lesson used examples from architecture, carpentry, and dressmaking to help

students understand the concept of symmetry; students were invited to provide their own examples as well.

The teacher began the study of the water cycle in a high school earth science class by noting that their state held the dubious honor of being the second driest state in the union.

The teacher in an honors pre-calculus class led a brief discussion of the Doppler effect as an application of trigonometric functions; she also used a Slinky to model the wave pattern of sine and cosine functions.

- ***Some lessons use "contrived" contexts to engage students.***

  Teachers sometimes use stories and other fictional contexts to engage students with the content of the lessons. For example:

In a 1st grade science lesson, the teacher read a story about a girl who discovers an arrowhead in her backyard. The class then engaged in an excavation activity in pairs, where one child was the "archeologist" who found the "hidden treasures" in their "midden [refuse heap]" and the other was a "curator" who put their "hidden treasures" in a "museum."

A teacher of a 3rd grade mathematics class worked to develop an understanding of how parentheses may be used to direct order of operations in number sentences by involving students in writing number models for different ways a basketball team might score 15 points.

In a high school Algebra I lesson, the teacher presented three line graphs showing data about two fictitious companies regarding productivity (intersecting lines), production cost (parallel lines), and sales (equivalent lines). She discussed each graph with the class and then asked the class to vote for the company they would hire based on the graphs.

- ***Other lessons use "games" to engage students with the content.***

  Some lessons use games to engage students with the mathematics/science content of the lesson. It is important to note that while the games provide a context that generates student interest, in lessons judged to be effective these games are designed to keep the focus on the learning goals. The following lessons illustrate this point:

After reviewing states of matter, the teacher of a 2nd grade class introduced a scavenger hunt for solids, liquids and gases in the classroom, which was "seeded" with some objects specifically for this lesson. The students took the items back to their tables and classified them as solid, liquid, or gas. The teacher then asked the students to explain to the rest of the class how the group had classified their objects.

The teacher started a mathematics lesson in a 3rd grade class by anchoring the content in the students' prior work with graphs, and then moved quickly to comparing the coordinate system to mapping and directions. To help make the comparison more real, she asked the students to close their eyes and began to talk through an example to show how following specific directions lead to an exact spot. She stated: "Go out this door. Turn right. Go through the double set of doors. Go a few feet further. Whose room is to the right?" The class in unison called out the name of the teacher who teaches in that room.

In introducing the concept of probability to a 5th grade class, the teacher used a spinner which she placed on the overhead. It had 8 sections; 5 sections had odd numbers in them and 3 had even numbers, but she did not point that out. She called two students to the front to be the players, and another to keep track of points on the board. One player got points every time the spinner landed on an odd number and the other every time it landed on a even number. The person to get 10 points first would win. The students took turns spinning and after a few spins into the game, one player, the one who had the even numbers, started to complain. The class discussed what was unfair about the spinner and what could be done to make it more fair.

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 review, the students in a high school Algebra II class played "Jeopardy"; the teacher would hold up a card and a student would call out the appropriate question. For example, for the card $(a)^m + (a)^n$, the student asked, "What is a to the (m plus n)?"

Portraying Mathematics/Science as a Dynamic Body of Knowledge

In addition to motivating students to engage with mathematics/science content, another characteristic of lessons judged to be effective is the manner in which they represent the disciplines of mathematics and science. Lessons can engage students with concepts so they come away with the understanding that each of these disciplines is a dynamic body of knowledge generated and enriched by investigation. Alternatively, lessons can portray mathematics or science as a body of facts and procedures to be memorized. Based on *Inside the Classroom* observations, only 18 percent of mathematics and science lessons nationally provide experiences for students that clearly depict mathematics/science as investigative in nature (rated 4 or 5 on a five-point scale). (See Figure 13.)

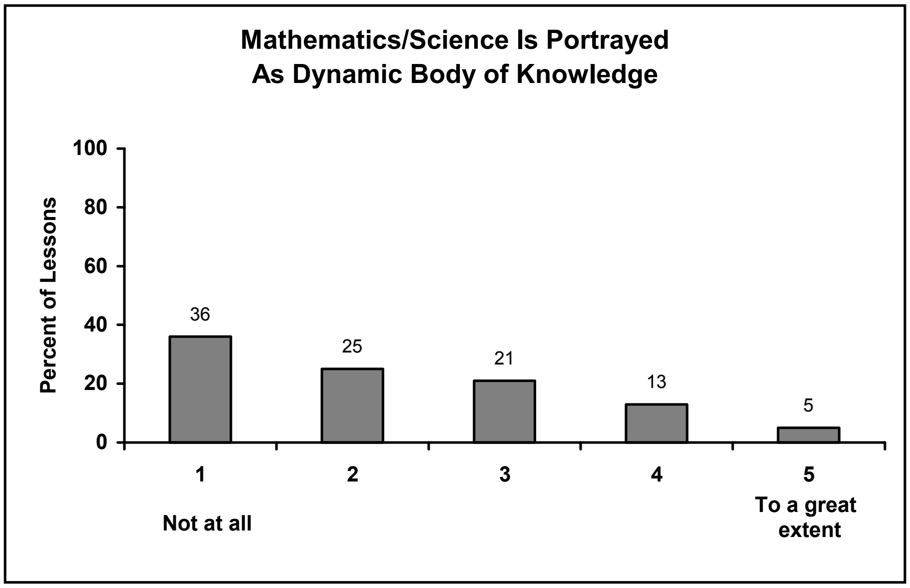


Figure 13

The following lessons are illustrative of this quality:

A 3rd grade science lesson focused on the idea that Earth is a "water planet." The teacher provided the background and motivation needed to launch the students into the investigation through whole group discussion. Students were asked to work in groups, first to make predictions, and then to toss a "beach ball model" of the Earth and observe if their finger landed on land or water. After each group had made ten tosses, the class shared their data and compared their observations to their predictions. The lesson ended by having each group of students try to explain the data, while the recorder wrote down the group's reasoning. The lesson was to be followed up the next day by representing the different oceans on Earth with squares on graph paper and using that to visualize how much of the Earth is made up of water, and to picture the relationships between bodies of water and land. The observer noted that the lesson was well designed, with "a focused experience using a model that should help students understand not only why the Earth is called 'the water planet,' but how scientists figure out the relative quantities of a substance on Earth by using scale models."

A 7th grade pre-algebra lesson began with the teacher introducing a new word problem. The purpose was to help reinforce the need for careful reading of problems, justification of strategies used and solutions presented, and the concept that there are multiple ways to approach solving a single problem. The students and teacher were engaged for three-quarters of this lesson in a whole class discussion about strategies used to solve this single word problem and presenting their solutions. The teacher stressed that there was "not a right way or a wrong way" to solve a problem, but "many ways to get into an investigation." Throughout the lesson, the teacher made statements like "I think it would be a good idea to make sure you can verify your answer with others in your group." and "I need you to convince me it's the right answer."

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.

In contrast, in many lessons mathematics and science are presented as static bodies of knowledge, focusing on vocabulary and algorithms. Observers of these lessons said things like "the teacher did the thinking throughout the lesson—there was no investigative spirit. The teacher had knowledge, which he attempted to transmit to students." The following examples are typical:

> Students in a 4th grade science class were given a worksheet consisting of statements from the textbook with multiple-choice response options. The students were instructed to find the right answer and to note the page in the textbook where the answer was found. The teacher circulated among the students and helped them find the answers if they were having difficulty. The observer indicated that the questions on the worksheet were factual and low level, requiring vocabulary recognition rather than application of knowledge. A question on air pressure read: "What does a barometer measure?" The answers from which the students were asked to select included: (a) humidity, (b) temperature, (c) air pressure, (d) wind. When the groups had finished the assignment, the teacher asked them to regroup with a new partner and compare their answers and reference pages. When this assignment was completed, the teacher read the correct answers and page references from her master copy and the students corrected their worksheets. The observer noted that the content was limited principally to definitions and terms; "although the vocabulary was important, the lesson did not encourage students to use the vocabulary as a way to communicate information and give meaning to observations."
>
> ❧ ☙
>
> According to the observer, "success in this 6th grade mathematics class hinged on students learning algorithms. Students were to learn rules and procedures, not the concepts behind them. Although the teacher had told them at the beginning of the lesson that moving the decimal place in both the divisor and dividend the same number of places was essentially the same as multiplying them both by the same power of 10, the message he gave students throughout the lesson was, essentially, 'Just do it.' When students pushed him for the reason they had to move the decimal, more than once the teacher responded: 'The divisor must be a whole number.'"
>
> ❧ ☙
>
> 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."
>
> ❧ ☙
>
> The observer of a 9th grade lesson on atomic theory noted that: "The lesson content was presented in a way that was inaccessible and uninspiring for students in this 9th grade class. The students copied notes from the book, listened to a lecture, and completed a worksheet on the same, low-level factual information."
>
> ❧ ☙
>
> 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.

A high school Algebra II lesson started out with the students working individually on the problem of the day, determining whether a particular relation was a function. After going over the problem, the teacher introduced the concept of the inverse of a function and walked the class through several examples. At the end of the lesson, the students were given a worksheet from the textbook and were assigned the odd-numbered problems to do for homework. Noted the observer, "the lesson design did little to engage students with the meaning of the concepts presented. The students were purely engaged in rote working of exercises with little understanding of the meaning of the exercises they were working."

The Influence of High Stakes Testing

High stakes accountability may help explain why some lessons tend to focus on facts and procedures rather than portraying mathematics and science in more authentic fashion. Based on *Inside the Classroom* observations, an estimated 18 percent of mathematics lessons and 5 percent of science lessons nationally include review/practice to prepare students for externally mandated tests. Although it is theoretically possible to assess student understanding, in practice it is very difficult and expensive to do so, and many tests used for accountability purposes focus at the factual level (Shepard, 2002).

On rare occasions, teachers are able to integrate test preparation fairly seamlessly into instruction that is clearly geared toward learning of mathematics/science. More often, the test preparation piece has the feel of an "add-on," or the entire lesson is focused on having students perform well on a high stakes test without also focusing on student understanding.

The following example illustrates high quality instruction in a lesson that focuses on test preparation for an externally-mandated test.

The teacher passed out two worksheets to the students in an 8th grade pre-algebra class. The first one contained the mango problem, in which members of a family each take $^1/_3$ or $^1/_5$ of the mangoes in a basket until finally there are only three left. The task for students was to determine how many mangoes were originally in the basket. The second worksheet was for students to use to write down their solution to the problem; it included prompts such as "what I know," "strategy," and "steps."

The students worked independently; the teacher moved around the room and looked over shoulders, but said little. His questions encouraged students to think about what they were doing, and challenged them to articulate their ideas with more than a one-word answer. For example:

Teacher: "What do you think about that answer?"
Student: "It's too high."
Teacher: "Why?"

Students felt free to ask questions of the instructor, and of their peers, even though the lesson did not specifically call for them to work together. The students and teacher were interested in the processes each used to get the answer, rather than simply finding the answer given in the book.

The teacher noted that he was trying to continue with the planned curriculum while getting students ready for an upcoming benchmarks exam. The observer indicated that the lesson in fact provided a nice combination of test-preparation and a review of problem-solving strategies.

In other lessons, the test preparation component is clearly separate from the rest of the lesson, but does not detract from the quality of the instruction. The following examples are typical.

> In a 1st grade mathematics lesson, the first ten minutes were spent to prepare students for a standardized test. The observer noted that the content of the lesson segment was out of sequence from the rest of the lesson, but that the teacher was able to use this external constraint to motivate students to assess their own proficiency. In this warm-up activity, the teacher showed addition problems on flash cards (e.g., 7 + 5 = __) and students raised their hands to answer. "They were very eager to participate and to prove to themselves that they got it right. Then students took a very rapid quiz to test their proficiency in addition, as required for the standardized tests. They were expected to finish only half of the 30 problems in the limited time available, but they wanted to do them all."
>
> The first part of a 6th grade lesson was review/reinforcement of computation skills in preparation for the mandated district and state tests. When the students walked in, the teacher had the problems for a review quiz already written on the chalkboard. This quiz took 10 minutes at the beginning of the lesson, then the teacher moved on to the content that was going to be the focus for the remainder of the lesson.

In other cases, the test preparation appears to have a negative effect on the quality of the instruction, with more of a focus on being able to get the test answers correct than on engaging students in learning the mathematics and science involved.

> 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."
>
> A 4th grade science lesson began with a segment to prepare students for the 5th grade state science assessment. The teacher reviewed specific strategies for test-taking as outlined in the booklet, and then directed the students to complete a written assignment. They were instructed to describe the differences in morning and afternoon temperatures using terms from the vocabulary list in the booklet. When the students had completed the exercise, the teacher selected several students to read their writing aloud. She commented positively on their use of the listed vocabulary: "Sounds like [name of student] used a lot of the listed words they told us to use."
>
> The observer indicated that the content of a middle school mathematics lesson on trigonometry ratios "was stripped down to just the knowledge needed for the state test. That ended up being the definitions of sine, cosine, and tangent and the meaning of opposite and adjacent sides. The context and the meaning were removed and, along with them, any motivation to do anything but memorize for a test. The students were not encouraged to reason about the content, and there was really nothing in the way the content was presented to reason about."
>
> The teacher of an 8th grade mathematics class reminded students that, "When you take the test, they might not give a specific unit, but all the units will be cubic." The teacher then turned to the topic of inequalities. She asked: "What's the opposite of an inequality?" Students responded: "An equality." The teacher said: "Okay, we're going to refer to these as inequalities. This is important because you can use inequalities to represent everyday situations. Why should you learn them? Because they're on the test."
>
> The teacher passed out a packet of sample questions from the 8th grade science state test. This review took half of the class time. The teacher then directed the students to a list of 30 terms on the board, which came from the

state science test. He told the students that they should already have the first 15 definitions done and that he had added 15 more. He reminded them that they would be tested on all 30 the next day.

The teacher told the 9th grade biology class, "I guarantee that there will be a question on the test about osmosis and diffusion. If you see passive transport on the test, you know it is diffusion." Moving to the next topic within classification, "I guarantee this next thing will be on the test."

The teacher wrote "Katie Put the Cat Out For Getting Smart" on the board. The students obviously knew this mnemonic and called out the categories as he wrote them: Kingdom, Phylum, Class, Order, Family, Genus, Species. The teacher once more repeated, "I guarantee that this will be on the test. I guarantee they will ask you this but it will be from largest to smallest."

The teacher said, "Any questions? Let's talk about the kingdom system"; and then wrote the five kingdoms on the board.

Teacher: "What is the classification system for man?"
Student: "Homo Sapiens."
Teacher: "What language is used?"
Another student: "Latin."

Teacher said, "You need to know that. I guarantee it will be on the test. I guarantee that they will ask you 'What is binomial nomenclature?'"

The observer of a high school Math Analysis class noted that, "Much emphasis during the teacher's lecture was placed on how many points a certain type of question would be on an upcoming classroom test and on different strategies to help students tackle questions on externally-mandated tests."

Taking Students From Where They Are and Moving Them Forward

Earlier sections described ways in which lessons engage, or fail to engage, students with the mathematics/science content. Although it is unlikely students are learning if they are not engaged, engagement is not enough; to enable learning, lessons need to be at the appropriate level for students, taking into account what they already know and can do, and challenging them to learn more.

- ***Gearing the lesson to the developmental level of the students***
  As can be seen in Figure 14, approximately half of all mathematics and science lessons are rated high for the extent to which the content is appropriate for the developmental level of the students in the class.

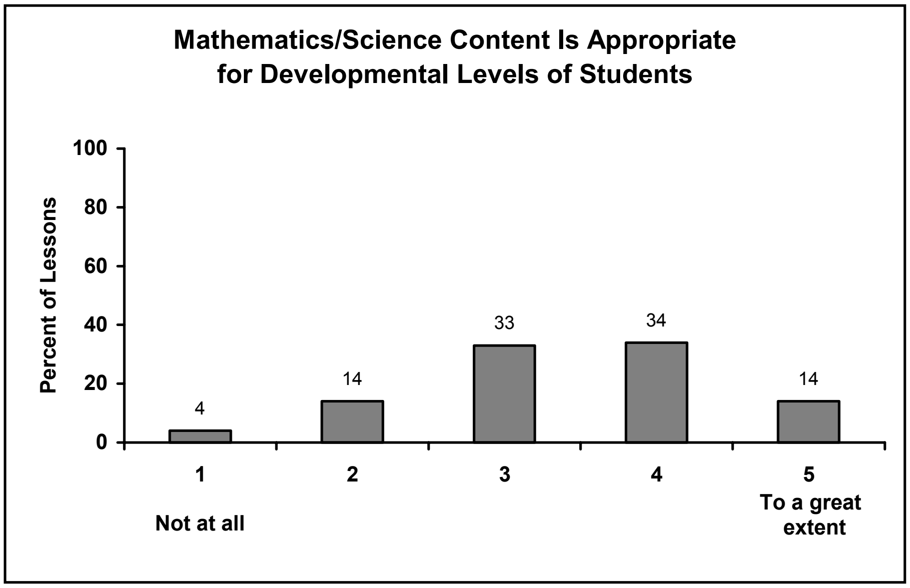


Figure 14

The following descriptions illustrate lessons that build effectively on students' existing knowledge and move them forward:

> A 7th grade mathematics lesson consisted of a teacher-led discussion of three warm-up problems on volume, followed by a review of area and an introduction to surface area. A tissue box was used to model the surface area of a rectangular prism, and other examples were drawn on the board. The lesson was designed to develop both a conceptual understanding of surface area and an algorithm; both were developed through questioning students in a discovery-based style. The whole class discussed the surface area of two example problems before being given a homework assignment of 8 problems in the textbook. The observer noted that "the lesson was carefully planned, with attention given to student readiness and prerequisite knowledge by reviewing volume and area before introducing surface area."
>
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> An 8th grade science lesson was designed for students to test their skills at identifying unmarked rocks based on characteristics that they had studied and recorded in their field notes. Students were divided into groups of four with each person being given a role to carry out in the group. Groups examined samples of unknown rocks, recorded their observations, and tried to identify the rocks. The class then came together as a whole, with the various groups describing their observations and conclusions. At the end, the correct answers were revealed to the entire class. The lesson ended with students taking a few minutes to individually "beef up" their notes on rock descriptions so they would be better prepared to use them for further identifications. The observer noted that "this lesson was excellently designed to take students' prior knowledge and experiences with rocks, which they themselves had been recording in a lab journal, and apply it in an investigative, cooperative manner to a new situation and set of rock materials."
>
> ☙ ❧
>
> The focus of the lesson in an advanced calculus class was on problem-solving. The class began with a discussion of previous problems, of "how they did in the past," to what types of problems the past methods applied, their limitations, and how they could be extended. Then the teacher introduced the new topic: the understanding of Cavalieri's theorem and its application to non-rotational bodies. The lesson was designed to let students do most of the thinking. After a brief presentation of the topic the teacher

> assigned part of a problem and had students work in pairs. Time for small group discussion was given after the pairs had sufficient work time. During this period the teacher walked around, encouraging students to confront the limitations of their own conceptions. Then the teacher brought the whole class together to explain the solution and to answer questions. There were several cycles like this, with students' work alternating with the teacher's presentations. The observer commented that one of the strengths in the lesson was that it was built around a small number of problems, breaking down the conceptual content so that it would connect with students' experiences, and extend the boundaries of their previous knowledge.

The estimated 18 percent of lessons nationally that are not developmentally appropriate are only occasionally too difficult for the students. Sometimes students lack the prerequisite knowledge/skills, and the content seems inaccessible to them. At other times, the vocabulary is at far too high a level for the students. The observer of the following 1st grade mathematics lesson noted that the students "did not understand what they were doing or why they were doing it."

> The teacher distributed crayons and worksheets, and began the lesson by noting: "Today, we're going to find differences for facts of five."
>
> Teacher: "When we say difference, does that mean add or subtract?"
> [Calls on a student.]
> Student: "Add?"
>
> Teacher repeats what she said.
> Another student says: "Subtract?"
> Teacher: "That's right."
>
> "Before we start, I want to pass out these mats and counters. Take 5 counters out of the bag. Place them on the top line of the mat. Now put three white counters on the bottom.
>
> If I tell you 5 plus 3, are you going to add everything or take something away?"
> Students: "Take away."
> Finally someone says: "Add."
>
> "If I say nine minus five, how many are you going to take away?"
> Students call out every number except 5.
> Teacher (getting impatient): "You're not listening."

The issue in a 1st–2nd grade science lesson was the complexity of the vocabulary.

> Teacher: "What does this bird eat?"
> Student: "Worms."
> Teacher: "Worms are animals. This is carnivorous. If you eat plants, you are herbivorous."
>
> Other terms introduced in this lesson included "oviparous" and "temperate climatic regions." The observer judged the "inappropriately advanced vocabulary" to be a serious weakness of the lesson, acting as a barrier to many of the students.

More often lessons were pitched at too low a level for some or all of the students. The following examples are typical:

> Some of the students in a 2nd grade mathematics class appeared to find the lesson too easy, and were handed worksheet after worksheet to keep them busy.

Students in a 6th grade science lesson demonstrated in the introductory whole-class discussion that they already had a good grasp of what owls eat, so the subsequent activity of dissecting owl pellets to determine an owl's diet would not advance their understanding.

Prior to the observed lesson the students had drawn the parts of the digestive system on the figure of a man, described the function of each part, and traced the path of a piece of food through the system. When they were then asked to write a story describing a cheeseburger's journey through the digestive system, many of the students were bored with the assignment. Said the observer, "they stated this fact on numerous occasions; they passed notes; they did their hair. They were not intellectually engaged. The assignment was too obviously busy-work—they had already done essentially the same thing the previous day."

The content of an 8th grade mathematics lesson seemed to be at too low a level for the students. "There were no instances in which the students seemed really stuck, when the process of moving to a deeper understanding of the content could occur. They were introduced to a new concept, they made sense of the definition, they applied it to different situations, but they didn't take the next step and see how this concept might be further explored."

- ***Providing multiple pathways to understanding a concept***

  Some lessons go further than simply providing content at a level that is appropriate for the students. These lessons use multiple representations of concepts to facilitate learning, both to give greater access to students with varying experiences and prior knowledge, and to help reinforce emerging understanding. Many lessons judged to be effective include a variety of experiences where students would be likely to "tap into" one or more of the pathways in developing or reinforcing a concept. Examples of such lessons follow:

A 5th grade mathematics lesson began with a teacher-led discussion of problem-solving strategies in mathematics. First, the teacher worked through an example using charting as a strategy for solving the problem. Students were then organized in small groups; each group was assigned a problem, and instructed to apply an appropriate strategy to solve it.

After the students had worked on their assigned problems, each group took a turn at the blackboard and explained their solution and strategy to the large group. The class was encouraged to ask questions and to copy the work in their own notebooks. At the end of the presentations, the teacher reviewed the various strategies used with the large group.

In the next segment of the lesson, students began working on a textbook assignment on the multiplication of decimals using calculators. After they had completed this assignment, they were instructed to work on the next section of the textbook lesson without the benefit of the calculator. The teacher indicated to the students that this would give them an opportunity to use the "guess and check" problem solving strategy.

A 6th grade mathematics lesson engaged the students in a number of different activities to help them explore the concepts of fractions, rates, and ratios. The lesson began with a review of fractions to help ground the students in what they already knew. Said the observer, "The teacher used multiple strategies (discussion, writing on the board, hands-on work with manipulatives at the overhead) to have students examine fractions, reflecting attention to students' different learning styles." The lesson then moved to explore rates and ratios, again involving different approaches (discussion, taking up questions from the overhead, reading definitions aloud, role playing a ratio). For the last quarter of the class, the teacher had students complete a worksheet to review what they had learned during the lesson.

Beginning with a review of the main facts about fossilization that students had been studying, the teacher in a 7th grade science class provided information about how fossils can be dated and went on to explain radiocarbon dating techniques. She then led the class in constructing standard radiocarbon dating curves, which the students used to date their own "fossils" (plastic bags of pennies). The "heads" represented C-14 atoms, which the students then replaced by paper clips, representing N-14 atoms. By counting the number of C-14 atoms in their "fossil," students were able to determine its age. Students who finished this task were then asked to create an N-14 standard curve. The observer noted that the lecture was effective, and that the use of the small group, hands-on activity "helped make this rather abstract concept more concrete and interesting."

The teacher introduced the concept of symmetry to a 7th grade class by first demonstrating the concept with examples. The concept development unfolded by engaging students in (a) exploring the concept, (b) investigating its application to familiar cases, (c) making connections to meaningful contexts, and (d) expanding it in a more challenging activity. First, the teacher used her body to illustrate the idea of symmetrical objects and line of symmetry. For instance she explained and acted: "If I fold my body, eye will fold on eye, ear will fold on ear, hands will fold on hands, fingers will fold on fingers." Students were attentive and excited. Students worked individually on specific examples, then participated in a teacher-led discussion about their exploration. Their task was to write the alphabet in capital letters and find which letters have a line of symmetry. The teacher drew examples on the chalkboard A, B, C, D, E, to explain, demonstrate, and discuss possible lines of symmetry. Students then worked on their own for a few minutes, investigating the symmetrical properties of each letter, expressing some puzzlement about letters like N, Z, and H.

A discussion about symmetry in real world and familiar examples followed. The teacher presented examples that helped students make connections between symmetry and familiar contexts. Then she continued soliciting students' input of their own examples. The teacher welcomed their ideas and expanded the discussion around each example. In the last 15 minutes of the lesson, students worked on a hands-on activity designed to apply the concept of symmetry. Students were to draw the left side of a Christmas tree (on graph paper), add decorations of their choice, (e.g., half of a star), then exchange with their neighbor and draw the other half of their neighbor's tree.

A teacher used tiles on an overhead projector to give students in an Algebra I class a sense of what it looks like when multiplying monomials, binomials, and polynomials; she asked questions of the group while she walked through a few examples. After going through the physical models with the algebra tiles, the teacher introduced the FOIL method to the whole group, detailing each step while she worked through examples on the board.

The entire class then went to the board and simultaneously practiced problems that the teacher read aloud; she walked around while they worked, and monitored their progress. After several examples, the students sat down and began work on their homework assignment. Again, the teacher walked around and helped individuals until the class ended. The observer noted that "the use of the algebra tiles and FOIL method provided different ways of getting students to understand the concept."

Creating An Environment Conducive to Learning

➢ **To be judged effective, lessons need to be both rigorous, and respectful of students.**

Important content and well-designed tasks at an appropriate developmental level are essential in order for students to have an opportunity to learn. So too is a classroom culture conducive to learning, one which is both rigorous and respectful. As can be seen in Figure 15, 45 percent of lessons nationally receive high ratings for having a climate of respect for students' ideas, questions and contributions; 27 percent receive low ratings in this area; and the remaining 28 percent are somewhat respectful. 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; 69 percent of lessons receive low ratings in this area, and 18 percent are somewhat rigorous. (See Figure 16.)

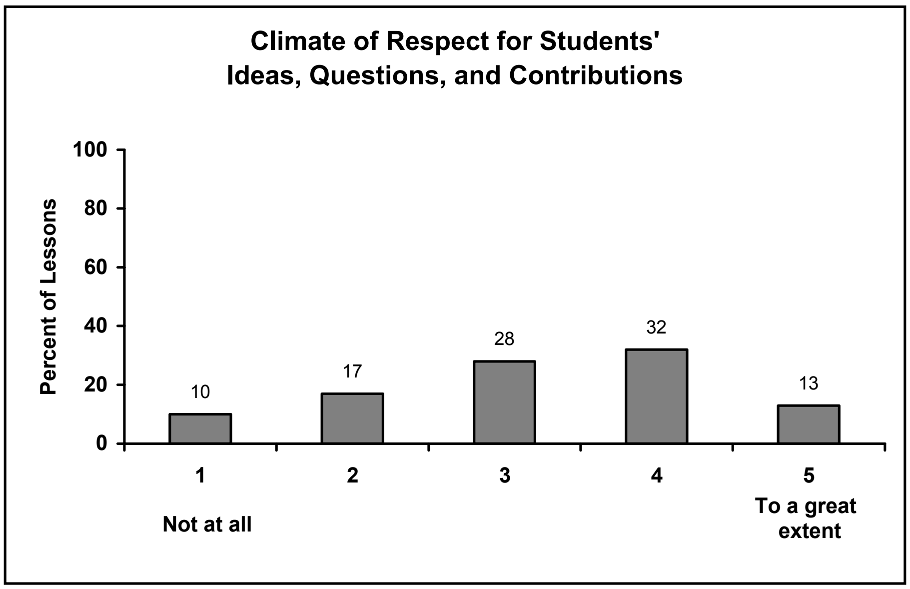

Figure 15

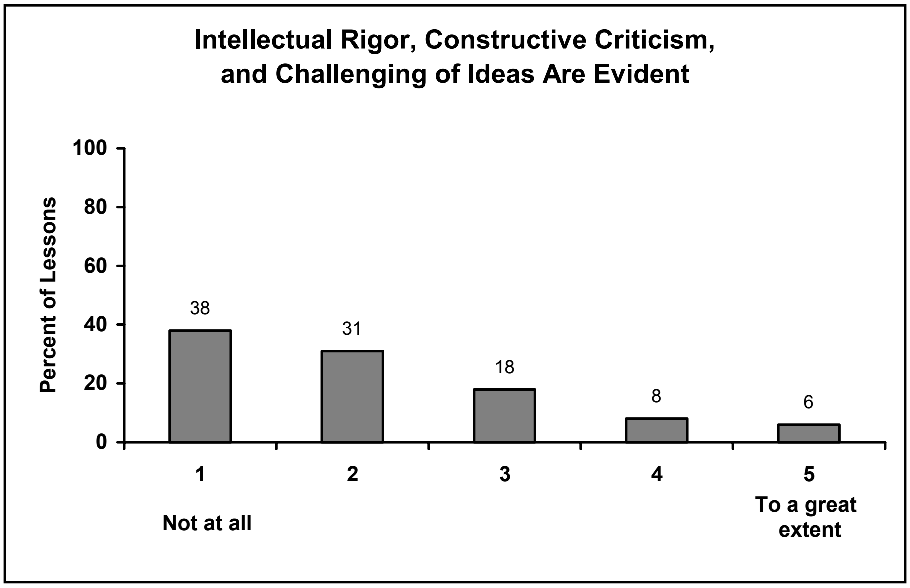

Figure 16

Table 18 shows a cross tabulation of the two variables; note that only 13 percent of lessons nationally are strong in both respect and rigor, and 26 percent are low in both areas.

Table 18
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

- ***Providing learning environments that are simultaneously respectful and rigorous***
  As noted above, only 13 percent of lessons are highly respectful and at the same time highly rigorous, encouraging the students to engage in serious learning. As the following examples illustrate, researchers observed highly respectful, highly rigorous lessons in both mathematics and science at the elementary, middle, and high school levels.

> An observer of a 1st grade science lesson described a climate of mutual respect between teacher and students, and among students. "The teacher's voice was always soft and her manner inviting. It was evident that she enjoyed being with these children, and they loved being with her…I was particularly impressed by the way the teacher was able to inject intellectual rigor into the lesson with children so young. Without putting students down, she was able to challenge them and encourage them to think. An excellent example of this came at the end of the lesson, when the children were discussing what they could infer from their findings. When one child said that finding an arrowhead meant that the Indians hunted buffalo, the teacher asked her if she had found any buffalo blood on it, and pointed out that

finding an arrowhead doesn't necessarily mean they hunted buffalo."

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 on coordinates 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 allowed other pairs to comment on the correctness of the placement. The observer noted that, "The teacher seemed to know the students well and was easily able to get nearly all students participating by calling on both volunteers and non-volunteers. Both the teacher and students were respectful of each other's thoughts. Discussions were lively and included multiple students' perspectives."

Students in a 5th grade science class worked extremely well in pairs, offering constructive criticism of each other's findings. The observer described an example where one student concluded that a rubber band conducted electricity, but her team-mate pointed out that she had accidentally touched the wire to one of the clips, completing the circuit. The pair of students then tried the experiment again, taking care to touch only the rubber band, and found that the rubber band was not a conductor. "The teacher eagerly answered questions, and encouraged exploration. There was—pardon the pun—an air of electricity and excitement in the room, and the students had to be shooed away from their activities for recess. It would be hard to imagine a classroom more conducive to learning."

The classroom culture in a 7th grade mathematics class "was based on a dynamic of serious work. As the lesson progressed, students who seemed somewhat indifferent at the beginning of the lesson began to fall into the rhythm of engaged learning. The teacher modeled respect for ideas and questions, and she pushed her students to monitor and assess their own learning. They talked intently with their partners about mathematics concepts and the meaning of different terms and phrases. The teacher encouraged them to use precise language in their responses to her questions. She exuded confidence in her ability to work with mathematical ideas, and the students displayed this same confidence in their own ability to learn mathematics."

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; it was clear that the teacher had a good relationship with the class. The culture facilitated the learning of all students."

Students in a high school geometry class were clearly comfortable participating and going to the board to work on problems. Said the observer: "The teacher called on volunteers as well as non-volunteers, and the teacher and students were respectful of each other's thoughts. One particular example that stands out was when a student 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. Although the work on the board was to be individually completed, the culture was such that students assisted, and benefited, from their neighbors. The rigor of this lesson was very high, and most of the teacher's questions caused students to really think about the mathematics. The teacher seemed able to relate to the students, and overall the classroom seemed to be a good environment in which to learn."

- ***Classroom climates that are respectful, but lacking in rigor***

  Seventeen percent of lessons nationally could be categorized as respectful but lacking in rigor. *Inside the Classroom* observers used phrases like "pleasant, but not challenging" to describe such lessons. The following examples are typical.

An observer described a 4th grade mathematics lesson where "the teacher was very enthusiastic, and encouraged her students to be the same. 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 through completing the task than really engaging with the concepts. The classroom was a welcoming environment for students, and there was a focus on 'learning,' but the level of learning expected seemed rather low."

In a 6th grade science lesson, "the teacher appeared to want all students engaged in the lesson, and distributed her questions to various students… [However,] intellectual rigor did not seem to be a priority, as long as students could give the verbatim responses for each cell part. Discussion of differences between plant and animal cells noted the different cell components (chloroplast, cell wall) but did not ask students to pose conjectures as to why the differences should exist, or what the effect would be, for example, if animal cells had a cell wall. The tone was friendly and supportive, but that was as far as it went."

Said the observer: "The tone of this 8th grade mathematics classroom was cordial, and the teacher appeared to encourage all students to participate. [However,] there was little in the way of challenging ideas, unless it was to note that a response was not the answer sought."

The observer reported that "emotionally, the culture of this 9th grade science class was good. The teacher had a warm relationship with the students, and it seemed clear that there was great deal of mutual respect. Intellectually, however, the culture in this classroom was very weak. Science was presented as facts and formulas to memorize, with no requirement that things make sense or even be internally consistent. Students were asked to respond to the teacher's questions but did not interact with each other, or propose new ideas for the class to discuss."

- ***Classroom environments that are lacking in respect for students***

  Roughly 1 in 4 lessons nationally are lacking in respect, in some cases even hostile and demeaning to students; nearly all of these are also very low in rigor.

The observer noted that: "There was little concern for learning and even less respect for the students as individuals" in this 2nd grade mathematics lesson. "Students were criticized and told they were wrong, but only occasionally helped by the teacher. Students who tried to contribute ideas ran a substantial risk of being told to stop. Most ideas from the students were met with a statement like the one given to a girl in the class, 'Please let me be the teacher.'"

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."

Said the observer: "The classroom culture in this 7th grade mathematics classroom was horrible! The entire lesson was a screaming match between teacher and students. The teacher did not treat the students with respect, nor did the students treat the teacher with respect. When the teacher asked a question, many students totally ignored him while others screamed out answers so as to be heard above others. When the students were supposed to be writing about their findings from the 'School Supplies' activity, most students were not doing it. The teacher shouted out, 'I don't see writing. I just hear talking.' Then the teacher turned to one student who had been out of his seat most of the period and shouted, 'Don't sit down now. I want you to stand up for the rest of the class.' Then he turned to another student and said, 'Where have you been while I went over all of this? That's okay. You can just have a zero.' At one point a group of girls were giggling and screaming and the teacher just joined in with their silly prattle. When the teacher took up the calculators, he said one calculator was missing and was very ugly to the class, as a whole, saying, 'I had 30 calculators at the beginning of this class; only 29 were turned in; all of you will have to pay for it.'"

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."

"The teacher in this high school physical science class spent the first few minutes of instructional time reminding the students of the discipline system that she has imposed in the classroom. If students 'misbehave,' they are given 'demerits.' Students with more than two demerits have to stay after school for 15 minutes. So, 'If you don't want it [a minus sign], what do you do? Behave!'… Several times during the class, she quietly went to the side board and placed a 'minus' sign next to a student's name. The classroom climate revealed anything but mutual respect between students and teacher."

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

- **To be judged effective, lessons need to ensure that all students are able to participate in learning important mathematics/science content.**

Part 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. Accordingly, researchers were asked to rate the extent to which lessons encouraged active participation of all students. They also described cases where some students were "left out" of the lesson, and cases where the teacher was particularly successful at engaging learners with special needs. As can be seen in Figure 17, only 47 percent of lessons nationally would be rated high in terms of encouraging active participation of all students.

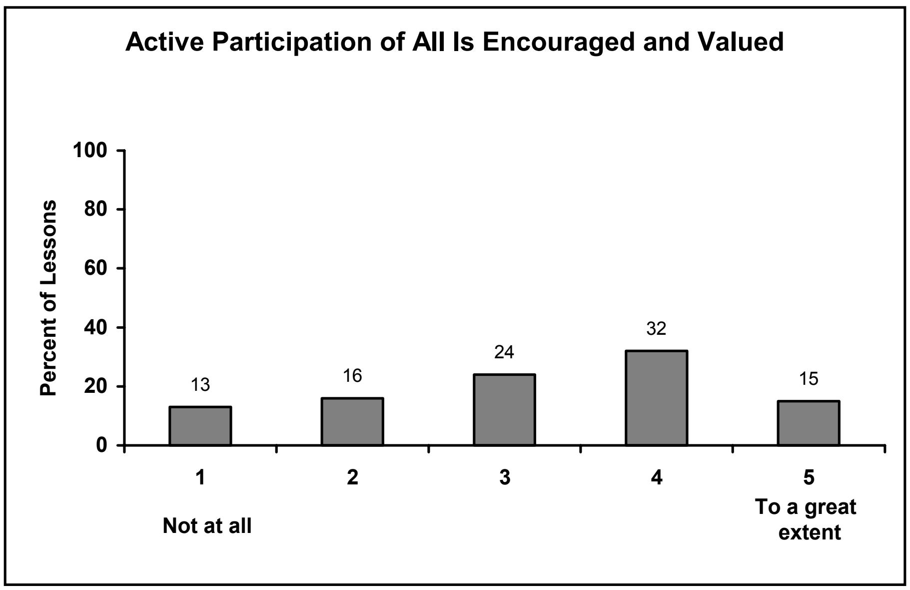

Figure 17

In most cases, low ratings on the active participation indicator reflect overall low levels of student engagement. In a few instances, observers noted differential patterns of participation by gender and/or race. For example, one observer noted that "of the 20 problems that were presented at the board [in a middle school mathematics lesson], only 3 were explained by the girls in the class. The teacher explained that she has tried different ways to get the girls to participate more, but they are often shy or embarrassed." In another lesson, the observer reported that one student was called on repeatedly and "this student happened to be the only Caucasian boy in the class."

In a very few cases, the observer described situations where the teacher clearly demonstrated unequal treatment.

> An observer reported that the 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.

Sometimes, teachers find it difficult to engage all students in a given lesson because of the extent of heterogeneity in their classes.

> 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."
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> 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."

Other observers described lessons where extensive efforts were made to ensure that all students had access to the lesson.

> 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."
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> 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.
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> An observer of a 7th grade mathematics class noted accommodations for special needs students. "There were at least two hearing-impaired students in the room. An aide used sign language, and the teacher wore a microphone to amplify her voice. It appeared as though the teacher consciously made an effort to somewhat exaggerate movement of her lips when talking, as if to facilitate lip reading. Another student [who was apparently visually impaired] moved close to the front of the room when the teacher wrote on the overhead."
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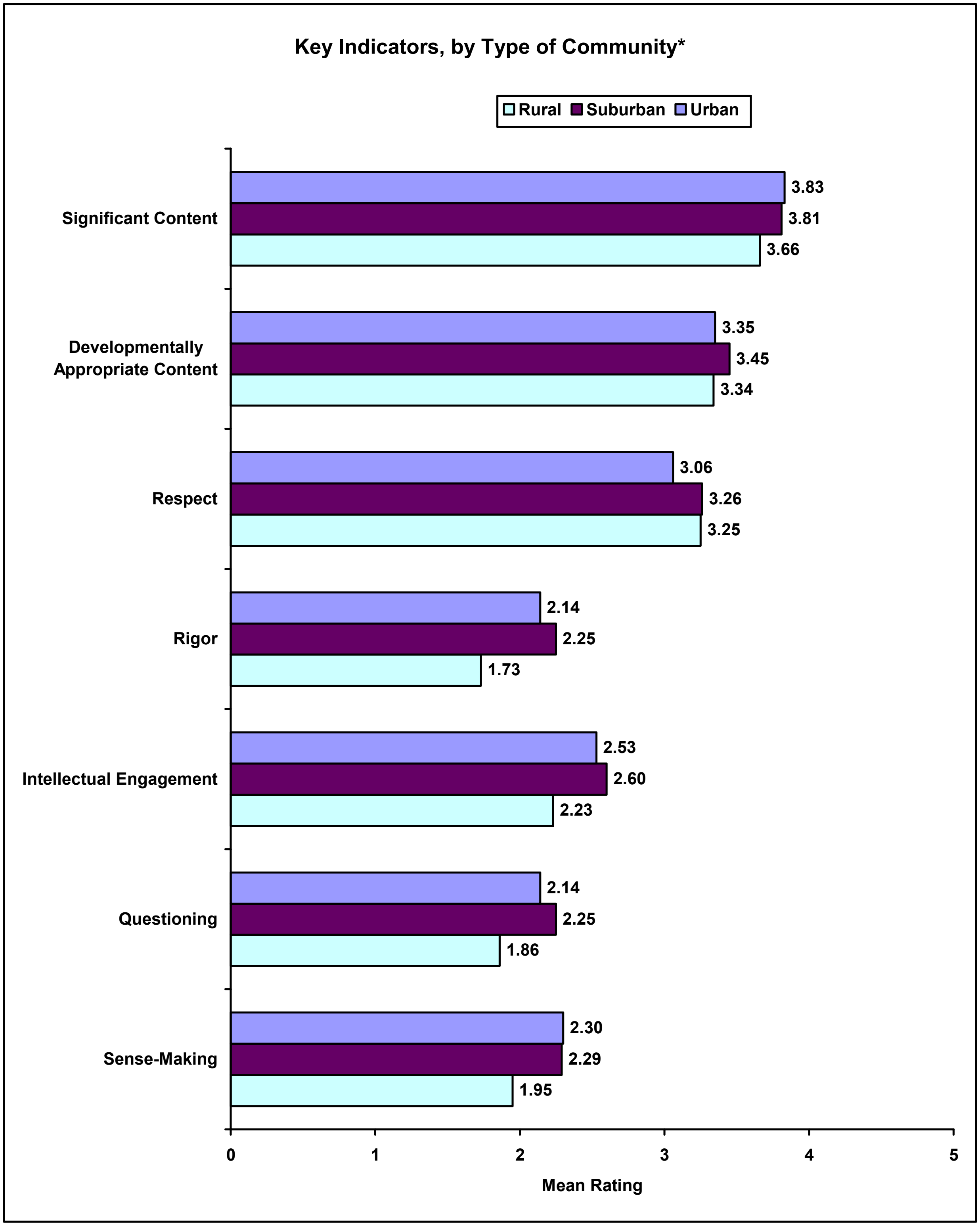
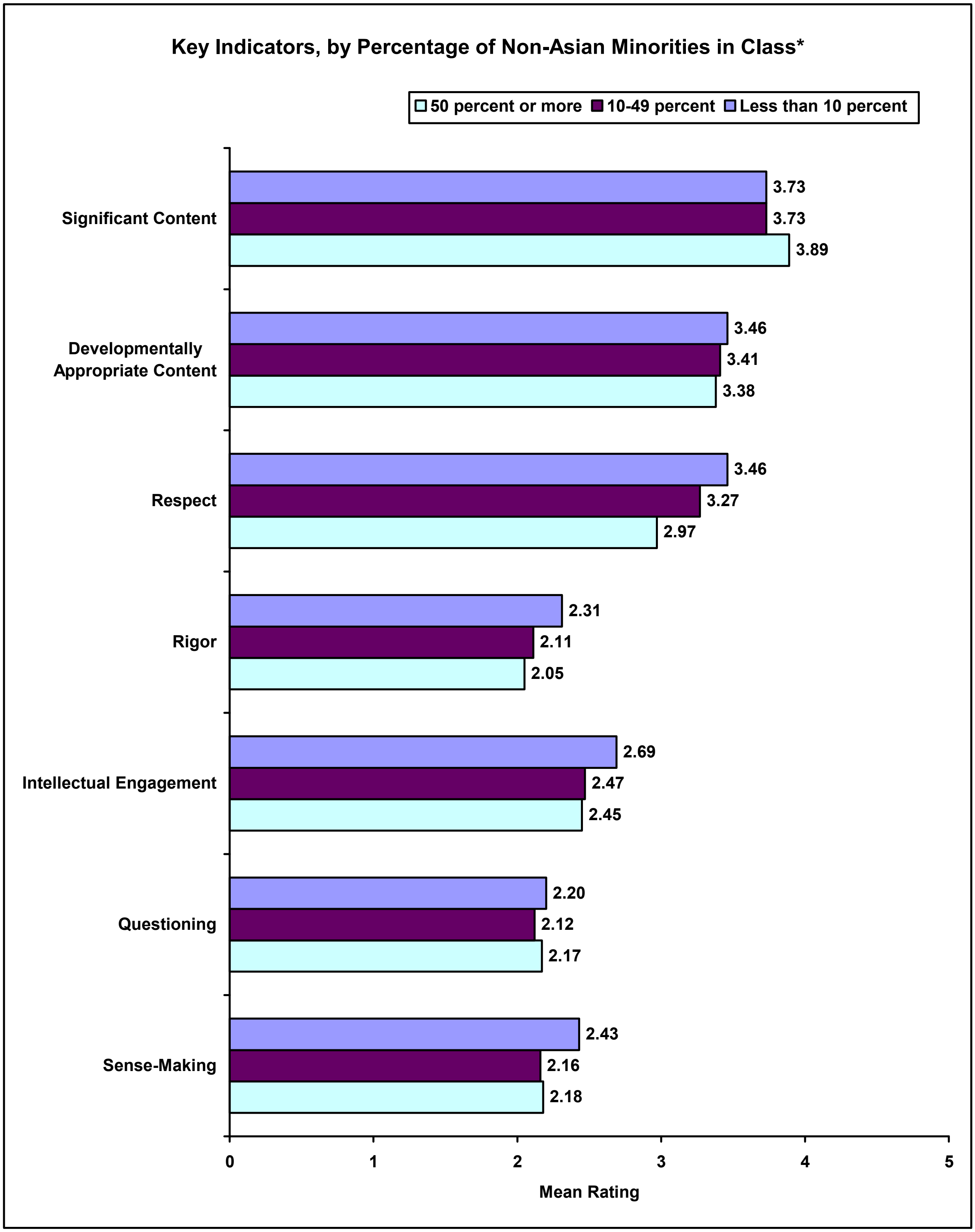
> ☙ ❧
>
> Another observer reported that "two non-English speaking students were included fully [in a middle school science lesson], using specially translated notes, translation tools, and lots of contact with the teacher and other members of their group. These students contributed to the making of observations, recording of information, and identification of the rock samples."

As part of the investigation of the extent to which lessons ensure access for all students, multivariate analysis of variance was used to determine if there were overall differences on a set of key indicators for each of a number of categorizations: type of community, class ability level, and percent minority students in the class. As can be seen in Figure 18, lessons in rural schools are significantly weaker in these key indicators than are lessons in urban and suburban schools. Lessons in classes with 50 percent or more of the students from traditionally underserved minorities are rated lower than lessons in classes with smaller proportions of minorities. (See Figure 19.) Finally, as shown in Figure 20, lessons in classes that teachers categorized as low in ability, and in those they considered "middle" in ability, are significantly weaker in these key areas than are lessons in heterogeneous and high ability classes.



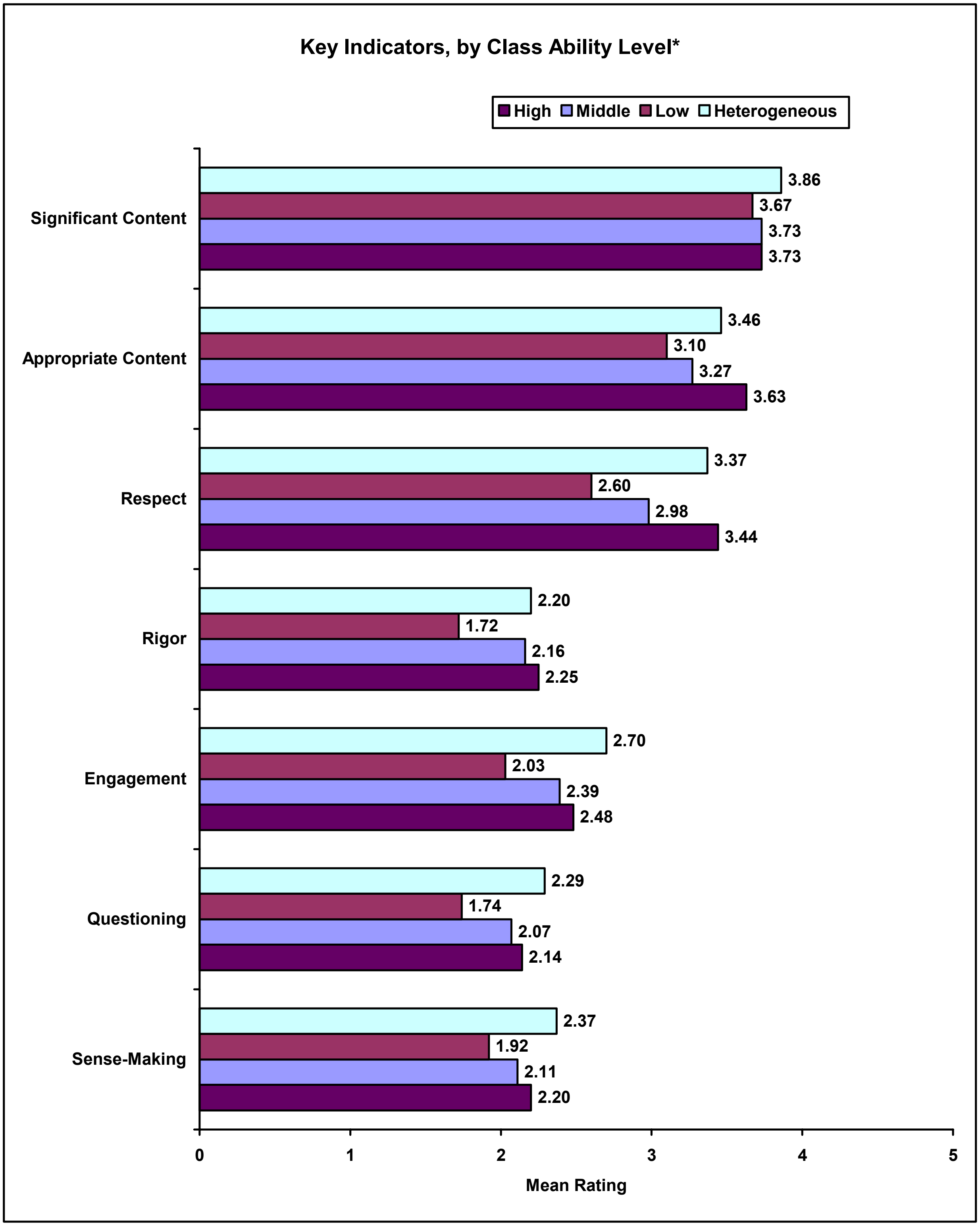
* On these indicators as a set, lessons in classes in rural communities rated significantly lower than lessons in classes in either suburban or urban communities, defined in this study as large and mid-size cities (MANOVA, $p < 0.05$).

Figure 18



* On these indicators as a set, lessons in classes with 50 percent or more students from underrepresented minorities rated significantly lower than lessons in classes with either fewer than 10 percent minorities or 10 to 49 percent minorities (MANOVA, $p < 0.05$).

Figure 19



* On these indicators as a set, lessons in classes with low or middle ability students rated significantly lower than lessons in classes comprised of either high ability students or heterogeneously grouped students (MANOVA, $p < 0.05$).

Figure 20

Helping Students Make Sense of the Mathematics/Science Content

➢ **To be judged effective, lessons need to help students connect their activities to the learning goals.**

Focusing on important mathematics and science content; engaging students; and having an appropriate, accessible learning environment set the stage for learning, but they do not guarantee it. It is up to the teacher to help students develop understanding of the mathematics and science they are studying. The teacher's effectiveness in asking questions, providing explanations, and otherwise helping to push student thinking forward as the lesson unfolds often appear to determine students' opportunity to learn.

- ***Questioning to encourage students to think more deeply***
  Researchers observed some extremely skillful questioning, where the teacher was able to use questions to assess where students were in their understanding, and to get them to think more deeply about the mathematics and science content. There were many more instances where the teacher asked a series of low level questions in rapid-fire sequence, with the focus primarily on the correct answer, rather than on understanding.

  Questioning is among the weakest elements of mathematics and science instruction, with only 16 percent of lessons nationally incorporating questioning that is likely to move student understanding forward. (See Figure 21.) Lessons that are otherwise well-designed and well-implemented often fall down in this area.

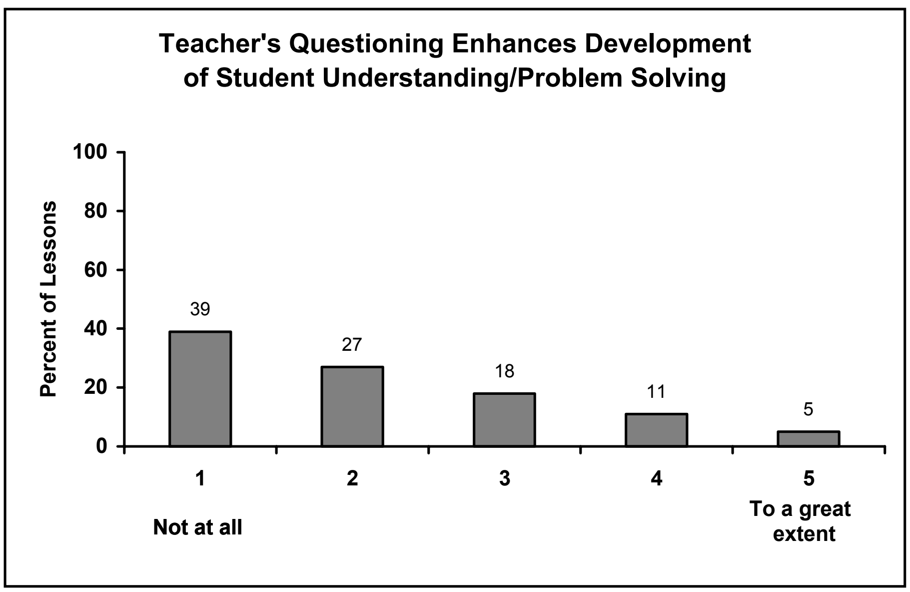


Figure 21

The following descriptions illustrate how some teachers are able to use questioning skillfully, both to find out what students already knew and to provoke deeper thinking in helping them make sense of mathematics and science ideas.

> The purpose of the lesson in a 5th grade science class was to help students understand methods of seed dispersal. The lesson began with the teacher asking the students what they had learned about plants thus far. The teacher used their responses to provoke more in-depth thinking. For example, one student volunteered, "They need sunlight." The teacher asked, "Why do they need sunlight?"
>
> After the class discussed this idea, and others prompted by the student responses, including talking about seeds, the teacher asked a question to focus the discussion on the topic for today: "How do those seeds disperse? In other words, how did they leave their parent plants, their homes and spread out to grow?" Students began volunteering answers, and the teacher asked questions of each to see if they were on target, and to make sure they were expressing their ideas clearly for the rest of the class.
>
> 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?"

- ***Using questioning to monitor student understanding of new ideas***
  When teachers ask questions, and individual students respond correctly, it is often difficult to tell if others in the class have a similar level of understanding. Some teachers were able to overcome this difficulty by asking for a show of hands (or as in the following example, "thumbs-up, thumbs down"), having established a culture where it was okay to be wrong in the process of working toward understanding. The importance of knowing not just how many, but which students are struggling and which students are "getting it," is illustrated in the following example, where the teacher used that information to assign students to small groups.

> A 7th grade mathematics lesson began with a five-minute warm-up exercise—a review of division and fractions. When the students were finished, the teacher read the correct answers and the class indicated whether their answers were correct by a "thumbs-up" or "thumbs down" signal. The teacher did a quick visual tally for each question and reported to the class, "Looks like we did well on that question. About 80% got the answer," or "That may be the kind of problem you need to look at again."

> At this point, the teacher instructed the students to complete the worksheet they worked on previously. She organized the students in pairs for this part of the lesson. Her rationale for the arrangement, as she explained it to the students, was, "I looked over your papers and tried to have you work with someone who understood the problem you had trouble with. You can help each other." The students worked together efficiently and with intensity, asking each other questions and often negotiating about the problem. The teacher circulated among the students, checking for understanding and offering suggestions.

More often observers noted that the teachers moved quickly through the lessons, without checking to make sure that the students were "getting it." As soon as the few most verbal students indicated some level of understanding, the teacher went on, leaving other students' understanding uncertain.

- ***Questioning that is unlikely to deepen understanding***

  By far, the most prevalent pattern in mathematics and science lessons is one of low-level "fill-in-the-blank" questions, asked in rapid-fire, staccato fashion, with an emphasis on getting the right answer and moving on, rather than helping the students make sense of the mathematics/science concepts. Said one observer, "The students who were working on the problems were concerned with finding the right numbers and which numbers to subtract from which number. Students likely were not connecting the numbers to any meaning. The teacher-provided content information was accurate but again superficial. There was no attempt at closure."

  The following examples illustrate this pattern as it played out in mathematics and science lessons across the grades.

> 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."
>
> ☙ ❧
>
> According to the observer, the teacher's questioning strategies in a 1st grade mathematics lesson "tended to focus on facts and single word student responses. That is, the teacher asked low order questions in a rapid-fire manner, with directions to students interspersed. For example, as she, very quickly, led the class discussion for #1 on the fact family handout:
>
> 'Find Problem #1, Complete the fact family.
> Read the first problem and tell me the answer (i.e., 6 + 4 = ___).
> You should write 10 in the blank.
> Who can tell me the addition fact that is related to 6 + 4 = 10?
> You need to write 4 + 6 = 10 on your paper.

Who can tell me a related subtraction fact?'"

Said the observer, "the pace of the lesson was often too fast for many of the students in the class; frequently the teacher left the students behind as she continued on with the 'discussion.' The teacher did not attend very well to students' levels of understanding, and she did not adjust instruction based on students' understanding."

☙ ❧

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?'"

☙ ❧

The following question and answer session 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"

☙ ❧

An observer reported that a teacher in a high school biology class asked students a series of questions about cells.

Teacher: "Animal cells don't have what?"
Student 1: "Chloroplasts and cell walls."
Teacher: "Plant cells don't have what?"
Student 2: "Centrioles."
Teacher: "If you are (constructing a model of) an animal cell make sure you don't have what?"
Students: "Chloroplasts and cell walls."
Teacher: "If you are doing a plant cell make sure you don't have what?"
Students: "Centrioles."

☙ ❧

The observer reported that questions asked of students in a 12th grade mathematics class tended to be low-level and leading. The students were given the following system of equations:

$6x + 5y = -2$
$5x - 4y = 31$

The following “discussion" occurred:

Teacher: “What do we want?”
Students: “x and y”
Teacher: “What do I need to do to get x and y?”
Students: “Get rid of the first matrix.”
Teacher: “What do I need to do to get rid of it?”
Students: “Multiply by the inverse.”

Said the observer, “discussions during this lesson were much more about identifying steps to do than about justifying the steps by considering conceptual underpinnings.”

- ***Teachers answering their own questions***
  Observers reported that some teachers asked good questions, but were so intent on getting the right answer that they supplied the answers themselves, in effect short-circuiting student thinking. Said one observer, “The teacher discouraged any comments or ideas that were not exactly what she asked for, answering her own question if the first response was not what she desired.” The following examples are typical of this pattern.

The researcher reported that the teacher moved too quickly for some students in this 1st–2nd grade science lesson, with her questions coming at them in rapid succession. “At times the teacher worked to get the students to think on their own, but mostly she answered her own questions if the students were not giving her what she wanted to hear. She was very leading in her questioning.” For example:

Teacher: “Are birds useful?”
Student: “We eat chickens, but we don’t eat blue jays.”
Teacher: “What about feathers? Some pillows are made with feathers.”
Student: “Oh, yeah.”

The observer of a 6th grade mathematics lesson noted, “Although some of her questions had the potential of generating good discussion, they mostly fell flat when she accepted a student’s answer and moved on. Questions intended to push students to process information became trivialized by students’ short answers. There was little wait time and in many cases she answered her own questions. For example:

Teacher: ‘There are 9 factors. Why aren’t there 81 products on the board?’
Student: ‘If you had 81, you need higher than 9 as factors.’
Teacher: ‘Why?’
Student: ‘Because some of the numbers have factors higher than 9.’
Teacher: (takes over the explanation) ‘If you put the paper clip on 6 and 2, what do you get?’
Student: ‘12’
Teacher: ‘What about 2 and 6?’
Student: ‘12’
Teacher: ‘What about 3 & 4 and 4 & 3?’
Student: ‘12’
Teacher: ‘So, since several numbers have more than one combination of factors we only have 36 products.’”

The observer noted that the purpose of a physical science lesson was to review the work that the class had been doing on speed and velocity. "Throughout the lesson, the teacher would ask a question such as, 'How do we calculate speed?' Either the student called upon would not know or would give a wild guess. Sometimes, a student would blurt out part of the answer. Using a series of 'hints,' with virtually no wait time, the teacher would supply the answer. 'What is the speed? We have 40 divided by 4? Visualize the fraction.' When a student answered '10,' the teacher told the class, 'Right, 10 Km/second.' She did not probe to see if they understood what the units would be; she gave it to them."

Said the observer of a high school calculus lesson, "When the teacher put a problem on the board and asked students to solve it, which they did in silence at their seats, the teacher often solved the problem on the board as they were working through the problem, or else waited about one minute and asked a student for input. On one problem 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."

- ***Helping the students "make sense" of the mathematics/science***

  Teacher questioning is one way, but not the only way to help students understand the mathematics/science at hand. The important consideration is 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 mathematics and science concepts being addressed. The following examples illustrate lessons that included appropriate "sense-making."

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. The lesson began with students working in groups of four. Each student in the group had a group member number. The teacher would give a digit for all the #1s to write on their marker board, then a digit for all the #2s, #3s, and #4s. The teacher would then give a number using all the digits and the students in the group would line up with their digits in the proper order to build the number. 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. The class did several examples like this and then the students worked individually on more examples. After that the teacher had the students put their marker boards away, then wrapped up the lesson by asking, "What did we learn in math today?" Students gave responses like, "If there's a zero, you have to count it" after which the teacher asked for more explanation. She emphasized, "When we write numbers, the digits have to be in the right spot. Remember that the zeros are important, too. This will get easier as we go along."

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."

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." A student asked, "Does it work that way with taste, hearing, and sight?" The teacher responded that it does, and the student asked "How does it work with sight?" 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.

The teacher summarized this portion of the lecture, reiterating the all-or-nothing principle and the differentiation of nerve receptors by threshold. He spent the last few minutes of the class moving on to the next portion of his outline, in which he drew and labeled the parts of a synapse. Said the observer, "this lecture was extremely engaging, accessible, and focused on worthwhile content. The teacher emphasized sense-making throughout the lesson, using examples familiar to the students and connecting the content to their lives. The students appeared to be very engaged."

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. The lecture itself moved through content sequentially, building from the specific to broader conclusions. Said the observer, "this was a well-designed lesson with clear objectives that were all met."

- ***Inadequate attention to "sense-making"***
  Although researchers observed some lessons where students were helped to make sense of the mathematics/science content as the lesson progressed or at its conclusion, most lessons lack adequate "sense-making;" as can be seen in Figure 22, only 16 percent of lessons in the nation would receive high ratings in this area. Teachers seem to assume that the students will be able on their own to distinguish the big ideas from the supporting details in their lectures, and to understand the mathematics/science ideas underlying their computations, problem-solving, and laboratory investigations.

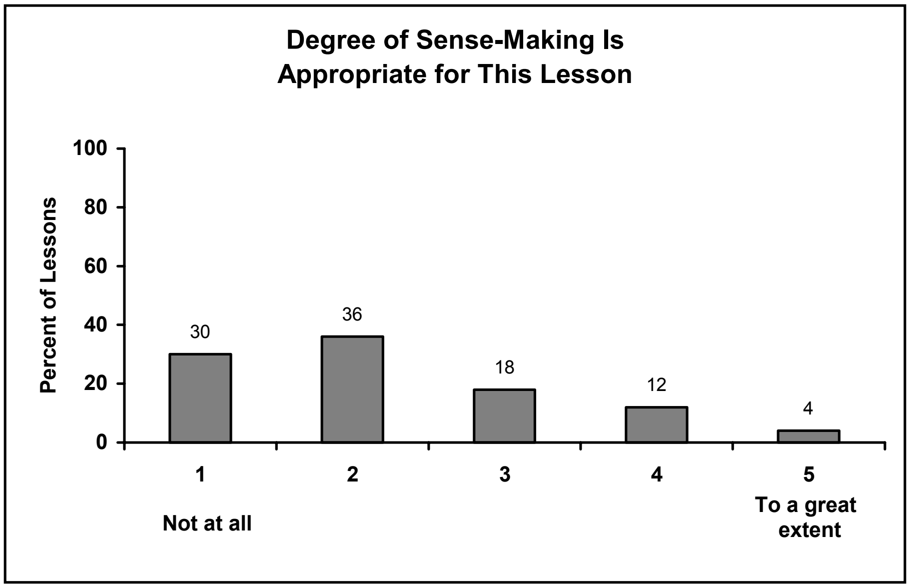


Figure 22

Many lessons consist of what one observer characterized as "working problems with no discussion of the relationship among topics or how the pieces fit into important mathematical concepts." The following lesson descriptions illustrate inadequate sense-making in elementary, middle, and high school mathematics and science lessons.

> 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.
>
> The purpose of a 4th grade mathematics lesson was to extend the students' knowledge to multiplying single-digit numbers by dollar and cents amounts, e.g., $3.42 x 7. The teacher indicated that she wanted "to get students used to using decimal points and dollar signs." As students completed problems on the board, she would answer with a simple, "Correct" or ask questions to guide them to their errors such as, "Where's your decimal" and "What's 6 times 3 plus 3?" Students would hurriedly correct their work and upon receiving the confirmation that the work was correct, erase it immediately. Very few of the seated students had the opportunity to even see the work of the students at the board. The teacher sought no input from the students in terms of pointing out others' errors and seemed to be only interested in the correct answer. After three sets of four students had come to the board and completed problems, she

directed them to put their books away and assigned them a page in their practice workbook.

☙ ❧

An observer of a 6th grade mathematics 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."

☙ ❧

Students in another 6th grade mathematics class were asked to complete a practice worksheet, which involved their measuring nine angles and identifying each as acute, right, obtuse, or straight. Said the observer, "instead of students being encouraged to make sense of mathematics, students were to follow directions. Students were not asked to explain their thinking—either during the whole-class discussion or on the assessment. Mathematics was presented as a set of rules and procedures."

☙ ❧

An observer of an 8th grade science lesson noted that the study of Newton's Laws of Motion was appropriate and worthwhile science content, and was presented at a developmentally appropriate level. "However, the way in which the content was presented, with the students copying down the information then reciting facts back to the teacher, did not allow the students to engage with the content in a meaningful way. Instead, sense-making of the content was left up to each individual, and most likely did not happen."

☙ ❧

The mathematics content in an 8th grade algebra class was the simplification of radical expressions. Said the observer, "Although the teacher's content was accurate, the students were engaged only in following the procedures. There was no sense-making of concepts—only understanding of the procedures to solve the problems."

☙ ❧

The observer noted that "each of the physical science topics demonstrated in this lesson was appropriate to the 9th grade curriculum (mechanical waves, sound and light waves, mixing colors), and could be grasped by these students at some level. Moreover, each of the demonstrations was in itself interesting and motivational for the students, and for the most part kept their attention. However, the teacher presented all of these demonstrations in rapid succession, without providing appropriate ties to the material studied in class. As a result, the overall effect was more show than substance. No attempt was made to anchor the demonstrations into any conceptual framework."

☙ ❧

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.

☙ ❧

The observer described what transpired in a high school earth science class after the teacher passed out a worksheet. "For each question, the teacher asked a student to read the question aloud, another student was called upon to attempt a short answer, then the teacher told the students exactly what he wanted while the class copied it down. The teacher even slowed down and repeated his answers verbatim for students who did not get it down the first time through. Neither time nor attention was given for students to grapple with the concepts inherent in the rock cycle and to make sense of it. In fact, the teacher instructed the students not to pay attention to the complexity of the interactions in the rock cycle, but rather to just copy down his simplified model. In this way he took out the conceptual nature of the content and replaced it with a list of terms that needed only to be remembered in the proper order."

An observer reported that the purpose of the lesson in a high school biology class was for the students to learn about adaptation and natural selection, but that it was unlikely the purpose was being achieved. "I have serious doubts, however, as to whether the students learned anything at all about the intended content. The students were not engaged in ideas; they were engaged in getting the handout done. Since the lab activity described on the handout was not accompanied by a meaningful discussion of the students' ideas, findings and questions, the activity reduced science to facts and vocabulary. There was no sense-making whatsoever in this lesson. A few of the questions on the handout might have required the students to summarize their learning, but they just got the answers for those questions from the teacher."

CHAPTER SIX
Influences on Lessons

Introduction

The previous chapters focused on describing the designs of mathematics and science lessons and the strengths and weaknesses of their implementation. 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; their perceptions of the needs of the students; and views of the principal, parents, and other key stakeholders. Following the *Inside the Classroom* observations, extended interviews were conducted with the 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.

Interview data were analyzed to determine which factors were most likely to influence teachers' selection of content, pedagogy, and instructional materials. As noted earlier, data were weighted in order to yield unbiased estimates for all mathematics and science lessons in the United States.

Influences on Selection of Mathematics/Science Content

The extensive interviews conducted with teachers observed in this study included a number of questions focused on the content of the lesson observed. Specifically, teachers were asked to describe what led them to teach the topics, concepts, and skills in the lesson. Researchers probed to determine whether the content of the lesson was included in the state or district curriculum or course of study; a state or district mathematics/science assessment; and/or the textbook/program designated for the class. In addition, teachers were asked about the degree to which each of these factors influenced their selection of the topics, concepts, and skills included in the lesson. Researchers also noted other factors mentioned by teachers as influencing their selection of content that were not directly asked about in the interview.

It is important to note that it is difficult to disentangle some of the influences on content. The data presented in this section are based on the teachers' descriptions of what was most salient in their selection of content for the lessons. However, teachers may not always be aware of the influences operating behind the scenes. For example, teachers were much more likely to cite state/district curriculum standards than state/district tests as influencing content, although there is substantial effort at the policy level to align the two. Similarly, teachers often cited state/district curriculum standards as an influence, but rarely mentioned national standards. At the same time, many state and district standards documents indicate that they are modeled on national standards.

As can be seen in Figure 23, state/district curriculum standards are the most frequently cited influence on lesson content, followed by the textbook/program designated for the class, and state/district accountability systems. The nature of the influence of these and other commonly-cited factors is described in the following sections.

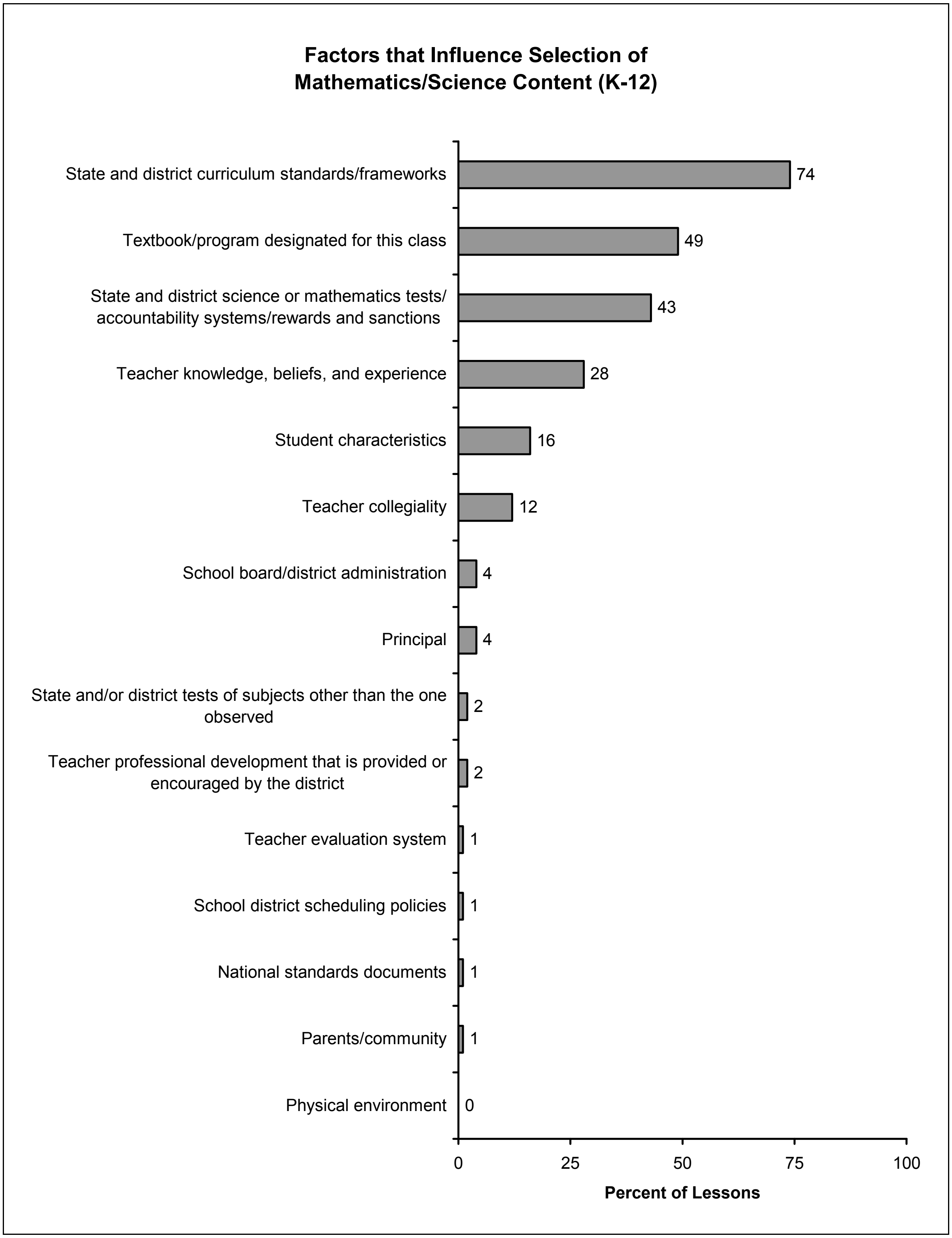

Factors that Influence Selection of
Mathematics/Science Content (K-12)
State and district curriculum standards/frameworks
74
Textbook/program designated for this class
49
State and district science or mathematics tests/ accountability systems/rewards and sanctions
43
Teacher knowledge, beliefs, and experience
28
Student characteristics
16
Teacher collegiality
12
School board/district administration
4
Principal
4
State and/or district tests of subjects other than the one observed
2
Teacher professional development that is provided or encouraged by the district
2
Teacher evaluation system
1
School district scheduling policies
1
National standards documents
1
Parents/community
1
Physical environment
0
0
25
50
75
100
Percent of Lessons

Figure 23

Influence of Curriculum Standards on Content Taught

Mathematics/science content is at the core of the instructional experience for students. The topics focused on lessons determine the potential knowledge students come away with at the end of each course. Based on the data collected for the *Inside the Classroom* study, for most mathematics and science lessons, the decision of what to teach is made by someone other than the teacher. According to teachers, state and district level policies communicated through curriculum standards have a substantial influence on the selection of content, providing a road map for what to teach in roughly 3 out of 4 mathematics/science lessons nationally.

Teachers frequently commented that they not only follow the guidelines in selecting the content they teach to their students, they are required to do so. For example:

> *[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)

> *Generally speaking, the standards dictate where I should be going. They say teach the human body systems, so I teach the human body systems.* (7th grade science 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 that we teach and don't teach.* (High School Honors Chemistry teacher)

> *I don't get to choose. I have to do what the curriculum says.* (High School Honors Trigonometry teacher)

> *Oh, I don't have a choice. If the district and state say this is what you teach, this is what you teach. End of story.* (High School Consumer Mathematics teacher)

Some teachers are given frameworks of what children are expected to know and have flexibility of when they teach particular content areas. Other teachers are provided with pacing guides which dictate the order in which topics should be taught, and in some cases how much instructional time should be devoted to a particular content area. Teachers describe this level of guidance as follows:

> *We try to follow the state benchmarks, and we have a curriculum guideline that is set up, K–12, and it should be when it's introduced, when it's gone over, and when it's mastered.* (7th grade mathematics teacher)

> *That's a big part of our curriculum guide…We have a curriculum map. And ours is only broken down into nine weeks. We must cover a certain amount of information in nine weeks. So, the curriculum map is what keeps us on track.* (7th grade mathematics teacher)

> *[Prior to the new scope and sequence] I could make it work the way I felt it was best and now we don't have that option. It's spelled out in a particular order and they give us nine week exams from the board…they are tracking to make sure you are doing what you are supposed to be doing.* (10th grade Biology teacher)

> *[The state] has a state curriculum framework. And then our school took that and did a curriculum mapping...and then they did pacing guides. And the pacing guide tells us what we're to teach in each chapter and how many days to spend on a chapter, it's a guideline. And so, one reason I did today's lesson is it's on our pacing guide that we do that.* (High School Algebra II teacher)

Given the emphasis on national standards in the last ten years, it is surprising that mathematics and science teachers rarely mention national standards as having an influence on their selection of content. When national standards were mentioned by teachers, it was most often in the context of describing their state or district standards and the alignment of these documents to national standards.

Influence of Textbook/Curriculum Programs on Content Taught

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. In some cases, teachers report following closely the sequence of topics laid out in the text. Said these teachers in describing their use of the designated curriculum program:

> *That's exactly where we were…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 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)

The book perhaps was the most influential. I trust the book. I can get everything from the book and teach the kids what I think they need to know. (8th grade Algebra I teacher)

When I get a little more experience I may deviate a lot more, but right now I pretty much follow the textbook. (High School Physical 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 on Content Taught

Based on the teacher interviews, the content selection for nearly 1 in 2 lessons nationally is influenced by some sort of accountability system related to student achievement. For many teachers, pressure for their students to do well on high stakes testing drives their selection of topics. Surprisingly, even though mathematics testing is more common, science teachers were just as likely to report tests as an influence on their selection of topics. Said these teachers:

It's really important for kids to be familiar with the information so when they get ready to take the assessment at the end of the year, they'll know what they're doing. (4th grade mathematics teacher)

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)

☙ ❧

I do five ACT problems every day with all of my classes. I find that they really need the review and they need to work on the problem types that appear on that test. (High School Algebra III teacher)

☙ ❧

Content has changed because the curriculum guide and the [state assessment] keeps changing, so when they shift, you shift. And what that test says you need to teach, that's what you teach. So that has changed from the first three years of my teaching. Some of this material I may not have covered but now that I know for a fact that this is something my students will be tested on, and I have my standards and benchmarks, I know what I've got to hit. (10th grade, Biology teacher)

It is interesting to note that the influence of testing on the topics selected for lessons is not limited to teachers whose students are being tested that school year. On occasion, teachers report that they select the content that is taught during the lesson because it will be on tests in future years. As described by two mathematics teachers:

They're tested in third and fifth, which is why you saw the worksheet that has nothing to do with what was taught. It's a review…we revisit so that we don't lose what we've gained…We do graphing in math, but we will continue to graph throughout the year because of the [state] test that they have to take. So we continue to reinforce things that we know they're going to see on this test. (4th grade mathematics teacher)

☙ ❧

I know on the [state test]—it [the concept fraction as part of a set] is definitely on there—from talking with a 5th grade teacher, I know it's on there. That's why I really wanted to cover and focus on fractions and decimals, because she told me that, it's part of her experience that it's part of the [state test]…But to prepare them—I want them prepared for 5th. (4th grade mathematics teacher)

Some teachers clearly feel pressure from testing, and select topics to prepare students for the tests, especially if they are uncertain about the extent of alignment between the standards and the test. Others who encounter high stakes testing describe a different perspective. These teachers trust that the tests will be aligned to the standards which outline what students should know. Instead of focusing on test preparation, they follow the curriculum standards in selecting the topics for their lessons.

The Teacher's Role in the Selection of Content

Teacher characteristics, knowledge, beliefs, and experiences emerge as having some influence on the selection of content in roughly a fourth of mathematics and science lessons in the nation. Included in this category are teacher background, preparation, and interest in the content area; teacher beliefs about content, and what students should know about the content; and teacher beliefs about student learning. Said these teachers:

> *I like to relate stuff that is interesting to me to what the state requires, even if it's not exactly [the same]. There are questions about plate tectonics in the guide. But, it may not be an exact match.* (8th grade Integrated Science teacher)

> *I make sure that I enjoy the topic that I'm teaching. I generally find something in the topic that I will enjoy, and I'll emphasize it. Things that I'm big on, I like classification and I like vocabulary. I think all these kids taking botany should be taking Latin instead. Whatever I can find along those lines to emphasize, I'll do that.* (High School Botany teacher)

Both mathematics and science teachers describe aspects of the content they believe to be important to students' understanding of the discipline; teachers indicate that they would teach these particular concepts regardless of whether they are included in the curriculum frameworks. As described by these teachers:

> *[The content of this lesson] is an essential thing that they need to have.…There's a lot of other things you can do in the classroom.…Once they know their numbers to 10 because you use numbers in a lot of different ways, not just during math time, so that kind of thing helps them.* (Kindergarten mathematics teacher)

> *Studying matter and the nature of matter is not part of the fourth grade curriculum, but I have a hard time thinking about beginning to discuss anything in science without some idea of what matter is and its forms.* (4th grade science teacher)

> *Certain things I think are important. One thing leads to another. So you have to understand the atmosphere to understand weather. And to understand weather you have to understand the water cycle. And to understand the water in the atmosphere—one concept simply leads into another concept…I like it. I think it's relevant.* (8th grade science teacher)

> *I teach what I believe general chemistry ought to cover…I think the gas laws are an important thing for people to learn. I think that understanding [the gas laws] is pretty*

fundamental. People can, if they know the gas laws, they can understand things like convection currents and maybe they can understand meteorology a little better, and lots of connections…I am kind of big on gas laws because they fit right in (to problem solving). (11th grade Chemistry teacher)

Influence of Student Characteristics on Selection of Content

Only about a fifth of mathematics and science teachers select content based on some characteristic of the students they are teaching. Most often in these situations, teachers pick content geared to address the ability levels of their students. For example, teachers with classes including low ability students often mention selecting content that is at a level the students could understand and that allows them to focus on the basics. Teachers with mixed ability classes report selecting content to address the "middle of the road" student, while teachers with high ability students report including challenging content in their lessons. For example, these teachers described the influence of student ability on their content decisions:

> *I have one student who [is at a] pre-primer reading level who happens to be straight from Africa…I have students who are at first and second grade up to seventh grade reading level in that class. So I try to keep things as basic as possible.* (6th grade science teacher)

> *Because of the different reading levels I try to get it right in the middle…But that's why I had a back up activity [for the more advanced students].* (6th grade science teacher)

> *You have to stress some things to kids…But as you get down, even in the pre-algebra and especially in the math, you have to put it down on a level where they can understand it…A lot of times you can't go with the language that's presented in the book. You have to put it in a simpler form.* (8th grade Pre-Algebra teacher)

> *They come to us woefully unprepared out of grade school; I consistently have kids who can't multiply one-digit numbers. And I'm supposed to teach a high school math curriculum. As a consequence a lot of what I do is cycling back, trying to find out where the kids are, to move them up. You never get to where they really need to be. I hate the thought of dumbing-down the curriculum, so my tension is to try to find ways to teach high-level mathematics using the kinds of problems that the kids can approach with their rudimentary skills.* (9th grade Integrated Mathematics teacher)

> *This class ranges from, I hate to [say] "slow learner" but, slow learner…And I have three students in there that could well fit into the regular biology curriculum that we*

have. But, because of the type of students I have you have to water it down a little bit. (10th grade Biology teacher)

☙ ❧

Since this is an honors class I try to make them do some harder things….I try to pull some things out of the pre-calculus book. (11th grade Honors Trigonometry teacher)

In some lessons, teachers select review content to include in the lessons because students have not yet mastered the concept. This lack of mastery is sometimes due to absenteeism in the class. For example:

I have a core group of maybe five in this class that have very high absenteeism…And I have several that were absent, so I determined to review that [worksheet]. (7th grade mathematics teacher)

Teacher Collaboration as an Influence on Content Selection

A small proportion of teachers (an estimated 12 percent nationally) indicate that their collaboration with other teachers influences their selection of content. This collaboration may be in the form of two or more teachers within a grade level working together to determine what students need to know and what should be taught, collaborating to provide a consistent program for students. Sometimes they assist each other in the design of lessons in areas where some of the teachers lack confidence; for example, a single teacher may decide what science content will be taught by all of the teachers in the grade. As described by these teachers:

I know the second grade classes, we try to do the same thing, you know, teach the same subject so that if you move from one class to the next, we would all be learning the same thing. Different styles, but the content is the same. (2nd grade science teacher)

☙ ❧

We work as a group. Everybody decides what our themes are going to be. Everybody gets together and donates whatever, and there are six of our teachers. This [lesson] is all an accumulation of all six of us getting together. All six are doing this math today. We get together and plan. (3rd grade mathematics teacher)

☙ ❧

The three of us that regroup our kids, we meet together because we want to stay on the same topics together in case we do have kids that need to move…And so we got together and decided that this week and next week would be our area and perimeter weeks because we have a list of all the different topics we need to teach for the state standards. (4th–5th grade mathematics teacher)

☙ ❧

Two years ago when I got the book, the other teacher and I went through it and we talked about what lessons to do, certain things to work on, and how much time we'd spend on each. (6th grade mathematics teacher)

There are three math teachers and we kind of collaborated. We try and stick to what the book has set up for us…We try to stick with the same schedule and be in the same place at the same time, or in the same lesson. (7th grade mathematics teacher)

I plan together with two other 9th grade science teachers. Neither of them has taught physical science at this level before. (9th grade Physical Science teacher)

Collaborations sometime go across grade-levels, with teachers from higher grades designating content students need to know prior to their class. Said this teacher:

I'll talk to the Calculus teacher and she will share things with me. She'll tell me, your kids were weak in this or that, and that will help me focus the following year. It's really up to us to decide what is going well and what is not. (High School Pre-Calculus teacher)

Influence of Other Factors on Selection of Content

Other potential influences investigated in the teacher interview are rarely cited as important in the selection of content. Although quite a few of the teachers mention their school board, district administration, and principal endorsing the inclusion of certain content in their lessons, very few teachers report that these individuals/groups have direct influence on their selection of content. Similarly, teachers rarely report that parents or the community, professional development sessions or graduate courses, or teacher evaluation systems influence their selection of content.

Influences on Selection of Instructional Strategies

Interviews with teachers in this study also included questions focused on the factors which influenced them to select the pedagogy and instructional materials for their lessons. As is the case with influences on content, it is difficult to disentangle influences on instruction. From the teacher's perspective, it may be the textbook or professional development that is influencing instruction, but these may in turn have been influenced by other factors such as state/district assessments, national standards, etc.

While teachers report that the content of most lessons is guided by external factors such as state and/or district curriculum standards or frameworks, these policy instruments appear to have much less of an influence on the selection of instructional strategies in lessons. Instead, teachers indicate that they have a great deal of latitude in selecting the strategies they employ to teach a particular content area.[7] A number of teachers commented on the contrast between detailed regulations guiding what they teach and freedom over how they teach the concepts. For example:

> *The state tells us specifically what is to be taught, but I can teach it any which way.* (8th grade Advanced Science teacher)

> *[The principal] wants to match things up with the upcoming [state goals and test], but he trusts us to do that…We have the freedom to select however means we want to get a concept across.* (10th grade Biology teacher)

Influence of Teacher Knowledge, Beliefs, and Experience on Instruction

This 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. While many of the factors examined in this study appear to have some influence on instructional strategies, the teachers' background, knowledge, and experience; and their beliefs—about the subject, about effective pedagogy, and about their students—most frequently influence their selection of particular instructional strategies. (See Figure 24.) The nature of these and other influences is described in the following sections.

[7] These interview data are consistent with data from the 2000 National Survey of Science and Mathematics, where teachers reported that they are far less likely to have control over the curriculum than they are over the methods to teach the curriculum.

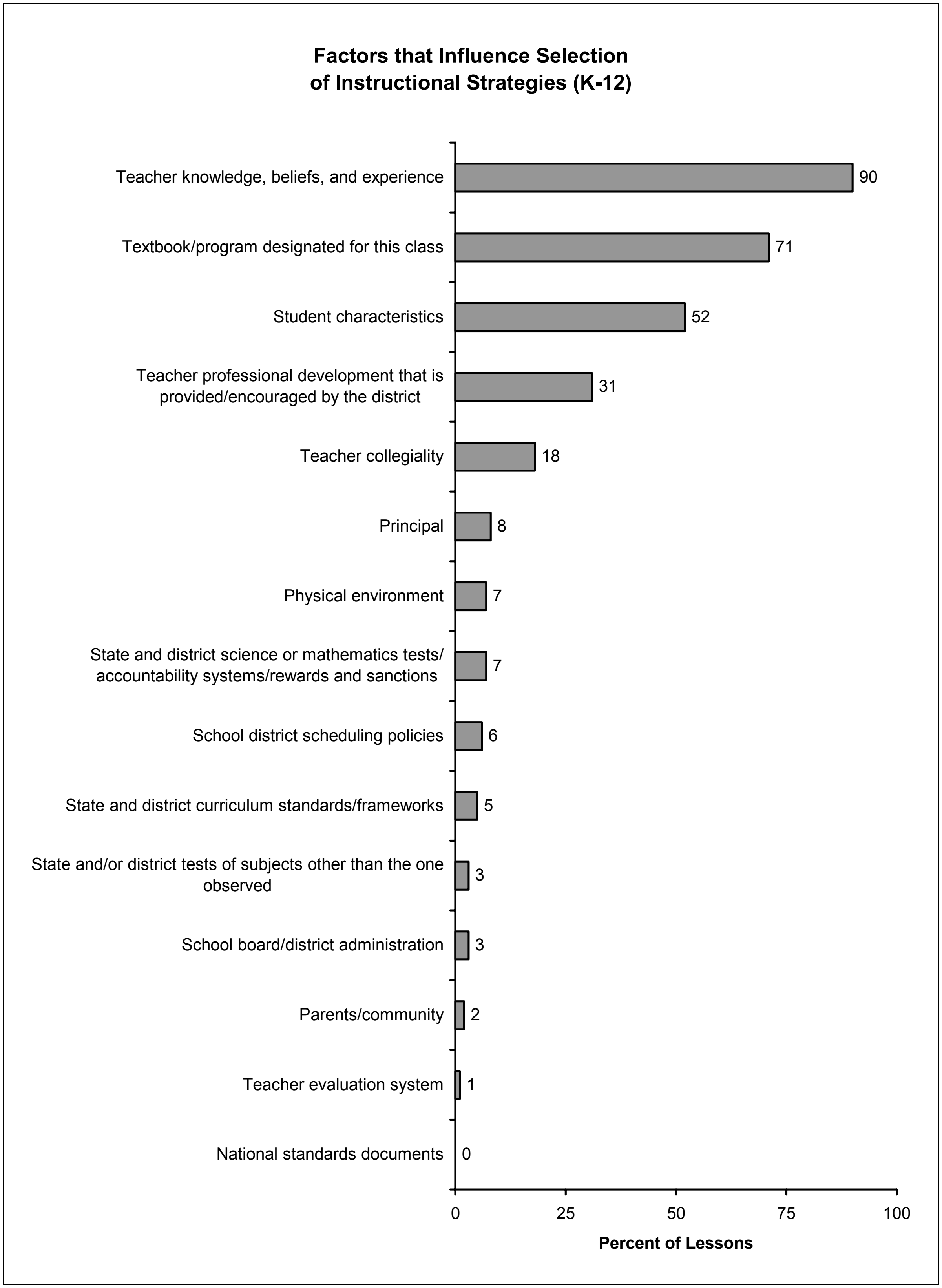

Factors that Influence Selection
of Instructional Strategies (K-12)
Teacher knowledge, beliefs, and experience
90
Textbook/program designated for this class
71
Student characteristics
52
Teacher professional development that is provided/encouraged by the district
31
Teacher collegiality
18
Principal
8
Physical environment
7
State and district science or mathematics tests/ accountability systems/rewards and sanctions
7
School district scheduling policies
6
State and district curriculum standards/frameworks
5
State and/or district tests of subjects other than the one observed
3
School board/district administration
3
Parents/community
2
Teacher evaluation system
1
National standards documents
0
0
25
50
75
100
Percent of Lessons

Figure 24

Teacher Beliefs About Effective Instruction

In many cases, teachers' decisions appear to be primarily influenced by their beliefs about instruction and how students learn best. Teachers report incorporating real-world examples to foster the engagement of students with concepts that otherwise might not interest them or would be too abstract for students to understand. They use examples both to provide a hook to engage students and to provide a bridge between what students already know and the more abstract concepts. Said teachers of the advantages of providing a real world context:

> *I have found that when you make yourself and what you're teaching real and human, the kids respond better…If there's something that I have or I know, or someone in my family, I always try to share that because they'll remember it…I use my husband a lot and the things from his job I share…So I pass on things that he has taught me or told me, and I try to make it like I said common to this area, things that kids can hold on to, because a lot is so abstract for them.* (3rd grade science teacher)

> *Well, they have a better understanding of fractions and hopefully they had seen the connection of the lesson with their lives because I think often times our problem in teaching is how to connect what we are teaching them in theory and concepts into their lives because if there is no connection, there is no interest.* (6th grade mathematics teacher)

> *They need to apply it to something that they are doing rather than just saying, "I can work this problem," and multiply it out. It is important that they know how to solve a problem in their life.* (8th grade mathematics teacher)

> *[I include examples that are relevant to their experience because] it's like you hit this place where they go "we don't know what you're talking about so we're just going to you know, zone out"; to where they realize that this does actually relate to something in their life. And it's always good when you get to that point. But I don't always get there. Some days they just sit there and zone out the whole time, and I don't think they ever connect at all with what I say…Today's examples come more from my multitude of experience fixing my cars. I only seem to have had clunkers.* (High School Physical Science teacher)

Hands-on, interactive pedagogies are often identified by teachers as effective strategies because they actively involve students in the lesson. Said these teachers:

> *I really believe that children must be actively responsible for their learning. If I just tell them, then I'm not helping them take what they already know and go to the next level. A lot of times the children know it, but you have to take the time to question them, take what they know and then move up. You can get them thinking and actively involved, then they'll remember next time. I want to get them thinking and expressing out loud…I'm not*

a big paper/pencil person…I do what I have to do to make sure they can do it independently and can explain their answer. (2nd grade mathematics teacher)

☙ ❧

I love it [hands-on]. They learn better than just reading from a book. (2nd grade science teacher)

☙ ❧

I believe that hands-on is most beneficial for students, but it is difficult to find good activities…and time-consuming, getting all the materials, nothing they can hurt themselves on…The longer I teach, the more I realize it's worth the time. (7th grade Earth Science teacher)

☙ ❧

It gets [the students] more interested, keeps them busy, they learn more when they are involved with hands-on activities. (10th grade Biology teacher)

Other teachers express a belief in the effectiveness of using multiple instructional strategies in order to address the varied learning styles of their students. For example:

They have different styles of learning. Some are audio, visual, tactile. I just try to present things in a variety of ways. (7th grade Life Science teacher)

☙ ❧

At the 7th grade level, with the mixed group that we have, I have a lot that are not identified with special needs. I still do integrate a lot of things in my lesson that would meet all of the needs—a lot of peer tutoring…I use a lot of hands-on and try to hit all the different learning styles with them. (7th grade mathematics teacher)

☙ ❧

The [materials I used] allow me to get to the students with all these different types of learning styles. The auditory learner, the visual learner. I'm trying to get a little bit of everybody. I'm touching everybody. (10th grade Biology teacher)

Some teachers note their belief that effective instruction requires the use of "traditional" as well as "reform-oriented" strategies. Said these teachers:

I'm not a person who strictly believes totally in discovery learning. I think…the hands-on kinds of things with the tangrams—I think that has its place. But, I also think kids…have to have the facts stated…I think they need a reference tool to use in their learning. And I think this textbook can provide that. (6th grade mathematics teacher)

❧ ☙

I talk very little. But I use a lot of strategies. Hands-on, but not extensive. Lecturing. Videos. Presentations through the computer. Now I have in the past used cooperative learning. Sometimes I let them work in pairs. (7th grade Life Science teacher)

❧ ☙

And I don't necessarily believe that is the only way we should teach. I think it's a mix. You've got to be able to do the hands-on work, but there is a time for lecture and example. To find that balance is hard. (8th grade Pre-Algebra teacher)

❧ ☙

This is my 29th year and so a lot of things I try to use…but I find that old time lecture is good. It is good. So I'm not as up-to-date perhaps as some of the younger teachers with all the technology. But I try to draw on a variety of methods. (8th grade science 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)

A number of mathematics teachers cite a belief in the link between repetition and learning as reasons for the selection of instructional strategies that allow for reiteration of concepts. These teachers describe the need for setting up an environment for students where there is frequent review of concepts. For example:

It's got to be that way [the re-teaching]. The kids who don't get it can see it the second time through…I remember taking a workshop once from Madeline Hunter, and her big thing is ITIP—instructional theory into practice—and she stated that things have to be repeated or taught 150 times before it becomes permanent memory, so you can't just teach things once and expect them to get it. (2nd–3rd grade mathematics teacher)

❧ ☙

And I believe with math you need total rote repetition to grasp concepts. (7th grade mathematics teacher)

❧ ☙

We don't make our kids memorize enough. I'm not unreasonable; I don't make them memorize everything. They need to know some basic math facts. Their understanding is going to be better. Some things just have to be memorized or they're handicapped when

> *they go on. On every test I give them an extra problem that has something to do with y = mx + b. Just to keep it fresh in their mind.* (11th grade Pre-Calculus teacher)

In discussing their lesson designs, some teachers talk about what they believe to be their role in the learning process, and how this belief influences their selection of instructional strategies. These teachers describe themselves as facilitators, helping to guide student learning and develop the students' abilities to be self-reliant learners. For example:

> *And I don't consider myself a teacher. To me, I'd like to consider myself as an educational facilitator. I'm here to help you learn, I'm not going to cause you to learn. But if I can help you, I'll try to provide the environment where you can learn. I will also not solve your problems for you, but I will show you how to solve them because I'm not taking on your responsibilities and accountability.* (8th–9th grade Algebra teacher)

Teachers' Background and Experience

In some cases, teachers' backgrounds influence their selection of strategies for lessons. For example, pre-service preparation may contribute to teachers' comfort with various pedagogical practices. Similarly, the extent of teachers' experience, or lack of experience, may lead them toward the use of particular strategies. Finally, the teachers' own experience as a mathematics/science learner sometimes proves an influential factor in instructional decisions.

A number of teachers noted that their pre-service preparation has led to their perceptions of how students learn best and their comfort with the pedagogical strategies they use. Teachers described a number of different pedagogies that were addressed in their pre-service experiences, indicating that they use these both in the observed lessons and more generally: hands-on approaches, lecture, questioning to guide learning, and the use of multiple strategies. For example:

> *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)

> *When I did my student teaching at [school name], the teacher there was very much, what do I want to say, straight-laced traditional-type person. And, I think he instilled within me that there's probably few substitutes for the type of teaching that I do that work any better…Now, I'm not saying that if I had a psychology class I might not put 'em all in a circle and have them pass around a football, or something. [But in my mathematics class], I feel the best thing is to do the lecture type, question type.* (8th–9th grade Algebra teacher)

> *Actually a lot of strategies that I've used come from just my educational courses, like my methods in teaching classes. They are really good at just introducing techniques that I do use, not just the lecture or what we used today, but there are a lot of different*

strategies that I do use that I must credit to [name of college] (10th grade Biology teacher)

While some teachers report that their teaching experiences contribute to their use of various instructional strategies, other teachers report that their lack of experience influences how they choose to teach a lesson. Specifically, teachers note that lacking the skills to implement other approaches, they choose more structured pedagogical strategies, and follow the textbook more closely. Said these teachers:

> *Sometimes when I got straight notes, they get a little boring. I understand that…I'm going to school, and so one of these days I will have more demos and activities than just straight notes. I'm working in that direction, haven't gotten there yet, but I'm getting there.* (11th grade Chemistry teacher)

> *I tend to be more teacher-directed. I would like to be less teacher directed. I would like for my classes to do more exploration. I like to get the kids involved as much as possible. But that is not always easy to do. So I would say that I am not real happy with this style of teaching and [it] is an area I am looking to improve.* (High School Pre-Calculus teacher)

Teachers' personal experience with learning mathematics and science also has some influence on instruction. Some teachers described how they themselves learned mathematics or science, indicating that they select instructional approaches that they hope will help their students learn as well. Said these teachers:

> *I always had to have something in front of me and that's why a lot of times I'll use things for the children, even though some of them may already know, I like to see them feel and touch and that sort of thing. And, like some of the children, even though they can add sometimes they might mis-add and so just to have it there in front of them reaffirms so…I was a visual learner, so I guess I just needed manipulatives as well.* (3rd grade mathematics teacher)

> *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 it's the way 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 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)

I realized that by experiencing it was how I learned, and I wanted to teach the same way. (High School Physics teacher)

Influence of Designated Textbook/Curriculum Program on Instruction

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 in their school or district in making decisions on how to teach. However, the extent to which instructional materials impact instruction varies widely. Many teachers describe these materials as the basis of their lessons, using them exactly as they are laid out. Others report that they design the structure of their lessons, picking and choosing activities from the designated materials and supplementing them with materials from other sources, or making some modifications to the design of the materials provided. Still others describe using the designated materials only as a resource in their development of what students experience in their lessons.

Following the Textbook Plan

Teachers who report closely following the textbook/curriculum material describe various reasons for doing so. Many of these teachers believe that the materials include all of the experiences students need to learn the content effectively. Others "trust" the textbook developers, and/or believe that the people who selected these materials did so because they are aligned to curriculum standards and district tests, so no modifications are needed. Said these teachers:

Everything is laid out and explained, step by step. I conducted the lesson just as it's laid out in the manual. (3rd grade mathematics teacher)

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'm trusting that some research went into development of these materials, that I can trust the solidity of them in terms of sound mathematics. (9th grade Integrated 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)

Modifying the Textbook Plan

Other teachers indicate that they do not use their textbook/materials as designed. Instead these teachers modify the materials, picking and choosing lessons and portions of the lessons, and supplementing them with resources from other sources. Teachers describe a variety of reasons for these decisions, including the need to make the material more interesting and accessible to students.

Materials-wise, sometimes I use it, sometimes I don't…So, you know, it's pick and choose. (Kindergarten mathematics teacher)

❧ ☙

It's [the math program] okay. It has some good ideas, it's fine. It's something you can build on, it's a base. It could be more creative, more hands on, I love hands-on. Although it does have hands-on, just more ideas. Because sometimes we have to go through books and find ideas to add to it to make it more interesting. (2nd grade mathematics teacher)

❧ ☙

They [the textbook authors] have a sequential way to teach the concepts. Personally the fourth grade teachers know [the textbook] is not the answer to everything. That's why we integrate. We have our other math lesson in the afternoon…I just don't think any grade level can rely on a single textbook to meet the needs of all the students for that particular year or of the district. (4th grade mathematics teacher)

❧ ☙

I don't like the book very well because it doesn't give enough practice in each area. It will give one page of something, and then go on to something else. So I'm not real thrilled with the book. (5th grade mathematics teacher)

❧ ☙

The other book was troublesome for parents because they couldn't follow it, so we've gone to this book, but we don't follow it religiously. We pick and choose the parts that we think the kids need. (6th grade mathematics teacher)

❧ ☙

This unit is in our textbook, and I have also pulled other resources to use in teaching it. [Its influence is] fifty percent. (8th grade science teacher)

Using the Textbook as a Resource

Although many teachers report some use of the textbook materials in their lessons, a handful of teachers report using the designated text only as a resource, rarely using it directly in lessons. Regarding why they rely only minimally on the text or curriculum program for their instructional decision-making, these teachers said:

We have a textbook, but it's really outdated. But I use it as a reference. (2nd grade science teacher)

It's okay for me to use as a reference, like I said I try not to do too much with it because a lot of the wording is kind of difficult for them. (7th grade Life Science teacher)

There are a lot of mistakes in our textbook, and I want a new one, so I didn't use it much, just for the review part. (8th grade Earth Science teacher)

I utilize the textbook very rarely. I've found that kids don't like the textbook anyway. Other than the assigned reading, I don't use the text at all…a lot of the ideas they have or the "labs" they have or the experiments they have for hands-on activities are not at all beneficial…This is the first year that [our school] has ever had an earth science class…and in a lot of respects…the exercises and the labs we're doing…are things that I have come up with or designed myself. I feel very comfortable using that because most of them are straight from my own head. (9th grade Earth Science teacher)

I used the standard text that we used to give me the idea and the general concept that I wanted to cover, but I got most of the information out of the other ones, since it covered the subject better and almost all of my examples were from basically out of my head, stuff that I remembered from other things. (12th grade, Advanced Placement Science teacher)

It should be noted that instruction in about 30 percent of lessons nationally is not at all influenced by the textbook/program materials designated for the class. In these instances, it appears that teachers are utilizing other resources they have at their disposal to design lessons.

How Characteristics of Students in their Classes Influence Instruction

Earlier in this section, teachers' beliefs about how students typically learn were described as having a large influence on instruction. About half of teachers nationally are influenced in their selection of instructional strategies/materials by the characteristics of the particular students in their classes, not just their beliefs about how children learn in general. The ability levels of the students, and their behavior, are the characteristics most often considered in determining the strategies that would be most effective. In addition, proficiency with the English language and student absenteeism influence teachers' selection of instructional strategies.

Gearing Instruction to Low Ability Students

Teachers frequently mention using specific instructional strategies and materials to address the needs of students they perceive as low ability. Strategies employed to provide access for these students include repetition, use of visual aids, and slowing the pace. Said these teachers:

> *My 5th graders are reading on a 3rd or 4th grade level. That's why we read everything aloud, I mean everything. Otherwise, the book would be way too difficult for them.* (5th grade science teacher)

> *The explanation at the top of the paragraph, it just wasn't broad enough. My kids need you to break it down piece by piece.* (6th grade science teacher)

> *I probably went a little slower today…But this group needs a lot of reinforcement on their skills.* (7th grade mathematics teacher)

> *So I've got this project right now and some other projects that I try to keep going to keep them hands-on and more data-oriented. We'd played Yahtzee in the past, just for half-days, just to do some recording and make some choices and adding stuff up.…I really found that with this low math group, it's really important to work a straight "how things go" and not just expect them to be in math class as in "here's the concept…go to work."* (7th grade mathematics teacher)

> *With that particular class, because a lot of them in there are either slow readers, or non-readers or remedial readers, they don't get anything out of reading stuff out of the textbook. So they actually have to be doing. That's why I kind of did the activity with them where they were looking through the newspaper. They have to do, so they like to do a lot of hands-on stuff.* (7th grade Life 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)

Gearing Instruction to High Ability Students

Instructional decision-making is similarly influenced by the presence of high ability students, in many cases allowing classes to move more quickly. Some teachers mention the need to incorporate the use of real-world applications to gain these students' interest; others talks about the use of discovery methods because they believe these students can handle the freedom associated with this pedagogy. Still other teachers believe that more traditional lecture-type strategies are more fitting to the learning styles of high ability students. Said these teachers:

These kids really get it. When I think I might have to explain something twice, they often surprise me by being ready to move onto something else. (High School Pre-Calculus 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)

Addressing the Needs of Heterogeneous Groups

Classes comprised of students with a wide range of ability levels present particular challenges for mathematics and science teachers. Some teachers report that they work individually with students, and use enrichment worksheets for those students completing work earlier than others. More often teachers indicate that they have students work in pairs/small groups of mixed abilities so they can help one another. For example:

From what I know about the students, some of them move quickly and then some rely on the others—and that's why I like the small group because I knew that such-and-such is going to rely on this person to help their understanding more than I could. (4th grade mathematics teacher)

In that class I have about four [students] I'd rate as high ability, and I have about five who are kind of in the middle, and the rest of them were kind of below the average working ability. So it's kind of a mixture. That's one of the reasons I was trying to pair them in a particular manner—so I would get the ones that have the greater ability to work with the ones that are a little bit slower or a little farther behind. (8th–9th grade Algebra teacher)

Teachers also talk about designing lessons to assist students who may be having difficulty understanding due to language and/or cultural barriers. In addition to using cooperative groups as part of their lesson, teachers report more emphasis on vocabulary and drawing pictures to ensure that these students understand what is being discussed.

Adjusting Instruction Based on Student Behavior

To some extent, the behavior of students has an impact on teachers' selection of instructional strategies for their lessons. Teachers who perceive their students as well-behaved and willing to follow classroom routines design their lessons accordingly. These lessons include strategies that allow for more individual freedom such as hands-on activities, time for individual work, and cooperative groups. The teachers trust that the students can handle the independence inherent in these strategies and will do well as a result. Said these teachers:

> *This group is real good at following directions. They take care of themselves a lot. They're an independent group of kids. They can do a lot on their own which is why I chose to do the experiment this way because I knew most of them would be able to handle it*. (1st 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)

In contrast, in classes where the teacher identifies students as having behavior problems, they report using instructional strategies such as lecture and whole group instruction to allow them to better control the students. Said these teachers:

> *You noticed we didn't use a lot of hands-on manipulatives today. I try to do that every once in a while, but when you throw that into the mix with [names of two students] today, it was tough to get them even listening to me anyway, but if they had something in their hands, and the rest of them had something in their hands, I could have forgotten it. We do use manipulatives, but not today.* (1st grade mathematics teacher)

> *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 safe lesson*. (5th grade science teacher)

> *These are the talkiest group of students I've ever seen. And if you really don't stay on top of them, they'll be talking about the weekend, they'll be talking about everything else, so [lecture/note-taking] is the best way I found this year to get information to them.* (7th grade science teacher)

Other teachers report making instructional decisions based on "out of class" behavior such as student absenteeism and tardiness. When students are not present for every lesson, teachers report that they have to allot more time for review of concepts and catching individual students up. Said these teachers:

> *It's always a balance, trying not to ignore kids who are out, because I have an obligation to help all kids to meet the standards. Saying clues like: "We did this yesterday"; "This is a review"; "One more time here it is"; I don't want to bore the kids who've been coming, but I try to keep doing this to give the absentee kids a chance to at least get caught up. Frankly, I'm not satisfied with it. The kids who miss a lot of days are not going to pass, at least not this year. They get so far behind and so confused that even sitting down with me and going over things doesn't help when all the other kids have given answers, have participated, and have insights into things that are really helpful.* (9th grade Integrated Mathematics teacher)

> *Absenteeism, there has been a pretty good bit of. It's frequently the same students. I just try to make them responsible, but then of course it takes me extra time to keep track of them and everything else. And really by policy they are responsible for their makeup work, so it's their duty to come find me and make sure that they get arrangements made. But I do try to keep after them to see that they do.* (High School Physical Science teacher)

Influence of Professional Development on Instruction

Professional development for mathematics and science teachers often focuses on the development of pedagogical skills, and an estimated 31 percent of the teachers nationally attribute their selection of instructional strategies, at least in part, to their professional development activities. Teachers report that courses they have taken or professional development sessions they have attended introduced them to a particular pedagogy, or reinforced strategies that they were already using in their lessons, including the use of manipulative/hands-on activities, cooperative learning, small group work, cognitive coaching and other strategies aligned with brain theory research. As these teachers said in describing their choice of instructional strategies for the observed lessons:

> *[Publisher workshops] bring a lot of the manipulatives and show you many different ways that you can use manipulative things. So, it was very helpful.* (Kindergarten mathematics teacher)

> *We have lots of staff development opportunities in cooperative learning groups and hands-on activities. We are required to get at least 12 staff development hours in the area of our choice. In this particular year I have over 50 staff development hours, and several have been in cooperative learning and hands-on activities. (They have been) very helpful.* (4th grade science teacher)

[The professional development] is where I saw the usefulness of manipulatives and visual materials for students to learn math better. (6th grade mathematics teacher)

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Probably some of the workshops and then some courses that I'm taking. Presently now I'm taking Introduction to Exceptional Children…so I try to make the lesson plans, you know, expand a little bit. And then, um, within my Educational Psychology try to understand what are some of the students thinking, why are they doing some of the things they are doing. So with those two types of things, with the courses and workshops, you know, I consider that to be very useful. (9th grade Integrated Science teacher)

❧ ☙

They try to provide you with different things that you can try and they always tell you: don't be teacher-oriented, be more student-oriented. So professional development provided me with some of the strategies that I use. (12th grade Consumer Mathematics teacher)

Influence of Teacher Collegiality on Instruction

Eighteen percent of teachers nationally are directly influenced in the instructional strategies and materials they select by their work with colleagues at their school. Teachers explain that they routinely plan with one or more teachers at their school, usually teachers at the same grade level. Some teachers describe the meetings as formal planning sessions; others characterize them as informal idea exchanges. In either case, these collaborations result in the sharing of strategies and materials used in lessons. Said teachers of these collaborations:

I work with the other first grade teacher. We decided this year to put the children in groups of three instead of working on their own like we have done in previous years. We thought the students could help each other with the measuring and cutting, plus learn some cooperation skills. (1st grade science teacher)

❧ ☙

We talk about how we present things; what works and what doesn't. When they were talking about the money unit, I know what didn't work for them, what trouble they had. It gave me ideas of what to avoid or what to hit hard with my kids. (2nd grade mathematics teacher)

❧ ☙

The other ladies I work with in 3rd grade, we get together and we plan together so all the 3rd graders do the same thing, so I am influenced by them. (3rd grade science teacher)

Other Factors Influencing Instruction

Other potential influences included in the interview protocol are less frequently cited as important in the design of instruction. For example, only about 10 percent of teachers nationally indicate that their principals influence their instruction; in most of these cases principals are cited as endorsing particular instructional strategies or materials. Teacher evaluation systems appear to have even less impact on instruction, with only 1 percent of teachers nationally citing teacher evaluation as influencing their lesson designs.

Surprisingly, given the age of many schools in the United States, and the current budget problems in many school systems, very few teachers indicate that their selection of pedagogy is influenced by constraints in the physical environment (7 percent nationally). When the physical environment is mentioned, it is usually by science teachers who are unable to use laboratory/ hands-on activities due to space and equipment deficiencies.

Similarly, very few teachers mention that scheduling policies, such as class length, have any impact on their selection of instructional strategies. Most teachers citing some influence of scheduling on their instructional decisions talk about how block scheduling allows them to slow the pace of their lessons and to implement a variety of instructional strategies during the extended class period.

Although state and district mathematics and science tests impact teachers' selection of content in almost half of lessons nationally, these tests appear to have relatively little influence on the selection of pedagogy or materials (7 percent). Where testing is a factor, teachers report using various strategies to prepare students for these assessments, including drill and practice and presenting content in a manner similar to the way it will appear on the test. In a number of mathematics lessons observed, teachers had selected or designed review worksheets or test preparation materials to use with students. In addition, due to the pressure of high stakes tests in reading and mathematics, a few science teachers reported that they altered the design of their lessons to include reinforcement of skills students will encounter on those tests.

A similar trend is found when examining the influence of state and district curriculum frameworks on instruction. While most teachers are guided by these frameworks in their selection of content, few teachers (5 percent nationally) report any direction from curriculum frameworks when selecting pedagogy or instructional materials for lessons. Finally, areas cited as influencing instruction by fewer than 5 percent of teachers, include school board and district administrators, national standards, and parents/community.

CHAPTER SEVEN
Conclusions

Inside the Classroom observations and interviews provided a great deal of information about the nature and quality of K–12 mathematics and science education in the United States. The findings of this study are summarized below, followed by a discussion of the implications of these findings for improving the quality of mathematics and science education.

Summary

This study included observations of a nationally-representative sample of 364 mathematics and science lessons in grades K–12. In addition, extensive interviews with teachers following the observations provided insight into the influences on those lessons—why particular topics and skills were taught, and why the particular instructional strategies were employed.

Trained observers described each lesson in detail, rated various components of the lesson, judged the likely impact of the lesson on students along a number of dimensions, and provided an overall assessment of the quality of instruction. Based on *Inside the Classroom* observations, mathematics and science lessons in the United States are relatively strong in a number of areas: a majority of lessons incorporate content that is both significant and worthwhile; have teachers who seem confident in their ability to teach mathematics and science; and 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. Overall, 59 percent of mathematics/science lessons nationally are judged to be low in quality, 27 percent medium in quality, and only 15 percent high in quality.

Lessons that are judged to be high quality generally share a number of key elements. Not only do they have important mathematics/science learning goals, but they also provide opportunities for students to grapple with that content in meaningful ways. There does not appear to be a single right way to engage students with the mathematics/science content; giving students experience with phenomena, making real-world connections, playing games that focus on important learning goals, and using contrived contexts to motivate the learners are all used effectively. Some high quality lessons are "traditional" in nature, incorporating the use of lectures and worksheets; other high quality lessons are "reform-oriented," involving students in more open-ended inquiries. In all cases, lessons that are judged to be high quality start where the students are, and provide opportunities for students to deepen their understanding.

The "culture" of the mathematics/science classroom appears to be a key factor as well. Lessons that are judged to be of high quality have learning environments that are simultaneously respectful and challenging of students. Teachers in these classes make sure that students are intellectually engaged with the mathematics/science content, and monitor student understanding as the lesson progresses. Finally, teachers of lessons that are judged to be of high quality help students to make sense of the mathematics/science concepts being addressed, rather than assuming that students will forge that understanding on their own.

In contrast, lessons judged to be low in quality are characterized by learning environments that are lacking in respect and/or rigor; questioning that emphasizes getting the right answer and moving on, without also focusing on student understanding; and "just starting" with no particular motivation and "just ending" without summarizing or other sense-making.

There also appears to be a pattern of differential quality of instruction across types of communities, in classes with varying proportions of minority students, and in classes of varying ability levels. Lessons in rural schools tend to be lower in quality on key indicators such as the extent of intellectual rigor and sense-making than are lessons in suburban and urban schools (those in large and mid-size cities). Similarly, lessons in classes with high percentages of minority students tend to be lower in quality than those in other classes. Finally, lessons in classes comprised of students considered "low ability" and those with students considered "middle" in ability tend to be lower in quality on key indicators than those in heterogeneous and high ability classes.

Based on interviews with teachers participating in the *Inside the Classroom* study, it appears that while most teachers are given a great deal of guidance on what to teach, they have considerable latitude on how to teach. External factors, such as state and district curriculum standards, assessments, and textbook/curriculum programs are identified by teachers as the most important influences on their selection of content for lessons. In contrast, teachers report designing their instruction using resources and strategies grounded in their background knowledge, experiences, and beliefs—about mathematics and science, about effective pedagogy, and about the students they teach.

Implications

Based on the observations conducted for the *Inside the Classroom* study, 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 the 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; 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 clearly 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, 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.

References

Helgeson, Stanley L. et al. *The Status of Pre-College Science, Mathematics, and Social Science Education: 1955–1975. Volume I, Science Education.* Columbus, OH: The Ohio State University, 1977.

Hiebert, J., Gallimore, R., Garnier, H., Givvin, K.B., Hollingsworth, H., Jacobs, J., Chiu, A.M.-Y., Wearne, D., Smith, M., Kersting, N., Manaster, A., Tseng, E., Etterbeek, W., Manaster, C., Gonzales, P., and Stigler, J. *Teaching Mathematics in Seven Countries: Results From the TIMSS 1999 Video Study* (NCES 2003-013). U.S. Department of Education. Washington, DC: National Center for Education Statistics, 2003.

Horizon Research, Inc., "Validity and Reliability information for the LSC Classroom Observation Protocol." Chapel Hill, NC: Horizon Research, Inc., 2003.

Kesidou, Sofia and Roseman, J. Ellen. "How Well Do Middle School Science Programs Measure Up?" Findings from Project 2061's curriculum review, JRST, Vol. 39, No. 6, pp. 522–549, 2002.

Mayer, Daniel P. "Measuring Instructional Practice: Can Policymakers Trust Survey Data?" in Educational Evaluation on Policy Analysis. Vol. 21, No. 1, pp. 29–46, Spring 1999.

National Council of Teacher of Mathematics. *Principles and Standards for School Mathematics*. Reston, VA: National Council of Teachers of Mathematics, 2000.

National Research Council. *Measuring What Counts: A Conceptual Guide for Mathematics Assessment.* Washington, DC: Mathematical Sciences Education Board, National Research Council, 1993.

National Research Council. *National Science Education Standards*. Washington, DC: National Research Council, 1996.

Shepard, Lorrie A. "The Hazards of High Stakes Testing" in Issues in Science and Technology. Vol. XIX, No. 2, Winter 2002–03.

Spillane, James P. and Zeuli, John S. "Reform and Teaching: Exploring Patterns of Practice" in the Context of National and State Mathematics Reforms, Educational Evaluation and Policy Analysis, Vol. 21, No. 1, pp. 127, 1999.

Stake, Robert E. and Easley, Jack. *Case Studies in Science Education, Volume I: The Case Reports.* Champaign, IL: University of Illinois at Urbana, 1978.

Stake, Robert E. and Easley, Jack. *Case Studies in Science Education, Volume II: Design, Overview and General Findings.* Champaign, IL: University of Illinois at Urbana, 1978.

Stigler, J.W., Gonzales, P., Kawanaka, T., Knoll, S., and Serrano, A. *The TIMSS Videotape Classroom Study: Methods and Findings From an Exploratory Research Project on Eighth-Grade Mathematics Instruction in Germany, Japan, and the United States.* (NCES 1999-074). U.S. Department of Education. Washington, DC: National Center for Education Statistics. 1999.

Weiss, I. R. *Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education*. Research Triangle Park, NC: Research Triangle Institute, 1978.

Weiss, I.R. *Report of the 1985–86 National Survey of Science and Mathematics Education*. Research Triangle Park, NC: Research Triangle Institute, 1987.

Weiss, I.R., Matti, M.C., and Smith, P.S. *Report of the 1993 National Survey of Science and Mathematics Education.* Chapel Hill, NC: Horizon Research, Inc., 1994.

Weiss, I.R., Banilower, E.R., McMahon, K.C., and Smith, P.S. *Report of the 2000 National Survey of Science and Mathematics Education.* Chapel Hill, NC: Horizon Research, Inc., 2001.

Appendix A

Instruments

Teacher Interview Protocol

Observation and Analytic Protocol

Mathematics Questionnaire

Science Questionnaire

Inside the Classroom
Teacher Interview Protocol

I appreciate your letting me observe your class. I have some questions I'd like to ask you related to this lesson. Would you mind if I taped the interview? It will help me stay focused on our conversation and it will ensure I have an accurate record of what we discussed.

Preliminary

If applicable, ask:
What is the name/title of this course?

What class period was this?

If applicable, ask:
Can I have a copy of the instructional materials you used for this lesson? [Specify what you would like to have copies of, if necessary.]

A. Learning Goals

1. I'd like to know a bit more about the students in this class.
   Tell me about the ability levels of students in this class.
   How do they compare to students in the school as a whole?

   Are there any students with special needs in this class?
   Are there any students for whom English is not their first language?
   Are there any students with learning disabilities?

2. Is student absenteeism or mobility a problem for you in this class?

3. Please help me understand where this lesson fits in the sequence of the unit you are working on. What have the students experienced prior to today's lesson?

4. What was the specific purpose of today's lesson?

5. How do you feel about how the lesson played out?
   What do you think the students gained from today's lesson?

6. What is the next step for this class in this unit?

B. Content/Topic

7. What led you to teach the mathematics/science topics/concepts/skills in this lesson?

   (Use the following probes, as needed, so you can assess the extent of importance of each of these influences:)

   Is it included in the state/district curriculum/course of study?
   If yes, or previously implied: How important was that in your decision to teach this topic?

   Is it included in a state/district mathematics/science assessment? What are the consequences if students don't do well on the test?
   If yes, or previously implied: How important were these tests in your decision to teach this topic?

   Is it included in an assigned textbook or program designated for this class?
   If yes, or previously implied: How important was that in your decision to teach this topic?

C. Resources Used to Design the Lesson

8. What resources did you use to plan this lesson?
   (Be sure to get details on sources of materials and activities.)
   (If teacher developed materials, SKIP to part D.)

9. Were these resources/materials/activities designated for this class/course or did you choose to use them yourself?

10. What do you like about these resources/materials/activities?
    (*Compared to what the district designated for the class/course, if applicable.*)
    What do you not like?

11. a. *If the lesson was based on one resource/material:*
    Did you plan this lesson essentially as it was organized in [name of resource/material] or did you modify it in important ways?

11. b. *If the lesson was based on more than one resource/material:*
    Did you plan this lesson essentially as it was organized in any one of these resources/materials?
    If yes:
    Did you modify it in important ways?

12. *If modified:*
Can you describe the modifications you made and your reasons for making them?

D. The Teacher

13. How do you feel about teaching this topic?
    Do you enjoy it?
    How well prepared to you feel to guide student learning of this content?
    What opportunities have you had to learn about this particular content area?
    (Probe for professional development opportunities.)
    How did you become involved in these professional development opportunities?
    Were they required or encouraged by the district?
    How helpful were they?

14. How do you feel about teaching with this pedagogy?
    How comfortable do you feel using the instructional strategies involved in teaching this lesson?
    What opportunities have you had to learn about using these strategies?
    (Probe for professional development opportunities.)
    How did you become involved in these professional development opportunities?
    Were they required or encouraged by the district?
    How helpful were they?

15. How many years have you been teaching prior to this year?
    Have you taught this lesson before?
    If yes: How different was today from how you have taught it previously?

    Is there anything about this particular group of students that led you to plan this lesson this way?

16. *If applicable ask*:
    I noticed there was another adult in the classroom. Who was that and what was his/her role?

E. Context

17. Sometimes schools and districts make it easier for teachers to teach science/mathematics well, and sometimes they get in the way.
    What about your teaching situation influenced your planning of this lesson?

PROBES:

Did the facilities and available equipment and supplies have any influence on your choice of this lesson or how you taught it?
Were there any problems in getting the materials you needed for this lesson?

18. Sometimes other people in the school and district can influence your planning of a lesson. Did your principal have any influence on your choice of this lesson or how you taught it?

    Other teachers in the school?
    Parents/community?
    School board?
    District administration?
    Anyone else?

Thank you for your time. If I have any additional questions or need clarification, how and when is it best to contact you?

Inside the Classroom
Observation and Analytic Protocol

Observation Date: ______________________________ Time: Start: _______________ End: ______________

School: ____ District: ______________________________________

Teacher: ____

PART ONE: THE LESSON

Section A. Basic Descriptive Information

1. Teacher Gender: ___ Male ___ Female

   Teacher Ethnicity:
   ___ American Indian or Alaskan Native
   ___ Asian
   ___ Hispanic or Latino
   ___ Black or African-American
   ___ Native Hawaiian or Other Pacific Islander
   ___ White

2 Subject Observed: ___ Mathematics ___ Science

3. Grade Level(s): ___________

4. Course Title (if applicable) ____

   Class Period (if applicable) ____

5. Students: ________ Number of Males ________ Number of Females

6. Did you collect copies of instructional materials to be sent to HRI?

   ☐ Yes ☐ No, explain:

Section B. Purpose of the Lesson:
In this section, you are asked to indicate how lesson time was spent and to provide the teacher's stated purpose for the lesson.

1. According to the teacher, the purpose of this lesson was:

2. Based on time spent, the focus of this lesson is best described as: (Check one.)

- ○ Almost entirely working on the development of algorithms/facts/vocabulary
- ○ Mostly working on the development of algorithms/facts/vocabulary, but working on some mathematics/science concepts
- ○ About equally working on algorithms/facts/vocabulary and working on mathematics/science concepts
- ○ Mostly working on mathematics/science concepts, but working on some algorithms/facts/vocabulary
- ○ Almost entirely working on mathematics/science concepts

Section C. Lesson Ratings
In this part of the form, you are asked to rate each of a number of key indicators in four different categories, from 1 (not at all) to 5 (to a great extent). You may list any additional indicators you consider important in capturing the essence of this lesson and rate these as well. Use your "Ratings of Key Indicators" to inform your "Synthesis Ratings". It is important to indicate in "Supporting Evidence for Synthesis Ratings" what factors were most influential in determining your synthesis ratings and to give specific examples and/or quotes to illustrate those factors.

Note that any one lesson is not likely to provide evidence for every single indicator; use 6, "Don't know" when there is not enough evidence for you to make a judgment. Use 7, "N/A" (Not Applicable) when you consider the indicator inappropriate given the purpose and context of the lesson. This section also includes ratings of the likely impact of instruction and a capsule rating of the quality of the lesson.

I. Design

A. Ratings of Key Indicators

	Not at all				To a great extent	Don't know	N/A
1. The design of the lesson incorporated tasks, roles, and interactions consistent with investigative mathematics/science.	1	2	3	4	5	6	7
2. The design of the lesson reflected careful planning and organization.	1	2	3	4	5	6*	7*
3. The instructional strategies and activities used in this lesson reflected attention to students' experience, preparedness, prior knowledge, and/or learning styles.	1	2	3	4	5	6	7
4. The resources available in this lesson contributed to accomplishing the purposes of the instruction.	1	2	3	4	5	6	7
5. The instructional strategies and activities reflected attention to issues of access, equity, and diversity for students (e.g., cooperative learning, language-appropriate strategies/materials).	1	2	3	4	5	6*	7*
6. The design of the lesson encouraged a collaborative approach to learning among the students.	1	2	3	4	5	6	7
7. Adequate time and structure were provided for "sense-making."	1	2	3	4	5	6*	7*
8. Adequate time and structure were provided for wrap-up.	1	2	3	4	5	6	7
9. ____	1	2	3	4	5		

* We anticipate that these indicators should be rated 1-5 for nearly all lessons. If you rated any of these indicators 6 or 7, please provide an explanation in your supporting evidence below.

B. Synthesis Rating

1	2	3	4	5
Design of the lesson not at all reflective of best practice in mathematics/science education				Design of the lesson extremely reflective of best practice in mathematics/science education

C. Supporting Evidence for Synthesis Rating

Provide a brief description of the nature and quality of this component of the lesson, the rationale for your synthesis rating, and the evidence to support that rating.

II. Implementation

A. Ratings of Key Indicators

	Not at all				To a great extent	Don't know	N/A
1. The instructional strategies were consistent with investigative mathematics/science.	1	2	3	4	5	6	7
2. The teacher appeared confident in his/her ability to teach mathematics/science.	1	2	3	4	5	6	7
3. The teacher's classroom management style/strategies enhanced the quality of the lesson.	1	2	3	4	5	6*	7*
4. The pace of the lesson was appropriate for the developmental levels/needs of the students and the purposes of the lesson.	1	2	3	4	5	6*	7*
5. The teacher was able to "read" the students' level of understanding and adjusted instruction accordingly.	1	2	3	4	5	6	7
➔ 6. The teacher's questioning strategies were likely to enhance the development of student conceptual understanding/problem solving (e.g., emphasized higher order questions, appropriately used "wait time," identified prior conceptions and misconceptions).	1	2	3	4	5	6	7
7. ______________________________	1	2	3	4	5		

* We anticipate that these indicators should be rated 1-5 for nearly all lessons. If you rated any of these indicators 6 or 7, please provide an explanation in your supporting evidence below.

B. Synthesis Rating

1	2	3	4	5
Implementation of the lesson not at all reflective of best practice in mathematics/science education				Implementation of the lesson extremely reflective of best practice in mathematics/science education

C. Supporting Evidence for Synthesis Rating

Provide a brief description of the nature and quality of this component of the lesson, the rationale for your synthesis rating, and the evidence to support that rating. (If available, be sure to include examples/quotes to illustrate ratings of teacher questioning (A6).)

III. Mathematics/Science Content

A. Ratings of Key Indicators

		Not at all				To a great extent	Don't know	N/A
➔1.	The mathematics/science content was significant and worthwhile.	1	2	3	4	5	6*	7*
➔2.	The mathematics/science content was appropriate for the developmental levels of the students in this class.	1	2	3	4	5	6*	7*
➔3.	Teacher-provided content information was accurate.	1	2	3	4	5	6	7
➔4.	Students were intellectually engaged with important ideas relevant to the focus of the lesson.	1	2	3	4	5	6*	7*
5.	The teacher displayed an understanding of mathematics/science concepts (e.g., in his/her dialogue with students).	1	2	3	4	5	6	7
6.	Mathematics/science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification.	1	2	3	4	5	6	7
7.	Elements of mathematical/science abstraction (e.g., symbolic representations, theory building) were included when it was important to do so.	1	2	3	4	5	6	7
8.	Appropriate connections were made to other areas of mathematics/ science, to other disciplines, and/or to real-world contexts.	1	2	3	4	5	6	7
➔9.	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.	1	2	3	4	5	6*	7*
10.	________________________________	1	2	3	4	5		

* We anticipate that these indicators should be rated 1-5 for nearly all lessons. If you rated any of these indicators 6 or 7, please provide an explanation in your supporting evidence below.

B. Synthesis Rating

1	2	3	4	5
Mathematics/science content of lesson not at all reflective of current standards for mathematics/science education				Mathematics/science content of lesson extremely reflective of current standards for mathematics/science education

C. Supporting Evidence for Synthesis Rating

Provide a brief description of the nature and quality of this component of the lesson, the rationale for your synthesis rating, and the evidence to support that rating. (If available, be sure to include examples/quotes to illustrate ratings of quality of content (A1, A2, A3), intellectual engagement (A4), and nature of "sense-making" (A9).)

IV. Classroom Culture

A. Ratings of Key Indicators

	Not at all				To a great extent	Don't know	N/A
➔1. Active participation of all was encouraged and valued.	1	2	3	4	5	6*	7*
➔2. There was a climate of respect for students' ideas, questions, and contributions.	1	2	3	4	5	6*	7*
3. Interactions reflected collegial working relationships among students (e.g., students worked together, talked with each other about the lesson).	1	2	3	4	5	6	7
4. Interactions reflected collaborative working relationships between teacher and students.	1	2	3	4	5	6*	7*
5. The climate of the lesson encouraged students to generate ideas, questions, conjectures, and/or propositions.	1	2	3	4	5	6	7
➔6. Intellectual rigor, constructive criticism, and the challenging of ideas were evident.	1	2	3	4	5	6*	7*
7. ______________________________	1	2	3	4	5		

* We anticipate that these indicators should be rated 1-5 for nearly all lessons. If you rated any of these indicators 6 or 7, please provide an explanation in your supporting evidence below.

B. Synthesis Rating

1	2	3	4	5
Classroom culture interfered with student learning				Classroom culture facilitated the learning of all students

C. Supporting Evidence for Synthesis Rating

Provide a brief description of the nature and quality of this component of the lesson, the rationale for your synthesis rating, and the evidence to support that rating. (If available, be sure to include examples/quotes to illustrate ratings of active participation (A1), climate of respect (A2), and intellectual rigor (A6). While direct evidence that reflects particular sensitivity or insensitivity toward student diversity is not often observed, we would like you to document any examples you do see.)

Section D. Lesson Arrangements and Activities

In question 1 of this section, please divide the total duration of the lesson into instructional and non-instructional time. In question 2, make your estimates based only on the *instructional time* of the lesson.

1. Approximately how many minutes during the lesson were spent:

   a. On instructional activities? ________ minutes

   b. On housekeeping unrelated to the lesson/interruptions/other non-instructional activities? ________ minutes

Describe:

   c. Check here if the lesson included a major interruption (e.g., fire drill, assembly, shortened class period): ☐

2. Considering only the *instructional time* of the lesson (listed in 1a above), approximately what percent of this time was spent in each of the following arrangements?

   a. Whole class _______ %

   b. Pairs/small groups _______ %

   c. Individuals _______ %

   100 %

Section E. Overall Ratings of the Lesson

1. Likely Impact of Instruction on Students' Understanding of Mathematics/Science

While the impact of a single lesson may well be limited in scope, it is important to judge whether the lesson is likely to help move students in the desired direction. For this series of ratings, consider all available information (i.e., your previous ratings of design, implementation, content, and classroom culture, and the interview with the teacher) as you assess the likely impact of this lesson. Elaborate on ratings with comments in the space provided.

Select the response that best describes your overall assessment of the *likely effect* of this lesson in each of the following areas.

	Negative effect		Mixed or neutral effect		Positive effect	Don't know	N/A
a. Students' understanding of mathematics/science as a dynamic body of knowledge generated and enriched by investigation.	○	○	○	○	○	○	○
b. Students' understanding of important mathematics/science concepts.	○	○	○	○	○	○	○
c. Students' capacity to carry out their own inquiries.	○	○	○	○	○	○	○
d. Students' ability to apply or generalize skills and concepts to other areas of mathematics/science, other disciplines, and/or real-life situations.	○	○	○	○	○	○	○
e. Students' self-confidence in doing mathematics/science.	○	○	○	○	○	○	○
f. Students' interest in and/or appreciation for the discipline.	○	○	○	○	○	○	○

Comments:

2. Capsule Rating of the Quality of the Lesson

In this final rating of the lesson, consider all available information about the lesson, its context and the teacher's purpose, and your own judgment of the relative importance of the ratings you have made. Select the capsule description that best characterizes the lesson you observed. Keep in mind that this rating is *not* intended to be an average of all the previous ratings, but should encapsulate your overall assessment of the quality and likely impact of the lesson.

O **Level 1**: **Ineffective Instruction**
There is little or no evidence of student thinking or engagement with important ideas of mathematics/science. Instruction is *highly unlikely* to enhance students' understanding of the discipline or to develop their capacity to successfully "do" mathematics/science. Lesson was characterized by either (select one below):

- ○ **Passive "Learning"**
  Instruction is pedantic and uninspiring. Students are passive recipients of information from the teacher or textbook; material is presented in a way that is inaccessible to many of the students.

- ○ **Activity for Activity's Sake**
  Students are involved in hands-on activities or other individual or group work, but it appears to be activity for activity's sake. Lesson lacks a clear sense of purpose and/or a clear link to conceptual development.

O **Level 2: Elements of Effective Instruction**
Instruction contains some elements of effective practice, but there are *serious problems* in the design, implementation, content, and/or appropriateness for many students in the class. For example, the content may lack importance and/or appropriateness; instruction may not successfully address the difficulties that many students are experiencing, etc. Overall, the lesson is *very limited* in its likelihood to enhance students' understanding of the discipline or to develop their capacity to successfully "do" mathematics/science.

O **Level 3: Beginning Stages of Effective Instruction.** (Select one below.)

○ Low 3 ○ Solid 3 ○ High 3

Instruction is purposeful and characterized by quite a few elements of effective practice. Students are, at times, engaged in meaningful work, but there are *weaknesses*, ranging from substantial to fairly minor, in the design, implementation, or content of instruction. For example, the teacher may short-circuit a planned exploration by telling students what they "should have found"; instruction may not adequately address the needs of a number of students; or the classroom culture may limit the accessibility or effectiveness of the lesson. Overall, the lesson is *somewhat limited* in its likelihood to enhance students' understanding of the discipline or to develop their capacity to successfully "do" mathematics/science.

O **Level 4: Accomplished, Effective Instruction**
Instruction is purposeful and engaging for most students. Students actively participate in meaningful work (e.g., investigations, teacher presentations, discussions with each other or the teacher, reading). The lesson is well-designed and the teacher implements it well, but adaptation of content or pedagogy in response to student needs and interests is limited. Instruction is *quite likely* to enhance most students' understanding of the discipline and to develop their capacity to successfully "do" mathematics/science.

O **Level 5**: **Exemplary Instruction**
Instruction is purposeful and all students are highly engaged most or all of the time in meaningful work (e.g., investigation, teacher presentations, discussions with each other or the teacher, reading). The lesson is well-designed and artfully implemented, with flexibility and responsiveness to students' needs and interests. Instruction is *highly likely* to enhance most students' understanding of the discipline and to develop their capacity to successfully "do" mathematics/science.

Section F. Descriptive Rationale

1. Narrative

In 1–2 pages, describe what happened in this lesson, including enough rich detail that readers have a sense of having been there. Include:

- Where this lesson fit in with the overall unit;
- The focus of this lesson (e.g., the extent to which it was review/practice versus addressing new material; the extent to which it addressed algorithms/vocabulary versus mathematics/science concepts);
- Instructional materials used, if any;
- A synopsis of the structure/flow of the lesson;
- Nature and quality of lesson activities, including lecture, class discussion, problem-solving/investigation, seatwork;
- Roles of the teacher and students in the intellectual work of the lesson (e.g., providing problems or questions, proposing conjectures or hypotheses; developing/applying strategies or procedures; and drawing, challenging, or verifying conclusions);
- Roles of any other adults in the classroom, e.g., teacher's aide; and
- The reasoning behind your capsule rating, highlighting the likely impact on students' understanding of science/mathematics.

This description should stand on its own. Do not be concerned if you repeat information you have already provided elsewhere, e.g., in your supporting evidence for your synthesis ratings (e.g., implementation).

2. Lesson Features

Indicate which of the following features were included in this lesson, however briefly. Then, if NOT already described in the descriptive rationale, provide a brief description of the applicable features in this lesson.

	Check all that apply	Describe, if NOT in descriptive rationale
a. High quality "traditional" instruction, e.g., lecture	○	
b. High quality "reform" instruction, e.g., investigation	○	
c. Teacher/students using manipulatives	○	
d. Teacher/students using calculators/computers	○	
e. Teacher/students using other scientific equipment	○	
f. Teacher/students using other audio-visual resources	○	
g. Students playing a game	○	
h. Students completing labnotes/journals/ worksheets or answering textbook questions/ exercises	○	
i. Review/practice to prepare students for an externally mandated test	○	
j. More than incidental reference/connection to other disciplines	○	

PART TWO: INFLUENCES ON THE SELECTION OF TOPICS/INSTRUCTIONAL MATERIALS/ PEDAGOGY USED IN PLANNING THIS LESSON

Section A. Areas of Influence

Lessons are designed and selected for a variety of reasons, some of which are under the control of the teacher and some of which are not. In Part Two of the protocol, researchers should draw upon the teacher interview in considering how each of a number of factors influenced the selection of topics/instructional materials/pedagogy in planning for this lesson.

1. Policy and Support Infrastructure

a. Curriculum and Assessment Policies

i. When talking about why s/he chose the mathematics/science topics/concepts/skills included in this lesson, the teacher spontaneously mentioned (Check all that apply):

- ☐ They are included in the curriculum/textbook/test; s/he is expected/required to teach them
- ☐ They have always been taught in this grade/course
- ☐ They are important for kids to learn
- ☐ The students need knowledge of/exposure to these topics/concepts/skills for future units in this class/course
- ☐ The students need knowledge of/exposure to these topics/concepts/skills for future classes/courses

In the interview, the teacher was explicitly asked about state and district curriculum and assessments. Please summarize the information the teacher provided about each of the following, including quotes when appropriate, being sure to note particular influences on the selection of topics, instructional materials, and/or pedagogy for this lesson. Then rate the extent of influence of each.

ii. State and district curriculum standards/frameworks

Describe:
Rate the extent to which this aspect influenced the selection of topics/instructional materials/pedagogy for this lesson. ○ Not at all ○ Somewhat ○ To a great extent ○ Not Applicable

iii. State and district science or mathematics tests/accountability systems/rewards and sanctions

Describe:
Rate the extent to which this aspect influenced the selection of topics/instructional materials/pedagogy for this lesson. ○ Not at all ○ Somewhat ○ To a great extent ○ Not Applicable

iv. Textbook/program designated for this class

Describe:
Rate the extent to which this aspect influenced the selection of topics/instructional materials/pedagogy for this lesson. ○ Not at all ○ Somewhat ○ To a great extent ○ Not Applicable

b. Support Infrastructure

In the interview, the teacher was asked about the professional development opportunities provided or encouraged by the district, as well as the influences of the principal, parents/community, school board, and other teachers in the school. Please summarize the information the teacher provided about each of the following, including quotes when appropriate, being sure to note particular influences on the selection of topics, instructional materials, and/or pedagogy for this lesson. Then rate the extent of influence of each.

i. Teacher professional development that is provided or encouraged by the district

Describe:
Rate the extent to which this aspect influenced the selection of topics/instructional materials/pedagogy for this lesson. ○ Not at all ○ Somewhat ○ To a great extent ○ Not Applicable

ii. Principal

Describe:
Rate the extent to which this aspect influenced the selection of topics/instructional materials/pedagogy for this lesson. ○ Not at all ○ Somewhat ○ To a great extent

iii. Parents/community

Describe:
Rate the extent to which this aspect influenced the selection of topics/instructional materials/pedagogy for this lesson. ○ Not at all ○ Somewhat ○ To a great extent

iv. School board/district administration

Describe:
Rate the extent to which this aspect influenced the selection of topics/instructional materials/pedagogy for this lesson. ○ Not at all ○ Somewhat ○ To a great extent

v. Teacher collegiality (within the school/district)

Describe:
Rate the extent to which this aspect influenced the selection of topics/instructional materials/pedagogy for this lesson. ○ Not at all ○ Somewhat ○ To a great extent

c. Other Elements of the Policy and Support Infrastructure

In the interview, the teacher may have mentioned other aspects of the policy environment and support infrastructure. For each of the following that were mentioned, please summarize the information the teacher provided, including quotes when appropriate, being sure to note particular influences on the selection of topics, instructional materials, and pedagogy for this lesson. Then, rate the extent of the influence of each.

i. National standards documents ☐ Not mentioned

Describe:
Rate the extent to which this aspect influenced the selection of topics/instructional materials/pedagogy for this lesson. ○ Not at all ○ Somewhat ○ To a great extent

ii. School/district tracking/course assignment policies, including multi-age grouping and/or students remaining with the same teacher for multiple years ☐ Not mentioned

Describe:
Rate the extent to which this aspect influenced the selection of topics/instructional materials/pedagogy for this lesson. ○ Not at all ○ Somewhat ○ To a great extent

iii State and/or district tests of subjects other than the one observed ☐ Not mentioned

Describe:
Rate the extent to which this aspect influenced the selection of topics/instructional materials/pedagogy for this lesson. ○ Not at all ○ Somewhat ○ To a great extent

iv. School/district scheduling policies, including class length/block scheduling ☐ Not mentioned

Describe:
Rate the extent to which this aspect influenced the selection of topics/instructional materials/pedagogy for this lesson. ○ Not at all ○ Somewhat ○ To a great extent

v. Teacher evaluation system ☐ Not mentioned

Describe:
Rate the extent to which this aspect influenced the selection of topics/instructional materials/pedagogy for this lesson. ○ Not at all ○ Somewhat ○ To a great extent

2. The Physical Environment

We are defining the physical environment as including:

- Size and "feel" of the room, including what's on the walls;
- State of repair of classroom facilities;
- Appropriateness and flexibility of furniture;
- Availability of running water, electrical outlets, storage space; and
- Availability of equipment and supplies (including calculators and computers).

a. Describe the physical environment of this classroom.

b. Did the physical environment constrain the design and/or implementation of this lesson? (Circle one.)

Yes No Don't know

If yes, explain:

3. Instructional Materials

a. Which best describes the source of the **instructional materials** upon which this lesson was based? (Check one.)

- ○ Materials designated for this class/course, from a commercially published textbook/program
- ○ Materials designated for this class/course, developed by district, school, or other non-commercial source
- ○ Materials selected or adapted by the teacher, from a commercially published textbook/program
- ○ Materials selected or adapted by the teacher, from a non-commercial source
- ○ Materials developed by the teacher

b. Describe the textbook/program/instructional materials, including publisher, title, date, and pages if applicable. If the teacher made modifications to the instructional materials for this lesson, describe the modifications, why the teacher made these modifications, and the impact of the modifications on the quality of the lesson design.

4. Student Characteristics

a. Number of students:

   i. Total in class: ____________
   ii. For whom English is not their first language: _________
   iii. With learning disabilities: ___________
   iv. With other special needs: __________

b. Describe the ability level of students in this class compared to the student population in the school. (Check one.)

   - ○ Represent the lower range of ability levels
   - ○ Represent the middle range of ability levels
   - ○ Represent the higher range of ability levels
   - ○ Represent a broad range of ability levels

c. Teachers may consciously or unconsciously base their decisions on their perceptions of the characteristics of a particular group of students. Describe how the characteristics of the students in this class may have influenced the selection of topics/instructional materials/pedagogy for this lesson.

   In this category, we include such factors as:

   - Cognitive abilities
   - Learning styles
   - Prior knowledge
   - Prior school experience
   - Fluency with English
   - Student attitudes towards science and mathematics
   - Perceptions of utility of content
   - Goals and aspirations
   - Facility with class routines
   - Student absenteeism/mobility
   - Influence of parents
   - Influence of peer culture

5. The Teacher

a. Number of years teacher has taught prior to this school year: ___________

b. In most situations, teachers have considerable latitude in making instructional decisions, and their decisions are often influenced by such factors as the teacher's:

- Knowledge of/attitudes toward/beliefs about the subject matter;
- Knowledge of/attitudes toward/beliefs about students as learners in general;
- Knowledge of/attitudes toward/beliefs about pedagogy;
- Pedagogical content knowledge/expertise; and
- Choices about professional development, conferences, networks.

Describe how the teacher's background knowledge, skills, and attitudes may have affected the selection of topics/instructional materials/pedagogy for this lesson.

c. If you think this lesson was very different from what is typical of this teacher's instruction in the class, check here ☐ and explain the likely differences and the evidence you have for them.

Section B. Why This Lesson?

In the previous section you considered separately how each of a number of factors (curriculum and assessment policies, supportive infrastructure, physical environment, instructional materials, student characteristics, teacher) may have influenced the selection of topics/instructional materials/pedagogy for this lesson. In this section, we would like you to consider how these various influences interacted, and highlight those which were most salient in determining why this lesson was taught and how it was designed. (Do not consider how well the design actually matched the students' needs, how well it was implemented, or your own judgement of the teacher's knowledge and skills. Rather, try to put yourself in the teacher's head—what s/he was thinking when planning this lesson. It would be appropriate to say "The teacher perceived himself as highly knowledgeable about…" or "The teacher indicated that the students already understood…" even if you have reason to believe that the teacher's perceptions are inaccurate.)

PART THREE: PUTTING IT ALL TOGETHER

We plan to use the data collected in this study to illustrate the status of mathematics and science education in the United States; to talk about the factors that affect the nature, substance, and quality of teaching practice in science and mathematics; and to understand how broadly and deeply "reform" has penetrated into science and mathematics classrooms. We will use narrative accounts (stories and vignettes) as devices to illustrate the nature of, quality of, and factors affecting science and mathematics lessons.

You have now had the opportunity to observe a lesson and also to find out what the teacher was thinking when s/he designed it. In this section, we ask you to "put it all together," highlighting "the story" of this lesson and providing a tag line that together communicate to us the narrative account that you would write about this lesson. We also ask you to assess the overall quality of the lesson, provide any additional information you would like to share about this lesson, and let us know if you think this lesson would make an interesting vignette.

1. **The Story of this Lesson**
   Summarize why this lesson was taught, why it looked the way it did, and how well it worked.

2. **Tag Line**
   Write a phrase or brief sentence that captures the essence of the story of this lesson.

3. **Overall assessment of the quality of the lesson in layperson's terms:**

   ______Bad
   ______Fair
   ______Good
   ______Very Good

4. **Additional Information**
   Use this space to write anything else you would like to say about this lesson, e.g., to suggest specific issues that may or may not be central to the story of this lesson, but illustrate a dilemma or issue particularly well.

5. **Recommendation**
   Check here if you would recommend that this lesson be considered for a vignette. ☐

2000 National Survey of Science and Mathematics Education

Mathematics Questionnaire

A. Teacher Opinions

1. Please provide your opinion about each of the following statements. (Darken one oval on each line.)

	Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
a. Students learn mathematics best in classes with students of similar abilities.	①	②	③	④	⑤
b. The testing program in my state/district dictates what mathematics content I teach.	①	②	③	④	⑤
c. I enjoy teaching mathematics.	①	②	③	④	⑤
d. I consider myself a "master" mathematics teacher.	①	②	③	④	⑤
e. I have time during the regular school week to work with my colleagues on mathematics curriculum and teaching.	①	②	③	④	⑤
f. Mathematics teachers in this school regularly observe each other teaching classes as part of sharing and improving instructional strategies.	①	②	③	④	⑤
g. Most mathematics teachers in this school contribute actively to making decisions about the mathematics curriculum.	①	②	③	④	⑤

2. How familiar are you with the NCTM *Standards*? (Darken one oval.)

- ① Not at all familiar
- ② Somewhat familiar
- ③ Fairly familiar
- ④ Very familiar

B. Teacher Background

3. Please indicate how well prepared you currently feel to do each of the following in your mathematics instruction. (Darken one oval on each line.)

	Not Adequately Prepared	Somewhat Prepared	Fairly Well Prepared	Very Well Prepared
a. Take students' prior understanding into account when planning curriculum and instruction	①	②	③	④
b. Have students work in cooperative learning groups	①	②	③	④
c. Use the textbook as a resource rather than the primary instructional tool	①	②	③	④
d. Teach groups that are heterogeneous in ability	①	②	③	④
e. Teach students who have limited English proficiency	①	②	③	④
f. Encourage participation of females in mathematics	①	②	③	④
g. Encourage participation of minorities in mathematics	①	②	③	④

4a. Do you have each of the following degrees?

Bachelors	① Yes	② No
Masters	① Yes	② No
Doctorate	① Yes	② No

4b. Please indicate the subject(s) for each of your degrees. (Darken all that apply.)

	Bachelors	Masters	Doctorate
Mathematics	①	①	①
Computer Science	①	①	①
Mathematics Education	①	①	①
Science/Science Education	①	①	①
Elementary Education	①	①	①
Other Education (e.g., History Education, Special Education)	①	①	①
Other, please specify ___________________________	①	①	①

PLEASE DO NOT WRITE IN THIS AREA

[SERIAL]

5. Which of the following college courses have you completed? Include both semester hour and quarter hour courses, whether graduate or undergraduate level. Include courses for which you received college credit, even if you took the course in high school. (Darken all that apply.)

MATHEMATICS

- ◯ Mathematics for elementary school teachers
- ◯ Mathematics for middle school teachers
- ◯ Geometry for elementary/middle school teachers
- ◯ College algebra/trigonometry/elementary functions
- ◯ Calculus
- ◯ Advanced calculus
- ◯ Real analysis
- ◯ Differential equations
- ◯ Geometry
- ◯ Probability and statistics
- ◯ Abstract algebra
- ◯ Number theory
- ◯ Linear algebra
- ◯ Applications of mathematics/problem solving
- ◯ History of mathematics
- ◯ Discrete mathematics
- ◯ Other upper division mathematics

SCIENCES/COMPUTER SCIENCES

- ◯ Biological sciences
- ◯ Chemistry
- ◯ Physics
- ◯ Physical science
- ◯ Earth/space science
- ◯ Engineering (any)
- ◯ Computer programming
- ◯ Other computer science

EDUCATION

- ◯ General methods of teaching
- ◯ Methods of teaching mathematics
- ◯ Instructional uses of computers/other technologies
- ◯ Supervised student teaching in mathematics

6. For each of the following subject areas, indicate the number of college semester and quarter courses you have completed. Count each course you have taken, regardless of whether it was a graduate or undergraduate course. If your transcripts are not available, provide your best estimates.

	Semester Courses	Quarter Courses
a. Mathematics education	0 1 2 3 4 5 6 7 8 >8	0 1 2 3 4 5 6 7 8 >8
b. Calculus	0 1 2 3 4 5 6 7 8 >8	0 1 2 3 4 5 6 7 8 >8
c. Statistics	0 1 2 3 4 5 6 7 8 >8	0 1 2 3 4 5 6 7 8 >8
d. Advanced calculus	0 1 2 3 4 5 6 7 8 >8	0 1 2 3 4 5 6 7 8 >8
e. All other mathematics courses	0 1 2 3 4 5 6 7 8 >8	0 1 2 3 4 5 6 7 8 >8
f. Computer science	0 1 2 3 4 5 6 7 8 >8	0 1 2 3 4 5 6 7 8 >8
g. Science	0 1 2 3 4 5 6 7 8 >8	0 1 2 3 4 5 6 7 8 >8

7. In what year did you last take a formal course for college credit in:

a. Mathematics: ________________

b. The Teaching of Mathematics: _____________

If you have never taken a course in the teaching of mathematics, darken this oval. ◯

8. What is the **total** amount of time you have spent on professional development in mathematics or the teaching of mathematics in the last 12 months? in the last 3 years? (Include attendance at professional meetings, workshops, and conferences, but **do not** include formal courses for which you received college credit or time you spent **providing** professional development for other teachers.) (Darken one oval on each line.)

	Hours of In-service Education				
	None	Less than 6 hours	6-15 hours	16-35 hours	More than 35 hours
In the last 12 months	◯	◯	◯	◯	◯
In the last 3 years	◯	◯	◯	◯	◯

9. In the past **12 months**, have you: (Darken one oval on each line.)

a. Taught any in-service workshops in mathematics or mathematics teaching?	◯ Yes	◯ No
b. Mentored another teacher as part of a formal arrangement that is recognized or supported by the school or district, not including supervision of student teachers?	◯ Yes	◯ No
c. Received any local, state, or national grants or awards for mathematics teaching?	◯ Yes	◯ No
d. Served on a school or district mathematics curriculum committee?	◯ Yes	◯ No
e. Served on a school or district mathematics textbook selection committee?	◯ Yes	◯ No

10a. Do you teach in a **self-contained class**? (i.e., you teach multiple subjects to the same class of students all or most of the day.)

- ① Yes, CONTINUE WITH QUESTIONS 10b AND 10c
- ② No, SKIP TO QUESTION 11

10b. ***For teachers of self-contained classes*:** Many teachers feel better qualified to teach some subject areas than others. How well qualified do you feel to teach each of the following subjects **at the grade level(s) you teach**, whether or not they are currently included in your curriculum? (Darken one oval on each line.)

	Not Well Qualified	Adequately Qualified	Very Well Qualified
a. Life science	①	②	③
b. Earth science	①	②	③
c. Physical science	①	②	③
d. Mathematics	①	②	③
e. Reading/Language Arts	①	②	③
f. Social Studies	①	②	③

10c. ***For teachers of self-contained classes*:** We are interested in knowing how much time your students spend studying various subjects. In a typical week, how many days do you have lessons on each of the following subjects, and how many minutes long is an average lesson? (*Please indicate "0" if you do not teach a particular subject to this class.*)

	Days Per Week	Approximate Minutes Per Day		Days Per Week	Approximate Minutes Per Day
Mathematics	______	__________	**Social Studies**	______	__________
Science	______	__________	**Reading/Language Arts**	______	__________

NOW GO TO SECTION C, ON THE NEXT PAGE .

11. ***For teachers of non-self-contained classes*:** For each class period you are currently teaching, regardless of the subject, give *course title*, the *code-number* from the enclosed blue "List of Course Titles" that best describes the content addressed in the class, and the *number of students* in the class. (**If you teach more than one section of a course, record each section separately below**. **If you teach more than 6 classes per day, please provide the requested information for the additional classes on a separate sheet of paper.)**

Course Title	*Course Code*	*Number of Sudents*

PLEASE DO NOT WRITE IN THIS AREA

[SERIAL]

C. Your Mathematics Teaching in a Particular Class

The questions in this section are about a particular mathematics class you teach. **If you teach mathematics to more than one class per day, please consult the label on the cover letter to determine which mathematics class to use to answer these questions.**

12. Using the blue "List of Course Titles," indicate the code number that best describes this course. ____________

    (If "other" [Code 299], briefly describe content of course:____

    ____

    ____)

13. Please indicate the grades of the students in this class. (Darken all that apply.)

    ○ K ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 ○ 11 ○ 12

14a. What is the total number of students in this class? ____________

14b. Please indicate the number of students in this class in each of the following categories. Consult the enclosed federal guidelines at the end of the course list (blue sheet) if you have any questions about how to classify particular students.

	Male	Female
American Indian or American Native	____________	____________
Asian	____________	____________
Black or African-American	____________	____________
Hispanic or Latino (any race)	____________	____________
Native Hawaiian or Other Pacific Islander	____________	____________
White	____________	____________

15. **This question applies only to teachers of non-self-contained classes. If you teach a self-contained class, please darken this oval** ○ **and skip to question 16.** What is the usual schedule and length (in minutes) of daily class meetings for this class? If the weekly schedule is normally the same, just complete Week 1, as in Example 1. If you are unable to describe this class in the format below, please attach a separate piece of paper with your description.

	Week 1	**Week 2**
Monday	____________	____________
Tuesday	____________	____________
Wednesday	____________	____________
Thursday	____________	____________
Friday	____________	____________

Examples

Example 1		**Example 2**	
Week 1	Week 2	Week 1	Week 2
45	_____	90	_____
45	_____	_____	90
45	_____	90	_____
45	_____	_____	90
45	_____	90	_____

16. Are students assigned to this class by level of ability? (Darken one oval.) ○ Yes ○ No

17. Which of the following best describes the ability of the students in this class relative to other students in this school? (Darken one oval.)

- ○ Fairly homogeneous and low in ability
- ○ Fairly homogeneous and average in ability
- ○ Fairly homogeneous and high in ability
- ○ Heterogeneous, with a mixture of two or more ability levels

18. Indicate if any of the students in this mathematics class are **formally** classified as each of the following: (Darken all that apply.)

- ○ Limited English Proficiency
- ○ Learning Disabled
- ○ Mentally Handicapped
- ○ Physically Handicapped, please specify handicap(s): ______________________________

19. Think about your plans for this mathematics class for the entire course. How much emphasis will each of the following **student objectives** receive? (Darken one oval on each line.)

	None	Minimal Emphasis	Moderate Emphasis	Heavy Emphasis
a. Increase students' interest in mathematics	1	2	3	4
b. Learn mathematical concepts	1	2	3	4
c. Learn mathematical algorithms/procedures	1	2	3	4
d. Develop students' computational skills	1	2	3	4
e. Learn how to solve problems	1	2	3	4
f. Learn to reason mathematically	1	2	3	4
g. Learn how mathematics ideas connect with one another	1	2	3	4
h. Prepare for further study in mathematics	1	2	3	4
i. Understand the logical structure of mathematics	1	2	3	4
j. Learn about the history and nature of mathematics	1	2	3	4
k. Learn to explain ideas in mathematics effectively	1	2	3	4
l. Learn how to apply mathematics in business and industry	1	2	3	4
m. Learn to perform computations with speed and accuracy	1	2	3	4
n. Prepare for standardized tests	1	2	3	4

20. About how often do **you** do each of the following in your mathematics instruction? (Darken one oval on each line.)

	Never	Rarely (e.g., a few times a year)	Sometimes (e.g., once or twice a month)	Often (e.g., once or twice a week)	All or almost all mathematics lessons
a. Introduce content through formal presentations	1	2	3	4	5
b. Pose open-ended questions	1	2	3	4	5
c. Engage the whole class in discussions	1	2	3	4	5
d. Require students to explain their reasoning when giving an answer	1	2	3	4	5
e. Ask students to explain concepts to one another	1	2	3	4	5
f. Ask students to consider alternative methods for solutions	1	2	3	4	5
g. Ask students to use multiple representations (e.g., numeric, graphic, geometric, etc.)	1	2	3	4	5
h. Allow students to work at their own pace	1	2	3	4	5
i. Help students see connections between mathematics and other disciplines	1	2	3	4	5
j. Assign mathematics homework	1	2	3	4	5
k. Read and comment on the reflections students have written, e.g., in their journals	1	2	3	4	5

21. About how often do students in this **mathematics** class take part in the following types of activities? (Darken one oval on each line.)

	Never	Rarely (e.g., a few times a year)	Sometimes (e.g., once or twice a month)	Often (e.g., once or twice a week)	All or almost all mathematics lessons
a. Listen and take notes during presentation by teacher	1	2	3	4	5
b. Work in groups	1	2	3	4	5
c. Read from a mathematics textbook in class	1	2	3	4	5
d. Read other (non-textbook) mathematics-related materials in class	1	2	3	4	5
e. Engage in mathematical activities using concrete materials	1	2	3	4	5
f. Practice routine computations/algorithms	1	2	3	4	5
g. Review homework/worksheet assignments	1	2	3	4	5
h. Follow specific instructions in an activity or investigation	1	2	3	4	5
i. Design their *own* activity or investigation	1	2	3	4	5
j. Use mathematical concepts to interpret and solve applied problems	1	2	3	4	5
k. Answer textbook or worksheet questions	1	2	3	4	5
l. Record, represent, and/or analyze data	1	2	3	4	5
m. Write reflections (e.g., in a journal)	1	2	3	4	5
n. Make formal presentations to the rest of the class	1	2	3	4	5
o. Work on extended mathematics investigations or projects (a week or more in duration)	1	2	3	4	5
p. Use calculators or computers for learning or practicing skills	1	2	3	4	5
q. Use calculators or computers to develop conceptual understanding	1	2	3	4	5
r. Use calculators or computers as a tool (e.g., spreadsheets, data analysis)	1	2	3	4	5

22. About how often do students in this mathematics class use **calculators/computers** to: (Darken one oval on each line.)

	Never	Rarely (e.g., a few times a year)	Sometimes (e.g., once or twice a month)	Often (e.g., once or twice a week)	All or almost all mathematics lessons
a. Do drill and practice	1	2	3	4	5
b. Demonstrate mathematics principles	1	2	3	4	5
c. Play mathematics learning games	1	2	3	4	5
d. Do simulations	1	2	3	4	5
e. Collect data using sensors or probes	1	2	3	4	5
f. Retrieve or exchange data	1	2	3	4	5
g. Solve problems using simulations	1	2	3	4	5
h. Take a test or quiz	1	2	3	4	5

23. How much of your own money do you estimate you will spend for supplies for this mathematics class this school year (or semester or quarter if not a full-year course)? ____________ If none, darken this oval: ○

24. How much of your own money do you estimate you will spend for your own professional development activities during the period Sept. 1, 2000 - Aug. 31, 2001? ____________ If none, darken this oval: ○

25. How much mathematics homework do you assign to this mathematics class in a typical **week**? (Darken one oval.)

○ 0-30 min ○ 31-60 min ○ 61-90 min ○ 91-120 min ○ 2-3 hours ○ More than 3 hours

PLEASE DO NOT WRITE IN THIS AREA

[SERIAL]

26a. Are you using one or more commercially published textbooks or programs for teaching mathematics to this class? (Darken one oval.)

- ○ No, SKIP TO SECTION D
- ○ Yes, CONTINUE WITH 26b

26b. Which best describes your use of textbooks/programs in this class? (Darken one oval.)

- ○ Use one textbook or program all or most of the time
- ○ Use multiple textbooks/programs

27a. Please indicate the title, author, publisher, and publication year of the **one** textbook/program used **most often** by students in this class.

Title: ____

First Author: ____

Publisher: ____

Publication Year: __________ Edition: _____________

27b. Approximately what percentage of this textbook/program will you "cover" in this course? (Darken one oval.)

○ < 25% ○ 25-49% ○ 50-74% ○ 75-90% ○ >90%

27c. How would you rate the overall quality of this textbook/program? (Darken one oval.)

○ Very Poor ○ Poor ○ Fair ○ Good ○ Very Good ○ Excellent

D. Your Most Recent Mathematics Lesson in This Class

Questions 28-30 refer to the last time you taught mathematics to this class. Do not be concerned if this lesson was not typical of instruction in this class.

28a. How many minutes were allocated to the most recent mathematics lesson? ____________
Note: Teachers in departmentalized and other non-self-contained settings should answer for the entire length of the class period, even if there were interruptions.

28b. Of these, how many minutes were spent on the following:
(The sum of the numbers in 1.-6. below should equal your response in 28a.)

____________ 1. Daily routines, interruptions, and other non-instructional activities

____________ 2. Whole class lecture/discussions

____________ 3. Individual students reading textbooks, completing worksheets, etc.

____________ 4. Working with hands-on or manipulative materials

____________ 5. Non-manipulative small group work

____________ 6. Other

29. Which of the following activities took place during that mathematics lesson? (Darken all that apply.)

- Lecture
- Discussion
- Students completing textbook/worksheet problems
- Students doing hands-on/manipulative activities
- Students reading about mathematics
- Students working in small groups
- Students using calculators
- Students using computers
- Students using other technologies
- Test or quiz
- None of these activities took place

30. Did that lesson take place on the most recent day you met with that class? Yes No

E. Demographic Information

31. Indicate your sex:

- Male
- Female

32. Are you: (Darken all that apply.)

- American Indian or Alaskan Native
- Asian
- Black or African-American
- Hispanic or Latino
- Native Hawaiian or Other Pacific Islander
- White

33. In what year were you born? ____________

34. How many years have you taught at the K-12 level prior to this school year? ____________

35. If you have an email address, please write it here: ____

36. When did you complete this questionnaire? Date: ______ / _______ / _______
Month Day Year

FOR OFFICE USE ONLY
Please do not write in this area.

Please make a photocopy of this questionnaire and keep it in case the original is lost in the mail. Please return the original to:

2000 National Survey of Science and Mathematics Education
Horizon Research, Inc.
326 Cloister Court
Chapel Hill, NC 27514

THANK YOU!

PLEASE DO NOT WRITE IN THIS AREA

[SERIAL]

2000 National Survey of Science and Mathematics Education
Science Questionnaire

A. Teacher Opinions

1. Please provide your opinion about each of the following statements. (Darken one oval on each line.)

	Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
a. Students learn science best in classes with students of similar abilities.	①	②	③	④	⑤
b. The testing program in my state/district dictates what science content I teach.	①	②	③	④	⑤
c. I enjoy teaching science.	①	②	③	④	⑤
d. I consider myself a "master" science teacher.	①	②	③	④	⑤
e. I have time during the regular school week to work with my colleagues on science curriculum and teaching.	①	②	③	④	⑤
f. Science teachers in this school regularly observe each other teaching classes as part of sharing and improving instructional strategies.	①	②	③	④	⑤
g. Most science teachers in this school contribute actively to making decisions about the science curriculum.	①	②	③	④	⑤

2. How familiar are you with the *National Science Education Standards*, published by the National Research Council? (Darken one oval.)

- ○ Not at all familiar
- ○ Somewhat familiar
- ○ Fairly familiar
- ○ Very familiar

B. Teacher Background

3. Please indicate how well prepared you currently feel to do each of the following in your science instruction. (Darken one oval on each line.)

	Not Adequately Prepared	Somewhat Prepared	Fairly Well Prepared	Very Well Prepared
a. Take students' prior understanding into account when planning curriculum and instruction	①	②	③	④
b. Have students work in cooperative learning groups	①	②	③	④
c. Use the textbook as a resource rather than the primary instructional tool	①	②	③	④
d. Teach groups that are heterogeneous in ability	①	②	③	④
e. Teach students who have limited English proficiency	①	②	③	④
f. Encourage participation of females in science	①	②	③	④
g. Encourage participation of minorities in science	①	②	③	④

4a. Do you have each of the following degrees?

Bachelors	○ Yes	○ No
Masters	○ Yes	○ No
Doctorate	○ Yes	○ No

4b. Please indicate the subject(s) for each of your degrees. (Darken all that apply.)

	Bachelors	Masters	Doctorate
Biology/Life Science	○	○	○
Chemistry	○	○	○
Earth/Space Science	○	○	○
Physics	○	○	○
Other science, please specify: ______________________	○	○	○
Science Education (any science discipline)	○	○	○
Mathematics/Mathematics Education	○	○	○
Elementary Education	○	○	○
Other Education (e.g., History Education, Special Education)	○	○	○
Other, please specify: ______________________	○	○	○

5. Which of the following college courses have you completed? Include both semester hour and quarter hour courses, whether graduate or undergraduate level. Include courses for which you received college credit, even if you took the course in high school. (Darken all that apply.)

EDUCATION
- ○ General methods of teaching
- ○ Methods of teaching science
- ○ Instructional uses of computers/other technologies
- ○ Supervised student teaching in science

MATHEMATICS
- ○ College algebra/trigonometry/ elementary functions
- ○ Calculus
- ○ Advanced calculus
- ○ Differential equations
- ○ Discrete mathematics
- ○ Probability and statistics

CHEMISTRY
- ○ General/introductory chemistry
- ○ Analytical chemistry
- ○ Organic chemistry
- ○ Physical chemistry
- ○ Quantum chemistry
- ○ Biochemistry
- ○ Other chemistry

EARTH/SPACE SCIENCES
- ○ Introductory earth science
- ○ Astronomy
- ○ Geology
- ○ Meteorology
- ○ Oceanography
- ○ Physical geography
- ○ Environmental science
- ○ Agricultural science

LIFE SCIENCES
- ○ Introductory biology/life science
- ○ Botany, plant physiology
- ○ Cell biology
- ○ Ecology
- ○ Entomology
- ○ Genetics, evolution
- ○ Microbiology
- ○ Anatomy/Physiology
- ○ Zoology, animal behavior
- ○ Other life science

PHYSICS
- ○ Physical science
- ○ General/introductory physics
- ○ Electricity and magnetism
- ○ Heat and thermodynamics
- ○ Mechanics
- ○ Modern or quantum physics
- ○ Nuclear physics
- ○ Optics
- ○ Solid state physics
- ○ Other physics

OTHER
- ○ History of science
- ○ Philosophy of science
- ○ Science and society
- ○ Electronics
- ○ Engineering (Any)
- ○ Integrated science
- ○ Computer programming
- ○ Other computer science

6. For each of the following subject areas, indicate the number of college semester and quarter courses you have completed. Count each course you have taken, regardless of whether it was a graduate or undergraduate course. If your transcripts are not

	Semester Courses	Quarter Courses
a. Life sciences	⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ >8	⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ >8
b. Chemistry	⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ >8	⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ >8
c. Physics/physical science	⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ >8	⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ >8
d. Earth/space science	⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ >8	⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ >8
e. Science education	⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ >8	⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ >8
f. Mathematics	⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ >8	⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ >8

7. In what year did you last take a formal course for college credit in:

a. Science: ________________

b. The Teaching of Science: _____________

If you have never taken a course in the teaching of science, darken this oval. ○

8. What is the **total** amount of time you have spent on professional development in science or the teaching of science in the last 12 months? in the last 3 years? (Include attendance at professional meetings, workshops, and conferences, but **do not** include formal courses for which you received college credit or time you spent **providing** professional development for other teachers.) (Darken one oval on each line.)

	Hours of In-service Education				
	None	Less than 6 hours	6-15 hours	16-35 hours	More than 35 hours
In the last 12 months	○	○	○	○	○
In the last 3 years	○	○	○	○	○

PLEASE DO NOT WRITE IN THIS AREA

[SERIAL]

9. In the past **12 months**, have you: (Darken one oval on each line.)

a.	Taught any in-service workshops in science or science teaching?	○ Yes	○ No
b.	Mentored another teacher as part of a formal arrangement that is recognized or supported by the school or district, not including supervision of student teachers?	○ Yes	○ No
c.	Received any local, state, or national grants or awards for science teaching?	○ Yes	○ No
d.	Served on a school or district science curriculum committee?	○ Yes	○ No
e.	Served on a school or district science textbook selection committee?	○ Yes	○ No

10a. Do you teach in a **self-contained class**? (i.e., you teach multiple subjects to the same class of students all or most of the day.)

○ Yes, CONTINUE WITH QUESTIONS 10b and 10c
○ No, SKIP TO QUESTION 11

10b. ***For teachers of self-contained classes*:** Many teachers feel better qualified to teach some subject areas than others. How well qualified do you feel to teach each of the following subjects **at the grade level(s) you teach**, whether or not they are currently included in your curriculum? (Darken one oval on each line.)

		Not Well Qualified	Adequately Qualified	Very Well Qualified
a.	Life science	(1)	(2)	(3)
b.	Earth science	(1)	(2)	(3)
c.	Physical science	(1)	(2)	(3)
d.	Mathematics	(1)	(2)	(3)
e.	Reading/Language Arts	(1)	(2)	(3)
f.	Social Studies	(1)	(2)	(3)

10c. ***For teachers of self-contained classes*:** We are interested in knowing how much time your students spend studying various subjects. In a typical week, how many days do you have lessons on each of the following subjects, and how many minutes long is an average lesson? (*Please indicate "0" if you do not teach a particular subject to this class.*)

	Days Per Week	Approximate Minutes Per Day		Days Per Week	Approximate Minutes Per Day
Mathematics	______	__________	**Social Studies**	______	__________
Science	______	__________	**Reading/Language Arts**	______	__________

NOW GO TO SECTION C, ON THE NEXT PAGE .

11. ***For teachers of non-self-contained classes*:** For each class period you are currently teaching, regardless of the subject, give *course title*, the *code-number* from the enclosed blue "List of Course Titles" that best describes the content addressed in the class, and the *number of students* in the class. (**If you teach more than one section of a course, record each section separately below. If you teach more than 6 classes per day, please provide the requested information for the additional classes on a separate sheet of paper.)**

Course Title	*Course Code*	*Number of Sudents*
______________________________	__________	__________
______________________________	__________	__________
______________________________	__________	__________
______________________________	__________	__________
______________________________	__________	__________
______________________________	__________	__________

C. Your Science Teaching in a Particular Class

The questions in this section are about a particular science class you teach. **If you teach science to more than one class per day, please consult the label on the cover letter to determine which science class to use to answer these questions.**

12. Using the blue "List of Course Titles," indicate the code number that best describes this course. ____________

(If "other" [Code 199], briefly describe content of course:____
____
____)

13. Please indicate the grades of the students in this class. (Darken all that apply.)

ⓚ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩ ⑪ ⑫

14a. What is the total number of students in this class? ____________

14b. Please indicate the number of students in this class in each of the following categories. Consult the enclosed federal guidelines at the end of the course list (blue sheet) if you have any questions about how to classify particular students.

	Male	Female
American Indian or American Native	____________	____________
Asian	____________	____________
Black or African-American	____________	____________
Hispanic or Latino (any race)	____________	____________
Native Hawaiian or Other Pacific Islander	____________	____________
White	____________	____________

15. **This question applies only to teachers of non-self-contained classes. If you teach a self-contained class, please darken this oval** ◯ **and skip to question 16.** What is the usual schedule and length (in minutes) of daily class meetings for this class? If the weekly schedule is normally the same, just complete Week 1, as in Example 1. If you are unable to describe this class in the format below, please attach a separate piece of paper with your description.

	Week 1	Week 2
Monday	____________	____________
Tuesday	____________	____________
Wednesday	____________	____________
Thursday	____________	____________
Friday	____________	____________

Examples

Example 1		Example 2	
Week 1	Week 2	Week 1	Week 2
45	_____	90	_____
45	_____	_____	90
45	_____	90	_____
45	_____	_____	90
45	_____	90	_____

PLEASE DO NOT WRITE IN THIS AREA

[SERIAL]

16. Are students assigned to this class by level of ability? (Darken one oval.) Yes No

17. Which of the following best describes the ability of the students in this class relative to other students in this school? (Darken one oval.)

- Fairly homogeneous and low in ability
- Fairly homogeneous and average in ability
- Fairly homogeneous and high in ability
- Heterogeneous, with a mixture of two or more ability levels

18. Indicate if any of the students in this science class are **formally** classified as each of the following: (Darken all that apply.)

- Limited English Proficiency
- Learning Disabled
- Mentally Handicapped
- Physically Handicapped, please specify handicap(s): ______________________________

19. Think about your plans for this science class for the entire course. How much emphasis will each of the following **student objectives** receive? (Darken one oval on each line.)

		None	Minimal Emphasis	Moderate Emphasis	Heavy Emphasis
a.	Increase students' interest in science				
b.	Learn basic science concepts				
c.	Learn important terms and facts of science				
d.	Learn science process/inquiry skills				
e.	Prepare for further study in science				
f.	Learn to evaluate arguments based on scientific evidence				
g.	Learn how to communicate ideas in science effectively				
h.	Learn about the applications of science in business and industry				
i.	Learn about the relationship between science, technology, and society				
j.	Learn about the history and nature of science				
k.	Prepare for standardized tests				

20. About how often do **you** do each of the following in your science instruction? (Darken one oval on each line.)

		Never	Rarely (e.g., a few times a year)	Sometimes (e.g., once or twice a month)	Often (e.g., once or twice a week)	All or almost all science lessons
a.	Introduce content through formal presentations					
b.	Pose open-ended questions					
c.	Engage the whole class in discussions					
d.	Require students to supply evidence to support their claims					
e.	Ask students to explain concepts to one another					
f.	Ask students to consider alternative explanations					
g.	Allow students to work at their own pace					
h.	Help students see connections between science and other disciplines					
i.	Assign science homework					
j.	Read and comment on the reflections students have written, e.g., in their journals					

PLEASE DO NOT WRITE IN THIS AREA

[SERIAL]

21. About how often do students in this science class take part in the following types of activities? (Darken one oval on each line.)

	Never	Rarely (e.g., a few times a year)	Sometimes (e.g., once or twice a month)	Often (e.g., once or twice a week)	All or almost all science lessons
a. Listen and take notes during presentation by teacher	(1)	(2)	(3)	(4)	(5)
b. Watch a science demonstration	(1)	(2)	(3)	(4)	(5)
c. Work in groups	(1)	(2)	(3)	(4)	(5)
d. Read from a science textbook in class	(1)	(2)	(3)	(4)	(5)
e. Read other (non-textbook) science-related materials in class	(1)	(2)	(3)	(4)	(5)
f. Do hands-on/laboratory science activities or investigations	(1)	(2)	(3)	(4)	(5)
g. Follow specific instructions in an activity or investigation	(1)	(2)	(3)	(4)	(5)
h. Design or implement their *own* investigation	(1)	(2)	(3)	(4)	(5)
i. Participate in field work	(1)	(2)	(3)	(4)	(5)
j. Answer textbook or worksheet questions	(1)	(2)	(3)	(4)	(5)
k. Record, represent, and/or analyze data	(1)	(2)	(3)	(4)	(5)
l. Write reflections (e.g., in a journal)	(1)	(2)	(3)	(4)	(5)
m. Prepare written science reports	(1)	(2)	(3)	(4)	(5)
n. Make formal presentations to the rest of the class	(1)	(2)	(3)	(4)	(5)
o. Work on extended science investigations or projects (a week or more in duration)	(1)	(2)	(3)	(4)	(5)
p. Use computers as a tool (e.g., spreadsheets, data analysis)	(1)	(2)	(3)	(4)	(5)
q. Use mathematics as a tool in problem-solving	(1)	(2)	(3)	(4)	(5)
r. Take field trips	(1)	(2)	(3)	(4)	(5)
s. Watch audiovisual presentations (e.g., videotapes, CD-ROMs, videodiscs, television programs, films, or filmstrips)	(1)	(2)	(3)	(4)	(5)

22. About how often do students in this science class use **computers** to: (Darken one oval on each line.)

	Never	Rarely (e.g., a few times a year)	Sometimes (e.g., once or twice a month)	Often (e.g., once or twice a week)	All or almost all science lessons
a. Do drill and practice	(1)	(2)	(3)	(4)	(5)
b. Demonstrate scientific principles	(1)	(2)	(3)	(4)	(5)
c. Play science learning games	(1)	(2)	(3)	(4)	(5)
d. Do laboratory simulations	(1)	(2)	(3)	(4)	(5)
e. Collect data using sensors or probes	(1)	(2)	(3)	(4)	(5)
f. Retrieve or exchange data	(1)	(2)	(3)	(4)	(5)
g. Solve problems using simulations	(1)	(2)	(3)	(4)	(5)
h. Take a test or quiz	(1)	(2)	(3)	(4)	(5)

23. How much of your own money do you estimate you will spend for supplies for this science class this school year (or semester or quarter if not a full-year course)? ____________ If none, darken this oval: ◯

24. How much of your own money do you estimate you will spend for your own professional development activities during the period Sept. 1, 2000 - Aug. 31, 2001? ____________ If none, darken this oval: (1)

25. How much science homework do you assign to this science class in a typical **week**? (Darken one oval.)

(1) 0-30 min (2) 31-60 min (3) 61-90 min (4) 91-120 min (5) 2-3 hours ◯ More than 3 hours

26a. Are you using one or more commercially published textbooks or programs for teaching science to this class? (Darken one oval.)

(1) No, SKIP TO SECTION D, ON THE NEXT PAGE
◯ Yes, CONTINUE WITH 26b

26b. Which best describes your use of textbooks/programs in this class? (Darken one oval.)

- Use one textbook or program all or most of the time
- Use multiple textbooks/programs

27a. Please indicate the title, author, publisher, and publication year of the **one** textbook/program used **most often** by students in this class.

Title: ____

First Author: ____

Publisher: ____

Publication Year: __________ Edition: ____________

27b. Approximately what percentage of this textbook/program will you "cover" in this course? (Darken one oval.)

- < 25%
- 25-49%
- 50-74%
- 75-90%
- >90%

27c. How would you rate the overall quality of this textbook/program? (Darken one oval.)

- Very Poor
- Poor
- Fair
- Good
- Very Good
- Excellent

D. Your Most Recent Science Lesson in This Class

Questions 28-30 refer to the last time you taught science to this class. Do not be concerned if this lesson was not typical of instruction in this class.

28a. How many minutes were allocated to the most recent science lesson? ____________
Note: Teachers in departmentalized and other non-self-contained settings should answer for the entire length of the class period, even if there were interruptions.

28b. Of these, how many minutes were spent on the following:
(The sum of the numbers in 1.-6. below should equal your response in 28a.)

____________ 1. Daily routines, interruptions, and other non-instructional activities

____________ 2. Whole class lecture/discussions

____________ 3. Individual students reading textbooks, completing worksheets, etc.

____________ 4. Working with hands-on or manipulative materials

____________ 5. Non-manipulative small group work

____________ 6. Other

29. Which of the following activities took place during that science lesson? (Darken all that apply.)

- Lecture
- Discussion
- Students completing textbook/worksheet problems
- Students doing hands-on/laboratory activities
- Students reading about science
- Students working in small groups
- Students using calculators
- Students using computers
- Students using other technologies
- Test or quiz
- None of these activities took place

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[SERIAL]

30. Did that lesson take place on the most recent day you met with that class? ○ Yes ○ No

E. Demographic Information

31. Indicate your sex:

○ Male
○ Female

32. Are you: (Darken all that apply)

○ American Indian or Alaskan Native
○ Asian
○ Black or African-American
○ Hispanic or Latino
○ Native Hawaiian or Other Pacific Islander
○ White

33. In what year were you born? ___________

34. How many years have you taught at the K-12 level prior to this school year? ___________

35. If you have an email address, please write it here: ____

36. When did you complete this questionnaire? Date: ______ / _______ / _______
Month Day Year

Please make a photocopy of this questionnaire and keep it in case the original is lost in the mail.
Please return the original to:

2000 National Survey of Science and Mathematics Education
Horizon Research, Inc.
326 Cloister Court
Chapel Hill, NC 27514

THANK YOU!

FOR OFFICE USE ONLY
Please do not write in this area.

Appendix B

Description of Composite Variables

Overview of Composites

Definitions of Teacher Composites

Overview of Composites

To facilitate the reporting of large amounts of survey data, and because individual questionnaire items are potentially unreliable, this report includes means for several "composite" variables. HRI used factor analysis of responses from the 2000 National Survey of Science and Mathematics Education that were included in the teacher questionnaire for the *Inside the Classroom* study to identify survey questions that could be combined into composites. Each composite represents an important construct related to mathematics or science education. Composites were calculated for both the science and mathematics versions of the teacher questionnaire.

Each composite is calculated by summing the responses to the items associated with that composite and then dividing by the total points possible. In order for the composites to be on a 100-point scale, the lowest response option on each scale was set to 0 and the others were adjusted accordingly; so for instance, an item with a scale ranging from 1 to 4 was re-coded to have a scale of 0–3. By doing this, someone who marks the lowest point on every item in a composite receives a composite score of 0 rather than some positive number. It also assures that 50 is the true mid-point. The denominator for each composite is determined by computing the maximum possible sum of responses for a series of items and dividing by 100; e.g., a nine-item composite where each item is on a scale of 0–3 would have a denominator of 0.27.

Composite definitions are presented below along with the item numbers. Reliability information is based on responses from the 2000 National Survey of Science and Mathematics Education.

Definitions of Teacher Composites

Composite definitions for the science and mathematics teacher questionnaire are presented below along with the item numbers from the respective questionnaires. Composites that are identical for the two subjects are presented in the same table; composites unique to a subject are presented in separate tables.

Instructional Objectives

These composites estimate the amount of emphasis teachers place on various objectives.

Table B-1
Nature of Science/Mathematics Objectives

	Science	Mathematics
Learn to evaluate arguments based on scientific evidence	Q19f	
Understand the logical structure of mathematics		Q19i
Learn about the history and nature of science/mathematics	Q19j	Q19j
Learn how to communicate ideas in science effectively*	Q19g	
Learn how to explain ideas in mathematics effectively*		Q19k
Learn about the applications of science in business and industry*	Q19h	
Learn how to apply mathematics in business and industry*		Q19l
Learn about the relationship between science, technology, and society	Q19i	
Number of Items in Composite	**5**	**4**
Reliability (Cronbach's Coefficient Alpha)	**0.84**	**0.73**

* The mathematics and science versions of this question are considered equivalent, worded appropriately for that discipline.

Table B-2
Science Content Objectives

	Science
Learn basic science concepts	Q19b
Learn important terms and facts of science	Q19c
Learn science process/inquiry skills	Q19d
Prepare for further study in science	Q19e
Number of Items in Composite	**4**
Reliability (Cronbach's Coefficient Alpha)	**0.60**

Table B-3
Basic Mathematics Skills Objectives

	Mathematics
Develop students' computational skills	Q19d
Learn to perform computations with speed and accuracy	Q19m
Prepare for standardized tests	Q19n
Number of Items in Composite	**3**
Reliability (Cronbach's Coefficient Alpha)	**0.69**

Table B-4
Mathematics Reasoning Objectives

	Mathematics
Learn mathematical concepts	Q19b
Learn how to solve problems	Q19e
Learn to reason mathematically	Q19f
Learn how mathematics ideas connect with one another	Q19g
Number of Items in Composite	**4**
Reliability (Cronbach's Coefficient Alpha)	**0.75**

Teaching Practices

These composites estimate the extent to which teachers use a variety of teaching practices and instructional technologies.

Table B-5
Use of Traditional Teaching Practices

	Science	Mathematics
Introduce content through formal presentations	Q20a	Q20a
Assign science/mathematics homework	Q20i	Q20j
Listen and take notes during presentation by teacher	Q21a	Q21a
Read from a science/mathematics textbook in class	Q21d	Q21c
Practice routine computations/algorithms		Q21f
Review homework/worksheet assignments		Q21g
Answer textbook or worksheet questions	Q21j	Q21k
Number of Items in Composite	**5**	**7**
Reliability (Cronbach's Coefficient Alpha)	**0.71**	**0.70**

Table B-6
Use of Strategies to Develop Students' Abilities to Communicate Ideas

	Science	Mathematics
Pose open-ended questions	Q20b	Q20b
Engage the whole class in discussions	Q20c	
Require students to supply evidence to support their claims*	Q20d	
Require student to explain their reasoning when giving an answer*		Q20d
Ask students to explain concepts to one another	Q20e	Q20e
Ask students to consider alternative explanations *	Q20f	
Ask students to consider alternative methods for solutions*		Q20f
Ask students to use multiple representations (e.g., numeric, graphic, geometric, etc.)		Q20g
Help students see connections between science/mathematics and other disciplines	Q20h	Q20i
Number of Items in Composite	**6**	**6**
Reliability (Cronbach's Coefficient Alpha)	**0.79**	**0.77**

* The mathematics and science versions of this question are considered equivalent, worded appropriately for that discipline.

Table B-7
Use of Computers

	Science
Use computers as a tool (e.g., spreadsheets, data analysis)	Q21p
Do drill and practice	Q22a
Demonstrate scientific principles	Q22b
Play science learning games	Q22c
Do laboratory simulations	Q22d
Collect data using sensors or probes	Q22e
Retrieve or exchange data	Q22f
Solve problems using simulations	Q22g
Take a test or quiz	Q22h
Number of Items in Composite	**9**
Reliability (Cronbach's Coefficient Alpha)	**0.91**

Table B-8
Use of Laboratory Activities

	Science
Work in groups	Q21c
Do hands-on/laboratory science activities or investigations	Q21f
Follow specific instructions in an activity or investigation	Q21g
Record, represent, and/or analyze data	Q21k
Number of Items in Composite	**4**
Reliability (Cronbach's Coefficient Alpha)	**0.80**

Table B-9
Use of Calculators/Computers for Investigations

	Mathematics
Record, represent, and/or analyze data	Q21l
Use calculators or computers as a tool (e.g., spreadsheets, data analysis)	Q21r
Do simulations	Q22d
Collect data using sensors or probes	Q22e
Retrieve or exchange data	Q22f
Solve problems using simulations	Q22g
Number of Items in Composite	**6**
Reliability (Cronbach's Coefficient Alpha)	**0.85**

Appendix C

Grades K–5 Mathematics

Typical Lessons

Ratings of Lesson Components

Overall Lesson Quality

Typical Lessons

The following lesson descriptions are based on a random sample of K–5th grade mathematics lessons.

Kindergarten: Time, Patterning, and Counting-on

Several content topics from the district's curriculum guide were included in this kindergarten lesson as the teacher strived to push students' thinking in ways that she felt would better prepare them for increasingly difficult state assessment tests. Activities based on telling time, creating patterns with blocks, and addition of whole numbers using a counting-on strategy were included along with a routine daily mathematics review of the days of the week, before and after, and place value.

The lesson began with an activity on time in which students were asked to show specified times using small paper clocks with movable hands. The daily mathematics review activity was next. Referring to a calendar that was hanging on the wall, the teacher asked students to name the day of the week for today, yesterday, and tomorrow and to say the day's date in unison. The class did a pattern of claps and snaps in unison as they went through the current month, giving a clap for every colored heart (days in school) and a snap for every clear one on the calendar (days not in school). The class then used straws and a place value chart to show the number of days they had been in school since the beginning of the year.

Working individually, students created patterns using whatever objects they chose from the manipulatives bin (e.g., bears, blocks, legos). The teacher then called for students to join her on the carpet. Together the students acted out an addition counting-on strategy that they had learned in an earlier lesson (i.e., 8 + 3 = ___ was acted out with "8 on the head and then 3 fingers up" and counting-on from 8). After they completed the addition activity, the teacher asked students to read a few sentences off a wall hanging, thereby signaling the end of the mathematics lesson.

Kindergarten: Comparing Lengths of Objects

This lesson focused on comparisons of lengths of objects and development of vocabulary related to comparisons (e.g., longest, shortest, between, order). The teacher supplemented the lesson from the textbook by reading the class a story related to this topic.

The students, sitting around the teacher, were led through several short activities that all involved comparisons of lengths of different objects: strips of paper, student height, and straws. For example, the teacher asked the students to look at three different lengths of paper strips and think about placing them in order by length. She asked the class to tell her which strip was the shortest, which was next, and which was the longest. The students called out the colors of the strips in order of increasing length. This same process was repeated as the teacher asked students of different heights to stand next to her. Following these two activities, the teacher read aloud *The Biggest Fish* by Sheila Keenan. In the book people from a small town were trying to make their town famous by catching the biggest fish. As the story progressed, each new person came with a bigger fish than the previous person. The children listened attentively as the teacher read the story.

Returning to the text activities, every student was given a bag containing an identical set of four straws of different lengths. The teacher asked them to decide which was the biggest or longest straw and to name its color. This was repeated until the straws were ordered from longest to shortest. The teacher asked questions focused on comparing the different lengths, "I want you to show me a straw that is shorter than your red straw and longer than your yellow straw and hold it up." The lesson ended as the teacher reminded the students of an activity in a previous lesson in which they had measured each other's feet and ordered them from shortest to longest and asked them to recall who had the longest foot and who had the shortest foot.

1st Grade: Addition Patterns

This 1st grade lesson on doubles occurred after the class had studied addition and subtraction facts to sum 12. The teacher stated that she adheres to the textbook ordering of topics, even though she thinks the text skips around a lot. She also references her lesson objectives to the state-mandated mathematics curriculum. Materials for this lesson came from the text and its supporting materials. Specifically, the teacher described the purpose of the lesson as teaching doubles facts and helping students see patterns in adding.

After a warm-up activity in which students were asked about the number of muffins that would fit in two, six-cup muffin pans, students were instructed to use a die to generate double facts. Every student rolled a die to get a number, wrote that number down, added the same number to it, and found the answer (e.g., if a 4 was rolled on the die, the number sentence 4 + 4 = 8 was written). For each of the six possible double facts, the teacher selected a student to write the equation on the board and to read the equation aloud to the class.

The teacher distributed a textbook enrichment activity worksheet containing six word problems (e.g., "My double is between 5 and 7. What number am I?" and "The parrot picks six nuts. Then he picks 6 more. How many nuts does he pick?"). The teacher read each problem aloud and worked it for the students. Students were given another worksheet to complete as independent practice and to place in their folders when finished. The final activity in this lesson was a game of math BINGO in which BINGO cards had an addition fact problem in each square (e.g., 5 + 5 = ___); students covered a square on the BINGO card as the matching sum was called.

1st Grade: Creating Bar Graphs

The purpose of this fourth lesson in a week-long unit on graphing for 1st graders was to provide students with practice activities related to graphing, including using tally marks as a record-keeping method and interpreting graphs. The teacher selected these topics for the lesson for three reasons: they are part of the district curriculum, they are included in the district's adopted mathematics program, and the teacher feels that graphing provides a nice change for students since it follows "harder units" on addition and subtraction. Although the teacher felt pressured by the district to use the textbook materials as prescribed in the teachers' manual, she did augment the lesson with a whole-class graphing activity before assigning the textbook-designated individual task.

The teacher modeled the graphing activities for the whole class. Students were asked the question, "What do you like to draw?" The teacher used tally marks to record students' responses and then asked a series of questions (e.g., "Which picture is drawn the most?" and "Which had less—ducks or fish?"). Next the teacher helped students form "human graphs" based on attributes of hair color, eye color, and favorite weekend activities. Students were then asked a series of questions that required them to interpret the graphs they created.

After practicing these graphing activities, the students returned to their desks and began working on the textbook-defined individual activity. In this activity students were asked to record the names of six pre-selected activities in the first column of the table on the worksheet and then to tally the responses from their classmates in the second column. The students were then asked to translate the tally marks into a bar graph, showing only the four activities with the most tally marks, and to answer questions based on their bar graphs (e.g., which activity was liked most, which activity was liked least, what would happen to the graph if building a snowman was added to the list). During the last segment of the lesson, groups of students rotated through five mathematics centers in order to practice skills, including addition facts, place value, and number recognition, using computer software and manipulatives.

2nd Grade: Addition of Two-Digit Numbers

Two sets of mathematics instructional materials were being used in this classroom—a traditional textbook series and specific units from an investigative mathematics series that was being piloted in the district. Prior to this lesson, the 2nd grade class had completed the addition/subtraction unit from the set of investigative materials. As part of the unit, students had invented a variety of algorithms for adding and subtracting two- and three-digit numbers. Students' poor standardized test results following the teaching of that unit led the school's 2nd grade teachers to decide that they should teach the traditional algorithms. The purpose of this lesson was to teach students the traditional addition algorithm and to provide students with the opportunity to practice the algorithm in a game setting.

The lesson began with a "Problem of the Day" in which students were asked to reason about how many apples were in a mystery bag on one side of a see-saw given information about what was on the other side; this problem was unrelated to the major content focus of the lesson. The students seemed to enjoy having the opportunity to explain the reasoning processes they used in solving the problem.

The teacher introduced students to a game from the traditional textbook series, "That's Sum Toss," and using the overhead projector she modeled a complete game. In the game, each player was to roll a pair of dice, write the larger of the two, two-digit numbers that could be written with the numbers represented on the top faces of the dice (e.g., 41 rather than 14), repeat with a second roll, and use the traditional addition algorithm to add the two numbers. Working in table groups, players were instructed to generate their own numbers and to keep a running total until they reached the total sum of seven, two-digit numbers. The object of the game was to be the player with the highest total sum. As the teacher modeled a complete game, she demonstrated the traditional algorithm for each sum. The teacher emphasized that students must start by adding the numbers in the ones place and move to the left. No mention was made of how the traditional algorithm related to algorithms the students had invented as they had done the investigative mathematics unit.

Initially, as they played the game in table groups, students either worked together on an addition problem or a student would do an addition problem for another student. Students at one table used calculators rather than the algorithm. As students finished getting their total sums, they worked independently on the exercises printed on the back side of the game recording sheet and, as time allowed, completed other worksheets that had been distributed during an earlier lesson. Students who were struggling with the algorithm (approximately one-third of the class) were then left to complete the game by themselves. When the teacher called time, two students were still playing the game and a few students had completed everything and were working on an assignment for another subject. The teacher ended the lesson by asking who had gotten the highest game total and by doing a quick discussion of the "challenge problem" on the back of the game recording sheet ("Find a number between 121 and 125 which, when you add 100 to it, results in a number with all three digits the same.").

2nd Grade: Subtraction Facts

The lesson, which occurred near the end of a 2nd grade unit on subtraction, was intended to extend students' knowledge of and facility with subtraction facts. It addressed two practice worksheets from the textbook resource materials that had been assigned for homework during the previous class. The first worksheet directed students to solve two word problems by using pictures as a solution strategy (e.g., "Use the number card pictures to solve the problem. Blaine had a birthday. How old was he? You say the number when you count by 3s. It is greater than the difference between 16 and 9. It is less than the difference between 12 and 1."). The second worksheet asked students to write an addition or subtraction number to go with each of six situations (e.g., "Cornelius has 13 crackers. He eats 7. How many crackers does he have now?"). The teacher began this lesson by asking students which homework problems gave them the most trouble. The problem that caused trouble for most of the students was the "Blaine's age" problem from the first worksheet. The teacher gave a step-by-step explanation of the solution to this problem and then she collected the homework.

The teacher did a brief introduction to the topic of subtracting numbers up to fourteen and gave students two minutes to think of as many number expressions as they could that equal fourteen. She listed the number expressions on the board as the students said them aloud. She asked the class questions about the number expressions they wrote (e.g., "How did you come up with 23 – 9?" and "How could you change 23 – 9 to get 25 – 11?"). The teacher asked students to open their mathematics workbooks to two pages that contained twenty-three exercises, seventeen of which were basic addition and subtraction fact problems (e.g., 14 – 9; 5 + 6). The teacher demonstrated how the first two exercises should be solved using the solution method presented in the textbook. Giving them the option of working individually or in pairs, the teacher instructed the students to complete the two workbook pages; most of the students chose to work alone. Students were allowed to use cubes and "Touch Math" to determine answers. The teacher circulated around the room, observing students' work but interacting with students only when a student asked her a question. Students who finished early were not given anything else to do. The lesson ended as the teacher began a lesson in another subject area.

3rd Grade: Fractions

This 3rd grade lesson on fractions was based on a lesson in the district-designated textbook series. The teacher taught the lesson as designed, alternating between whole class discussions/demonstrations and tasks which students completed independently.

To begin the lesson, the teacher asked each student to scoop up two handfuls of pattern blocks from a large bin. After the students had played freely with the blocks for ten minutes (creating large and sophisticated arrangements and complex sequences of colors and shapes), the teacher asked the students to separate the yellow, red, blue, and green blocks from the rest of the blocks and to put the other blocks back into the original pattern block bin. Using the textbook lesson script, the teacher led the students through an exploration of the fractional relationships of the red, blue, and green pieces (parts) relative to the yellow piece (whole). Throughout this segment of the lesson, the teacher talked about the colors of the blocks but not the shapes (e.g., ½ of yellow is red; $^1/_3$ of yellow is blue; $^1/_6$ of yellow is green). At the end of the exploration the teacher summarized their findings, "The red is ½, the blue is $^1/_3$, the green is $^1/_6$," without any discussion of the "whole." Next the teacher asked students to hold up pattern block pieces that show 1½ (1 yellow and 1 red), 2½ (2 yellow and 1 red), and 3½ (3 yellow and 1 red).

The teacher distributed a worksheet that had eight separate hexagons drawn on it; each hexagon was the same size as a yellow pattern block piece. Students were assigned the task of covering each hexagon on the worksheet with any combination of red, blue, and green blocks. For each arrangement, they were asked to (a) trace the blocks used in covering the hexagon and to color each region the same color as the block that had covered the region and (b) write a number sentence corresponding to the arrangement. The teacher demonstrated the task on the overhead by placing one red, one green, and one blue block on a hexagon and writing the number sentence $½ + ^1/_6 + ^1/_3 = 1$. Students worked individually on this task until the end of the class.

3rd–4th Grade: Long Division

The lesson for this class of 3rd and 4th graders focused on introducing students to the traditional long division algorithm and to related vocabulary (i.e., divisor, dividend, quotient, and remainder). The teacher taught this lesson because division with remainders was a content topic found on the district's list of core concepts. The design of this lesson was based on the teacher's belief that manipulatives are an important component of instruction, and her perception that students need to have a lot of experience with mathematical procedures.

The teacher began the lesson by giving each student in the class a bag of M&Ms. Together the class modeled five problems using the M&Ms (e.g., "Count out 29 M&Ms. How many groups of 4 can you make?"). For each problem the teacher demonstrated the traditional long division algorithm, step-by-step, emphasizing the sequence of steps—divide, multiply, subtract.

The teacher told the students to put the M&Ms away, and she gave each student a worksheet and a multiplication basic facts table. The teacher showed how the multiplication table could be used to get the quotient for a division problem. The class worked the first three problems on the worksheet together, with the teacher asking the same set of questions for each problem (e.g., "Where do we put the divisor?" and "What do we do next?"). When one student found the remainder first (i.e., subtracted the closest multiple of the divisor from the dividend first, then determined the quotient), the teacher quickly told him that he was skipping the "divide" step in the divide/multiply/subtract procedure. When several students tried to use mental strategies, the teacher insisted that they adhere strictly to the designated sequence of steps. The teacher assigned the remainder of the worksheet problems for independent practice.

4th Grade: Creating Bar Graphs

This 4th grade lesson on graphing was a continuation of a textbook activity begun the previous day. The teacher modified the textbook-described lesson in ways that she thought would make the lesson more appropriate for her class of low-achieving students. She simplified the procedure so that students would be constructing single bar graphs instead of double bar graphs, and, because she believes that computer use is an important skill for students, she added a computer-graphing component to the textbook lesson.

The teacher began the lesson with two "problems of the day" (e.g., "My product is 48. If I add them it will be 14. If I subtract them it will be 2. Who am I?"). Students worked independently on the two problems while the teacher gave them words of encouragement but no assistance in obtaining answers. As students successfully completed the problems, the teacher rewarded them with praise and candy.

Each student was then instructed to return to the activity began during the previous lesson—starting from where they were, individually, at the end of that class. In this activity students worked independently to collect data (i.e., count how may drops of water could fit on a penny, nickel, dime, quarter, half-dollar, and dollar coin), to enter the data into an Excel spreadsheet and produce a bar graph, and to construct a bar graph by hand on a large piece of chart paper. Throughout the lesson the teacher's attention was on keeping students focused and providing students with instructions on what to do next. Although students were at different phases of the activity, the teacher decided to call them together midway through the class to give instructions for making bar graphs by hand. She showed them how to set up the graphs, recommending but not requiring a vertical interval of 10. She drew a sample graph on the overhead projector to demonstrate how to label a bar graph. At this point in the lesson, two students were still collecting data, two were working on computers, and four were working on their by-hand graphs. Near the end of the class period the teacher engaged students in a discussion that focused on reasons why the data varied (e.g., why one student got 23 drops of water on a penny and another student was able to get 26 drops on it). The teacher ended the lesson by saying, "Finish up what you're doing. We'll look at what you've done and then work on line graphs tomorrow."

4th–5th Grade: Constructing Rectangles with Specific Areas

The teacher indicated that the purpose of this lesson was "to help students understand what area is and to also reinforce the formula of how to find the area." More specifically, this lesson for 4th and 5th grade low-achieving students was designed to show students how they can construct rectangles that have specified areas. The teacher stated that she chose this content for the lesson because (a) it is listed in the state mathematics standards, (b) she and the two other teachers at her grade level, collectively, planned for these two weeks of instruction on area, and (c) she felt that her students needed more practice with finding areas of rectangles and that they especially needed a more hands-on approach than she had used in introducing the concept in the previous lesson. (In the previous lesson the teacher introduced the concept of area using worksheets and she "went over" the formula for calculating areas of rectangles.) The teacher stated that she never uses the designated textbook because she prefers to select activities from her collection of resource materials.

As a warm-up activity, each student was given a sheet of paper and asked to complete the four number sentences shown on the overhead (98 – 39 = ___; 80 – 59 = ___; 8 × 4 = ___; and 56 × 3 = ___). The teacher collected the students' papers and graded them before continuing with the lesson.

The teacher then led a brief whole-class discussion that was designed to recap the previous lesson on areas of rectangles. During this discussion, students talked about "counting boxes inside rectangles" and using the length and width of rectangles to find areas. Next the teacher described the activity she wanted the students to work on for the remainder of the lesson; the worksheet used in this activity was copied from one of the teacher's many resource books. Students were told to use centimeter grid paper, scissors, and crayons for the activity. Their task was to cut out 20 squares (1 cm x 1 cm), color each square, and glue squares on a piece of construction paper to form two different rectangles. Students were told that they could make rectangles having areas of 8 cm^2, 12 cm^2, 16 cm^2, 18 cm^2, or 20 cm^2. The teacher explained what 1 cm by 6 cm and 2 cm by 3 cm rectangles would look like; she modeled these two rectangles on construction paper and hung the model beside the overhead projector to serve as an example of what the students were being asked to do. Students worked independently on the task for the remainder of the class period. Two minutes before the end of class only a few students had formed rectangles with their squares and several students were still cutting out squares. The teacher told the students to put all the materials away and return to their respective classrooms.

5th Grade: Improper Fractions and Mixed Numbers

The teacher stated that the purpose of this lesson for 5th grade low-performing students was "to make sure students could find equivalent fractions and change improper fractions to mixed numbers and vice versa." He considered this mathematics content to be important because, according to the state curriculum framework, this content is to be mastered by all 5th grade students and because the state's 5th grade mathematics test contains many items on fractions. The design of the lesson was based on the teacher's belief that students need to review skills and facts daily and that an oral presentation of material is the most meaningful way to teach the children.

The lesson began with a 40-minute, whole-class, mixed review. During this segment of the lesson, the teacher asked questions about the metric system; the meaning of base 10; place value; multiplication; division; fractions; decimals; mixed numbers; improper fractions; fraction names for one; equivalent fractions; simplifying fractions; divisibility rules for 2, 3, 5, and 10; writing numbers in base 5 and base 3; place value in these two bases; changing mixed numbers to improper fractions; defining fractions as division; real-world occupations that use fractions; comparing fractions using cross multiplication, common denominators; and changing a fraction to a decimal and then to a percent. The review was almost totally an oral review. Students had no paper, pencils, worksheets, or text, and the teacher wrote very little on the board. The same group of students repeatedly volunteered answers while the rest of the students were quiet.

For the remainder of the lesson students worked independently on four worksheet pages; the problems on these pages required that students convert mixed numbers to improper fractions and convert improper fractions to mixed numbers. As the students worked on the assignment, the teacher worked at his desk unless a student asked a question. When one student asked the teacher for help in converting $1^1/_3$ to a mixed number, the teacher responded with a series of instructions (i.e., "What division problem does $1^1/_3$ represent?... No, switch the numbers around, read from top to bottom... Okay, now write the division problem... Now, do the division."); the teacher pulled out a bag of chips and told the student to use the chips to do the division. Students continued to work on the worksheets until the class ended.

5th Grade: Problem-Solving Strategies

This was a stand-alone lesson on problem solving that was embedded in a textbook unit on multiplication of decimals. The purpose of this lesson was to give the class of 5th graders opportunities to apply previously learned problem-solving strategies to a set of textbook word problems. The teacher admitted that she did not like interrupting the flow of the syllabus to teach a lesson on problem solving, but she did so because that was what was in the textbook. The pedagogy she implemented was based on her belief that students work better in groups than on their own.

The lesson began with a teacher-led discussion of problem-solving strategies that the class had used in previous lessons. Students named several strategies (i.e., making charts, making tables, estimating, working backward, and guess and check). The teacher worked through a problem example with the students, using charting as the selected problem-solving strategy, and then divided the class into groups of three and assigned each group one problem from the set of problems in the textbook lesson. Students were told that they would be asked to explain the solution to the problem to the large group and that each member of the group should be prepared to answer any questions the large group might ask about the solution. While students worked on their assigned problem, the teacher circulated among the groups. When a group seemed stalled, she asked questions to redirect their thinking. Sometimes the teacher's question pointed out a piece of information the group had failed to include in its thinking (e.g., "How many feet are in a yard?"). At other times, the teacher's question asked the students to think about the problem in a different way (e.g., "Have you considered using 'guess and check' to solve this problem?").

When the groups had finished, each group took a turn at the blackboard describing the problem situation and displaying their solution on the board. Students at their seats asked questions about the displayed solutions and also copied the work from the board into their notebooks. At the end of the presentations, the teacher asked the students to consider all the different problem-solving strategies the groups had used. A student asked a question about how to choose a good way to solve a problem. The class discussed this for a few minutes but did not arrive at a definitive answer.

In the last segment of the lesson, students were assigned a group of textbook practice problems related to the multiplication of decimals. They were given the choice of working together or working alone; individuals and groups of students worked on the assigned problems until the end of the class period.

Ratings of Lesson Components

The designs of elementary mathematics lessons are, on average, most highly rated for utilizing the available resources to accomplish the purpose of the lesson and for reflecting careful planning and organization. Elementary mathematics lessons are rated lowest in encouraging collaboration among students and for providing students with the time and structure needed for sense-making and wrap-up. The relatively low ratings in these areas may explain why over twice as many lessons receive low synthesis ratings for their design than high ratings (39 percent and 18 percent, respectively).

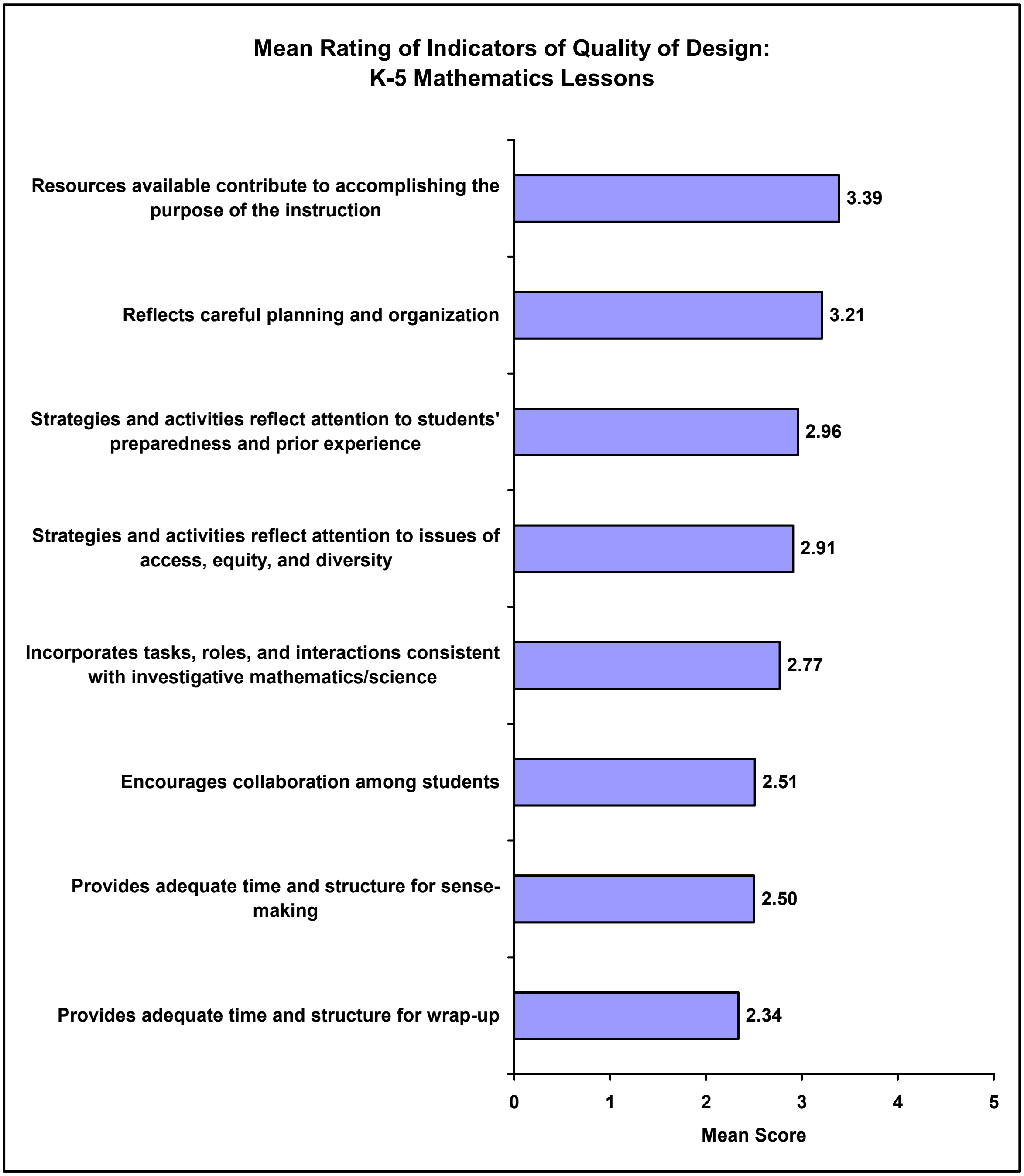

Mean Rating of Indicators of Quality of Design:
K-5 Mathematics Lessons
Resources available contribute to accomplishing the purpose of the instruction
3.39
Reflects careful planning and organization
3.21
Strategies and activities reflect attention to students' preparedness and prior experience
2.96
Strategies and activities reflect attention to issues of access, equity, and diversity
2.91
Incorporates tasks, roles, and interactions consistent with investigative mathematics/science
2.77
Encourages collaboration among students
2.51
Provides adequate time and structure for sense-making
2.50
Provides adequate time and structure for wrap-up
2.34
0
1
2
3
4
5
Mean Score

Figure C-1

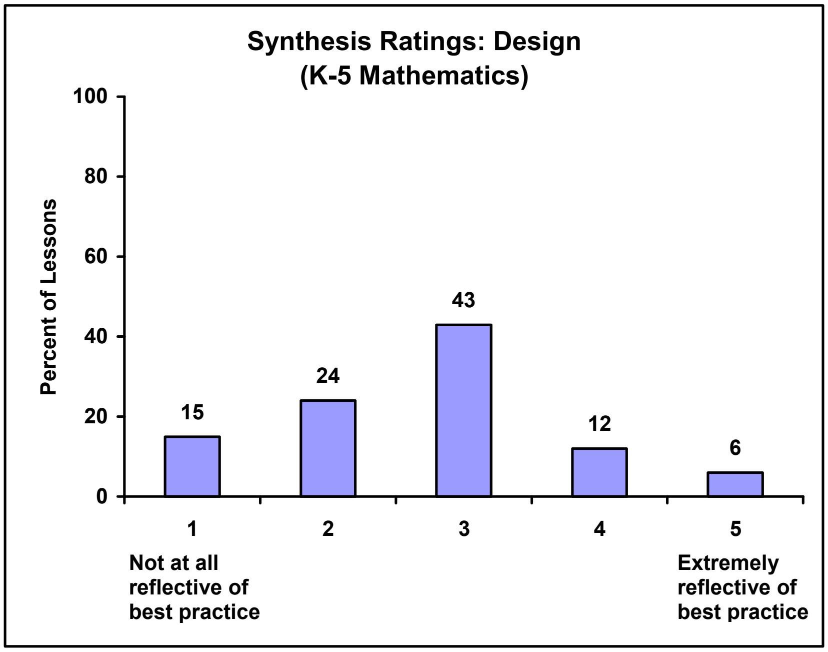


Figure C-2

The implementation of elementary mathematics lessons is rated most highly for teachers' confidence in their ability to teach mathematics. Lessons are relatively strong in regards to teachers' classroom management as well. However, lessons are weaker in terms of pacing (moving either too quickly or too slowly), using instructional strategies consistent with investigative mathematics, and adjusting instruction according to the level of student understanding. Asking questions that enhance student understanding is the weakest element of elementary mathematics lessons. These low ratings are reflected in the implementation synthesis ratings. Forty-six percent of lessons receive a low rating for implementation, while only 17 percent receive a high rating.

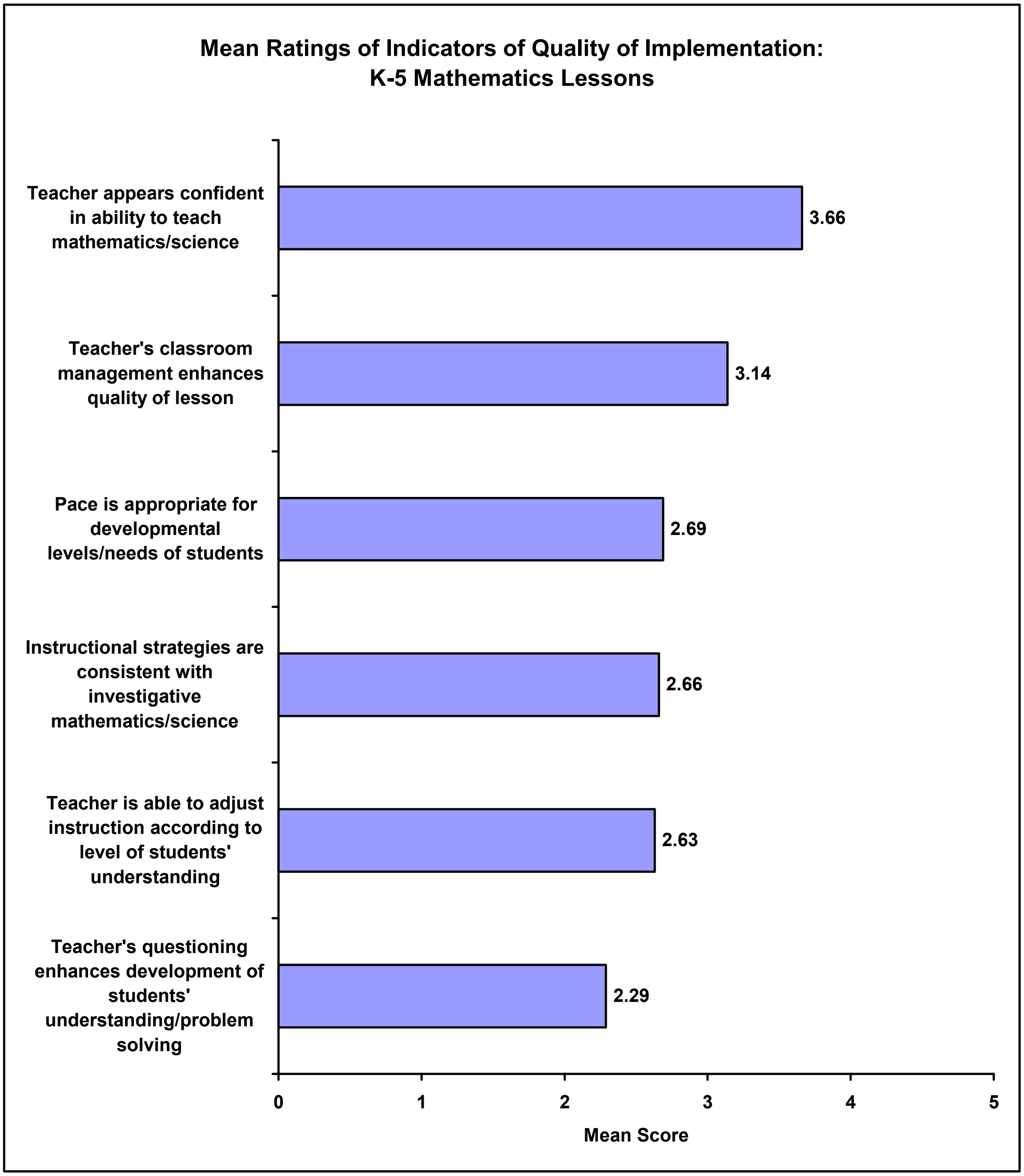

Mean Ratings of Indicators of Quality of Implementation:
K-5 Mathematics Lessons
Teacher appears confident in ability to teach mathematics/science
3.66
Teacher's classroom management enhances quality of lesson
3.14
Pace is appropriate for developmental levels/needs of students
2.69
Instructional strategies are consistent with investigative mathematics/science
2.66
Teacher is able to adjust instruction according to level of students' understanding
2.63
Teacher's questioning enhances development of students' understanding/problem solving
2.29
0
1
2
3
4
5
Mean Score

Figure C-3

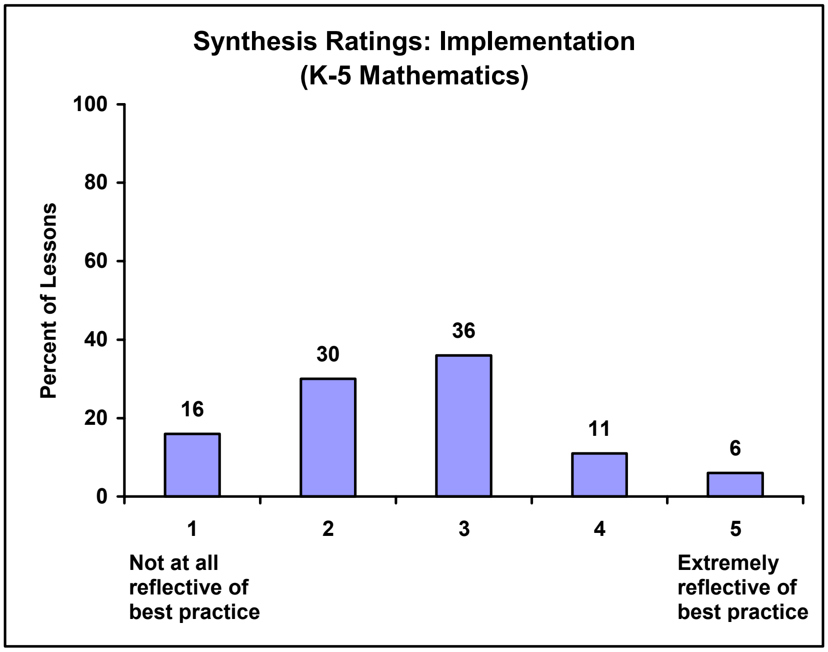


Figure C-4

The content of elementary mathematics lessons is, on average, rated highest for focusing on significant and worthwhile content and doing so accurately. Lessons are weak in engaging students with the content in a meaningful way, portraying mathematics as a dynamic body of knowledge, and providing opportunities for students to make sense of the content. Twenty-five percent of lessons receive a high synthesis rating for content, 34 percent receive a medium rating, and 40 percent receive a low rating.

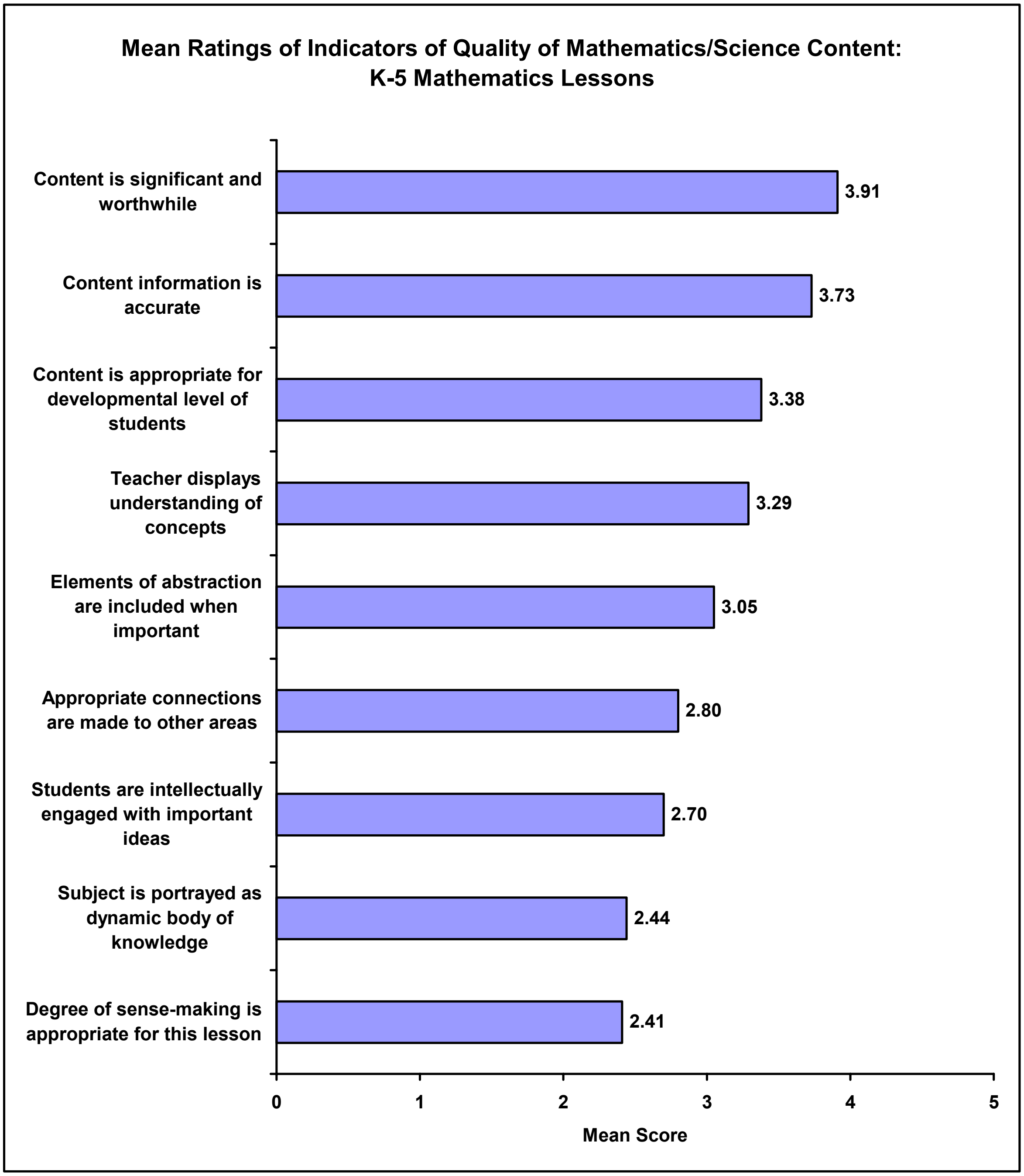

Mean Ratings of Indicators of Quality of Mathematics/Science Content:
K-5 Mathematics Lessons
Content is significant and worthwhile
3.91
Content information is accurate
3.73
Content is appropriate for developmental level of students
3.38
Teacher displays understanding of concepts
3.29
Elements of abstraction are included when important
3.05
Appropriate connections are made to other areas
2.80
Students are intellectually engaged with important ideas
2.70
Subject is portrayed as dynamic body of knowledge
2.44
Degree of sense-making is appropriate for this lesson
2.41
0
1
2
3
4
5
Mean Score

Figure C-5

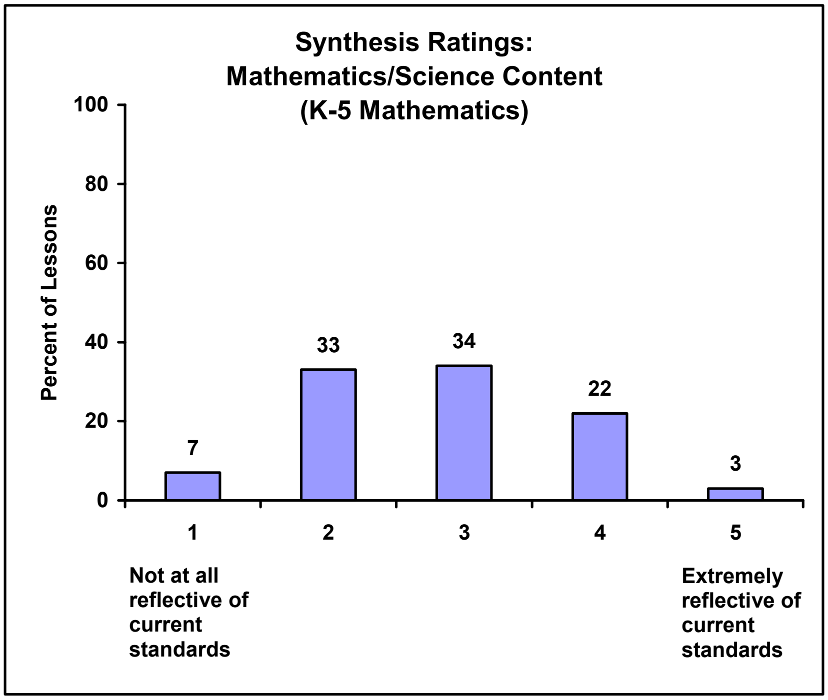


Figure C-6

The strongest aspect of classroom culture is the encouragement of active participation of all students. Although lessons are rated relatively highly for having a climate of respect for students' ideas, questions, and contributions, lessons are weak in encouraging students to generate ideas and questions. Further, lessons are weakest in their level of intellectual rigor. The synthesis ratings for classroom culture reflect these indicators with 19 percent of lessons receiving a high rating, 47 percent receiving a medium rating, and 33 percent receiving a low rating.

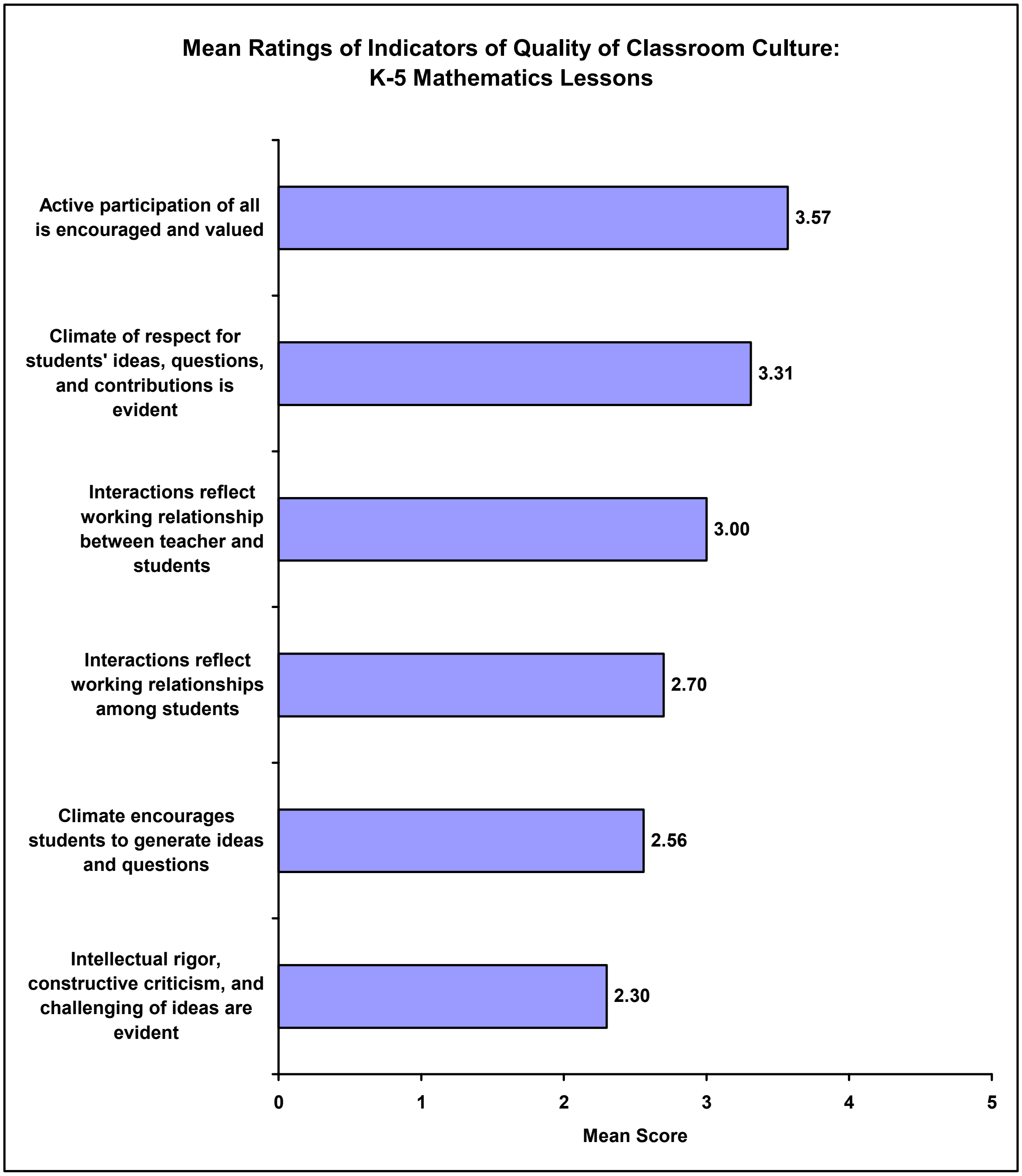

Mean Ratings of Indicators of Quality of Classroom Culture:
K-5 Mathematics Lessons
Active participation of all is encouraged and valued
3.57
Climate of respect for students' ideas, questions, and contributions is evident
3.31
Interactions reflect working relationship between teacher and students
3.00
Interactions reflect working relationships among students
2.70
Climate encourages students to generate ideas and questions
2.56
Intellectual rigor, constructive criticism, and challenging of ideas are evident
2.30
0
1
2
3
4
5
Mean Score

Figure C-7

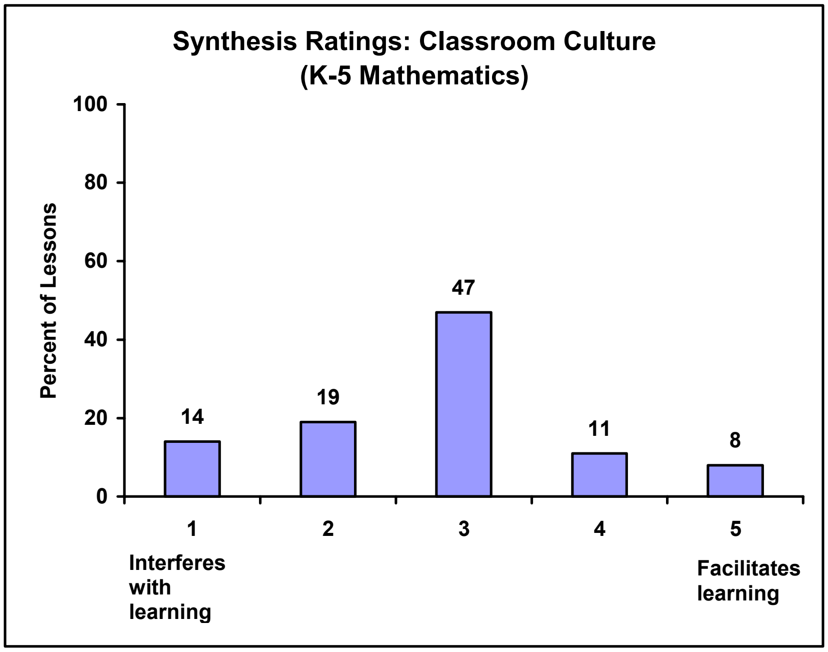

Synthesis Ratings: Classroom Culture
(K-5 Mathematics)
Percent of Lessons
100
80
60
40
20
0
14
19
47
11
8
1
2
3
4
5
Interferes with learning
Facilitates learning

Figure C-8

Overall Lesson Quality

Following the ratings of the individual components of the lesson, the researcher was asked to consider the likely impacts of the lesson as a whole. Forty-three percent of lessons or fewer have positive impacts on students' confidence to do mathematics, interest in the discipline, understanding of important mathematics concepts, or ability to apply the skills and concepts they are learning to other disciplines or real-life situations. (See Table C-1.)

Table C-1
Likely Impact of the Lessons: Mathematics K–5

	Percent of Lessons		
	Negative Effect	**Mixed or Neutral Effect**	**Positive Effect**
Students' self-confidence in doing mathematics/science	20	37	43
Students' interest in and/or appreciation for the discipline	23	34	43
Students' understanding of important mathematics/science concepts	14	48	39
Students' understanding of mathematics/science as a dynamic body of knowledge generated and enriched by investigation	22	43	35
Students' ability to apply or generalize skills and concepts to other areas of mathematics/science, other disciplines, and/or real-life situations	11	57	32
Students' capacity to carry out their own inquiries	20	49	30

Figure C-9 shows the percentage of K–5th grade mathematics lessons in the nation rated at each of a number of levels. (See page 9 of the Observation and Analytic Protocol in Appendix A for a description of these levels.) Forty-five percent of elementary mathematics lessons are rated as low in quality on the capsule rating, 37 percent are rated as medium in quality, and 18 percent are rated as high in quality.

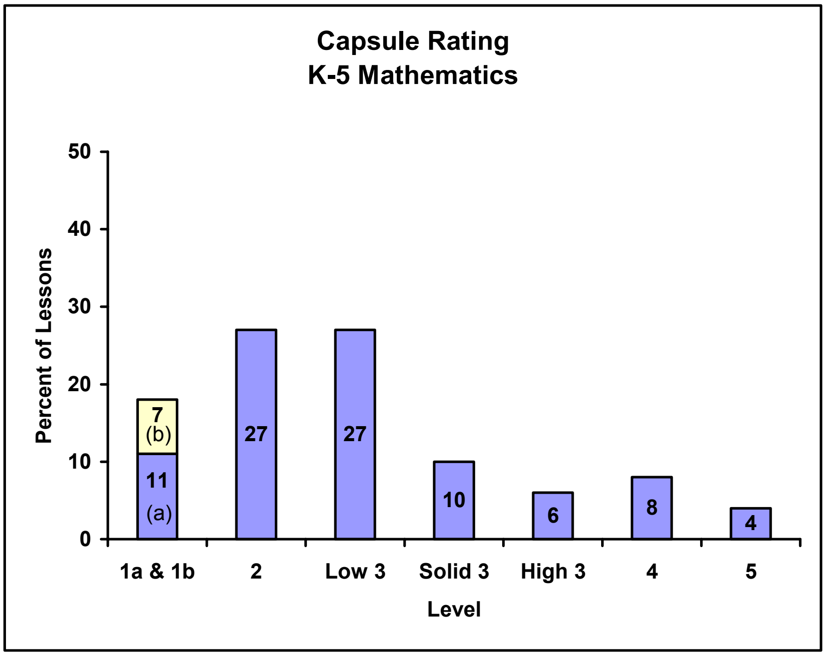


Figure C-9

The following illustrate lessons that were rated low, medium, and high in quality.

Sample Low Quality Lesson: Passive "Learning"

The teacher explained that the purpose of this 5^{th} grade lesson was to help students better understand equivalent fractions and how to change improper fractions to mixed numbers.

The lesson started with the students participating in an oral exercise directed by the teacher. The exercise involved the teacher asking a series of questions across a very broad range of concepts. Most of the questions appeared to focus on previously learned facts, vocabulary terms, and basic operational skills, e.g., "What's the operation represented by a fraction?" and "How do we change a mixed number to an improper fraction?" Some questions asked during this part of the lesson appeared to be unrelated to the overall goal of the lesson or not well thought out. For example, the teacher asked students how to write numbers in base ten and base five. A few students volunteered answers repeatedly, while many others sat silently through the discussion.

As the teacher explained strategies to solve different problems during this oral exercise, often times his explanations were confusing. For example, one of his questions asked students to compare $^1/_5$ to $^1/_3$ and identify the sign that would separate the two quantities. In response to the teacher's question, students suggested using the less than sign and mentioned the process of cross multiplication as a means of checking to see if the symbol was correct. In following the students' thinking, the teacher proceeded to demonstrate how the process of cross multiplication could be used in this case. He multiplied 5×1 and 3×1 and wrote 5 ___ 3. The teacher then summarized the process saying, "Since 5 is greater than 3, then $^1/_5$ is less than $^1/_3$." The explanation appeared to confuse many.

Another student suggested division as a way of determining which fraction had greater value, to which the teacher responded by walking the class through the process of changing both fractions to decimals. However, upon completion of the conversions, he failed to go back and connect what this process had to do with comparing the two fractions. Instead, he launched into a discussion of how $^1/_3$ is a repeating decimal and could be written as $33^1/_3$%. The explanation went as follows: "Well, since you are dividing 100 by 3, the closest you get to 10 is 9, with a remainder of 1. So the 1 becomes $^1/_3$ or you could continue dividing and get 33.3333….You wouldn't have enough paper to carry it out, so we use the fraction form. We carry out the division to two decimal places and then use a fraction." Throughout this explanation there was nothing written on the board, nor was there anything available to help students make better sense of what was being said.

This whole group discussion lasted roughly 40 minutes with the teacher presenting information that was incomplete, confusing, or likely to foster misconceptions. Following the discussion, the teacher had students work individually on a practice worksheet for the remaining 15 minutes in the class period. Overall, the lesson did very little to help students deepen their knowledge of equivalent fractions or converting improper fractions to mixed numbers.

Sample Low Quality Lesson: "Activity for Activity's Sake"

In the prior lesson for this 4th and 5th grade class, students discussed the concept of area and were introduced to the formula of length times width. The observed lesson was designed to build on this experience by having students use manipulatives to represent area and, in the process, develop a deeper understanding of the concept.

The lesson began with a warm-up activity involving four basic computation problems written on the overhead: 98 – 39; 80 – 59; 8 × 4; 56 × 3. After students were given time to solve the problems individually, the teacher called on students to walk her through the answers. As correct answers were provided, the teacher wrote them on the overhead. However, her questioning strategies were limited and highly directed toward getting students to say the correct answers. Her answers to students' questions were similarly brief and did very little to help students make sense of the errors being made. Upon receiving answers to the four problems, the teacher abruptly moved to the "main lesson" for the day, without mention of how, if at all, the warm-up problems related to the topic.

The teacher started this activity with a brief recap of the prior lesson's discussion of area. She proceeded to read through the directions as they were printed on the handout, warning the students that they needed to pay attention because the directions contained several steps and were complex. The activity involved students cutting out twenty, 1 cm by 1 cm squares, coloring them, and then gluing them onto a piece of construction paper to form different rectangles. The worksheet specifically asked students to create two rectangles for each of a number of different areas, such as 8, 12, 16, 18, and 20 square centimeters.

To further orient the students to the task, the teacher demonstrated the process for an area of 6 square centimeters by forming a 1 × 6 and a 2 × 3 rectangle and hanging her paper by the overhead as an example. She then quizzed the students on the steps to take before finally giving students the opportunity to work on the activity themselves.

With roughly 20 minutes of class time remaining, the students began cutting out squares. During this time, the teacher moved about the classroom and answered questions individually. Most of these questions were about the procedures students were supposed to follow, as opposed to the concept of area. For example one student asked, "Do we color the squares now, or glue them to the paper and then color them?"

With two minutes remaining, the teacher instructed the students to clean up, and the lesson ended without any time being dedicated to making sense of the mathematics. In fact, only a handful of students actually started to address the mathematics, with others still cutting and coloring the squares.

Although understanding area is a reasonable expectation for students at this level, the teacher spent more time having students understand the steps to creating manipulatives rather than actually using the manipulatives to deepen their understanding of area. The lesson likely confused students, and helped perpetuate the myth that mathematics is about strict procedures that need to be followed.

Sample Medium Quality Lesson: Beginning Stages of Effective Instruction

The lesson in this 2nd grade class focused on getting students to visualize addition and subtraction story problems by acting them out, then drawing "cartoon" representations of them, and then representing them with a number sentence. The teacher began the lesson by telling students to look at the calendar on the bulletin board. (This was a large, brightly colored calendar with numbers and days of the week that everyone could see from a distance.) She spent the first few minutes asking rapid-fire questions about the calendar and other mathematics displays (e.g., the day of the week, the time of day, how many days until the weekend, etc.). Students eagerly answered the questions (e.g., "What is the third day of the week?" "How many more [birthdays are there] in November than in April?" "What is one less than thirty-six?"). Students went to the board as called upon to manipulate the clock to the time the teacher requested or to point to numbers as the group counted forward and backwards out loud.

Following the "math meeting," as the teacher called this portion, the lesson was introduced when the teacher reminded students of "some, some more" stories from previous mathematics lessons. She called four children by name to come forward to stand in front of the class while she said, "Four children went to the mall." She then called three more names and these students came forward as she remarked, "Three more children joined them. How many are at the mall now?" Next, students acted out a "some, some went away" story.

The teacher explained that these stories couldn't always be acted out, so they would need to draw the problem on the board or on their paper. She recited a problem from the curriculum. ("Darlene went fishing with her sister. She caught two fish in the morning. In the afternoon she caught three fish.") The teacher drew simple fish shapes on the board and asked the children to classify this problem ("some, some more" as opposed to "some, some went away"). And she asked a volunteer for a number sentence to describe the problem.

In the next three examples, students came forward to draw the objects in the word problems (pencils, chickens, eggs, etc.). Other students were asked to supply number sentences. When a student supplied the wrong answer, the teacher questioned further (e.g., "A minus sign? Are we taking away?" or "Is there a three up there? You need to pay attention.").

With no real wrap-up, the students were next given a worksheet containing 25 addition problems to test their proficiency with "plus-two" facts. The students were clearly familiar with this drill of doing as many problems as they could in one minute. They began working excitedly when the teacher said, "On your mark, get set, go." After one minute, children pulled out colored crayons to correct their work. The teacher read each problem and called out the answer while students marked their papers. She then asked for a show of hands to see how many students scored more than 15 correct, and then who had all 25 correct. The last part of the lesson was spent with the children completing a worksheet. The reverse side of the worksheet contained similar problems that were to serve as homework for the evening. The lesson ended, and the teacher instructed students to get out their language notebooks.

The teacher emphasized drill and repetition in the use of the mathematics meeting and the worksheets. Connections to daily life were obvious during the "math meeting" as they talked about the calendar and in the story problems that students did at the board. The teacher made it very clear that she expected the participation of all and made a point of calling on nearly every child at least once during the lesson. She seemed to call on them with tasks that they could do, for the most part. Though she kept them "on their toes" with rapid questioning, the questions were nearly all directed towards getting the right answer, rather than sharing their thinking, and she sometimes short-circuited by letting another student supply an answer instead of letting the first student grapple with the mathematics.

Sample High Quality Lesson: Traditional Instruction

The goal of this 2nd grade lesson was to strengthen students' ability to count money. Students had already learned how to count money using pennies, nickels, and dimes; today's lesson focused on counting quarters.

The lesson began with a 20-minute review where students were seated on the carpet in an area of the classroom away from their desks. During this time, the teacher reviewed a broad variety of skills, including some that had connections to science, such as reading a thermometer and completing a weather graph. The teacher used a variety of visual aids such as real money, color tiles, and erasable pens for marking on a bulletin board graph.

The variety of activities maintained student interest. Questions like, "What are some different ways to make $0.66 with coins?" encouraged a number of different student responses. In addition, questions like "What are some different number sentences that will make 23?" encouraged students to invent number sentences such as "23 × 1," "23 + 0," and "10 + 13." Students had many opportunities to write on the bulletin board, write on the white board, and manipulate money and color tiles. At the close of the review, the teacher had students participate in a skip counting exercise as they returned to their desks.

The teacher then began to present the new material on counting quarters, asking students to compare different numbers of quarters to one dollar, to count by 25, to tell how much 7, 5, or 9 quarters equals, and to tell how many quarters were in different dollar amounts, such as $2.25. Symbols and drawings were effectively used to connect these oral responses, and the teacher's questions did a fine job of challenging students' thinking. Questions included: "What is ¾ of a dollar?" and "How many quarters make $1.25?" The teacher also used tiles to aid students' counting and a drawing to relate fourths to quarters in a dollar.

Approximately five minutes were spent at the end of the lesson on a subtraction fact review. Pairs of children reviewed basic subtraction facts at different places in the room while the teacher walked around to check their progress.

The teacher used the script and materials provided by the textbook to implement this well-paced and well-organized lesson on counting money. The teacher guided the entire lesson, so there were no opportunities for student-initiated investigation. However, the variety of instructional strategies provided many opportunities for students to explore the concept of counting money in different ways, and the teacher built in adequate time for processing and sense making. Throughout the lesson the teacher maintained focus on the content goals and incorporated challenging questions that maintained intellectual rigor. The lesson was highly likely to strengthen students' ability to count money.

Sample High Quality Lesson: Reform-Oriented Instruction

This 3rd grade class had recently finished studying congruency and symmetry. This lesson focused on coordinate geometry in the first quadrant. The teacher stated that the purpose of the observed lesson was to get students to be able to read a graph using coordinate pairs and to know how to find a specific point in the first quadrant.

The teacher introduced the topic for the day by relating the content of the coordinate system to students' prior work with mapping and directions. To help make the comparison more real, she asked all the students to close their eyes and began to talk through an example to show how following specific directions leads to an exact spot. She stated, "Go out this door. Turn right. Go through the double set of doors. Go a few feet further. Whose room is to the right?"

The class in unison yelled the name of the teacher who teaches in that room. She gave another similar example, and students once again in unison called out the location. She then smoothly segued into how coordinate pairs are similar but much more specific. She made another comparison to city streets and walked the class through the process of setting up the first quadrant of the coordinate plane. During this time she wove in important vocabulary terms such as quadrant, vertical, and horizontal. She also 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 students practiced to create their own grid, the teacher then introduced a ready-made grid for the overhead and gave each group a laminated grid of the first quadrant for the upcoming assignment. However, neither grid had the axes numbered, so she walked the class through how to number the grid for these particular examples.

The teacher then guided the class through a couple of examples. She called students up to do other examples, and then let the students work in pairs on a few more. Instead of placing a regular point on the position, she had cut out pictures of various objects such as balloons, cars, and people for students to place at the spot. As pairs worked on plotting their coordinates, the teacher walked around and monitored their work. After pairs completed the assignment, the teacher called the class together to go over their work. Students came up and placed pictures on the overhead version of the grid, and the teacher allowed other pairs to comment on the correctness of the placement.

This sense-making activity was followed by a worksheet for students to complete individually. The worksheet had similar questions but also extended their knowledge by asking them to list the coordinates instead of finding the coordinates. Although each student had an individual sheet to finish, the entire table of four students was responsible for helping those that needed more guidance. The teacher ended the lesson by going over the worksheet and discussing common errors.

The lesson had a very strong design that attended to a variety of learning styles and excellent implementation including questioning that clearly moved students forward. The lesson was highly likely to improve the students' understanding of coordinate pairs.

Appendix D

Grades 6–8 Mathematics

Typical Lessons

Ratings of Lesson Components

Overall Lesson Quality

Typical Lessons

The following lesson descriptions are based on a random sample of 6th–8th grade mathematics lessons.

6th Grade: Division with Decimal Divisors

This 6th grade lesson on division with decimal divisors was situated according to textbook design; in the teacher's words, "I'm just following the book, basically." The lesson also included a review of writing fractions as repeating decimals and a "Problem of the Day" that involved students making predictions based on a set of related multiplication sentences.

As the teacher returned graded papers, students got out their completed homework assignment – a set of textbook exercises that involved re-writing fractions as repeating decimals. Students checked their homework as the teacher read aloud the correct answers and answered students' questions about the homework exercises. The students were given a worksheet containing similar exercises to complete individually; the teacher graded the completed worksheets as they were submitted. Students were asked to work individually on the Problem of the Day (i.e., Find the products 15873×7, 15873×14, and 15873×21 and use those products to predict the product 15873×28). The teacher led a whole-class discussion of this problem.

The teacher introduced the new content material—division with decimal divisors—by modeling an example on the overhead projector. He demonstrated how to move the decimal points in the divisor and dividend the same number of places in the same direction. When asked by a student, "Why do we move it over?" the teacher replied, "The divisor must be a whole number." For the second example modeled on the overhead, students were asked to help by stating each step, one-by-one, in the procedure. A few students asked questions about the procedure (e.g., "What do we do about remainders?"). The teacher assigned twelve similar textbook exercises for homework. Students worked individually on the homework. Students who finished the homework before the end of the period were allowed to work on their assigned art projects.

6^{th} Grade: Fractions, Ratios, and Rates

The teacher focused on the topics of fractions, ratios, and rates during this lesson because these topics would be included in the upcoming state assessment tests. The teacher expressed concerns about the ramifications, on both his school's and his own evaluations, if his students did not perform well on the test. Specifically, this lesson was designed to help students tie in their previous knowledge of fractions with the concepts of ratios and rates.

The lesson began with a review of several fraction concepts: definition of a fraction, proper and improper fractions, and equivalent fractions. The teacher asked a student to "prove" to the class that one-half and two-fourths are equivalent by showing both fractions using an overhead circular fraction kit; this was repeated for $^1/_2$ and $^3/_6$, $^1/_2$ and $^4/_8$, $^1/_3$ and $^2/_6$, and $^1/_3$ and $^4/_{12}$.

The teacher began instruction on ratios and rates by asking a student to define "ratio." The student read the definition from the textbook ("a ratio compares two numbers by division"). The teacher asked students to provide examples of different ways to write a ratio; by looking at the textbook, students were able to suggest "3:4," "3 out of 4," and "3 to 4" as equivalent ways to write the ratio expressed as a fraction, "¾." The teacher directed students to write the definition for ratio in their mathematics notebooks and to complete the textbook's "five-minute check" which provided practice on ways to represent ratios.

The teacher put a definition of rate ("a rate is a ratio that compares quantities with different units") on the overhead and asked a student to read the definition aloud. The teacher wrote the formula "total number of units = rate × time" on the board and discussed a couple of rate examples. He then switched back to ratios and showed how "cross multiplication" could be used to determine if two ratios are equivalent or proportional. After working a few examples, the teacher distributed a textbook worksheet. The exercises on the front side of the worksheet focused on writing ratios in different ways, expressing ratios as fractions, and expressing ratios as rates; on the back of the sheet were exercises that involved solving proportions. The teacher asked the students to work on the worksheet for the last 15 minutes of class and complete it for homework. Some students worked independently on the assignment and others together as the teacher provided additional instruction, as needed.

6^{th} Grade: Metric Measuring Units

The primary goal for the lesson was to expand the 6^{th} grade students' understanding of metric units and to help them develop a sense of scale and meaningfulness by relating these units to relevant examples from the real world. The teacher used the district-adopted textbook for the instructional materials, examples, and organization of the lesson. She indicated that, in general, she follows the textbook order of topics in teaching the curriculum.

The teacher began the lesson with a whole-class review of the metric units for length (m, cm, dm, km, mm), capacity (L, kL), and mass (g, kg). Students were asked to draw a two-column chart with the headings "standard" (i.e., U.S. Customary) and "metric." From a collection of grocery store items on her desk, the teacher read information off the labels and asked students to enter that information into their charts (e.g., for the first item the teacher read "1.01 ounces" and "30 milliliters"). The teacher quickly called out several other pairs of measures found on the labels of a variety of products; the students continued to enter the measures into their charts. She asked a couple of students to contribute another pair of measures from the grocery items that they had brought from home.

The teacher asked students to think about the relationships between sizes of containers and measures on the labels. Most of the class seemed to think that bigger packages would contain a larger amount and thus carry a larger number on the label. Comparisons of measures focused on magnitudes, but not on units, so at times students were comparing the mass of one package with the capacity of another package. At one point in the discussion the teacher held up an 8-ounce can of beans (also labeled in grams) and an 8-ounce bottle of Pepsi (also measured in milliliters) and explained to the class that these two items "have the same measure in standard units but different metric units." For the two items there was no discussion of the fact that measures of different quantities were reported on the two packages (i.e., weight and mass were given on the can of beans while capacity was given on the bottle of Pepsi).

The teacher asked the class a series of questions from the textbook (e.g., "How many kg in a gram?" and "Which unit—liters, milliliters, or kilograms—is appropriate for representing the capacity of a milk container? A swimming pool?"). The teacher wrote the answers on the board and students copied the answers down on their papers. About ten minutes before the end of the period the teacher assigned a set of similar exercises (e.g., "What units would you use for bottled juice?") for the students to complete independently. Students worked on these exercises and the homework assignment for the remainder of the period.

7^{th} Grade: Number Patterns, Fractions, and Percents

The lesson was a fast-paced review to pull everything together at the conclusion of a 7^{th} grade unit on number patterns, fractions, and percents. The teacher planned this lesson because the students had done poorly on a recent test. The lesson was designed to help students identify their own weaknesses and to provide opportunities for them to deepen their levels of understanding. The teacher was particularly concerned that her students develop a better understanding of the content of the lesson because the topics are a part of the district's prescribed mathematics curriculum and framework, and the topics are on the mandated state-level 8^{th} grade assessment test.

The lesson began with a whole-class, five-minute warm-up exercise—a review of division and fractions—followed by a homework check. The teacher then used the newspaper to discuss current stock market quotes. (The class was participating in a simulated computerized stock market activity in which the students worked in teams of four and bought and sold stocks and competed against other teams around the state.) In the discussion of current stock quotes and trends, the teacher pointed out that stock quotes are being converted to decimals and shortly all stocks would be reported in that way.

The students participated in a whole-class flash card review of the decimal equivalents of common fractions. After the students had checked their answers, the teacher reminded them that they would be taking a placement test the next day to determine their mathematics course next year and that they needed to use the results of this exercise to guide their study for that test.

The teacher instructed the students to complete the textbook worksheet, "Using Number Patterns, Fractions, and Percent," that they had worked on in an earlier class. She organized students in pairs for this part of the lesson, trying to pair students she thought would be able to help one another.

The final activity was a modeling of the concept of positive and negative integers and absolute value. The teacher asked several students to line up along a number line that was drawn on the floor in the center aisle of the room. One student marked zero and others took either positive or negative positions. She involved other students by having them define the "value" of each student, in positive or negative terms, and then explain what the absolute value was. The students shifted positions and the process was repeated once more before the period ended.

7th Grade: Percents, Fractions, and Decimals

The lesson on percents, fractions, and decimals was taught by a first-year, un-credentialed teacher. The teacher used the district's 7th grade curriculum and adopted textbook in planning this lesson. She seemed confident in her mathematical content knowledge (she had been an accountant before entering the teaching profession). Her students were used to an established classroom routine that began with practice problems for the district's quarterly assessment tests, followed by going over homework, doing some type of mathematics activity, and completing practice worksheets.

The lesson began with a worksheet that served as a general review of equivalent fractions, the distinction between rational and irrational numbers, and calculating percent increase and decrease. The teacher looked over students' homework (a set of converting-percents-to-fractions exercises) while the students worked on the review worksheet. She called on students individually to provide answers to all but the last two worksheet problems. She decided to omit any discussion of these last questions because they involved calculating percent decrease, a topic that the class had not yet studied. She asked students to exchange homework papers and grade each others' work. If a student raised a question about a homework answer, the teacher solved the problem on the overhead, explaining each step as she wrote.

The teacher had planned a group activity for this lesson but changed it to a whole-class demonstration because of time. Three students were asked to come to the front of the class. One student measured the height and arm spread of a second student, while the third student wrote the numbers on the board. The ratio of arm spread to height was written as a fraction, and the teacher asked the class to calculate the corresponding percent. The teacher demonstrated and discussed the proportion method for calculating the percent (i.e., 59/64 = x/100). Students were then instructed to complete a textbook practice worksheet that included expressing decimals as percents and percents as decimals and comparing percents and decimals (<, >, or =). The teacher helped students individually as needed but provided no closure to the lesson.

7th Grade: Prime and Composite Numbers

The lesson, which followed a lesson on divisibility rules, was designed to introduce students to prime and composite numbers, prime factorization, and factor trees. The teacher's choice of content for this lesson was based on the NCTM standards and the state's mathematics goals for 7th graders. The teacher explained that, as she plans lessons, she goes through the national and state standards to pick out a topic and then chooses related instructional materials from the district-adopted textbook.

The teacher began the lesson with a whole-class review discussion focused on finding areas of rectangles. She reminded students of the formula "A = L × W" and asked the students to find the areas of four rectangles (e.g., "L = 11 in, W = 7 in"). The teacher helped students as they worked on the exercise, after which she asked individual students to put solutions to each problem on the board.

In the second segment of the lesson the teacher asked students to work in cooperative groups on the problem: "Lois, Trisha, Mark, and Dean traded stamps. Lois had 38 stamps when the trading was over. She knew she had given 9 to Trisha and received 11 from Mark and 13 from Dean. How many stamps did she start with? (Hint: Start with 38 stamps and work backwards.)" Each group solved the problem, wrote down both a solution strategy and a verbal explanation of how they worked the problem, and wrote down the calculator keystrokes they used in obtaining the final answer. The teacher quickly debriefed the problem by explaining her solution strategy.

The teacher told students to get out their homework (i.e., determine whether the numbers 630, 351, 97, 3744, 1720, 61776, 22548, and 11216 are divisible by 2, 3, 4, 5, 6, 8, 9, 10). Students exchanged papers; the teacher quickly called out the correct answers while the students graded each others' work. The teacher told students to get out their spiral-bound notebooks. She wrote the word "divisible" on the board and asked a student to read aloud the definition found in the textbook glossary while she wrote the definition on the overhead. She asked the students to copy the definition from the overhead to their notebooks. This process was repeated for the terms prime number, composite number, prime factorization, and factor tree. When discussing prime numbers, the teacher made a list of primes up to 37, and, when discussing prime factorization, the teacher worked through several examples for the class (e.g., $60 = 2 \times 2 \times 3 \times 5$), forming a factor tree for each. There was no mention of alternative factor trees that might be written for a given composite number. The class ended when the bell rang, with no wrap-up or closure to the lesson.

7th Grade: Subtraction of Integers

The instructional materials for this lesson on subtraction of integers were taken from the new, district-adopted textbook materials. This series, which focuses heavily on drill and practice, replaced a more hands-on textbook series that the district had selected for its previous adoption. The current adoption was in response to teachers' complaints that the former adoption did not provide students with enough work on mathematics vocabulary or enough practice on important procedures.

The lesson began with a warm-up activity that included a review of adding and subtracting integers. The teacher wrote on the overhead projector as a few students volunteered answers to the teachers' questions; many students were inattentive. During this review the teacher wrote symbolic rules for adding and subtracting signed numbers (e.g., "(+) + (+) = (+)") on the overhead. Following the warm-up activity, students checked their answers to the homework assignment from a copy of answers that the teacher placed on the overhead. The teacher worked the last four homework problems for the class.

The teacher distributed three worksheets copied from resource materials that accompanied the district-adopted textbook series. The first worksheet provided practice on subtraction of integers (e.g., (-3) + 5 = __), the second was a "multicultural problem set," and the third contained a word search for mathematical terms. Students worked independently on the worksheets. At the end of the time allotted for the class, students packed up their materials and left the classroom.

7th Grade Pre-Algebra: Problem Solving and Inequalities

Prior to this lesson, the 7th grade pre-algebra students had worked on an extended investigation focused on multiple strategies for solving word problems. In this lesson, a new word problem was used to reinforce the need for careful reading of problems, justification of strategies used and solutions presented, and the concept that there are multiple ways to approach solving a single problem. A second focus of this lesson was on extending what students had learned previously about solving one-step equations to the solution of inequalities. The teacher stated that the content of the lesson was selected because she knew students needed to learn it in order to do well on the up-coming state assessment. The primary component of the lesson, small and large group discussion around a single word problem, was designed to have students articulate their mathematical thinking, thereby instilling both competence and confidence in their own mathematical abilities. The student make-up in this class, as per the teacher's request, represented a greater diversity than the district's and school's tracking practices usually allowed.

At the beginning of the lesson the teacher collected students' work on an extended problem-solving investigation and posed a new word problem: "Tim's father bought some baseball cards. He paid $8.00 for every six cards he bought. Later, he sold them, making a profit of $4.00 on every 3 cards. If he made a profit of $24.00 altogether, how many cards did he buy and then sell?" The teacher wrote the problem on the blackboard and students copied the problem into their mathematics notebooks. The teacher set a timer for 6 minutes and asked students to work on their own or discuss the problem with others in their group. During this time the teacher circulated among the groups, listening to students' discussions and providing encouragement. When the timer went off, the teacher asked students to share the strategy they used (e.g., picture, list, working backward) with the class. She asked a few students to present to the class, step-by-step, their solution to the problem. An open-ended, at times student-directed, discussion ensued. After about three-fourths of the class time had elapsed, the teacher stopped the discussion to move the students on to the inequalities worksheet: "I'm going to leave you to think about this more; I hope you wrote it down and can look at it tonight and ask your parents for their thoughts."

The teacher directed students to go to a box on the side counter and pick up their worksheet on inequalities from the previous day. For the remainder of the period, students worked individually or with others in their group on the inequalities worksheet. The teacher circulated around the room, answering student questions and checking on student progress. Incomplete worksheets were collected in the last few minutes of the lesson as students prepared to leave for their next class.

8th Grade: Percents, Decimals, and Fractions

The lesson in this 8th grade class focused on percents, decimals, and fractions. The teacher had learned about the hands-on activity incorporated in this lesson at a district-provided professional development workshop that was held two weeks earlier. The lesson was structured to allow students opportunities to talk with each other about mathematics and to engage in hands-on activities.

The lesson began with a whole-class discussion of percents, including procedures for converting among percents, decimals, and fractions. Students were asked to open their texts to a specific page and the teacher began an interactive discussion by asking students a series of questions about the meaning of "25%" and then "125%." The teacher wrote all responses on the board (e.g., 125% means 125 "out of 200," "out of 1000," "out of 100"), but moved rapidly to the correct answer. The teacher posed the problem of converting 125% into a fraction and a decimal. Students were told to work the problem on their papers as she worked it on the board. Students were then assigned three textbook problems to work on for independent practice (e.g., change 220% to a fraction, whole number, or mixed number, giving each answer in simplest form).

In the previous lesson students had begun a hands-on activity in which they used data about the way a student's budget was apportioned, per dollar, for lunch, clothing, recreation, CDs, and savings (e.g., 25 cents of every dollar was for the purchases of lunches) to create a bar graph and then turned the bar graph into a pie chart. The teacher explained that, for the rest of the period, they were to continue working on that activity. An assistant supervised the students as they worked on the activity while the teacher went to another room to teach a lesson to a different set of students. The teacher returned to the original classroom midway through their group work and again at the end. The lesson ended as the teacher collected the students' completed pie charts.

8th Grade: Pythagorean Theorem and Trigonometric Ratios

The 8th grade mathematics class was at the end of their study of the Pythagorean Theorem and the beginning of a study of trigonometric ratios. The teacher said that she would prefer not to deal with trigonometric ratios in 8th grade, but was doing it to teach to the state standards and thus prepare the students for the state assessment. She stated that the year before she made the students memorize the definitions of sine, cosine, and tangent, but has since realized that they are included on the formula chart passed out with the state assessment test; she now focuses instruction on making sure that students understand the terms opposite, adjacent, and hypotenuse and how they relate to the trigonometric ratios. The teacher used a non-interactive, whole-group approach for most of the lesson. A classroom rule was that there is absolutely no student talking during a mathematics lesson except to ask the teacher a question or to answer a question posed by the teacher.

The lesson began with a warm-up problem that the teacher put on the overhead and students worked on independently: "Use the figure (rectangle ABCD with an X marking the point of intersection of the two diagonals) to name an obtuse triangle." The teacher asked two students to say their answers and the teacher repeated them, briefly explaining why each answer was correct. She asked students to open their textbooks and get out their homework on the Pythagorean Theorem. She worked a few homework problems for the students, asked if there were any questions, and directed students to get out a piece of notebook paper for their journal writing that would follow the quiz. The teacher passed out the quiz sheets, and the students worked quietly and independently, putting their paper in the "in-box" as they finished and moving on to the journal-writing task. Some students finished early; other students had not begun the journal writing task when the teacher asked for papers to be turned in. The teacher told the students to make sure they had at least copied the journal assignment so they could work on it later.

The teacher distributed a handout that was a combination of worksheet and notes on trigonometric ratios. She explained, "Trigonometric ratios can be used to find the measure of one side of a right triangle if the measure of one side and the acute angles are known." The teacher demonstrated how they could solve an equation for the unknown (e.g., If $\tan 30^o = x/21$, then $x = 21 \tan 30^o$) and then asked them to do an analogous example ($\cos 45^o = x/27$). There was no exploration of what a 45^o angle in a right triangle implied about the other acute angle or the length of the other leg. The teacher walked around checking student progress on this problem. The teacher went through a third sample problem, reviewing what she meant by opposite and adjacent. Referring to the 9 practice problems on the worksheet, the teacher worked 3 for the class and then directed the students to complete the remaining 6 exercises.

On the overhead the teacher drew a 6-8-10 right triangle with acute angles P and Q and right angle R and she listed the prompts: (1) sin P, (2) cos P, (3) tan P, (4) sin Q, (5) cos Q, and (6) tan Q. She stated that she didn't know the value for angle P. She wrote the trigonometric ratios for the first three prompts, reducing each to a fraction in lowest terms, before being interrupted by the bell signaling the end of class.

8th Grade Geometry: Algebraic Multiplication and Geometric Proofs

The teacher described this 8th grade geometry course as being exactly the same as the district's high school geometry course, a course which is taught with emphasis on undefined terms, definitions, fixed sets of procedures, and formal proof. The teacher stated that she likes the textbook and that she does not depart from the structure of the course presented in the text, although she does occasionally supplement the text with problems taken from other texts. Because her students are required to take the state-mandated assessment test (which is based on the state's regular 8th grade mathematics curriculum) at the end of the year, the teacher stated that she provides daily instruction designed to help students prepare for that test alongside instruction in geometry.

The block scheduling for this class divided the period into two segments with a lunch period in the middle. For the before-lunch segment the teacher began with two warm-up problems on multiplication of algebraic fractions, e.g.:

$$\frac{10a^2 + 5a}{6m^2} \bullet \frac{18m}{4a^2 - 1}$$

Students were given time to work independently on these problems while the teacher offered assistance to individual students. The teacher then led a whole-class discussion of the solutions. The teacher returned a set of graded geometry quizzes and assigned students to pair groupings for a peer-tutoring session. Students were asked to work through the quizzes together, helping their partners as needed. After approximately 10 minutes of peer tutoring, the teacher reassembled the class and several problems from the quiz were worked on the board. Frequently, the teacher would remind students of an underlying characteristic or property that was illustrated by a given problem (e.g., reflexive property, distributive property), and she used the set of problems to illustrate differences among mathematical properties. The class continued to work on problems from the quiz until the beginning of the lunch period.

After lunch the teacher asked students to put the graded quizzes into their mathematics folders and to open their geometry textbooks to a section on geometric proof. Students were asked to read the first page quietly, after which the teacher asked if everybody understood. Hearing no questions, the teacher asked them to read on and study the proof on the next page. The lesson was devoted to the conventions of proof, so the teacher emphasized or elaborated on several points made in the text. The class continued in this way through two more textbook pages. The teacher assigned homework from this section before distributing a practice test for the state assessment. The teacher pointed out that several students were still having problems with calculation of area and perimeter, and she suggested that students memorize the formulas for calculating perimeter and area of circles. The class continued using the practice test to review for the state assessment until the period ended.

8th Grade Pre-Algebra: Similar Triangles and Problem-Solving Strategies

The lesson was designed to provide students with practice on similar triangles and proportions and then to move into problem-solving strategies and mathematical thinking. The class began with a review problem and a homework check and then moved into the major portion of the lesson, a problem-solving activity which was designed to prepare students for the upcoming benchmark test. The teacher described the benchmark test as being focused on problem solving and involving both multiple-choice and open-ended items. In this lesson the teacher wanted to provide an example, and a structure, for students to use when responding to open-ended problems on the test.

The teacher drew two similar triangles on the board and provided the lengths of some of the sides, asking students to determine the length of the side marked "x." Students worked alone while the teacher moved about the room to provide encouragement and answer questions. Some students began working together, and, even though the teacher did not specifically request that students talk with one another about their work, he did not seem to mind that they did so. After allowing the students a few minutes to work on the problem, the teacher led a whole-class discussion of the solution. The teacher wrote the numbers and equations on the board while the students identified and described the sequence of steps leading to a solution. The teacher asked students to check their homework (i.e., eight similar-triangle problems analogous to the warm-up problem) as he called out the answers from the teacher's edition of the textbook. The discussion turned lively when students started to debate the answers, and the teacher realized that one of the answers given in the textbook was incorrect. The teacher invited several students to the board to show how they had arrived at a different answer.

The teacher distributed two worksheets. The first one contained a word problem about mangoes, in which members of a family each take $^1/_3$ or $^1/_5$ of the mangoes in a basket until finally there are only 3 mangoes left; the task for students was to determine how many mangoes were originally in the basket. The second worksheet was for students to use to write down their solution to the problem. This worksheet contained several prompts, such as "what I know," "strategy," and "steps." The teacher asked students to carefully read the problem on the first worksheet and to answer the "what I know" question on the second worksheet by describing and paraphrasing the information given in the problem. As the students moved to the "strategy" question, some students went to a poster at the side of the room that described various problem-solving strategies (e.g., guess and check, draw a picture, work backwards). As the teacher worked with individual students, he would ask them about their strategies and answers. Throughout this segment of the lesson, students frequently discussed the problem and their thinking with each other. Work on this problem continued until the end of the class period as the students and teacher focused on processes and mathematical reasoning in problem solving. The class ended as the teacher said, "We're about out of time... Finish it for homework."

Ratings of Lesson Components

The designs of middle school mathematics lessons are, on average, most highly rated for reflecting careful planning and organization and for utilizing the available resources to accomplish the purpose of the lesson. Middle school mathematics lessons are, on average, weak in many areas, including providing students with the time and structure needed for sense-making and wrap-up, incorporating strategies consistent with investigative mathematics, and encouraging collaboration among students. The relatively low ratings in these areas may explain why over three times as many lessons receive low synthesis ratings for their design than high ratings (58 percent and 17 percent, respectively).

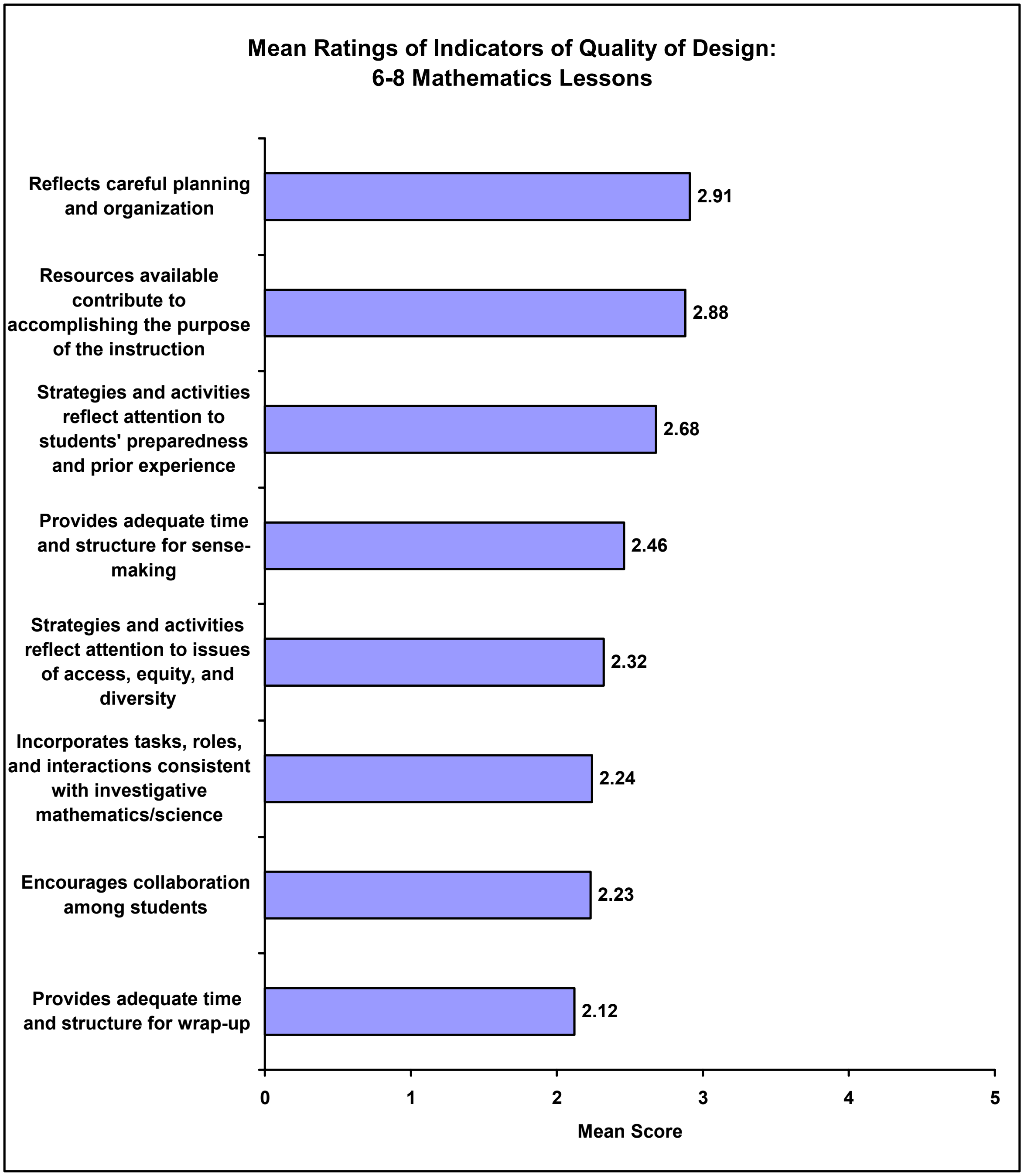

Mean Ratings of Indicators of Quality of Design:
6-8 Mathematics Lessons
Reflects careful planning and organization
2.91
Resources available contribute to accomplishing the purpose of the instruction
2.88
Strategies and activities reflect attention to students' preparedness and prior experience
2.68
Provides adequate time and structure for sense-making
2.46
Strategies and activities reflect attention to issues of access, equity, and diversity
2.32
Incorporates tasks, roles, and interactions consistent with investigative mathematics/science
2.24
Encourages collaboration among students
2.23
Provides adequate time and structure for wrap-up
2.12
0
1
2
3
4
5
Mean Score

Figure D-1

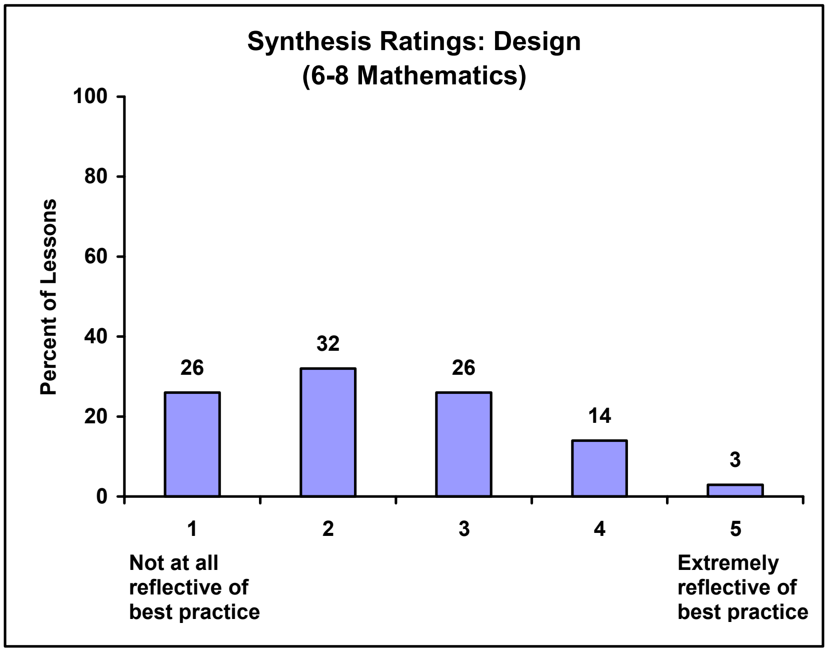


Figure D-2

The implementation of middle school mathematics lessons is rated most highly for teachers' confidence in their ability to teach mathematics. Lessons are weaker in regard to teachers' classroom management and pacing (moving either too quickly or too slowly). Middle school mathematics lessons are weakest in regard to adjusting instruction according to the level of student understanding, using instructional strategies consistent with investigative mathematics, and posing questions that enhance student understanding. These low ratings are reflected in the implementation synthesis ratings. Sixty-seven percent of lessons receive a low rating for implementation while only 20 percent receive a high rating.

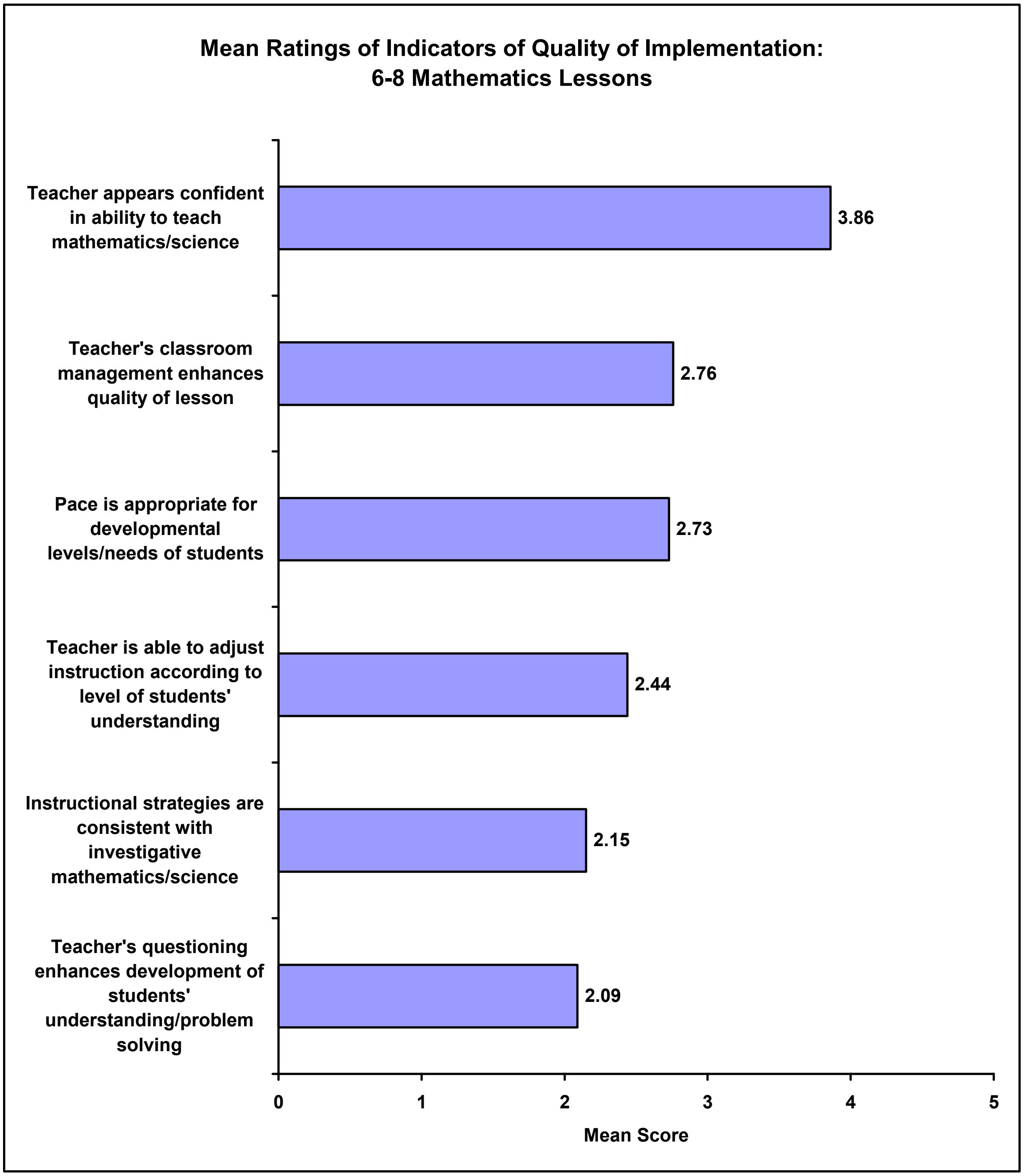

Mean Ratings of Indicators of Quality of Implementation:
6-8 Mathematics Lessons
Teacher appears confident in ability to teach mathematics/science
3.86
Teacher's classroom management enhances quality of lesson
2.76
Pace is appropriate for developmental levels/needs of students
2.73
Teacher is able to adjust instruction according to level of students' understanding
2.44
Instructional strategies are consistent with investigative mathematics/science
2.15
Teacher's questioning enhances development of students' understanding/problem solving
2.09
0
1
2
3
4
5
Mean Score

Figure D-3

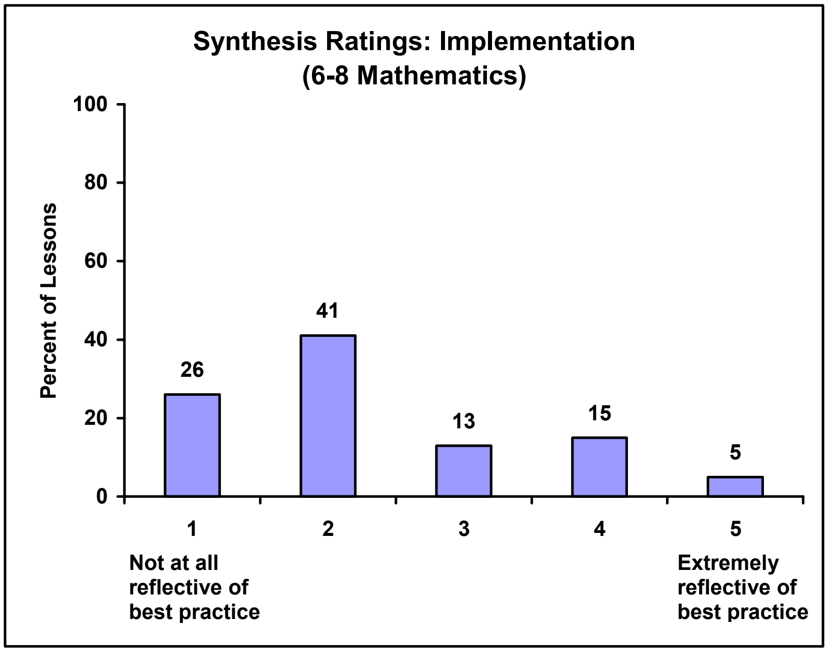


Figure D-4

The content of middle school mathematics lessons is, on average, rated highest for focusing on significant and worthwhile content at a developmentally appropriate level and doing so accurately. Lessons are weaker in the appropriate inclusion of abstract principles, engaging students with the content in a meaningful way, and making connections to other areas. Middle school mathematics lessons are weakest in providing opportunities for students to make sense of the content and portraying mathematics as a dynamic body of knowledge. Fifteen percent of lessons receive a high synthesis rating for content, 29 percent receive a medium rating, and 56 percent receive a low rating.

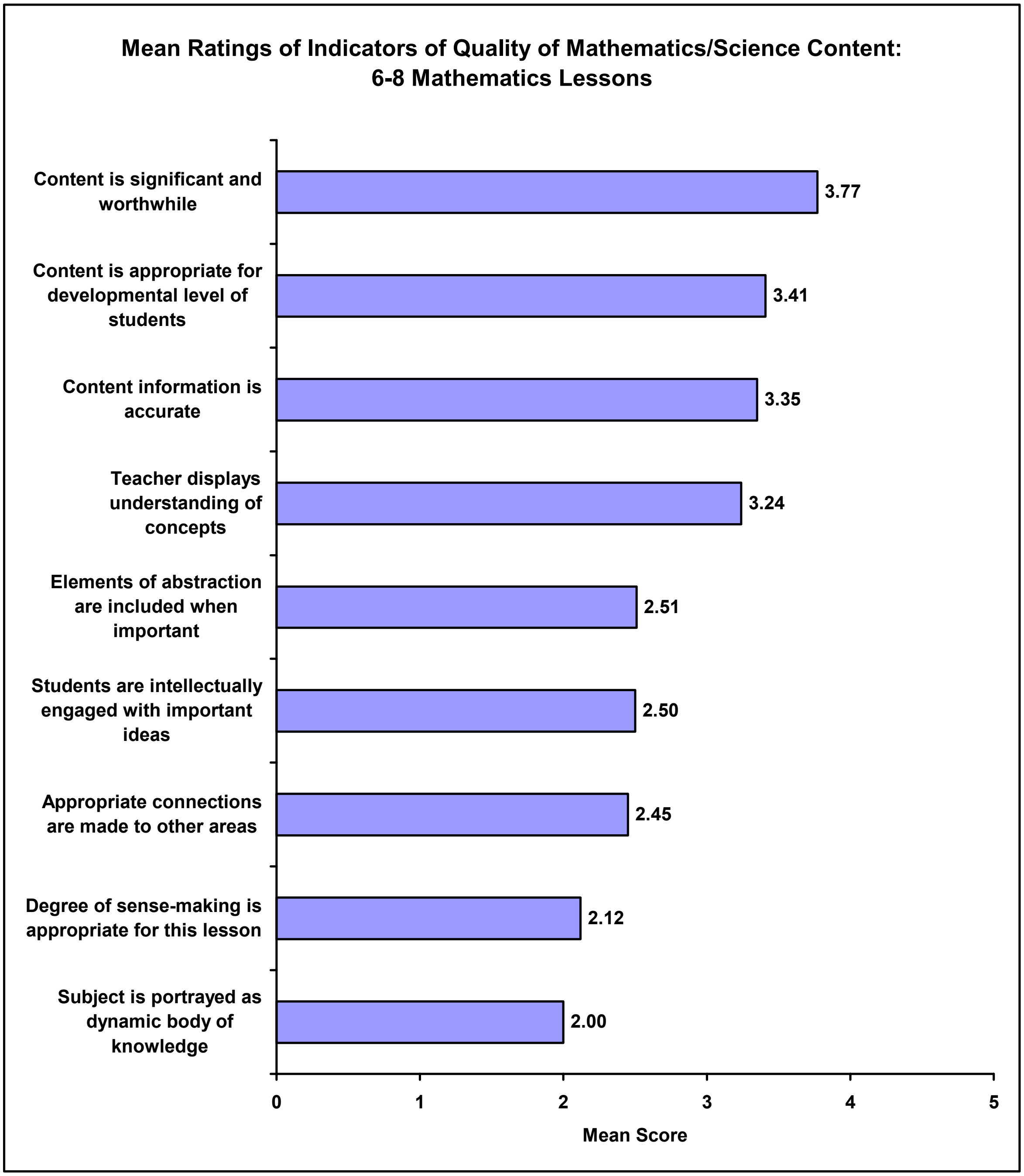

Mean Ratings of Indicators of Quality of Mathematics/Science Content:
6-8 Mathematics Lessons
Content is significant and worthwhile
3.77
Content is appropriate for developmental level of students
3.41
Content information is accurate
3.35
Teacher displays understanding of concepts
3.24
Elements of abstraction are included when important
2.51
Students are intellectually engaged with important ideas
2.50
Appropriate connections are made to other areas
2.45
Degree of sense-making is appropriate for this lesson
2.12
Subject is portrayed as dynamic body of knowledge
2.00
0
1
2
3
4
5
Mean Score

Figure D-5

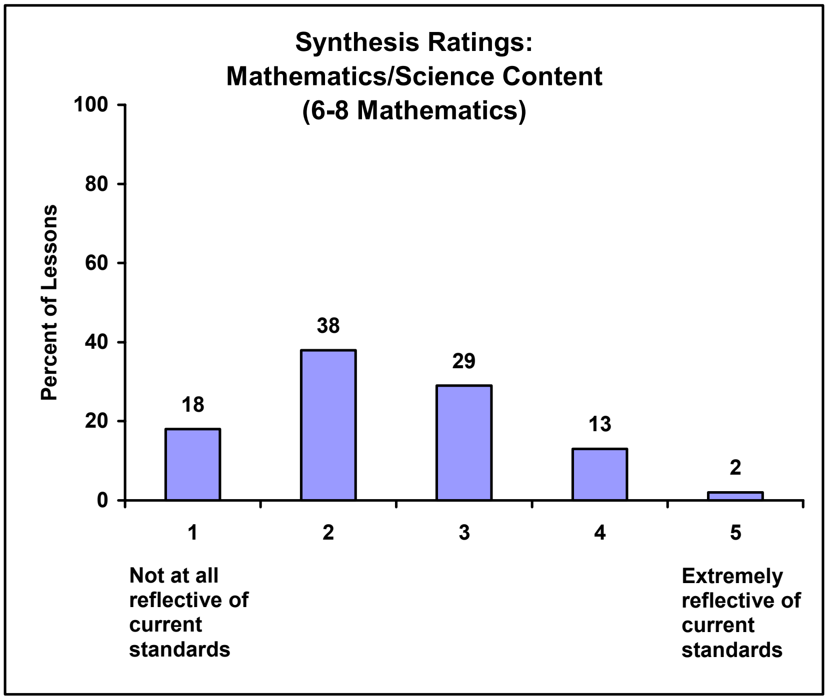
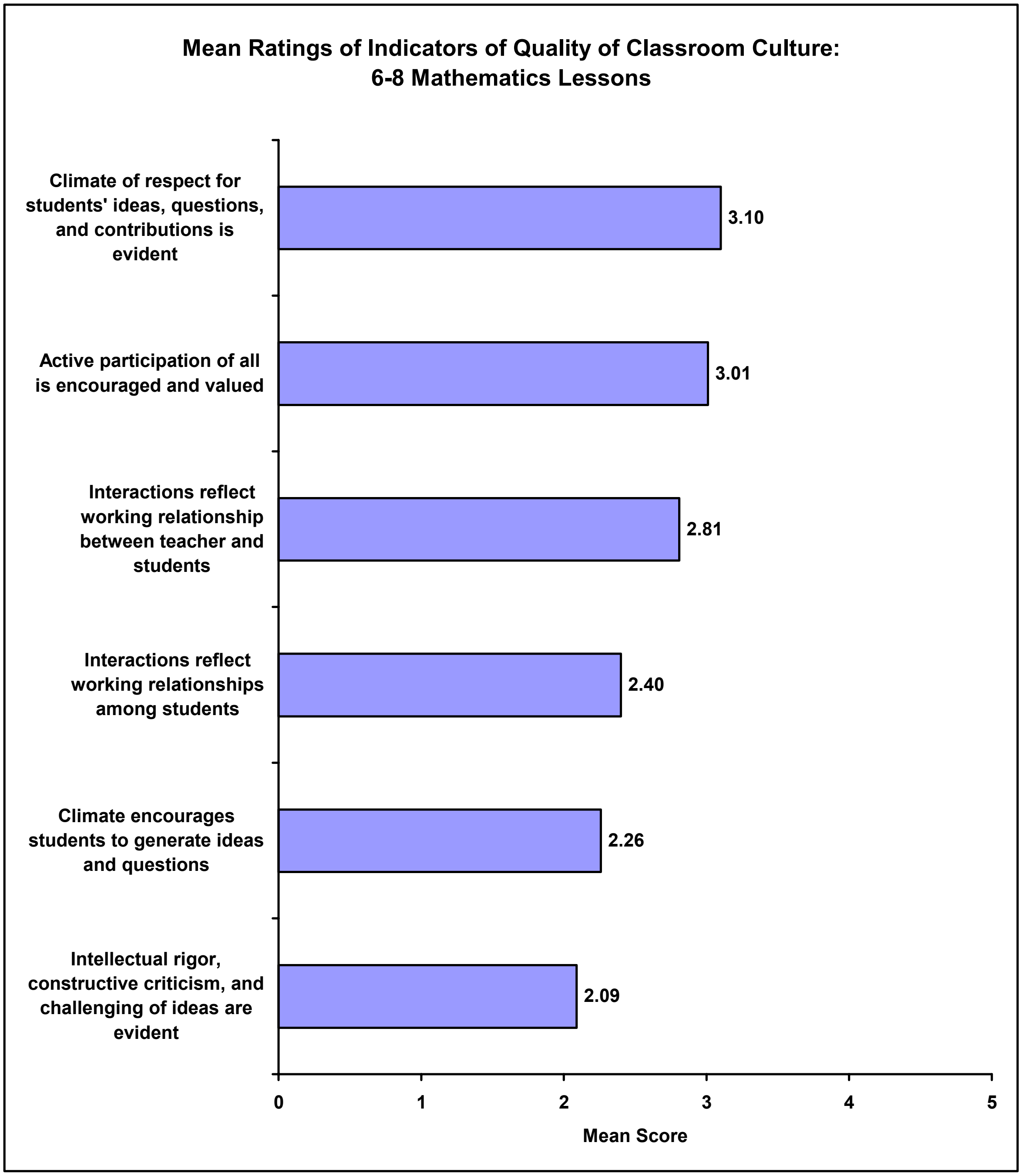


Figure D-6

In regard to classroom culture, middle school mathematics lessons are rated strongest for having a respectful climate and for encouraging active participation of all students. Lessons are weakest in encouraging students to generate ideas and questions and in their level of intellectual rigor. The synthesis ratings for classroom culture reflect these indicators with 25 percent of lessons receiving a high rating, 23 percent receiving a medium rating, and 53 percent receiving a low rating.



Mean Ratings of Indicators of Quality of Classroom Culture:
6-8 Mathematics Lessons
Climate of respect for students' ideas, questions, and contributions is evident
3.10
Active participation of all is encouraged and valued
3.01
Interactions reflect working relationship between teacher and students
2.81
Interactions reflect working relationships among students
2.40
Climate encourages students to generate ideas and questions
2.26
Intellectual rigor, constructive criticism, and challenging of ideas are evident
2.09
0
1
2
3
4
5
Mean Score

Figure D-7

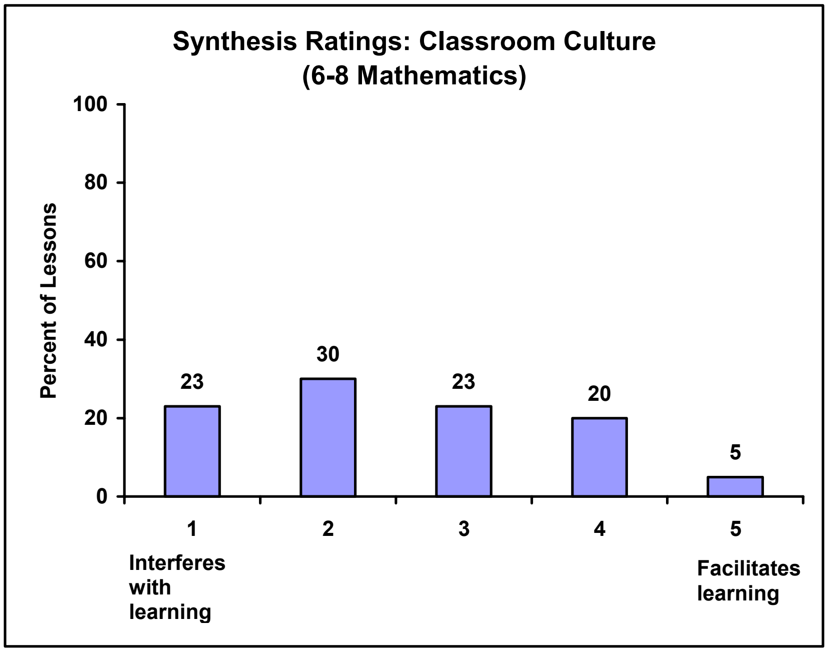

Synthesis Ratings: Classroom Culture
(6-8 Mathematics)
Percent of Lessons
100
80
60
40
20
0
23
30
23
20
5
1
2
3
4
5
Interferes with learning
Facilitates learning

Figure D-8

Overall Lesson Quality

Following the ratings of the individual components of the lesson, the researcher was asked to consider the likely impacts of the lesson as a whole. Less than a third of the lessons have positive impacts on students' understanding of mathematics, confidence to do mathematics, ability to apply the skills and concepts they are learning to other disciplines or real-life situations, or interest in mathematics. (See Table D-1.)

Table D-1
Likely Impact of the Lesson: 6–8 Mathematics

	Percent of Lessons		
	Negative Effect	**Mixed or Neutral Effect**	**Positive Effect**
Students' understanding of important mathematics/science concepts	24	46	29
Students' self-confidence in doing mathematics/science	29	42	29
Students' ability to apply or generalize skills and concepts to other areas of mathematics/science, other disciplines, and/or real-life situations	24	49	27
Students' interest in and/or appreciation for the discipline	35	45	20
Students' understanding of mathematics/science as a dynamic body of knowledge generated and enriched by investigation	49	33	18
Students' capacity to carry out their own inquiries	39	43	18

Figure D-9 shows the percentage of 6^{th}–8^{th} grade mathematics lessons in the nation rated at each of a number of levels. (See page 9 of the Observation and Analytic Protocol in Appendix A for a description of these levels.) Sixty-six percent of middle school mathematics lessons are rated as low in quality on the capsule rating, 20 percent are rated as medium in quality, and 16 percent are rated as high in quality.

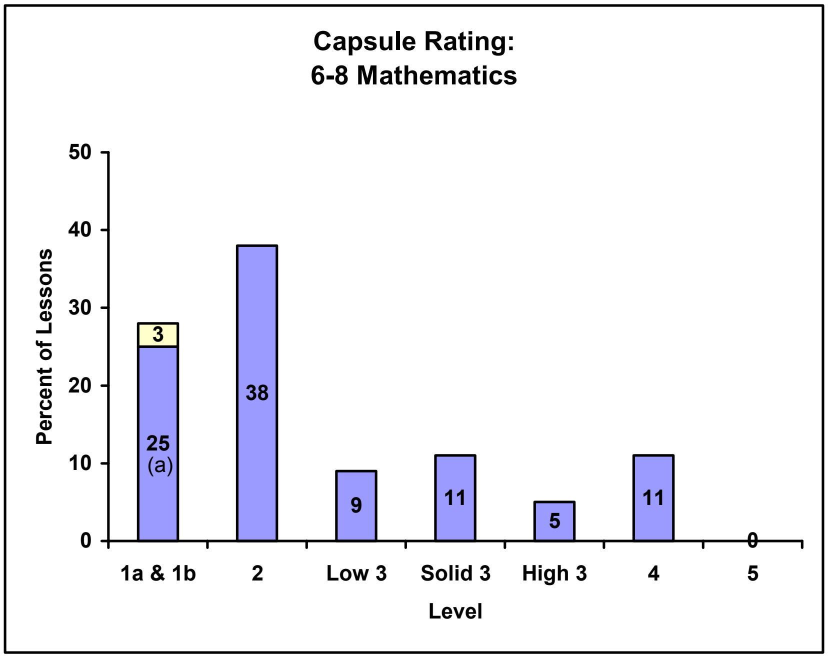


Figure D-9

The following illustrate lesson descriptions that were rated low, medium, and high in quality.

Sample Low Quality Lesson: Passive "Learning"

This lesson occurred in the middle of a 6th grade unit on fractions. The class had been working on adding and subtracting fractions and mixed numbers with like denominators. According to the teacher, the purpose of the lesson was for students to learn how to find the least common denominator for a set of fractions with different denominators. Ultimately she wanted them to be comfortable enough with fractions so they would not have to consult a calculator for this work

The teacher walked the class through a couple of examples that involved addition of fractions with unlike denominators, such as $1/4 + 1/8$. Questions such as: "What are the first five multiples of 4?" and "What's our LCM?" and "How did I go from 4 to 8?" were typical as she explained how to do the problems. After roughly five addition examples, the teacher painstakingly repeated the process for subtraction, as if the concept was drastically different.

Following this, the teacher sent two students to the board to give the class more practice. As students worked through the problem, the teacher would probe to help them along. Upon seeing incorrect work on the board, she asked questions like, "Five times what equals ten?" and "How did you go from a 10 to a 10?…And so what's 1 times 1?"

She checked the class' understanding by asking if there were any questions. Upon receiving no questions, she passed out calculators and issued a two-page, 39-problem homework assignment for students to begin to complete individually. Although one of the pages was labeled "enrichment," it appeared to be just like the other one. Of the 39 problems, one problem involved three different fractions, but still only two different denominators. Instead of waiting to see how the students approached solving this problem, she talked through the solution.

The teacher then spent the rest of the lesson monitoring the students as they completed their work. At times she took care of logistical issues in the classroom, like organizing bookshelves. At other times she walked around and looked over students' shoulders and answered questions from individuals. As the period ended with the students working silently, the teacher collected the calculators and reminded the students to finish the rest of the work for homework.

This lesson on adding and subtracting fractions with unlike denominators was geared primarily toward having students master specific procedures without any attention toward conceptual understanding. Low-level, procedure-oriented questions dominated the teacher's discussions with the students. Poor pacing through relatively simple content and low rigor also decreased the likelihood that this lesson increased students' understanding of the content.

Sample Low Quality Lesson: "Activity for Activity's Sake"

This 7th grade lesson occurred near the end of a unit on ratios and proportions. The lesson was designed to help students better understand how to use cross-multiplication to compare fractions and how ratios and proportions can be used in real-life situations, particularly in comparison shopping.

At the beginning of the lesson, students were responsible for completing three practice problems, all of which focused on comparing fractions. Although some students did not even attempt the problems, the teacher proceeded to briefly explain the solutions. For example, in one case he asked, "Just tell me—3 × 9 and 4 × 7—is that equal?" Answering his own question, he stated, "No, so the fractions are not equal." In discussing the three problems, the teacher asked the students to tell him whether the fractions were "equal" or "not equal," with no attention to truly comparing fractions by determining which fraction was greater in value. Throughout the discussion, students merely had to respond with a yes or no to his questions.

The teacher then moved to introduce the main activity for the lesson by asking the students what they looked for when they shopped. This served as a poor hook because students mostly discussed brand names instead of prices. Nonetheless, the teacher transitioned to the proportion activity, asking the students to work in pairs to simulate shopping for seven school supply items. The pairs were presented prices from two different stores and asked to use proportions to determine which items would be cheaper at each store. Students were asked to determine which store would be the better choice if they only had time to shop at one and how much money they could save if they had time to go to both stores.

Throughout the activity, students selected their own ways to approach the task and to write up their work and most made use of calculators. The teacher did very little to help students focus on important mathematical ideas through his questioning or his facilitation of discussion. For example, as he worked to assist students, the teacher asked the question, "What are you supposed to do?" This as well as other questions clearly focused more on the directions for the activity and the set procedure of cross-multiplying than on the important mathematics concepts. As the activity drew to a close, the teacher asked a couple of groups to report their results to the class and then asked the students to individually write three paragraphs about their results. There was no additional discussion of ideas or approaches.

While students wrote, the teacher distributed an extra practice worksheet for homework and worked the first problem on the board. His work through the first homework problem was again completely procedural in nature and ended in a final answer that was procedurally sound, but written incorrectly as a string of equalities.

Overall, there was very little intellectual work done in this lesson. Although the content of ratio and proportion is significant for 7th grade students, the ways in which the teacher managed the content undermined the opportunity for students to develop a better understanding. The teacher primarily focused on the procedure of cross-multiplying and checking fractions for equivalence. He did very little to encourage students to make sense of how these procedures aided in determining the best prices for the school supplies. Throughout the lesson students were not asked to share ideas or justify their reasoning. The lesson did not seem to interest students and did very little to increase their knowledge of proportions.

Sample Medium Quality Lesson: Beginning Stages of Effective Instruction

This 6th grade lesson came in the beginning of a unit designed to help students build an understanding of factors and multiples. The goal of the observed lesson was to "to reinforce what a factor is and to move into what multiples are." Prior to this lesson, students had played the "product game," and in this lesson, students were to create their own game board.

The lesson began with a discussion of the product game and the advantages and disadvantages of being the first player. They then moved on to examine the composition of the game board and discuss why some numbers were missing from the product board. Finally, the children were given an example of how to build a 3x3 game board and asked to build their own 4 x 4 board. The end of the lesson was spent with children working independently to create their own boards.

The students seemed eager to build their own game board and a few were adventurous enough (as was the intention of the design) to explore unique and different boards. The majority, however, followed the lead of the example given and used a procedure for building the board that was just like the one the teacher had given as an example. This scaffolding took away from the desired outcome of getting students intellectually engaged in an interesting problem.

The teacher's questions were very leading, and they required little thinking by the students. In fact, the majority of the students were just watching as she did all the work at the overhead projector and filled in the table and the board. In addition, the teacher was quick to hear the right answer to her questions and to move on, or did not hear the answer the way she wanted and provided the answer herself, often short-circuiting the thinking process for the students. It appeared that the teacher was not tuned into the students' understanding, until she started to circulate and watch them work on the game boards at the end of the lesson. Her focus throughout the large group discussion was on getting through the sequence of questions she had prepared.

At times there was a lack of rigor in addressing the content. For example, it was never made explicit why some prime numbers were not on the board (e.g., the prime numbers 2, 3, 5 and 7 were found on the board and 13 was not). On occasion, sloppy language, such as the student who said that 26 only had two factors 2 and 13, was not corrected or clarified. In addition, while the teacher had a number of discussions about the mathematical content with various groups of students, there was no mechanism that allowed all students to engage with all of the mathematical ideas being raised.

The lesson was rated a low 3 because there is evidence of the beginnings of effective practice. The teacher was enthusiastic about choosing a task that had the potential of being an excellent investigation of important mathematical ideas for her 6th grade students. However, the questioning strategies used by the teacher limited the effectiveness of the lesson and limited the opportunities for students to make sense of the mathematics at a deeper level of understanding.

Sample High Quality Lesson: Traditional Instruction

This 8th grade lesson was intended to extend a brief geometry unit the teacher designed on triangles. Students had learned about right triangles and the Pythagorean Theorem. The observed lesson was the third day on the topic of similar triangles. In addition to deepening students' understanding of similar triangles, the lesson was designed to better prepare students for an open-ended benchmark assessment that was to be given soon.

Following the warm-up problem and check of homework, the teacher passed out an open-ended problem that students worked on for the rest of the class. The first page contained the problem, and the second sheet of the handout served as a recording tool for students. This sheet contained several prompts, such as "what I know," "strategy," and "steps."

After a few minutes in which students read and reflected on the problem, the teacher had students turn to the second page of the handout and begin answering the first question, which asked them to list information given in the problem that could help them solve it. Students worked independently while the teacher moved around the room and looked over shoulders. Some students went to the poster at the side of the room that described the various problem-solving strategies. The teacher also talked with one student about working backwards.

All of the questions posed by the teacher encouraged students to think about what they were doing, and challenged them to articulate their thinking with more than a one-word answer. For example, the teacher asked one student what she thought of the reasonableness of her answer. After the student responded that she thought her answer was too high, the teacher further probed to find out why the student thought that. To another student who was uncertain of his answer because it contained a decimal, the teacher asked, "What about that answer makes you think that it's unlikely?"

He seemed to provide just the right amount of support and encouragement as students struggled to solve the problem. For example, at one point he stopped the whole group to clear up an issue that was starting to be a barrier for numerous members in the class. He also drew a diagram on the board to further encourage some students to draw a diagram to help them solve the problem.

Students felt free to ask questions of the teacher and of their peers, even though the lesson did not specifically invite them to work together. The teacher allowed students to interact when it was clear they were working on the problem. At other times, students left their seats to get a closer look at some problem-solving posters hanging on the wall, and the instructor allowed this as well.

The content included in this lesson was appropriate and was presented through methods that interested and challenged the students. The lesson did a fine job of combining test-preparation and a review of problem-solving strategies. Although the pieces were not a perfect fit, the culture of the class and the investigative quality of the sections pulled the class together. The students remained engaged throughout the class, with the teacher clarifying and focusing their efforts when needed. The lesson was highly likely to extend students knowledge of similar triangles as well as better equip students to conduct their own mathematics investigations.

Sample High Quality Lesson: Reform-Oriented Instruction

The purpose of this 7th grade pre-algebra lesson was to help students better understand the measurement of interior and exterior angles of polygons. Students were in the middle of a geometry unit and had already learned about angles, triangles, and quadrilaterals.

The class began with students completing and discussing a starter problem from a book of mathematics Olympiad exercises. After allowing students to talk through their approach to the problem, the teacher shifted gears and gave answers to the homework from the previous day. She then began a whole-group discussion on the new material.

The teacher's skill as a facilitator enabled the whole-group discussion to develop into a rich, discovery-based lesson. As the teacher asked probing questions, students were willing and eager to share ideas. At times, the teacher directed specific questions to the few students who were not so quick to respond.

To assist students in making sense of the content, the teacher used several polygons as examples. As she drew on the overhead, students followed along by recording ideas in their learning logs. The teacher frequently invited peer criticism for students' work. At their seats, students were instructed to consult one another and to check their neighbors' work. In addition, the teacher solicited students' thoughts on work others presented in the class. For example, after one student displayed her solution to a problem, the teacher asked, "How many got the same answer? Did anyone use a different approach?" After another student volunteered to come up to the board to show another strategy, the teacher then remarked, "Interesting. How many students got that for an answer? Are there other answers different than either of these? Which makes more sense?"

The teacher also incorporated several techniques for gauging the understanding of the group. For example, the class was asked to give feedback at several critical points in the discussion. "Thumbs up if you agree, down if you disagree, and sideways if you aren't sure," she stated periodically during the lesson. Students appeared very comfortable sharing their thoughts and uncertainties.

Throughout the discussion, the teacher continued to question students to help them better understand the concepts. In one case, after an extended period of discussion and much anticipation, she asked the students for a drum roll right before she divulged the correct answer to the mathematical issue.

The overall implementation and classroom culture of this lesson were outstanding. Students were intellectually engaged in meaningful mathematical content that was developmentally appropriate for a pre-algebra course. The teacher gave frequent praise and encouragement, and regularly checked for student understanding. She also provided ample opportunity for students to make sense of the content, as well as challenge the thoughts of their peers. It is quite likely that students were able to leave the lesson with a deeper understanding of interior and exterior angles of polygons.

Appendix E

Grades 9–12 Mathematics

Typical Lessons

Ratings of Lesson Components

Overall Lesson Quality

Typical Lessons

The following lesson descriptions are based on a random sample of 9^{th}–12^{th} grade mathematics lessons.

8^{th}–9^{th} Grade Algebra I: Identifying and Graphing Linear Equations and Non-Linear Functions and Relations

This Algebra I lesson consisted mainly of a review of graphing, vocabulary, and an algorithm for finding the equation of a line given points on the line; and a quiz on functions. The teacher changed the text's approach, using the concept and notation of delta for the slope (i.e., slope = $\Delta y/\Delta x$) because he wanted to prepare these students for going into calculus.

The teacher began the class with a short interactive review of graphing, ordered pairs, quadrants, relations, functions, and inverses. The class discussed four ways to describe a relation: mapping, table, ordered pairs, and a T-chart. The teacher reminded students that some relations are functions, and he drew a picture of a mapping from the domain to the range showing that a function cannot include a "duplication of y's for x." The teacher asked how to tell a function from its graph. The students suggested using the vertical line test but some were unsure when the teacher drew and asked about the graph of $x = 5$.

The teacher asked students to tell him what they knew about linear equations. Students suggested $Ax + By = C$ and the teacher told them that if they can get an equation into that form, it is a linear equation. When the teacher suggested the equation $3x^2 – 7x = 2$, the students told him that this was not a linear equation. The teacher helped students come up with the formula, $y = (\Delta y/\Delta x) x$, and led the class through a problem in which they began with a table of x,y-values and ended with the equation in slope-intercept form. A student asked about a problem of similar structure that had been assigned for homework the night before. The teacher told the class that he didn't expect them to get that one because it is a parabola and has to have an x^2 term in the equation.

The teacher put eight quiz problems on the overhead, four questions in which students had to determine if various relations were functions and four on evaluating a function given specific numerical values for x (i.e., given $g(x) = x^2 – 3x + 2$, what are $g(–4)$, $g(2a)$, $g(^1/_3)$ and $g(0.1)$). Students worked independently on the quiz, and then the quizzes were graded in class. Because some of the students were confused about the non-linear functions in the last four quiz problems, the teacher graphed the corresponding parabola and showed that it passes the vertical line test. In the evaluation of $g(2a)$ some students thought that $4a^2 – 6a$ should be combined into a single term; the teacher explained why this was not correct. The teacher gave students their midterm grades and told them to study for the upcoming chapter test.

9th Grade: Integers and Equivalent Expressions of Quantities

The teacher stated that the students in this class, 9th graders who are below average in achievement, would not be likely to persist if presented with a difficult intellectual task; he tries to choose tasks that are easy for them to perform and provides lots of explanations and demonstrations of procedures. The lesson topics, integers and equivalent expressions of quantities, were taught because they were next in the faculty's scope and sequence agreement and in the district-adopted textbook.

The teacher began the class by asking students to get out their homework notebook for him to check. He went desk to desk to check whether students had completed the homework assignment; some had not. Students were asked to work independently on a set of six "Do Now" problems displayed on the board:

1. Write 3 numbers between 5 and 6.
2. Write 3 numbers between –5 and –6.
3. $2\frac{1}{2}$, 2.78, and $2\,{}^{3}/_{5}$ fall between which two integers?
4. ${}^{1}/_{7}$, ${}^{2}/_{8}$, and $\frac{3}{4}$ fall between which two integers?
5. $-{}^{4}/_{5}$, $-{}^{3}/_{7}$, and $-{}^{5}/_{9}$ fall between which two integers?
6. Name 3 words between "cheese" and "chicken."

The teacher demonstrated how to change fractions into decimals and instructed students to use the method he demonstrated to answer problems like #3. After discussing problem #6, the teacher observed that there are a finite number of words between "cheese" and "chicken" but the number of numbers between any two integers is infinite. During the discussion some students were attentive, answering questions that the teacher asked and taking notes, while others were not engaged in the lesson. The teacher ignored off-task behavior as long as the students were not disruptive.

Following the discussion of the "Do Now" problems, the teacher said, "Okay, now I'm going to pass out the punishment." He distributed a worksheet that the students were to do for homework. He directed the students to look at a specific homework problem in which they were asked to compare a pair of fractions. The teacher demonstrated, again, how to convert fractions to decimals. The teacher directed students to work on their homework assignment. Some students began working, while others, chose not to do the assignment. (One student appeared to be sleeping; another just sat and stared into space.) As students worked on homework, the teacher circulated through the room, sometimes stopping to answer a question from students. Near the end of class the teacher told students the difference between the = and ≠ signs and demonstrated shading on a number line. The teacher said, "Please have your homework tomorrow," as students packed up slightly in advance of the bell.

9^{th} Grade Algebra Support: Graphing Algebraic Inequalities

The title of this course is Algebra Support. Students in this class (first and second quartile students based on the state's 8^{th} grade assessment) are 9^{th} graders concurrently enrolled in the Algebra Support class and a regular Algebra I class. This lesson on algebraic inequalities was taught as a review lesson to prepare the Algebra Support students for the district-wide Algebra I, Semester I test that they would be taking the next week. In particular, this lesson taught graphing systems of two, two-variable inequalities (e.g., the system $y \geq -x - 2$ and $x - 2y < 4$) and reviewed graphing of two-variable inequalities (e.g., $x + 2y \geq 4$) and graphing of one-variable inequalities (e.g., $|x + 2| < 3$). The content of the lesson was based on Chapter 6 of the district-adopted textbook and was selected by this teacher in collaboration with the other two Algebra Support teachers and the five Algebra I teachers at the school.

The teacher began the lesson by presenting his solutions to two homework problems (e.g., $y > 2x$). He then asked students to turn to a section, "Graphing Linear Equations," in a handout entitled "Intensive Math Algebra Lab First Semester Exam Review." The teacher modeled the solutions for the first two problems on this sheet and asked students to work independently on the third problem. After the students had worked for a while, the teacher modeled the solution. This procedure was repeated for three more problems.

The teacher displayed six quiz problems on the overhead (e.g., Solve and graph $|x + 2| < 3$; Solve, graph, and shade $y - x < 6$). Students worked independently on these problems; as they finished they turned in their quiz papers and waited quietly for the rest of the class to finish. When all students had finished, the teacher asked specific students to work some problems from the review packet on the board. The teacher helped students at the board get the correct answers, and he explained the students' solutions to the rest of the class. At the end of the class the teacher reminded students to turn in their notebooks during the next class and to turn in their completed exam review packet at the beginning of the exam period the following week.

9th–10th Grade Algebra I: Solving Systems of Linear Equations

The lesson topic, solving systems of linear equations, was part of the Algebra I mathematics content mandated by the state and district curriculum guides, and the district's pacing guide specified how to sequence topics and how much time to spend on each topic. The teacher talked about the importance of using the curriculum guide to make sure all topics tested on the state assessment are covered. The teacher classified the students in the class (9th and 10th graders) as being "average to a little below average" and explained that, because the textbook problems are sometimes too difficult for her students, she has to begin with easier problems that she selects from other textbooks. The lesson was the beginning of a unit on systems of equations and focused on finding solutions to systems of equations by graphing; in the subsequent two days the teacher planned to teach students the substitution and elimination methods.

The teacher began the lesson with a whole-class discussion and demonstration of procedures. She asked students to define the terms "infinite" and "coincide" and explained that, in this lesson, they were going to learn how to solve a system of linear equations involving only two equations. The teacher worked three problems (e.g., the system $y = 2x$ and $x + y = 3$) on the board while students worked the examples at their desks. For the first example the teacher stated steps that the students were to do (e.g., "draw a coordinate plane on your graph paper") and explained her thinking to the class (e.g., when graphing $y = 2x$, "I'm thinking, well, it's in the y-equals form... $y = mx + b$... I do not see a 'b' ... So that tells me the y-intercept is 0"). The first system had one solution (i.e., lines intersected at one point), the second had no solution (i.e., the lines were parallel), and the third had an infinite number of solutions (i.e., the two lines coincided). The teacher classified the three systems as consistent independent, inconsistent, and consistent dependent systems, respectively. The teacher asked the students what they saw as drawbacks to the graphing method of solving systems of linear equations. Students were asked to complete another example, a consistent independent system, as independent practice and to share their solutions with the class. The teacher presented, one at a time, three contextual line graphs showing data about two fictitious companies regarding productivity (intersecting lines), production cost (parallel lines), and sales (equivalent lines). She discussed each graph with the class and then asked the class to vote for the company they would hire based on the graphs. The teacher assigned homework, and students worked on the homework assignment until the end of the class period.

9^{th}–11^{th} Grade Algebra I: Solving Linear Inequalities

The teacher explained that his district's Algebra I course of study and the designated Algebra I textbook are aligned by content and that he uses both in the planning of each lesson. In particular, this lesson was designed as a review lesson on the textbook chapter entitled "Solving Linear Inequalities." The teacher said the purpose for this lesson was to help students prepare for the next day's chapter test. Procedures for solving one-variable compound inequalities and absolute value inequalities were the major focus of the lesson.

Most of the class period was used for a whole-class discussion of the homework problems assigned during the previous class. The homework problems required students to solve compound inequalities (e.g., $2 < x + 2 \leq 5$) and to identify properties used in solving this kind of inequality (e.g., If $4x – 1 < 7$, then $4x – 4 < 4$ is an example of the subtraction property for inequality). The assignment consisted of a mixture of multiple choice and open-ended items. The teacher called on students, individually, to give answers to the multiple choice problems, and then he asked students to display their solutions to a few of the open-ended problems on the board. The teacher corrected any errors in the students' board work and answered questions the students asked about solution steps.

The teacher briefly reviewed the meaning of absolute value. He put the problem, $|4k + 2| \leq 14$, and the first solution step, $4k + 2 \leq 14$ and $– 1 (4k + 2) \leq 14$, on the board. Students were given three minutes to complete the problem, working independently. A student was asked to put the complete solution on the board, and the teacher went over some of the steps, but not all, due to time considerations. The teacher concluded the class by assigning a set of homework problems; the assignment provided students with additional practice in solving and graphing compound inequalities and absolute value inequalities.

10^{th} Grade Algebra II: Applications and Solutions of Quadratic Equations

This was an Algebra II lesson on applications of quadratic equations and use of calculators to solve quadratic equations. In the previous lessons of this unit, students had learned to solve quadratic equations by factoring and by completing the square. The teacher indicated that while the course content and sequence is defined by the district and state curriculum standards and the designated textbook, his instructional decisions were shaped by his perception of the students' low ability (several students were repeating the course), by his opinion that the book is too hard for them, by his desire to see them succeed on tests, and by time constraints.

The entire lesson was taught in a whole-class, lecture format. The teacher selected four textbook problems and modeled solutions for the students. The problems were:

1. By how much do you need to extend the dimensions of a 10×6 rectangle in order to double its area?
2. How can you double the area of a 4×4 square?
3. n is greater than its reciprocal by 1. Find n.
4. A rectangular field has an area of 5000 m^2 and is surrounded by a 300-m fence. Find the dimensions.

For the first problem, the teacher drew a diagram and translated the verbal description of the word problem into a quadratic equation. He demonstrated the calculator keystroke sequence to use in finding the square root of a positive number. The teacher wrote the value for the positive value of the variable without mentioning the negative value. He followed a similar method for the remaining three problems, asking a few questions, but answering most of them himself. Throughout the lesson, students attentively watched the teacher and took notes. As time ran out, the teacher assigned the next two textbook problems for homework.

10^{th}–11^{th} Grade Algebra Tech II: Central Tendency—Mean, Median, and Mode

The lesson in this Algebra Tech II class of 10^{th} and 11^{th} graders came near the end of a unit on statistics. The teacher designed this 90-minute lesson to provide an opportunity for students to finalize their study of statistics terms. She purposefully included basic mathematics skills—division, fractions, decimals, and percents—in the lesson because she is trying to prepare the students for the required state exit exam. There were three main segments in the lesson; first, the teacher led a whole-class review of a worksheet given for homework; second, the teacher gave the students another review worksheet to complete in class; and, third, students were given time to work on their independent statistics projects.

The lesson began with the teacher asking students, "What are the measures of central tendency?" After students identified mean, median, and mode, the teacher asked them to get out their homework worksheet. The homework worksheet contained problems on finding mean/median/mode of data sets, determining median and mode from a line plot, and reading stem and leaf plots, and it ended with a couple of word problems. The teacher called on each student to provide an answer for a homework problem, but approximately half of the student answers were incorrect. If the student she called on had not done the problem, then class discussion came to a halt while the teacher waited for the student to produce an answer. Most students had problems with the stem and leaf plots; they either couldn't determine median and mode or converted the stem and leaf plot to a list in order to arrive at an answer. The teacher was not concerned about how students got an answer as long as the answer they got was correct. The teacher summed up this part of the lesson by giving a couple of examples illustrating when measures of central tendency might be helpful (e.g., planning which meat to buy for a barbeque based on a survey of 50 people).

The teacher distributed four worksheets. She explained that they were to do the first three worksheets in class and the fourth sheet for homework. Students were directed to work alone on the worksheet pages. In general, students could successfully complete routine calculations of mean, median, and mode but had a great deal of difficulty with matching statistics terms with descriptions (e.g., "A measure of variability used to compare such things as the temperature differences of the warmest and coldest days of the year."). Students who could not figure out an answer typically guessed rather than ask the teacher for help. By the time the class ended, nearly all the students were working on the required bar graph of their survey data from their independent statistics project, mostly an exercise in drawing and coloring. As the bell rang, the teacher reminded the students several times that they only had to do problem #2 on the homework worksheet.

10^{th}–11^{th} Grade Honors Pre-Calculus: Trigonometric Functions

The Honors pre-calculus lesson for sophomores and juniors focused on trigonometry. Previously, students had studied definitions of trigonometric functions, the unit circle, and right angle trigonometry. In this lesson students learned how changing parameters in the equation $y = d + a \sin b (x - c)$ affects the shapes of the corresponding graphs. The lesson was taught because it fit into the logical sequence given in the department-adopted textbook and the teacher considered it to be important content for the majority of students in this class, students who would go on to Calculus and Physics classes the next year.

The lesson began with review problems to reinforce the definitions of the six trigonometric functions and their relationships (e.g., Find the quadrant and the values for the other five trigonometric functions of an angle if its cotangent is $-\sqrt{3}/3$ and its cosine is greater than 0). The teacher wrote on the board "Amplitude, Period, Phase Changes of Sine and Cosine." She drew the unit circle and labeled some of the special angles. She used a Slinky to model the wave nature of sine and cosine functions and discussed independent and dependent variables, the period of the function, and its amplitude. The teacher led a brief discussion of the Doppler effect as an application of trigonometric functions. She demonstrated how to graph $y = \cos x$ using its maximum, minimum, and intercepts and asked students to describe differences between the graphs of the sine function, $y = \sin x$, and the cosine function, $y = \cos x$; students noticed that they are the same shape but with an offset. The teacher led the students through a series of one-parameter changes (e.g., $y = 3 \sin x$, $y = \sin 2x$, $y = 2 + \sin x$, $y = \sin (x + \pi/2)$. The class discussed the effects of a, b, c, and d in the equation $y = d + a \sin b (x - c)$. Together the class created the function $y = -3 + 4 \sin 6(x + \pi/3)$, and the students computed the amplitude, period, and horizontal and vertical shifts of the graph of this equation. The class ended with a quiz on the unit circle.

Except for the time when students were working independently on the quiz, they were engaged in a whole-class discussion of review and new material. The teacher typically called on a student, the student answered, the teacher told the student whether the answer was right or wrong, gave the student a chance to correct the answer if necessary, or called on another student. The teacher encouraged students to participate in the class discussion. Students were attentive throughout the lesson.

10^{th}–12^{th} Grade Algebra II: Binomial Expansion

The teacher taught this lesson on binomial expansion because this content is mandated in the state and district objectives for Algebra II and because she decided that the content fit well in the instructional sequence. As the lesson began, students knew they could expand a binomial like $(2x – 3y)^5$ by using (2x – 3y) as a factor five times or by using Pascal's triangle method. In this lesson the teacher wanted to teach students another way to expand binomials.

The lesson began with a warm-up activity in which students were asked, first, to identify terms, coefficients, and degrees in a four-term polynomial expression and, second, to classify four polynomials as monomial, binomial, trinomial, or other. After allowing a few minutes for students to work independently, the teacher led a whole-class discussion of the warm-up problems. As an additional review, students participated in a whole-class game of Jeopardy in which the teacher would hold up a card, and a student would call out the appropriate question (e.g., for the card $a^m a^n$, the student asked, "What is a to the (m plus n)?"). Using an interactive-discussion format, the teacher reviewed special products of binomials (e.g., $(a + b)^2 = a^2 + 2ab + b^2$) and how the distributive property is used in multiplying polynomials.

The teacher put a copy of Pascal's triangle on the overhead and reviewed Pascal's triangle procedure for binomial expansion using the example $(x + d)^4$. The teacher carefully stated each step in the procedure—"write the coefficients, write the exponents, put the signs between the terms." The teacher continued the review by working two more problems of this type. The teacher told the students that she wanted them to watch her closely as she expanded the binomial, $(x – 2y)^5$, by a different method, the binomial theorem method. She stressed that they were to watch her, without taking any notes, and she promised to give them a handout containing notes on the method after she finished demonstrating the method. The teacher demonstrated a well-defined procedure without providing any explanation of why the procedure worked. As a second example, she selected a problem that she had done the previous day using Pascal's triangle method and worked it this time using the binomial theorem method. Students agreed that the final answer was the same by the two methods.

The teacher distributed notes on the binomial expansion method and a worksheet containing ten binomial expansion problems. Students were asked to work in groups to complete the ten problems, by either method, and to turn in one set of solutions per group at the end of the class period. The teacher provided some help to students as they were doing group work, but mostly, she was keeping a check on the groups' progress toward completing the assignment. Students in each group tended to work on different problems so they could finish the assignment more quickly. Some students watched as other students did the assignment. The teacher interrupted the group work to demonstrate to the class how to do one of the problems using the Pascal's triangle method. The lesson ended with students turning in the group assignment, whether complete or incomplete.

11th–12th Grade Pre-Calculus: Finding Roots of Polynomial Equations

The topic of this lesson, finding roots of polynomial equations and relating roots to graphs, was chosen because it was part of the Pre-calculus curriculum and followed sequentially from the previous lesson; it was also the next lesson in the textbook. The teacher had personally chosen the textbook based on his perception that it was the best match for the district curriculum and as preparation for the calculus course that most of the students would take the next year.

The lesson began with a short warm-up review exercise which required students to divide polynomials using synthetic division and to identify possible graphs for given polynomial equations. After he had answered all the student questions on the review, the teacher introduced a short worksheet on zeros of polynomials. The students were given two tasks: (1) to use the graphing calculator to graph three polynomials, identify the zeros in each polynomial, and write each equation in factored form and (2) to write a polynomial equation that could be an equation for the graph shown in the fourth worksheet problem. During this exercise the teacher circulated among the students to monitor their work. At one point, he brought the group back into a large-group discussion to review the use of synthetic division.

During the next segment of the lesson, students were given a set of graphs and asked to predict the nature of an equation that would result in a graph with that set of characteristics. Again, the teacher moved among the students to monitor their solutions and to create small discussion groups to look at each other's work and to discuss solutions. When students had completed their work, the teacher led a large group discussion. Students shared their predictions and discussed their work. The teacher probed student responses and involved other students in suggesting alternative solutions and rationales for these solutions. The teacher introduced two polynomials and asked the students to solve one using the graphing calculator and the second using a non-calculator procedure. Again, the teacher monitored student work and facilitated a whole-group discussion of the process and mathematical reasoning underlying the non-calculator method. The teacher assigned some homework problems from the textbook, and the students worked on this assignment, individually or in small groups, until the end of the period.

11th–12th Grade Statistics: Working Probability/Combination Problems

The lesson focused on problem solving in the area of probability, specifically combinations. The course was a teacher-designed statistics course for high school juniors and seniors that was offered because the state's high school exit exam contained statistics questions. This course, offered as an elective in mathematics, was put into the curriculum in response to a sense that there was not enough time in existing mathematics courses to adequately address statistics concepts. Definition of the curriculum for this course was totally the responsibility of the teacher; the teacher's development of the curriculum was based on finding common themes and problems in "seven or eight" introductory statistics books. The students had not been issued a textbook.

During the previous lesson the teacher had given students a mini-lesson on procedures to use in working probability/combination problems, and he had given them four worksheet pages of practice problems drawn from two statistics textbooks. As students entered the classroom they moved desks around to form clusters as needed for their own group while the teacher continued grading papers at his desk. The size of the groups ranged from 2 to 6 students. Students each got a graphing calculator from the teacher's desk and picked up their class folder from the side of the room. Students got out their copies of the worksheet pages and began working, within their groups, on the problems. The teacher announced to the class that he was preparing a homework assignment for them on probability and that the homework assignment would be due in two weeks. Other than this announcement the teacher was not involved in the lesson except when asked questions by students. When a student asked a question about a particular problem, the teacher, without looking at the student's work or asking the student what he had tried, would work the problem on the board and then check the answer key to see if he got the correct answer. If other students noticed the teacher working a problem on the board, they would copy his solution. Most of the students tried to apply the procedures the teacher had shown them the previous day. Some students were not working on the worksheets; the teacher did not attempt to engage these students in the task. The students spent the whole period working on the set of worksheet pages; the teacher did not debrief the lesson or provide any closing comments.

12th Grade Advanced Placement Calculus: Differential Equations

The topics for the lesson—integration, partial separable differential equations, and growth and decay—were selected because they are in the College Board's Advanced Placement Calculus curriculum. The teacher chose the textbook specifically for the problem sets it contains, which he likes because they are similar to the kinds of questions he expects the AP exam to contain, and because they include a number of application problems, such as those emphasized in this lesson. His pedagogy in this lesson included lecture, working examples, guided practice, and independent practice—pedagogy which, in the teacher's opinion, is typical of college-level mathematics instruction. The students in this class were very able, and highly motivated to learn the content of the course.

The lesson began with a set of seven warm-up exercises selected to review recently-taught methods of taking indefinite integrals. Students worked these problems independently or in informal groups or pairs. After giving students the answers to these exercises, the teacher answered students' questions and worked several of the problems at the board. Additional review followed as the teacher gave students the answers to the previous night's homework. Students asked the teacher to work a few of the homework exercises, which he did.

The teacher began a lecture on integrating partial separable differential equations with a few examples (e.g., $dy/dx = (x + 3x^2)/y^2$). He moved quickly to a derivation of the general exponential growth and decay formula, $y = Ce^{kt}$. The remainder of the lecture focused on applications of the growth and decay formula (e.g., "At noon a bacteria population is 10,000 organisms. Two hours later, 40,000 organisms are counted. Assuming exponential growth, how many bacteria are there at 5:00 p.m.?"). As more application problems were presented, the teacher moved toward guided practice for the students, with decreasing guidance for each problem. The teacher made an assignment from the textbook which the students began in class and were to finish for homework. The students worked individually, but often compared answers and frequently asked one another for help with procedures.

Ratings of Lesson Components

The designs of high school mathematics lessons are, on average, most highly rated for reflecting careful planning and organization and for utilizing the available resources to accomplish the purpose of the lesson. High school mathematics lessons are weaker in many areas, including incorporating strategies and activities that reflect attention to students' preparedness and prior experience, and providing students with the time and structure needed for sense-making. Lessons are weakest in encouraging collaboration among students, providing time and structure for wrap-up, and incorporating tasks consistent with investigative mathematics. The relatively low ratings in these areas may explain the low synthesis ratings for lesson design as 69 percent receive low ratings and only 9 percent receive high ratings.

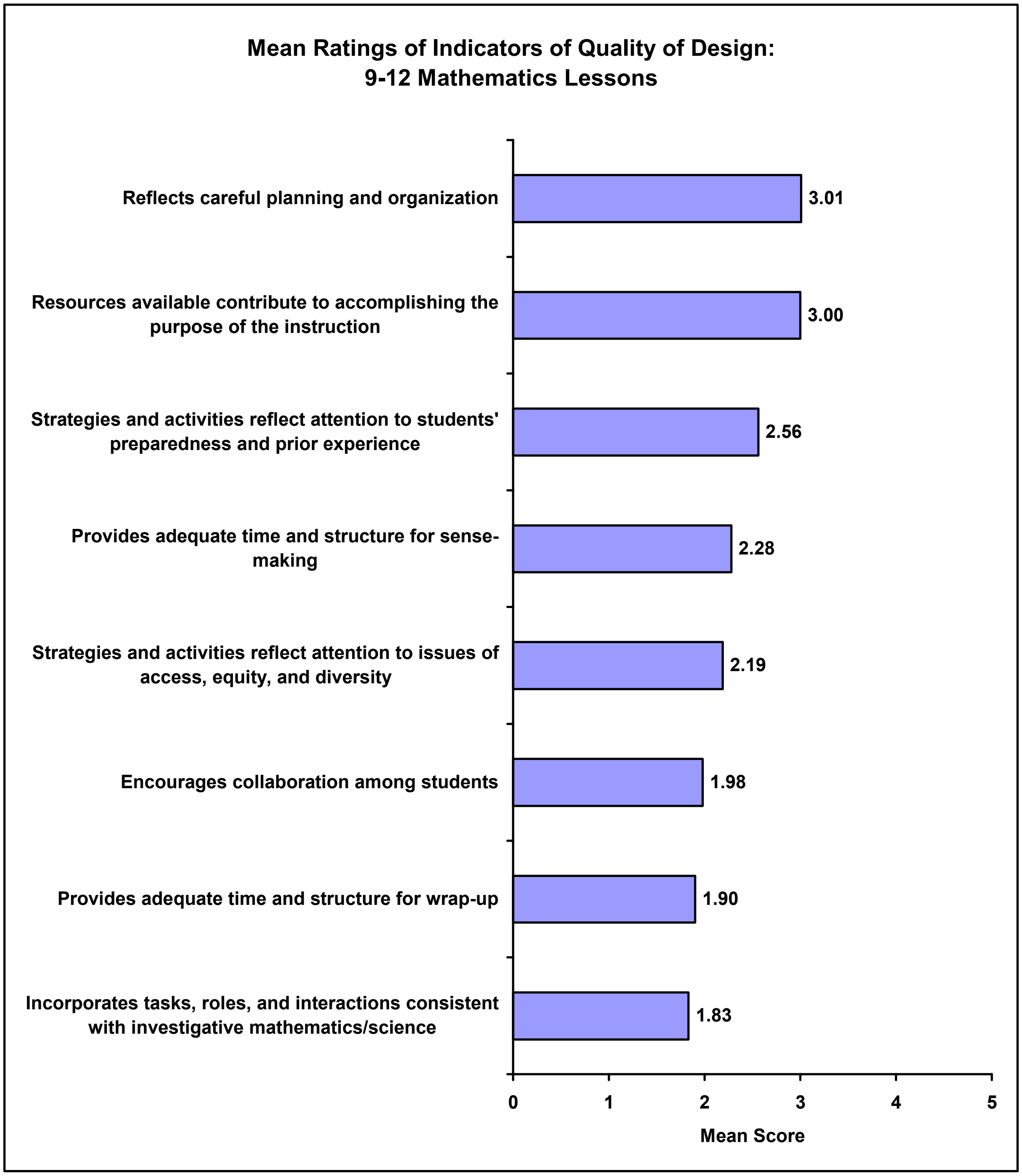

Mean Ratings of Indicators of Quality of Design:
9-12 Mathematics Lessons
Reflects careful planning and organization
3.01
Resources available contribute to accomplishing the purpose of the instruction
3.00
Strategies and activities reflect attention to students' preparedness and prior experience
2.56
Provides adequate time and structure for sense-making
2.28
Strategies and activities reflect attention to issues of access, equity, and diversity
2.19
Encourages collaboration among students
1.98
Provides adequate time and structure for wrap-up
1.90
Incorporates tasks, roles, and interactions consistent with investigative mathematics/science
1.83
0
1
2
3
4
5
Mean Score

Figure E-1

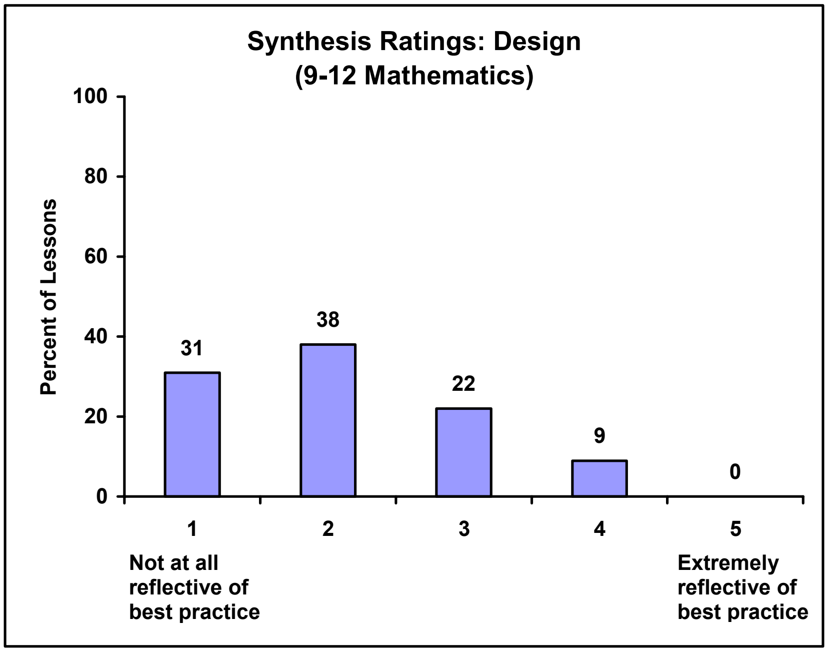


Figure E-2

The implementation of high school mathematics lessons is rated most highly for teachers' confidence in their ability to teach mathematics. The implementation of lessons is weaker in regard to teachers' classroom management and pacing (moving either too quickly or too slowly). High school mathematics lessons are weakest in adjusting instruction according to the level of student understanding, using instructional strategies consistent with investigative mathematics, and posing questions that enhance student understanding. These low ratings are reflected in the implementation synthesis ratings. Seventy-one percent of lessons receive a low rating for implementation while only 12 percent receive a high rating.

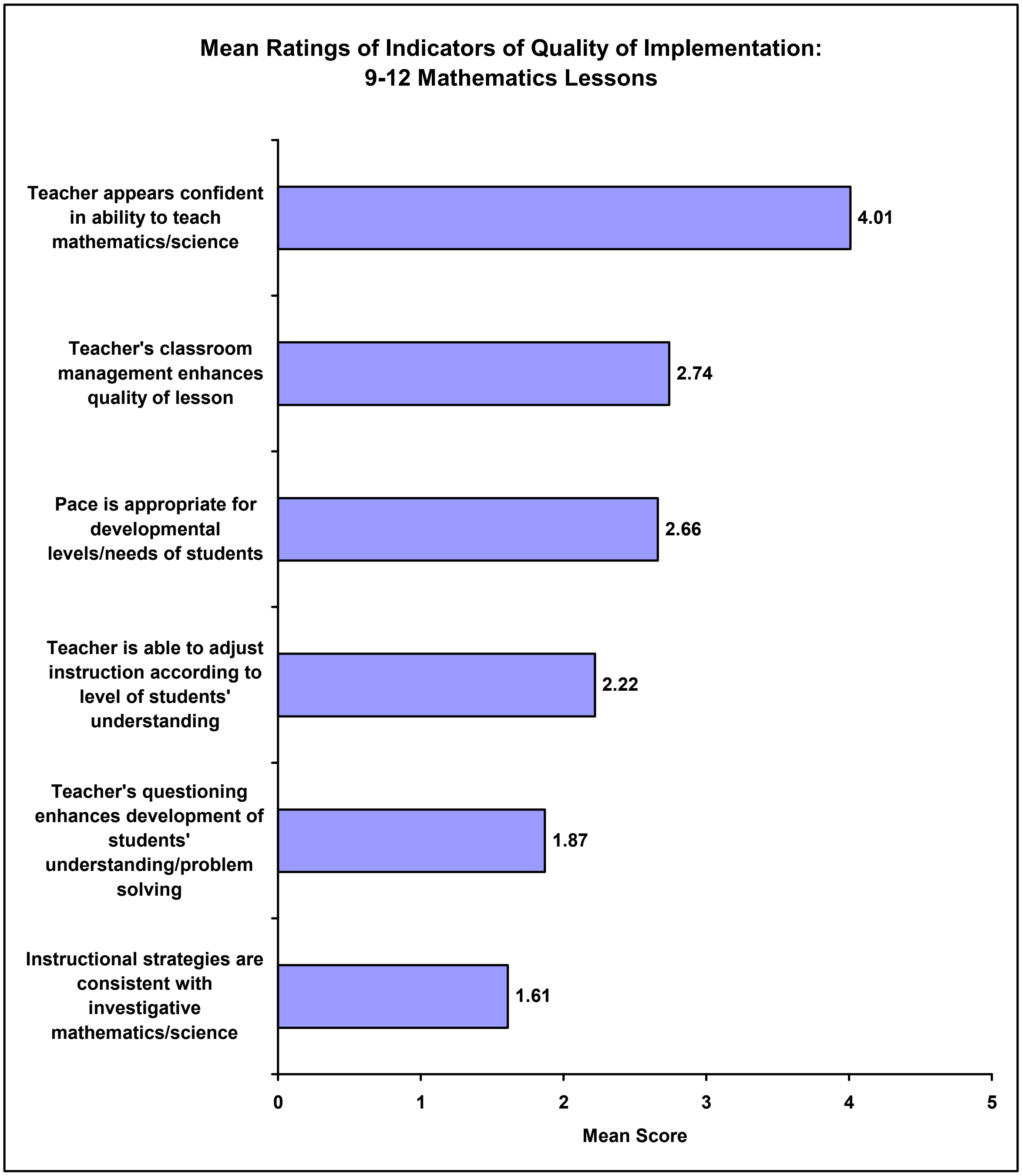

Mean Ratings of Indicators of Quality of Implementation:
9-12 Mathematics Lessons
Teacher appears confident in ability to teach mathematics/science
4.01
Teacher's classroom management enhances quality of lesson
2.74
Pace is appropriate for developmental levels/needs of students
2.66
Teacher is able to adjust instruction according to level of students' understanding
2.22
Teacher's questioning enhances development of students' understanding/problem solving
1.87
Instructional strategies are consistent with investigative mathematics/science
1.61
0
1
2
3
4
5
Mean Score

Figure E-3

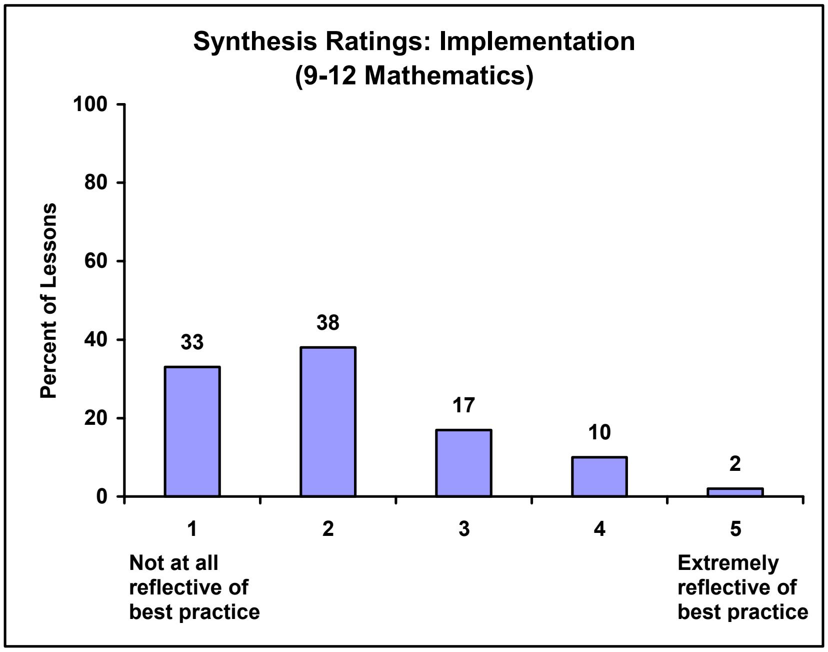
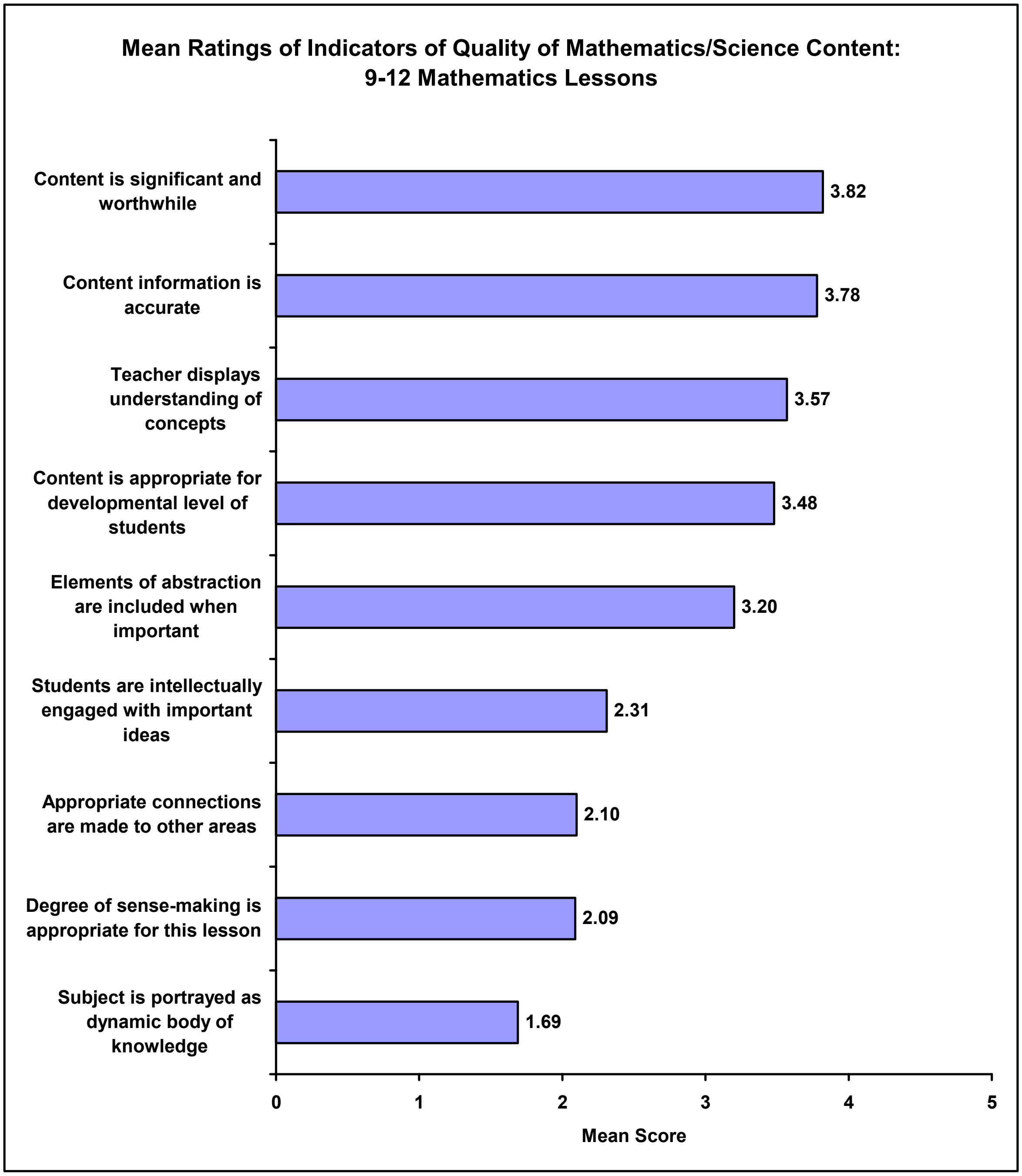


Figure E-4

The content of high school mathematics lessons is, on average, rated highest for focusing on significant and worthwhile content at a developmentally appropriate level and doing so accurately. In addition, lessons are rated highly for teachers displaying an understanding of the concepts. High school mathematics lessons are weakest in intellectually engaging students with important ideas, making connections to other areas, providing opportunities for students to make sense of the content, and portraying mathematics as a dynamic body of knowledge. Seventeen percent of lessons receive a high synthesis rating for content, 30 percent receive a medium rating, and 53 percent receive a low rating.



Mean Ratings of Indicators of Quality of Mathematics/Science Content:
9-12 Mathematics Lessons
Content is significant and worthwhile
3.82
Content information is accurate
3.78
Teacher displays understanding of concepts
3.57
Content is appropriate for developmental level of students
3.48
Elements of abstraction are included when important
3.20
Students are intellectually engaged with important ideas
2.31
Appropriate connections are made to other areas
2.10
Degree of sense-making is appropriate for this lesson
2.09
Subject is portrayed as dynamic body of knowledge
1.69
0
1
2
3
4
5
Mean Score

Figure E-5

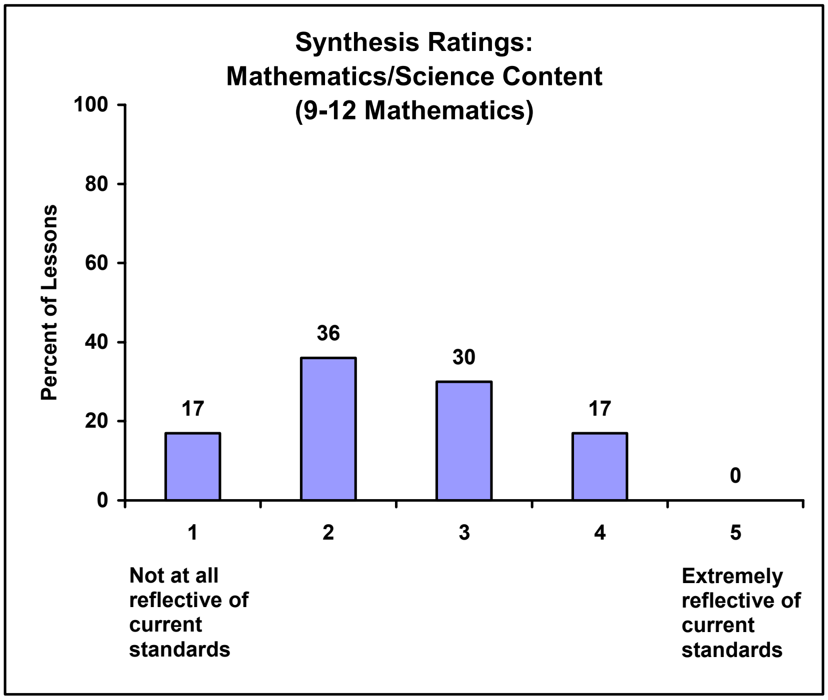


Figure E-6

In regard to classroom culture, high school mathematics lessons are rated strongest in having a respectful climate. Lessons are weakest in encouraging students to generate ideas and questions and in their level of intellectual rigor. The synthesis ratings for classroom culture reflects these indicators with 13 percent of lessons receiving a high rating, 22 percent receiving a medium rating, and 65 percent receiving a low rating.

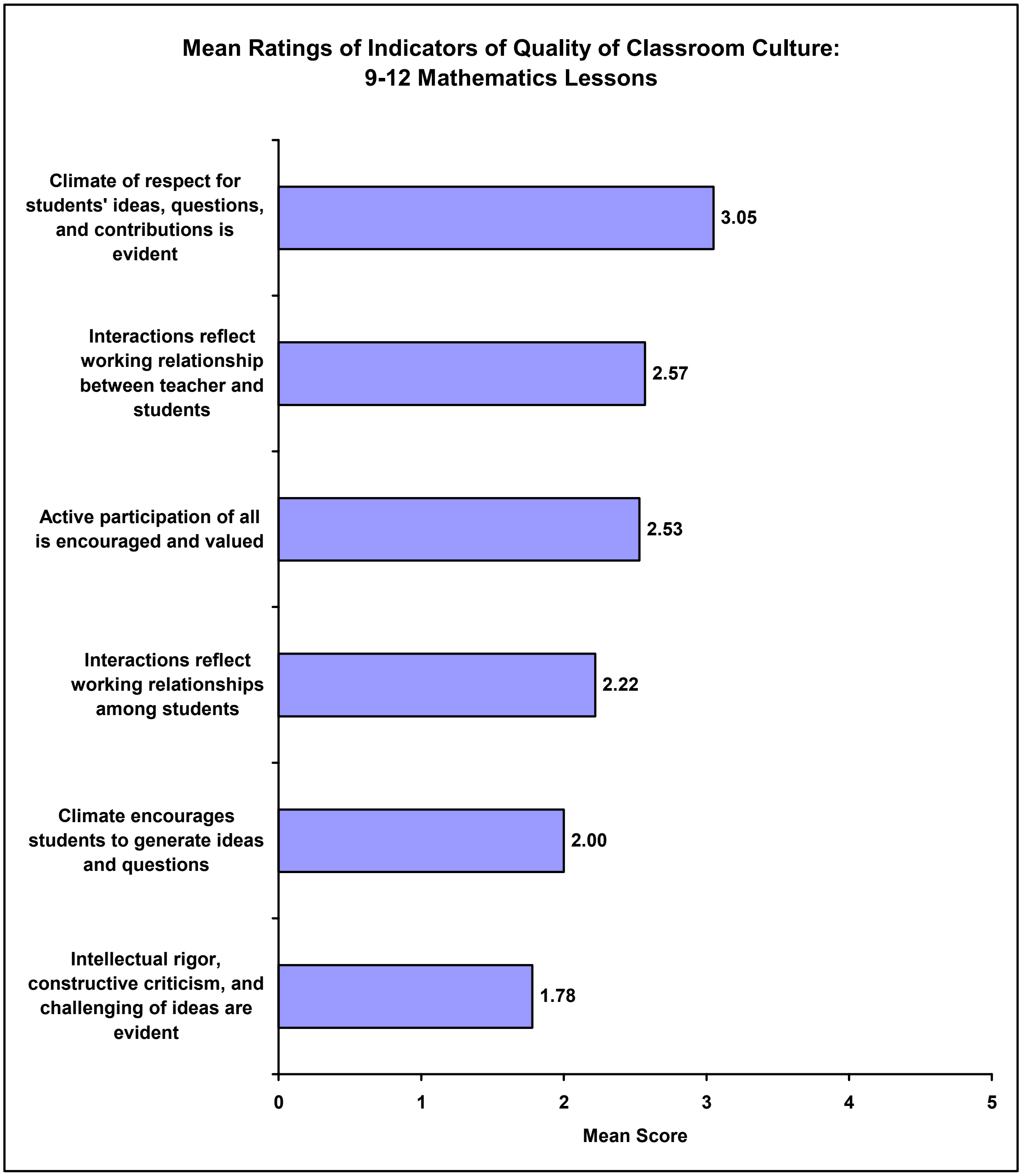

Mean Ratings of Indicators of Quality of Classroom Culture:
9-12 Mathematics Lessons
Climate of respect for students' ideas, questions, and contributions is evident
3.05
Interactions reflect working relationship between teacher and students
2.57
Active participation of all is encouraged and valued
2.53
Interactions reflect working relationships among students
2.22
Climate encourages students to generate ideas and questions
2.00
Intellectual rigor, constructive criticism, and challenging of ideas are evident
1.78
0
1
2
3
4
5
Mean Score

Figure E-7

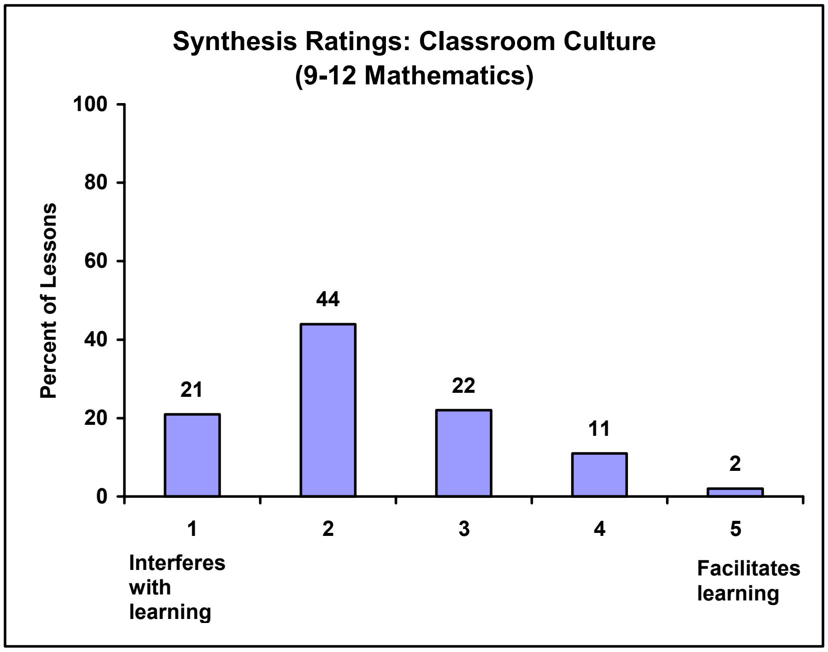

Synthesis Ratings: Classroom Culture
(9-12 Mathematics)
100
80
60
40
20
0
Percent of Lessons
21
44
22
11
2
1
2
3
4
5
Interferes with learning
Facilitates learning

Figure E-8

Overall Lesson Quality

Following the ratings of the individual components of the lesson, the researcher was asked to consider the likely impacts of the lesson as a whole. Less than a third of the lessons have positive impacts on students' understanding of mathematics or confidence to do mathematics. Sixteen percent or fewer lessons have a positive impact on students' interest in the mathematics, ability to apply the skills and concepts they are learning to other disciplines or real-life situations, and capacity to conduct mathematical inquiry. The majority of lessons are likely to have a negative impact on students' understanding of mathematics as a dynamic body of knowledge generated and enriched by investigation, a reflection of the rote, algorithmic methods being used in most mathematics lessons. (See Table E-1.)

Table E-1
Likely Impact of the Lesson: Mathematics 9–12

	Percent of Lessons		
	Negative Effect	**Mixed or Neutral Effect**	**Positive Effect**
Students' understanding of important mathematics/science concepts	19	51	30
Students' self-confidence in doing mathematics/science	24	48	27
Students' interest in and/or appreciation for the discipline	44	41	16
Students' ability to apply or generalize skills and concepts to other areas of mathematics/science, other disciplines, and/or real-life situations	29	59	12
Students' capacity to carry out their own inquiries	28	61	11
Students' understanding of mathematics/science as a dynamic body of knowledge generated and enriched by investigation	61	30	8

Figure E-9 shows the percentage of 9th–12th grade mathematics lessons in the nation rated at each of a number of levels. (See page 9 of the Observation and Analytic Protocol in Appendix A for a description of these levels.) Sixty-nine percent of high school mathematics lessons are rated as low in quality on the capsule rating, 23 percent are rated as medium in quality, and 8 percent are rated as high in quality.

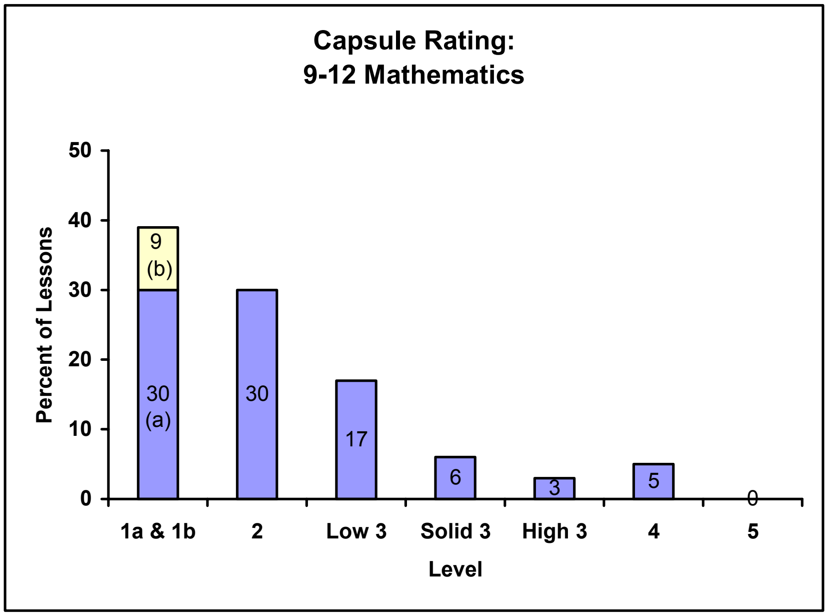


Figure E-9

The following illustrate lesson descriptions that were rated low, medium, and high in quality.

Sample Low Quality Lesson: Passive "Learning"

This lesson was the beginning of a unit on equations and inequalities in a 9th grade class. The lesson was designed to provide students with an introduction to solving equations.

After roughly ten minutes of taking attendance and returning graded assignments to the students, the teacher introduced solving linear equations by working through several examples on the overhead projector. The teacher appeared to know the content and used correct terminology. However some examples, such as $\square + 5 = 17$, appeared to be too simple for these 9th grade students.

In the teacher's effort to help students better understand how to solve the equations, he merely asked them to remember and repeat the procedures he demonstrated. 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 but instead spent time asking about the particulars of the upcoming assignment.

Upon completing his presentation of the content, the teacher handed out a worksheet for students to complete individually. He then read the answers for students to check their work. With no further discussion of potential problems or any indication of how well students understood the mathematics from the first worksheet, the teacher handed out three more worksheets for students to complete during the remaining 65 minutes of this block lesson. While the students were completing the worksheets, the teacher monitored what students were doing and occasionally assisted individual students. Students who finished before the class ended talked for the last 15 to 20 minutes.

Overall this lesson was very poor in helping these 9th grade students better understand the mathematics involved in solving linear equations. The teacher's presentation of the content was procedurally-focused and emphasized memorizing and duplicating the steps he defined for solving the problems. The examples he provided failed to challenge many of the students, and his questioning and management style did very little to engage the class. Further, the excessive amount of time dedicated to individual practice, the lack of opportunity for students to discuss their work or interact with one another, and the absence of any type of wrap-up of ideas seriously hindered students' ability to make sense of the content.

Sample Low Quality Lesson: "Activity for Activity's Sake"

Students in this high school Geometry class had nearly completed a unit on congruent triangles. The bulk of the class time was spent in review, copying and constructing geometric figures using only a compass and a straight edge. One new construction was added, that of constructing a perpendicular line from only a point and a line segment.

The teacher began the lesson by telling students to get out their index cards, references that the students had created to help them remember proofs and the procedures for various geometric constructions introduced thus far this year. She then passed out a worksheet containing five construction problems. She instructed the students to do the first problem (constructing or copying a line segment) and then suggested that they look at the instructions on their index cards.

After a few minutes, the students were told to go on to problem number two. There had been no large group review of the first problem, but the teacher had walked around the room looking over their work. At one point she said, "I want to see all your markings. Label them."

Student desks were grouped together in clusters of 4–5 to make "tables." Some students talked to their neighbors during the seat work; others did not. Students had their bundles of index cards out on their desks and appeared to be using them. They were required to complete the worksheets individually, though the teacher encouraged them to ask for help from their peers. ("Look around…if you're having trouble, if you can find someone who knows, you can ask them.")

Students began to talk more and the teacher, noticing some behavior she wanted to correct told them, "Do not move on to number three. Do *not* make helicopters out of your protractor." After about 25 minutes, the activity changed. The teacher instructed them all to get out their textbooks and copy onto one of their index cards the three-step process for constructing a perpendicular line given only a point and a line segment.

After students had finished copying the instructions, the teacher asked, "How many of you think you could do it following the instructions? Try it. Use my worksheet." She told them to be careful not to change the compass (the length of the arc), but there was no discussion about why this would be important in the construction.

This lesson did not provide much of an opportunity for students to deepen their understanding of mathematics. Construction was discussed in strictly procedural terms and the concept of congruence was completely missing. The only mention of keeping a measurement consistent in these drawings completely missed the mark in terms of furthering students' understanding of the role of congruent triangles in verifying constructions made without a protractor or ruler. There was no evidence of higher-order thinking.

Sample Medium Quality Lesson: Beginning Stages of Effective Instruction

This 8th grade class had been studying systems of equations and most recently had completed a test on the topic. Unhappy with the results, the teacher chose to return to the topic for this lesson.

The lesson was designed around the school's adopted text, although the teacher also incorporated examples from another textbook that he had found in his room at the start of the year. The lesson began with the teacher writing the definition of systems of equations on the board and beginning to review three methods for solving systems of equations: substitution, addition/subtraction, and multiplication. The teacher talked through the different methods and worked one example. The review was spirited and well-organized, with ample student participation. The teacher's questions were appropriate for the task and kept students thinking; the students raised questions and from time to time asked the teacher to slow down. Overall the review activities provided guidance that seemed to benefit students as they worked individually.

After the review, the teacher gave the students two systems to practice individually:

(Add/Subtract)	(Multiply)
$y + x = 3$	$2x - y = 6$
$y - x = 1$	$-3x + y = 1$

Each system was titled by the specific strategy that was to be used to solve it. Although this appeared to be a bit too much guidance for some students, a number of students may have needed this level of directedness initially. Students were attentive and focused during individual practice time, and the time allotted for students to complete the problems was sufficient. The teacher left students to grapple with the content and was hardly ever called for assistance. He followed the individual work with students going to the chalkboard to complete and explain the different problems. Students eagerly volunteered to come forward and talked through their work. During the students' presentations the class listened attentively and often asked questions. The teacher probed for student understanding and emphasized clarity of language.

Most of the teacher's questions were focused on the procedural steps for solving the system, for example, "When I add a $-3x$ to a $2x$, what do I get?" and "I multiplied every term by…?"; However some questions were a little more thought-provoking and less leading, for example, "Since I'm looking for $+y$, how am I going to change $-y = -4$?"

After going over the first problems that students did individually, the teacher wrote three more problems on the board from the supplementary textbook. The problems were similar to the ones listed above, and again students were asked to complete the three problems individually. The discussion went just the same as the prior one.

This pattern—the teacher giving two or three problems then having the students work them on the board and explain—continued until the end of the period. Although sense-making was tended to throughout the lesson, there was no wrap-up of the topic. Overall, the lesson was built on strong content but had a flawed design that involved the re-teaching of a topic in the exact same way it was taught the first time. The students were not given the opportunity to connect the topic to other subjects, nor to see where the topic fit in the subject of algebra.

Sample High Quality Lesson: Traditional Instruction

In the lesson prior to this one, this Geometry class had been introduced to two theorems: the Dual Perpendicular Theorem and the Dual Parallel Theorem. The class had also worked on defining parallel lines. This lesson was designed to review these ideas because many students were absent due to a school field trip. An additional purpose of the lesson was for students to better understand the fundamentals of compass and straight edge constructions.

The teacher started the lesson with an activity designed to help students review the skills that had been taught during the prior lesson. Students were asked to copy both theorems that the teacher had already written on the board and to list five ways of showing that two lines are parallel to one another. After students completed copying the theorems and making their list, the teacher began to ask questions of the students to check their understanding. Of particular notice was the depth of the teacher's questions and his wait time. For example, the teacher asked students why the word "coplanar" was included in one theorem but not the other. He probed further as to whether the word was necessary for one or both theorems and had students provide examples that helped support their thinking. Other questions during this segment ("Why are *l* and *n* parallel?"; "How do I illustrate that?"; and "Can you think of another way of showing that?") were similarly rich in getting students to think more deeply about the mathematics content as well as helping them connect the concepts to previously-learned material.

Following this discussion, the teacher had all students go to the dry erase boards that surrounded the room to simultaneously practice problems. The problems called for students to recall geometric concepts that had been previously covered in class, as well as to discover the ways these concepts connected with what they were presently learning about the theorems. Students appeared to be very comfortable listening to the teacher's set of directions for each problem, and for the most part students were able to solve the problems and identify connections. Students worked individually, but looked to their neighbors on either side for guidance and approval. The teacher also served as a guide and checked the work of each student. As the activity progressed, he paid closer attention to those students who appeared to be having more difficulty completing the problems.

After walking the students through several problems, the teacher began the new unit on basic constructions. Students took out their notebooks and were given an unmarked straight edge and a compass. The teacher directed them step-by-step through three constructions. As the teacher completed and explained a step on the board, students duplicated the step in their notebooks. The teacher's questioning and pace appeared to keep the content engaging for the class.

The teacher then gave students the option of working individually or in pairs to complete an assignment that required them to apply what they had just learned in creating three additional constructions. During this time, the teacher walked around and provided assistance to those who were struggling.

The design of the lesson appealed to a variety of learning styles and appeared to match the needs of these geometry students. The lesson was centered on content that was rich and appropriate. Throughout the lesson students grappled with the content and continually moved forward in their understanding as a result of the teacher's management style.

Sample High Quality Lesson: Reform-Oriented Instruction

The purpose of this high school pre-calculus lesson was to help students learn to factor polynomials, using both a calculator and a non-calculator method. The lesson began with a short warm-up exercise that was designed to be a review. The activity required students to divide polynomials by using synthetic division and to identify possible graphs for the given polynomial equations. After the teacher answered student questions about the activity, he asked students to use graphing calculators to graph three polynomials, identify the zeros in the polynomials, and write the equations in factored form. Students were also asked to write a polynomial equation that could be an equation for another graph he provided.

During the exercise, the teacher effectively helped students make sense of the mathematics by circulating and assisting where needed. He constantly assessed student understanding and modified his instruction to address issues that emerged as barriers to students' progress. For example, after noticing the trouble many students were having using synthetic division, the teacher brought the group back together for additional review. When one student stated that she could follow the process but did not understand a particular operation, the teacher asked another student to explain the operation. Continuing to make good use of the collective problem solving skills of the group, the teacher solicited another explanation from a third student.

The next segment of the lesson involved students analyzing a set of graphs to predict the nature of the equation that would result in a graph with that set of characteristics. At times the teacher asked small groups to look at each other's work and to discuss their solutions. When the students had completed their work, the teacher led a large group discussion, asking students to share their predictions. As students offered their thoughts, the teacher again probed their responses and involved other students in suggesting alternative solutions and providing their rationales for these solutions.

After going through an additional activity that involved students solving two polynomials, one using the graphing calculator and one without, the teacher assigned homework problems from the textbook. As students started on the assignment, some worked individually while others worked in small groups. Several students talked together about the operations of the calculators, and one student showed the group another way he had found to use his calculator to factor the polynomial.

The design of this pre-calculus lesson effectively kept the interest and engagement of the students. It included content that was appropriate and challenging, as well as tools and instructional approaches that enabled students to focus on the underlying mathematics concepts. Throughout the lesson, the teacher challenged students to think about different strategies by involving them in critiquing each other's work in a non-threatening manner. The teacher posed questions that pushed the students to extend their thinking and also incorporated ample time for sense-making through both large and small group discussions. Overall the lesson was implemented with great skill, and was highly likely to increase student understanding of factoring polynomials.

Appendix F

Grades K–5 Science

Typical Lessons

Ratings of Lesson Components

Overall Lesson Quality

Typical Lessons

The following lesson descriptions are based on a random sample of K–5th grade science lessons.

Kindergarten: Basic Needs of Plants

This kindergarten class was in the middle of a unit on living and non-living things. Prior to this lesson, they had discussed the characteristics of living things, seeds, and the parts of a plant. After this lesson on the basic needs of plants, the class would move on to how plants grow and change. This lesson was taught because it is in the recently-adopted textbook series, which is also aligned with the state standards. In addition, the teacher believes that students at this age need to work on their reading and fine motor skills, and that they enjoy hands-on work.

The lesson started with a review of what the class had done up to this point with plants. Students sat on the floor, and the teacher asked them to list their activities over the last few weeks, which included planting sunflowers, reading a story about a seed, conducting an experiment by depriving a plant of water, and creating a concept web about what plants need. The teacher showed them the web they had made, and the students recited the needs of plants (sunlight, soil, air, and water).

Next the teacher showed an example of the project the students would be working on in this lesson. The picture consisted of a magazine photograph of a flower, a watering can and sun made from construction paper, and crayon drawings of soil and air. Each part was labeled with the typed words "light, soil, air, and water"; and at the top were the words "What do plants need?" The teacher showed the students what the labels looked like, and read them aloud with the students. She then showed them where on the tables they could find each of the materials and instructed them to make their picture look exactly like hers.

Students worked on their projects for the remainder of the lesson as the teacher circulated and offered help or asked questions. She did the cutting and pasting for some students and simply offered encouragement to others. Many of the students had trouble reading the labels and could not even begin to sound out the words when coached. For these individuals, the teacher read off the word and asked them to place it on the appropriate part of the picture. After half an hour, the teacher called students back to their seats and asked, "Have we learned what plants need?" and students replied in a chorus, "Yes. Water, sun, soil, air."

1st Grade: Plant Growth

This is the third lesson in a kit-based unit on organisms. Prior to this lesson, the students in this 1st grade class brainstormed different organisms and discussed how they are alike and how they are different. They also observed different types of seeds and described each of them. The primary purpose of this lesson was to set up an ongoing observation of plant growth and for the students to begin to think about what might happen to the seed. A secondary focus was to continue building students' observation skills, as the students will observe the seeds as they grow into plants over the next several weeks.

The lesson consisted of two parts. In the first half of the lesson, the students planted two seeds in a clear cup. All students at a table had the same kind of seeds but different tables had different seeds. The teacher provided step-by-step instructions on how to plant the seeds and waited until all students had completed a task before she gave instructions for the next one. She elicited minimal input from the students about how the seeds should be planted and offered no explanations about why those particular steps were being used to plant the seeds. There was a brief discussion about how they could keep the seeds warm and wet to help them germinate, during which the students suggested different methods. Based on one student's suggestion, the students put the cups with the seeds back in the plastic bags.

In the second half of the lesson, students individually completed a worksheet on which they circled the type of seed that they had planted and completed a sentence about the planting experience which began, "I would like to find out…" The teacher introduced the worksheet to the group of students by reading to them each of the sentences they were supposed to complete. While the students were working on the worksheet, the teacher assisted them with the spelling of words, often helping them to sound out words and checking what they wrote.

1st–2nd Grade: Temperature

This lesson on the concept of temperature falls roughly in the middle of a unit on weather. The teacher began with a brief discussion of temperature during which she took a poll asking how many students thought the temperature would differ between inside and outside and which they thought would be warmer. Students were then given an alcohol thermometer and asked to gently hold their thumb on the bulb and watch what happened. After this observation, the teacher asked students to put the thermometers down on the table. She then led a discussion of what the thermometers were measuring when the students had their thumbs on them and what they were measuring now that they lay on the table. While the thermometers were equilibrating, students worked on a sheet on which they had been recording wind observations for several days. Questions on the worksheet were answered, as a class, by looking at their wind graph. About 20 minutes into the lesson, the class returned to the concept of temperature as they read their thermometers and recorded the temperature on another worksheet, coloring a picture of a thermometer to indicate how high the alcohol had risen. The teacher circulated to make sure that students were making and recording their temperature measurements. When students noticed that not everyone had recorded the same temperature, the teacher explained that sometimes instruments in science do not all give the same readings. In the last few minutes of the lesson, the class moved outside to place thermometers on the ground in the shade and measure the temperature. They then returned to the classroom to record the outside temperature.

2nd Grade: Effect of Temperature on Dissolving Rate

This 2nd grade science lesson was in the middle of a unit on change. In the most recent lesson, the students had performed a dissolving race between a sugar cube and sugar grains. In this lesson, the students compared how quickly granulated sugar dissolved in warm water versus cold water. This lesson was taught because it was the next lesson in a district-chosen unit titled Changes. The purpose was to start the students thinking about change in the natural world and to notice changes that they might otherwise take for granted.

The teacher began the lesson by asking students to give her some examples of changes, after which she reminded them of the sugar cube race they had had in the previous science lesson. When she asked them directly, "What did we learn from the race?" the students remembered that the sugar grains had dissolved more quickly. The teacher then introduced the day's topic by telling students, "In the summertime, I like to make sun tea. I like to put a little sugar or honey in my tea. I've noticed that the sugar dissolves faster when the tea is still warm from the sun than after it has been cooled in the refrigerator." She then explained that they would be conducting a "dissolving race" in which they would test the rate at which sugar dissolved in warm water versus cold water. While some new vocabulary words were used, such as evaporation and dissolving, the focus was on the concept and meaning of change rather than on definitions.

Before they started the activity, the teacher asked the students to predict which temperature would win the dissolving race. Most students voted for the warm water, but several also voted again for the cool water and then again for waiting to see what happened. The teacher's aide then distributed materials to pairs of students, and they were instructed to pour the small cups of sugar into the hot and cold water and stir until it dissolved. Once the sugar had dissolved, they were told to stand up and stop stirring. Although there were hand lenses on the trays, the students were not asked to use them and none did. As soon as all students were standing, they were asked to sit back down and asked to describe what happened. One student said, "I think the warm water evaporated the sugar." The teacher reminded them that evaporation meant going into the air and dissolving meant going into the liquid. When she asked them if the sugar was still in the liquid, half voted for yes and half for no. She then polled the student pairs as to which cup "dissolved first." Everyone agreed the warm water had won the race.

The teacher wrapped up the lesson by asking the class, "Can you tell me two things that help sugar dissolve faster?" One student suggested small grains and then a second offered that stirring helps, to which the teacher responded, "That's probably right, but we haven't tested that yet." Finally, someone suggested warm water. All the students then helped with cleaning up the tables and putting away the materials, after which the teacher instructed them to draw an example of change on a piece of paper that was divided in half. They worked on these pictures for the remainder of the science period.

2nd Grade: Properties of Water

This introduction to a unit on weather in a 2nd grade class was "to start students thinking and wondering about weather," beginning with a guided inquiry activity using water as part of developing student understanding of the water cycle. The class had a wide range of abilities, including two students with mild mental retardation, as well as two students for whom English is a second language.

The teacher began by asking the class to write down what they already knew about weather in sentences and/or pictures with captions. After a few minutes, the teacher asked each student to pick one idea and share it with the class.

The teacher then handed out the wax paper and toothpicks the students would need for the day's activity and walked around the room using an eyedropper to scatter water droplets on each piece of wax paper. She asked students to use the toothpicks to "explore" the water. The students were quite involved in this activity, commenting on the size and motion of the drops as they prodded them with the toothpicks.

Following this period of open exploration, the teacher suggested that the students try a number of specific moves, including stretching a water drop "into a big, long worm" and cutting a drop into two equal pieces. She then asked the students to write down their observations. The teacher used the subsequent sharing of individual observations to probe for understanding. For example, when one student expressed surprise that "the water bubbles didn't pop" the teacher said, "Did you expect it to pop?" The student said, "Yes, the toothpick is pointy."; at which point the teacher commented, "That rounded shape made you think of balloons."

After the sharing of observations, the teacher asked, "Who knows what a scientist does after observations?" to which a student responded, "Make a conclusion." The teacher then asked the students to write a sentence describing what they had learned about water based on today's observations.

2nd–3rd Grade: Plants vs. Animals

This class is at the start of their third and final science unit of the year which focuses on organisms. The teacher taught this lesson on the differences between plants and animals because the topic is included in the state curriculum/benchmarks and in the kits provided by the district. This lesson was designed by combining aspects of different lesson outlines provided with the "Organisms" kit to make one shortened lesson that could be completed in the 30 minute period allotted for science.

This was the third lesson in the "Organisms" unit. Students had already discussed what organisms are and made distinctions between the Plant and Animal kingdoms. They had also drawn an organism and made a list of its needs. The observed lesson focused on learning more about the two main kingdoms by comparing the similarities and differences of organisms in each of these groups. A secondary focus was to introduce Venn diagrams to the class. The teacher planned to continue talking with students the next day about commonalities between the plant and animals groups, after which students would create two different habitats (terrarium and aquarium) to further compare different organisms in these groups.

The lesson began with the students sitting on the floor in front of the teacher, who was sitting on a chair beside a small easel with a white board on it. In a whole-class, question-and-answer format, the teacher had students recall what they had already covered in previous lessons in this unit as she wrote down key words on the board. She also introduced the current lesson's activity in this setting, demonstrating with a list on the board how students were to brainstorm what they knew about plants and animals. Students were assigned to small groups to work at their desks. Those in the classroom for whom English was not a first language were given the option to brainstorm in Spanish. Again, in a whole-class format, the teacher elicited students' thoughts from the brainstorming exercise, writing out their comments on large circles (one for plants, one for animals) on the front board. Then she asked students to tell her which items were shared by both plants and animals, and she wrote these in the center of the two circles she moved to overlap. She ended the lesson by explaining the concept of a Venn diagram.

3rd Grade: Alka Seltzer Experiment

The activity in this 3rd grade lesson was modified from one the teacher encountered in a professional development workshop. The content was included in the 3rd grade curriculum as part of a unit on gases by common decision of the teachers at that grade level.

The lesson began with a whole-class review of an experiment with Alka Seltzer and water in a bottle topped by a balloon that the class had done previously, including a review of the predictions they had made and what they had actually observed. The lesson then proceeded with an introduction to a variant of this experiment, using capped film canisters instead of the bottle and balloon. First, the children made predictions of what might happen, "It will blow the lid off, because there is so much pressure, it will blow the lid off." In response, the teacher asked, "Will it always happen?" The student answered, "Maybe not. Because you put in a little piece [of Alka Seltzer]." The teacher then had a student do a demonstration of Alka Seltzer and water in a canister, and the children reacted with glee at the "pop" of the lid. After a thorough briefing on safety issues, the class adjourned to the school playground to experiment. Working in pairs, the children lined up on the basketball court and tried out different sizes of pieces of Alka Seltzer tablets along with different numbers of drops of water. The teacher walked among the children asking them questions about their observations. The teacher asked students why they thought that the lids were popping off, or in some cases, not popping off. After fifteen minutes of experimenting, during which all of the students had a chance to pop their canisters several times, the class reassembled in the classroom. The children then had a chance to talk about what they had observed, and to consider how it related to the idea of a solid and liquid producing a gas that they had discussed before the experiment. The lesson was brought to closure by having the students either write and draw what they had done and observed, or draw a cartoon depicting the events.

3rd Grade: Animal Survival Needs

This 3rd grade class had just finished a chapter on animal classification and was beginning to study what animals need to survive. Prior to this lesson they had read through the chapter. This lesson was designed to generate notes on the material as a class, and was taught because it is in the district curriculum and the teacher expected the content to show up on the state test. It was organized as a reading comprehension activity, with the students reading aloud and deciding together what the important points were, because the teacher had noticed that the students were struggling with the high reading level of the textbook.

The lesson began with the teacher asking students to open their books and look up the definitions for "environment" and "savanna," which they called out in unison and she copied onto chart paper at the front of the room. She then called on a student to read aloud from the first paragraph in the chapter, after which she asked them to find the important facts in the paragraph. After the students had identified what they considered to be the key points, the teacher wrote them on the chart paper. She then called on another student to read aloud, and the rest followed along silently. This continued for the rest of the lesson, with the teacher calling on a different student to read each time and asking students to identify key phrases or facts. She occasionally asked questions about the material in the chapter, such as: "Does that (the category of animals) include us? What kind of animals are we?", "How long can we go without eating?" and "Do you think animals could have more than one shelter?" To this last question a student responded, "No, because they lay their eggs in one nest and need to take care of them." The teacher praised this answer then went on to ask, "What if the eggs don't hatch? What if it's a bad nest—can they go to another?" Most of her questions, however, were variations of "What's important in this paragraph?" or "Who sees something really important that we need to put on our wall?"

Toward the end of the lesson, the teacher pointed out a picture in the book and said, "These animals are all the way in Africa, and they need …?" Students replied together with a shout, "Food, water, shelter!" The teacher then asked "What about Washington?… Pakistan?… Anywhere I call out?" and students gave the same (shouted) answer. They then finished the reading, and the lesson ended with the teacher instructing the students to put their books away and prepare for the next subject.

3rd Grade: How Wind Changes the Land

This was a beginning lesson in an earth science unit in the 3rd grade class. The teacher reported that earth science topics are included in the district standards, but she has flexibility with the order in which topics are covered. This earth science unit was chosen in part based on student interest. They had recently attended a symphony performance at which "space" was the theme and were very interested by the concept. The teacher is focusing on earth science as a prerequisite to talking about space.

Today's lesson was based on reading the students did in the text as homework the night before. At the start of the class, the teacher asked questions about the reading and recorded their responses in the form of an outline on the chalkboard. Students answered questions but did not take notes. The teacher then called on students to read aloud a page in the textbook and periodically asked questions about the content. She tied in spelling with a quick game of Hangman to spell the word "erosion." Then the class began a discussion of sand dunes, including an explanation of how wind causes sand dunes to move. The teacher began by drawing diagrams of sand dunes on the chalkboard, then gave a demonstration in which she blew on a pile of glitter to simulate sand dune movement, and finally used a group of students to represent grains of sand. For this last demonstration, the students stood in a line with the teacher at the front, and students moved to the back of the line as the teacher blew on them. They repeated this process several times, after which the teacher asked them to explain the process. The teacher then made a closing statement on how sand dunes move and class ended.

3rd Grade: Properties of Matter

This 3rd grade lesson occurred towards the end of a unit of study on the properties of matter, with the purpose of reviewing the basic ideas and definitions of terms for the unit test. Prior to this lesson, students had read and answered questions about matter from the textbook and had observed water as a solid, liquid, and a gas. The content of this lesson included several facts and definitions about the physical properties of matter, specifically changes in the states of matter.

The teacher began the class by having the students open their textbooks to the chapter on the properties of matter, while she handed them a review worksheet from a workbook. She then guided the class through the completion of the worksheet by referring the class to a particular question on the worksheet, 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, and then writing the answer on an overhead transparency copy of their worksheet. The topics on the worksheet included three physical properties of matter, three states of matter, changes in states of matter, the idea that matter is made up of atoms, and measuring matter as volume and mass.

After the completion of the worksheet, the teacher reread the questions and answers to summarize the content in the lesson. The students were instructed to keep their worksheets for tomorrow's lesson as this lesson came to a close.

4th Grade: Introduction to Flight

This day's lesson was an introduction to a unit on flight. The teacher's stated purpose for the lesson was "to introduce [students] to the concept of how air acts and how it reacts; air pressure and how air is a force and we breathe it; to get them to understand some basic things about air." The lesson was taught as an introduction to the next unit in the textbook. The teacher indicated that he closely followed the text as a guide for topics to be taught. In addition, the teacher said that he covered all topics in the state standards and that this topic was a part of those standards.

This lesson began with the teacher asking students to take out a sheet of paper and then sit still with their eyes closed and imagine themselves as birds. The teacher asked students what they felt, and someone answered, "air." The teacher then introduced a series of teacher-led demos (using student volunteers) to illustrate concepts associated with air. Demonstrations included dropping a piece of paper in the wastebasket, indicating the presence of air keeping it from dropping straight in; placing a cup in a tub of water to show the release of air bubbles when tilted; blowing up a balloon to show that air fills space; and blowing a piece of paper to see it stand straight out.

The teacher then introduced various terms, including matter, air pressure, force, gas, atmosphere, and oxygen. These were quickly referred to, and as homework, students were to copy the definitions from the back of their textbooks.

4th Grade: Vertebrates and Invertebrates

Students in this 4th grade class have been working on an animal unit for the past nine weeks. Prior to the lesson, students had learned about ecosystems, food chains, and most recently, habitats. The class was working through a series of lessons on animal classification, which would be followed by lessons on heredity and adaptation.

This lesson on vertebrates and invertebrates within the context of animal classification was taught because the teacher was required to do so. The topic was in the district designated scope and sequence, which told the teacher what to teach and when to teach it. The topic was also to be on the upcoming, district, nine-week test, and the district would use the exam to make an assessment of whether the teacher was keeping pace with the content as she was required to do.

The lesson began with a brief review of why classification is important and the main characteristics of vertebrates and then invertebrates. Next, the class played a game where they identified animals from each of these two groupings. The teacher then introduced a Venn diagram drawn on the board and had each student copy it onto a sheet of paper. The teacher probed students so she could fill in the diagram on the board, first filling in the center where two circles overlapped with characteristics shared by both vertebrates and invertebrates. Students then worked on their own to think of characteristics specific to each of the groups. The teacher wrote these ideas on the diagram as well. Half way through the hour-long lesson, the class stopped for a 30-minute pre-scheduled library visit where they worked on CD-ROMs or read a book (work that was unrelated to the lesson). During the second half of the lesson, students first looked in their textbooks at two pages that outlined simple facts about vertebrates and invertebrates. The students were told to read the pages and add more information to their diagram for homework. The teacher then handed out an “animal study” worksheet and a picture of an animal to each student and asked them to answer all of the questions on the sheet about their given animal. Students worked on this individually for several minutes. The teacher circulated to answer questions. The final few minutes of the lesson were spent revisiting why classification is important.

Ratings of Lesson Components

The designs of elementary science lessons are, on average, most highly rated for utilizing the resources available to accomplish the purpose of the lesson and for reflecting careful planning and organization. The lessons also tend to reflect attention to students, either in terms of their prior knowledge and experience or their background. However, elementary science lessons are weakest in regard to providing students with the time and structure needed for sense-making and wrap-up. The relatively low ratings in these two areas may explain why over twice as many elementary lessons receive low synthesis ratings for their design than high ratings (43 percent and 18 percent, respectively).

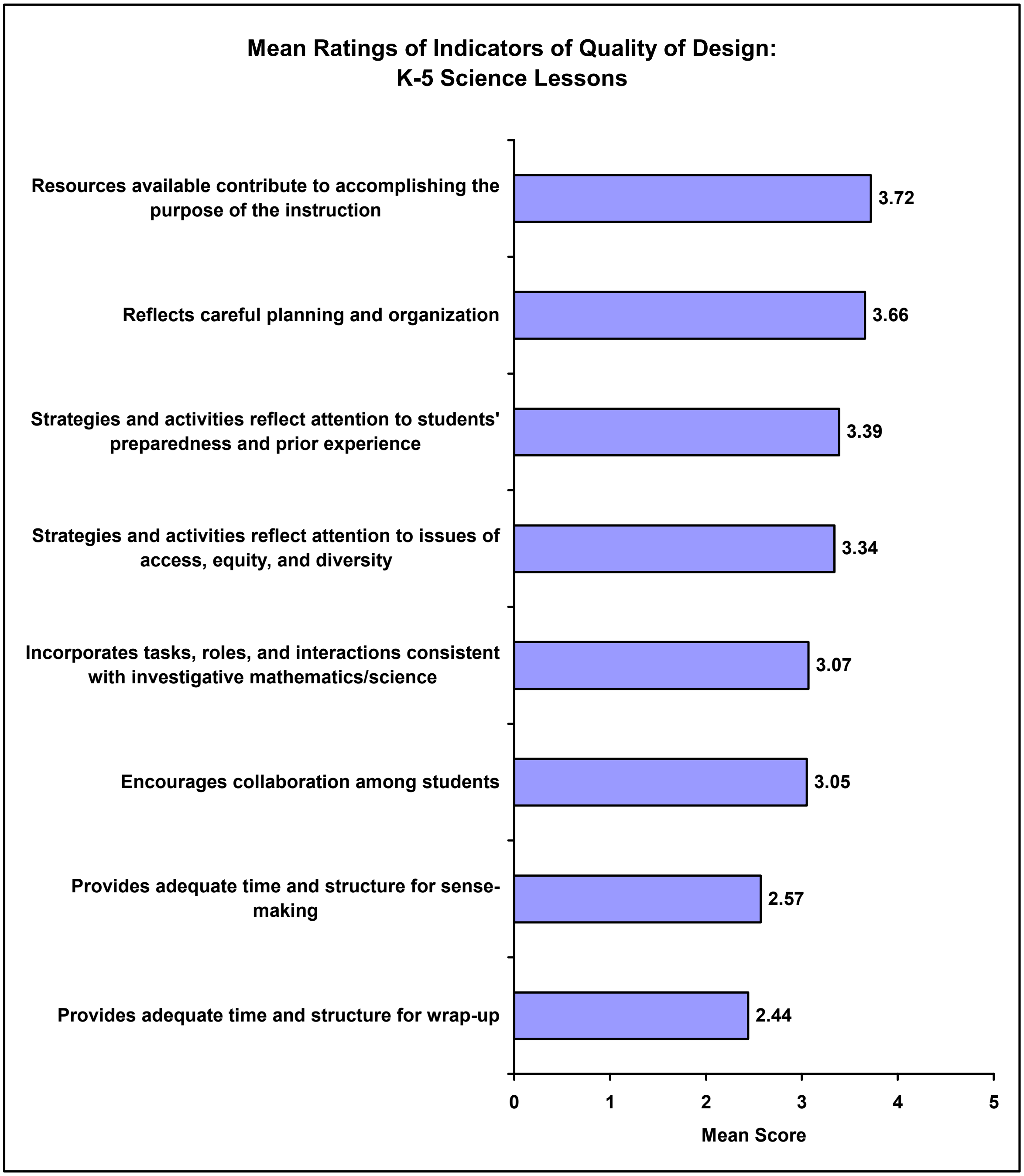

Mean Ratings of Indicators of Quality of Design:
K-5 Science Lessons
Resources available contribute to accomplishing the purpose of the instruction
3.72
Reflects careful planning and organization
3.66
Strategies and activities reflect attention to students' preparedness and prior experience
3.39
Strategies and activities reflect attention to issues of access, equity, and diversity
3.34
Incorporates tasks, roles, and interactions consistent with investigative mathematics/science
3.07
Encourages collaboration among students
3.05
Provides adequate time and structure for sense-making
2.57
Provides adequate time and structure for wrap-up
2.44
0
1
2
3
4
5
Mean Score

Figure F-1

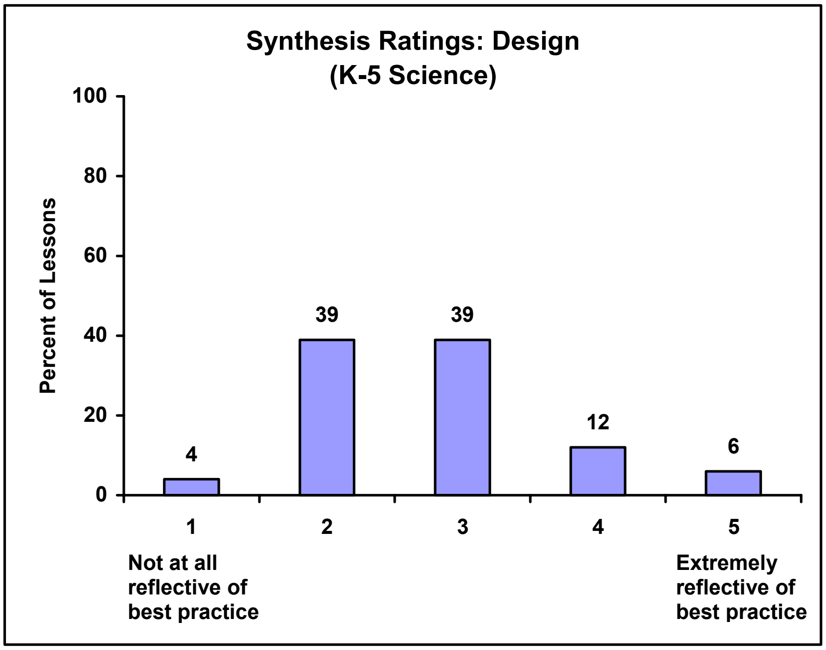


Figure F-2

The implementation of elementary science lessons is rated most highly for teachers' confidence in their ability to teach science. Lessons are relatively strong in regard to teachers' classroom management as well. However, lessons are weaker when it comes to using instructional strategies consistent with investigative science and moving at an appropriate pace (either too quickly or too slowly). Teachers' ability to adjust their instruction according to student understanding and to ask questions that enhance student understanding are the weakest elements of elementary science lessons. These low ratings are reflected in the implementation synthesis ratings. Fifty-six percent of lessons receive a low rating for implementation while only 18 percent receive a high rating.

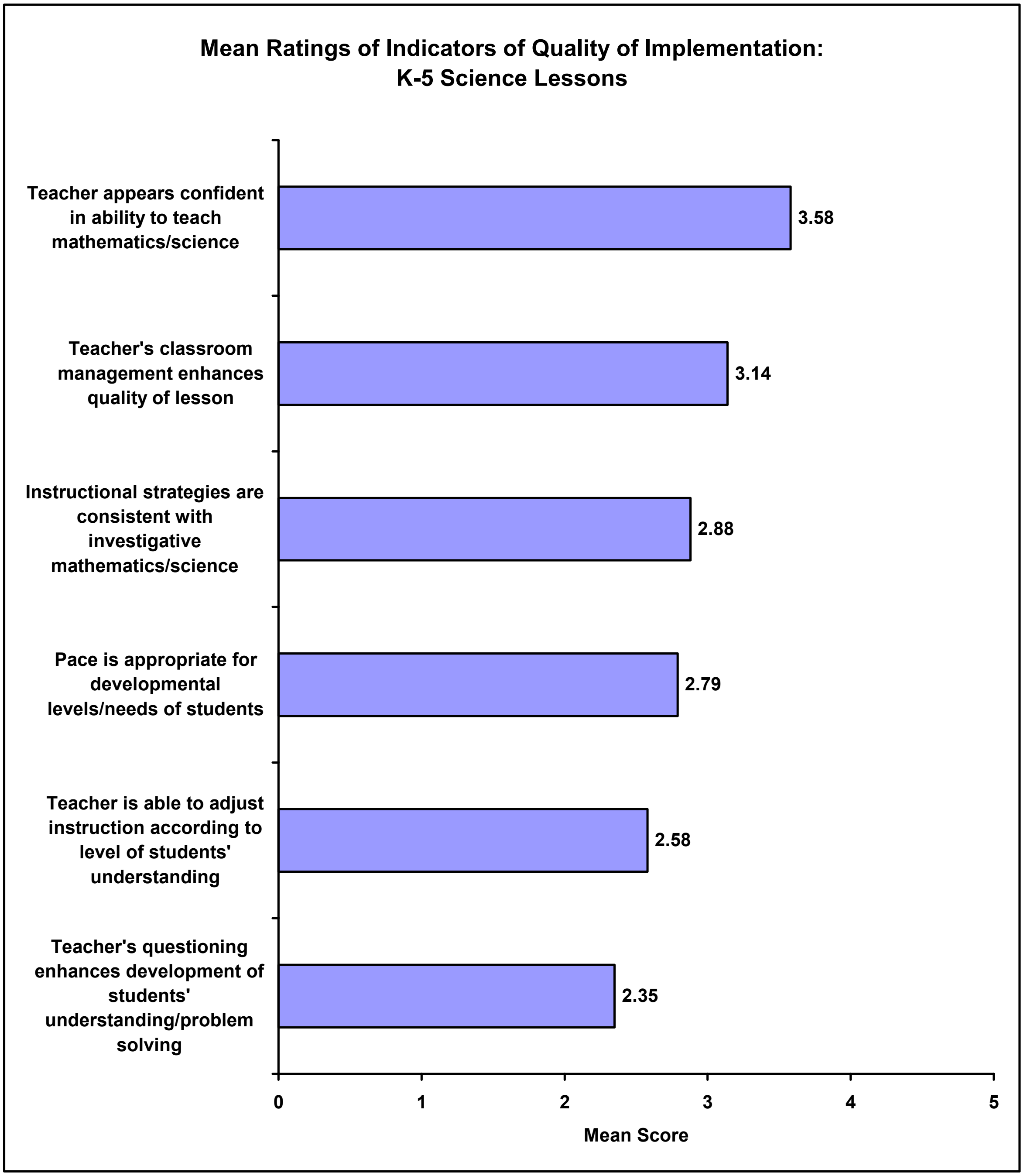

Mean Ratings of Indicators of Quality of Implementation:
K-5 Science Lessons
Teacher appears confident in ability to teach mathematics/science
3.58
Teacher's classroom management enhances quality of lesson
3.14
Instructional strategies are consistent with investigative mathematics/science
2.88
Pace is appropriate for developmental levels/needs of students
2.79
Teacher is able to adjust instruction according to level of students' understanding
2.58
Teacher's questioning enhances development of students' understanding/problem solving
2.35
0
1
2
3
4
5
Mean Score

Figure F-3

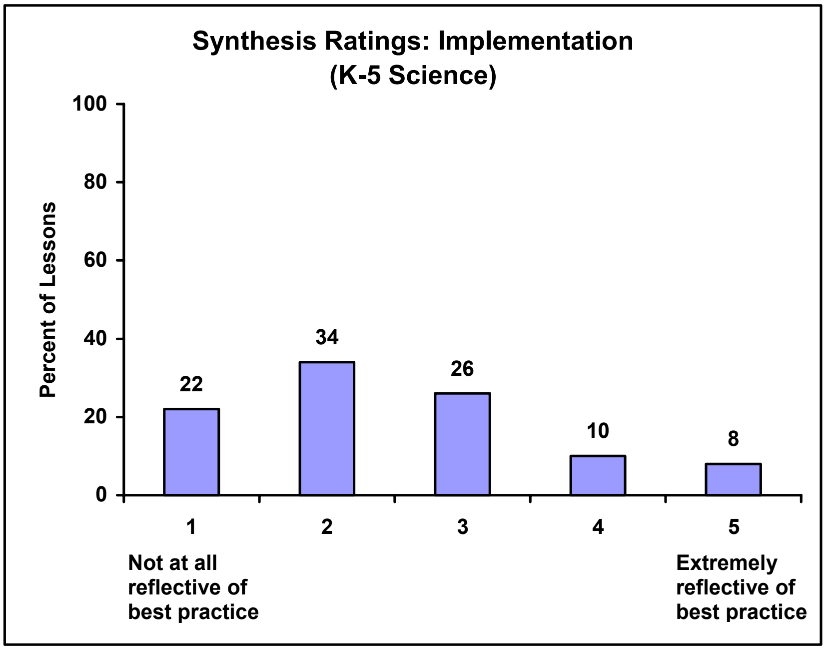


Figure F-4

The content of elementary science lessons is, on average, rated highest for focusing on significant and worthwhile content at a level appropriate for the students in the class. Further, lessons are strong in teacher understanding of the content. However, lessons are weak in engaging students with the content in a meaningful way and in providing opportunities for students to make sense of the content. Twenty-one percent of lessons receive a high synthesis rating for content, 28 percent receive a medium rating, and 52 percent receive a low rating.

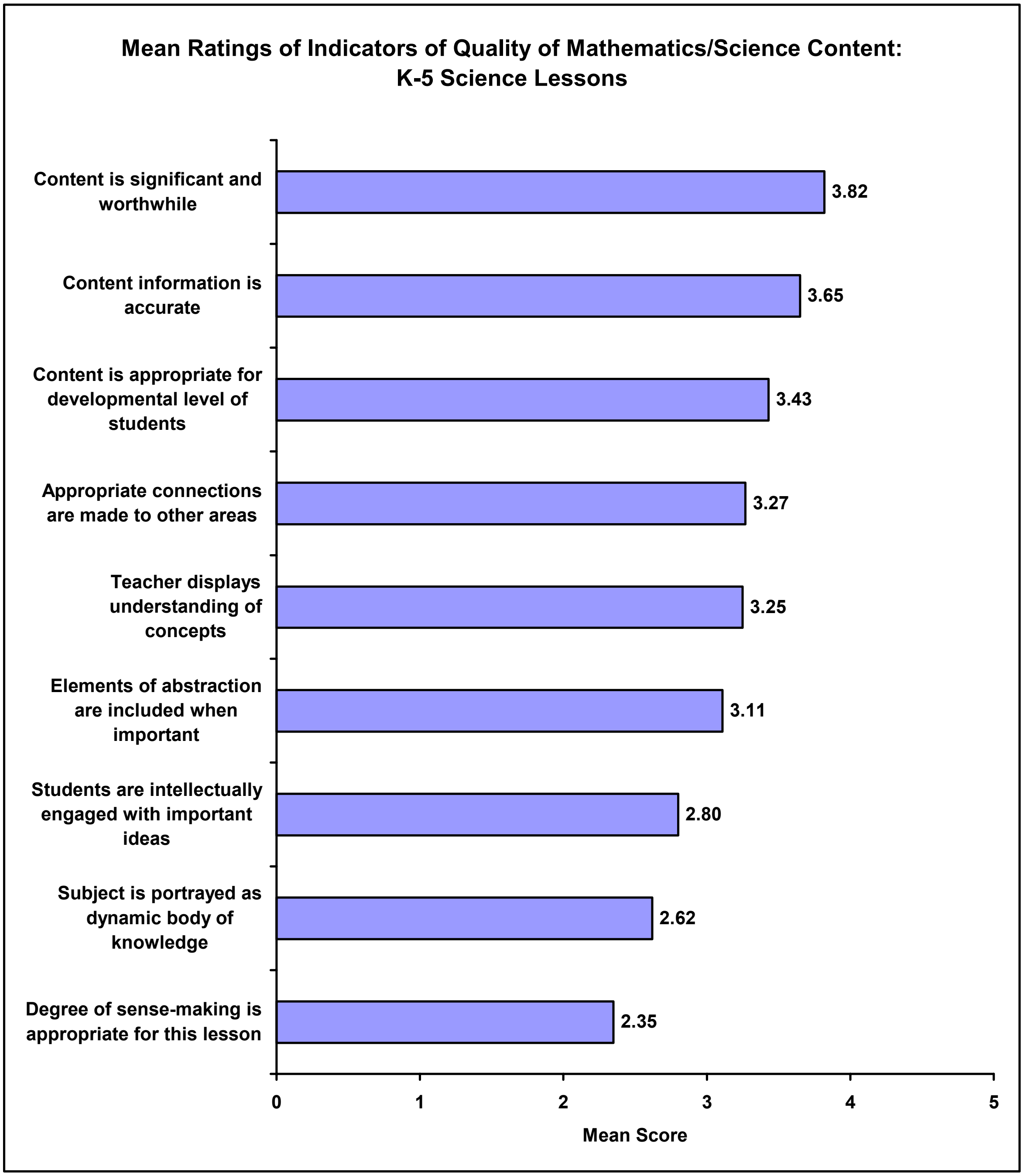

Mean Ratings of Indicators of Quality of Mathematics/Science Content:
K-5 Science Lessons
Content is significant and worthwhile
3.82
Content information is accurate
3.65
Content is appropriate for developmental level of students
3.43
Appropriate connections are made to other areas
3.27
Teacher displays understanding of concepts
3.25
Elements of abstraction are included when important
3.11
Students are intellectually engaged with important ideas
2.80
Subject is portrayed as dynamic body of knowledge
2.62
Degree of sense-making is appropriate for this lesson
2.35
0
1
2
3
4
5
Mean Score

Figure F-5

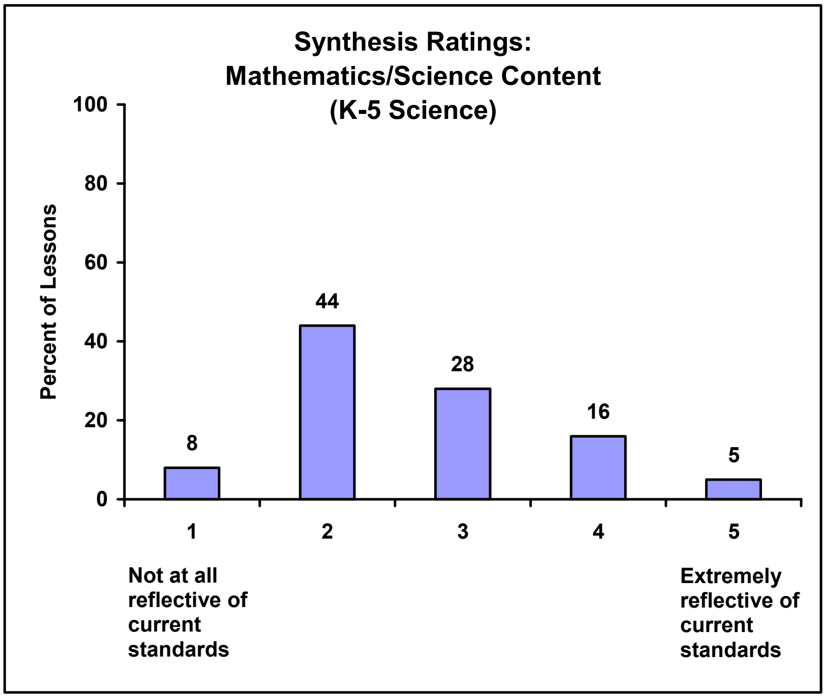


Figure F-6

The strongest aspect of classroom culture is the encouragement of active participation of all students. Although lessons are rated relatively highly for having a climate of respect for students' ideas, questions, and contributions, lessons are weak in encouraging students to generate ideas and questions. Further, lessons are weakest in their level of intellectual rigor. The synthesis ratings for classroom culture reflect these indicators with about one-third of lessons receiving a high rating, one-third receiving a medium rating, and one-third receiving a low rating.

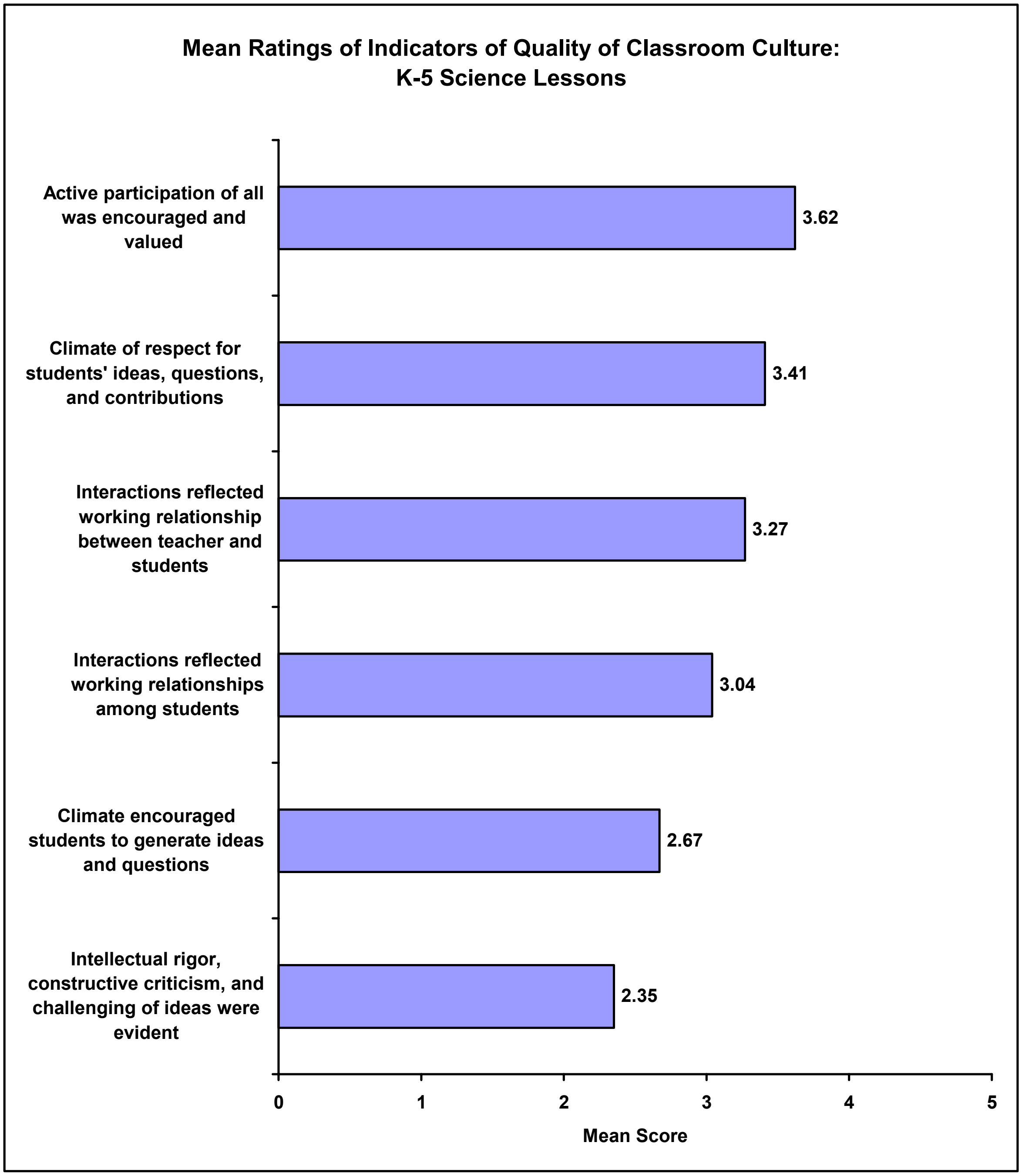

Mean Ratings of Indicators of Quality of Classroom Culture:
K-5 Science Lessons
Active participation of all was encouraged and valued
3.62
Climate of respect for students' ideas, questions, and contributions
3.41
Interactions reflected working relationship between teacher and students
3.27
Interactions reflected working relationships among students
3.04
Climate encouraged students to generate ideas and questions
2.67
Intellectual rigor, constructive criticism, and challenging of ideas were evident
2.35
0
1
2
3
4
5
Mean Score

Figure F-7

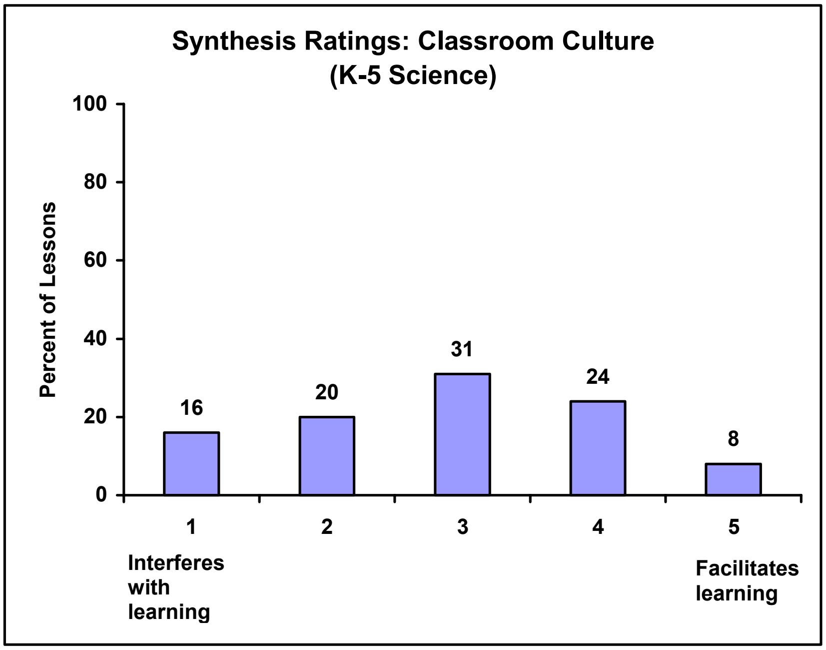

Synthesis Ratings: Classroom Culture
(K-5 Science)
Percent of Lessons
100
80
60
40
20
0
16
20
31
24
8
1
2
3
4
5
Interferes with learning
Facilitates learning

Figure F-8

Overall Lesson Quality

Following the ratings of the individual components of the lesson, the researcher was asked to consider the likely impacts of the lesson as a whole. Roughly one-third of lessons have positive impacts on students' understanding of important science concepts, ability to do science, or ability to apply the skills and concepts they are learning to other disciplines or real-life situations. (See Table F-1.)

Table F-1
Likely Impact of the Lesson: K–5 Science

	Percent of Lessons		
	Negative Effect	**Mixed or Neutral Effect**	**Positive Effect**
Students' interest in and/or appreciation for the discipline	14	42	43
Students' understanding of important mathematics/science concepts	15	51	34
Students' capacity to carry out their own inquiries	13	53	34
Students' understanding of mathematics/science as a dynamic body of knowledge generated and enriched by investigation	18	49	33
Students' ability to apply or generalize skills and concepts to other areas of mathematics/science, other disciplines, and/or real-life situations	9	58	32
Students' self-confidence in doing mathematics/science	13	57	31

Figure F-9 shows the percentage of K–5th grade science lessons in the nation rated at each of a number of levels. (See page 9 of the Observation and Analytic Protocol in Appendix A for a description of these levels.) Fifty-four percent of elementary science lessons are rated as low in quality on the capsule rating, 28 percent are rated as medium in quality, and 17 percent are rated as high in quality.

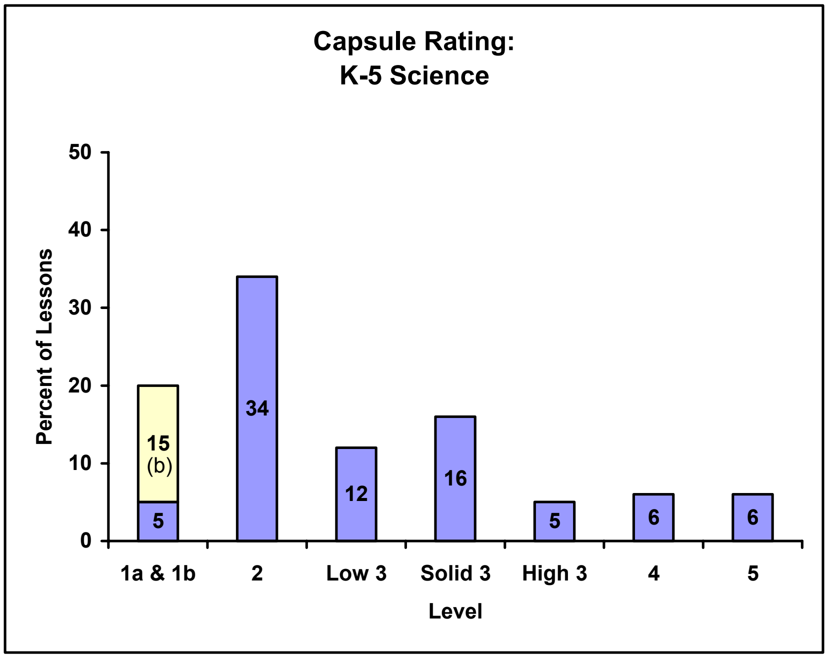


Figure F-9

The following illustrate lesson descriptions that were rated low, medium, and high in quality.

Sample Low Quality Lesson: Passive "Learning"

This was the fourth lesson in a unit on ocean and pond habitats. Prior to this lesson, these 2nd grade students had studied what organisms live in ponds and how they are adapted to their freshwater environment. The focus of this lesson was for students to understand the concept that certain mammals can and do live in sea water. The characteristics of mammals was review for the students, while recognizing and understanding how mammals survive in the ocean was new.

The teacher began the lesson by showing the students a videotaped program on whales, during which she allowed students to talk and play, making it difficult for many to concentrate on the program. After the video, the teacher led the whole class in a discussion, which began with the students listing animals that live in the ocean, such as fish, turtles, and lobsters. Then the lesson jumped to the teacher listing the characteristics of mammals on the board, such as fur, live births, and warm-blooded.

Next, the teacher passed out a worksheet that included pictures of mammals that live in the ocean. She proceeded to read information off of the worksheet to the class, then had the class read the same information again out loud with her. The information from the worksheet included: "Mammals on land breathe with lungs. Mammals in the ocean breathe with lungs too. They can stay underwater for a long time, but they must still come to the surface to breathe."

Following the reading, the teacher led the class through the pictures, asking if each animal relied on fat or fur to keep warm. She then told the students to put a box around the sea otter because it relied on fur to keep warm and to put an X on the whale because it was the largest mammal. Throughout the implementation of this lesson, the teacher stopped every few minutes to discipline a child or two by pointing out what rule they were breaking and giving them a mark on her clipboard.

The teacher's questioning was narrow in scope, and she usually led students to one specific answer. For example, as the teacher was asking the class to tell her if each animal pictured on the worksheet used fat or fur to keep warm, she said, "OK, what about the sea otter?" and a student answered, "Fur." The teacher then asked, "What about the sea lion?" and the same student responded "Thick fur." The teacher asked, "OK, what else could he have? If it's not thick fur, it's what?", and the student replied, "Fat fur." The teacher then said, "No, no. Just fat. OK, let's move down to the whale and the dolphin." Not only did the teacher's search for one specific answer discourage students from volunteering their own thoughts, but in this case it also may have created a misconception that mammals have either fur or fat, not both.

The teacher ended the lesson by telling the class that they could color their worksheet while she read a book on dolphins and whales. After reading a few pages, the teacher recognized that many of the students were not working, so she pulled them together by having the class stand up and sing a song.

Throughout this lesson the teacher did most of the thinking for the students, short-circuiting any opportunity for the students to become intellectually involved with the content. The students were very passive intellectually, with some acting out physically (such as by crawling on the floor and poking other students), which resulted in their being disciplined in front of the whole class. Due to the vagueness of intended purpose and the deficiencies in the implementation, this lesson is unlikely to have helped students deepen their understanding of important science content.

Sample Low Quality Lesson: "Activity for Activity's Sake"

The objective of this 3rd grade lesson was to introduce students to food webs. The students had been studying ecosystems, and were now beginning to study how animals interact. They had recently finished an activity on food chains and their "index card food chains" with pictures of organisms hung on the wall. The lesson began with the teacher asking the students to read aloud the step-by-step instructions for making a paper model of a food web. She told them, "On Tuesday we made food chains; today we are going to make a food web, although we have not read about food webs yet." She drew different food chains on the board, each in a different color, then had the whole class follow in lock-step the directions in the book on how to label pieces of index cards with the names of six organisms and paste them in a circle on construction paper. The questions she asked of the class were mostly rhetorical, with very little wait time. When she asked, "Is everybody listening?" and "Do you see what you are going to do today?" a few children answered, "yes," unenthusiastically. Finally, she led the whole class as they connected some of the organisms into a food chain on the board using one color crayon and depicted another food chain by using another color. All of the students copied the food chains drawn by the teacher. There was no time for discussion or closure, but the teacher told the children that they might add another food chain to the web later in the week, when they would read about food webs in their textbook.

In the teacher's modification of the textbook's design, all but the "hands-on" activity was deleted, and that activity was reduced to following a set of instructions. With almost no conceptual foundation and very little discussion, the lesson design had the children spend nearly the entire class period writing the names of organisms on little pieces of paper and pasting them in a circle. Throughout the class period, the teacher had the children work individually doing exactly the same activities, even though they demonstrated vastly different levels of ability. Thus, many children were restless and bored, waiting for the next step, while the slower students painstakingly wrote the names and pasted them on the paper. The activity was designed so that the only important conceptual work, considering the connections in the food webs, was done during the last five minutes of the class and was entirely teacher-directed.

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. "Show me that you want points by sitting on your seats correctly and zipping your lips." Thus all of the rewards for the activity were external and unrelated to science. By the time the class reached the "meat" of the lesson, constructing food webs using the organisms they had pasted on the construction paper, they had run out of time. The teacher did not see this as a problem, however, and told the children, "Good class, we are onto the last activity and we only have five minutes left." The only individual contribution that students could make to their food webs was to decide which color crayon to use to connect the organisms.

Sample Medium Quality Lesson: Beginning Stages of Effective Instruction

According to the teacher, the purpose of this 2^{nd} grade lesson was for students to identify and be able to name the basic characteristics of an insect. Students had previously considered characteristics of other types of animals within the Animal kingdom. This day's lesson on insects came near the end of the animal unit. After this lesson, the class would make a collage and play a classification game to conclude the animal unit.

The lesson began with students sitting together on the floor participating in a whole-class discussion. The teacher quickly reviewed characteristics of animals other than insects that had been covered previously (mammals have fur, fish have scales, etc.). Five animal types and their characteristics were listed on a flip chart. During the observed lesson, the teacher added insects to the chart. The teacher related some facts about insects and asked students to share with the class any experiences they had had with insects. During the whole-class discussion, she asked things like, "How does it feel when you step on insects with your bare feet?" Students responded with things like "they crunch" and "their insides squish out." By the end of a 20-minute discussion, the teacher had added four characteristics to the flip-chart: "insects have three body parts (head, thorax, and abdomen), 6 legs, hard shell, and eggs (soft)."

Following the discussion, students were instructed to create an imaginary insect using colored construction paper, and they were reminded that whatever they created needed to have 3 body parts and 6 legs. Concurrent with this arts-and-crafts activity, which students conducted individually at their desks, there was a silent video playing in the background showing close-up images of insects. Students also had access to a wide array of books about insects, which they used for reference and to spark their imaginations about insect diversity. The teacher circulated around the room during this portion of the lesson asking individual students some factual-recall-type questions such as, "What are the names of the body parts of your insect?" None of the questioning was truly higher-order. She also informed some individuals that they had mistakenly attached legs to an abdomen. In these cases, she instructed the students to correct their mistakes by tearing off legs and re-attaching them to the thorax. The creation of imaginary insects lasted 40 minutes at which point most students had completed the task and it was time for lunch.

The lesson design reflected attention to various learning styles and student interests. Some students were clearly quite captivated by the video, others enjoyed perusing the reference books, and still others dedicated their entire attention to the creation of the imaginary creatures. The resources (the video, reference books, and craft materials) were plentiful, varied, and of high quality.

The teacher was competent in guiding the whole-class discussion and clearly had prepared her students well to use hands-on materials appropriately. The lesson included very little in the way of investigation, however, and lacked time or structure for sense-making or wrap-up. There was some inaccurate content (including the teacher's saying that spiders are insects that disobey the general rule of having six legs). Overall, the teacher was nurturing and demonstrated concern for her students' learning, but didn't challenge the students to think very deeply. The lesson was strong as an arts-and-crafts lesson, but in the final analysis, deficiencies in both design and content limited the lesson's likelihood to enhance students' knowledge about insects.

Sample High Quality Lesson: Traditional Instruction

This 5th grade lesson focused on the skeletal system as part of a unit on the human body. As class started, the teacher stood at the side of the room waiting for students to come in from recess and take their seats. Students seemed excited to see the life-size skeletal model. The teacher introduced "Mr. Bones" and the skeletal system using the student booklet, which was developed by the teacher, as a discussion outline. She talked freely about specific bones of the body, capturing students' attention by telling stories and asking probing questions.

Throughout the class discussion, the teacher used a questioning pattern that seemed to work well. She would ask students a question, wait for them to raise their hands, call on one student, let the student give an answer, emphasize the information by restating it, add more information, then repeat the process with another question. For example, the teacher said, "The adult body has 206 bones. How many bones does a baby have?" Several students raised their hand and the teacher called on one of them who responded, "Over 300." The teacher said, "That's right. Why does the number of bones change as we get older?" No one could articulate the correct answer so the teacher continued explaining how some of the bones "fuse or knit together as we get older." She continued, "What about the skull? It looks like one bone, but it isn't. Why is that?"… "You're right. This helps allow for growth." Throughout the discussion, students demonstrated their intellectual engagement by raising their own questions based on family experiences or their own interest in the subject matter, such as, "Can you die if you break your neck?" "My dad blew a disc. What does that mean?" "How much weight can your spinal cord hold?" and "What allows people to pop their knuckles?" The teacher encouraged such questions about the human body and was very confident and thorough in her answers.

The lesson design was enriched by a brief demonstration in which a stack of papers was used to hold up two textbooks. The books could not balance when the papers were standing on end, but they could when the papers were rolled up. This helped students see that circular bones are stronger than flat bones.

The teacher captured students' attention by her stories and personal experiences. She told of her husband's broken collar bone from a bike accident, actor Christopher Reeve being paralyzed by a spinal cord injury, her father having arthritis in his neck and not being able to turn his head, teachers at school with carpal tunnel syndrome, how baseball catchers wear chest gear to protect their sternum, and how you can simulate having arthritis by wearing heavy gloves and trying buttons and zippers. Students shared similar stories about the mailman with carpal tunnel syndrome and a mother with TMJ.

The teacher demonstrated her experience and effectiveness in teaching, as well as her wealth of knowledge about science. She encouraged student questions about the human body and was very comfortable in her answers to a variety of questions. The teacher had a knack for inspiring students to listen, think deeply, and ask further questions related to the topic. Her classroom management style appeared to be based on caring and respect. She showed high expectations for on-task participation and attention, encouraged the sharing of ideas, and listened intently. Sense-making and wrap-up were facilitated by a review of "what you know" at the end of the discussion.

This was a fairly traditional, teacher-directed lesson. Due to the teacher's high level of content knowledge, her ability to relate science concepts to familiar circumstances, and the creation of a positive learning environment, it is highly likely that student understanding of the skeletal system was enriched by this lesson.

Sample High Quality Lesson: Reform-Oriented Instruction

This was a beginning lesson on wind, designed to tie in with earlier units on weather. This kindergarten class had been doing a morning weather report including weather charts and graphs and would work wind into that routine.

As students moved into the classroom from lunch, they quickly took their seats on a carpet in the center of the room. The teacher got down on the floor with them to begin the lesson. After reviewing air by "catching" air in a bag, the teacher started a discussion on what wind is. Toward the end of the discussion, the teacher let students know that they would be doing an experiment with wind that they would create in the classroom with a fan. She told them that they would predict whether objects would blow in the wind and quickly reviewed "predictions." Students were familiar with the term; some explained it as a "guess." The teacher clearly outlined expectations for the students now and during the entire lesson, making them comfortable and therefore willing to talk and participate.

Students were divided into two groups, one to be led by the teacher, and the other by a paraprofessional. Once in groups, each student chose an object that had been provided and was asked to predict whether or not it would blow in the wind. As they made their predictions, students placed their objects on a teacher-prepared chart with two columns. One column was labeled "The Wind Will Blow" and the other "The Wind Will Not Blow." Objects included items such as cotton balls, yarn, lace, scissors, clothespins, and a cassette tape.

Once predictions were made, students moved back to the whole group. The teacher facilitated transitions with effective classroom management techniques; for example, soon after students started moving, the teacher sat on the floor and said, "Give me 5" and held up her hand, indicating that all students were to be sitting quietly, holding up their hands.

Once settled in the whole group, students tested their predictions one at a time by placing their objects on a table in front of a fan. Students were asked to give their thoughts on why each object did or did not move, and the class chart was updated to reflect the results. When students' predictions turned out to be inaccurate, the teacher explained that was okay and that they need to predict, experiment, and change predictions "just as scientists do."

During this time, the teacher was able to weave in content that had previously been taught, both science content and language arts content. For example, an object in today's lesson was yarn, and the teacher took the opportunity to review the letter "y" that they had just learned. The teacher also skillfully handled misconceptions; for example, when reviewing where air is a student said, "space." The teacher reminded them of the space unit that they had done and led them to remember why people in space need oxygen tanks.

Then the discussion turned into one of *why* certain objects blew. The teacher's questioning strategies helped students realize that lighter objects were blown more easily. Her strategies also helped students move beyond misconceptions, such as that "hardness" determines what objects will be blown by the wind. For example, the teacher asked, "Why do you think those blew?" and a student responded, "Because they're not real hard." The teacher followed by asking, "But what about the clothespin? That's hard," and the student responded, "But it's not so heavy." This dialogue continued until students moved beyond misconceptions and formed solid ideas.

The lesson was designed to be investigative and was well executed in an extremely positive and supportive environment.

Appendix G

Grades 6–8 Science

Typical Lessons

Ratings of Lesson Components

Overall Lesson Quality

Typical Lessons

The following lesson descriptions are based on a random sample of 6th–8th grade science lessons.

6th Grade: Food Chains

The primary activity during the period was an owl pellet dissection, but the lesson began with a ten-minute, whole-class discussion of multiple-choice questions from a standardized test-prep booklet called Test-Ready. Preceding this lesson had been a lecture in which guest presenters brought an owl and red-tailed hawk to show the students. Students had also spent one class period removing the largest bones from the fur. In future lessons, students were going to record findings in their lab books, pool their data within the class and with other classes, and analyze the number and diversity of skeletons found within all of the pellets.

The prep session for an upcoming standardized test was held because the teacher believed these students needed practice with this type of test and because going over test questions was a quick way for the teacher to cover lots of content. The dissection portion of the lesson was taught in part because it supported the standards, but the teacher noted he would have taught it anyway because it was fun.

During the first part of class, the teacher would ask a student to read a question aloud from the test-prep booklet, and then he would ask other members of the class to offer ideas related to the question. After a short discussion, the teacher would provide the reasoning behind the correct and incorrect answers. For the remainder of the class period, students worked in pairs picking up where they had left off the previous week dissecting owl pellets. This day's lesson provided an opportunity to pick through the fur more carefully for smaller bones and match them to a bone identification chart. During the dissection, the teacher circulated from group to group to help identify bones. This help came in the form of questions and statements such as, "That looks like a rat vertebrae, do you have a rat skull?" and "That's probably a ______."

6th Grade: Light

This day's lesson was a review for an upcoming chapter test on light. The teacher indicated that the review would cover material that the class had been studying for the last week and a half. The objective written on the board was, "Describe the importance of light in our everyday lives and review for Chapter 3 test on light."

At the start of the lesson, students were asked to write a half-page response on how their lives would be different without electric light, a question taken from the textbook. Students worked quietly and independently to do this, and then discussed responses as a class. The assignment was not collected.

After the initial writing activity, the lesson turned to a teacher-led review of information from the textbook. The teacher flipped through the textbook and asked questions from it. Students raised their hands to respond. Questions included: "What has the longest wavelength?" "If it has the longest wavelength, what do you know of the frequency?" "What is the smallest region of the electromagnetic spectrum?" "An object that can produce its own light is said to be what?" and so on. Toward the end of the lesson, students worked in groups to write five questions for a class review game of "Who Wants to Be a Millionaire?" The teacher also passed around a prism for students to look at. The class then broke into two teams and played "Who Wants to Be a Millionaire?" with the questions they had created.

6th Grade: Sedimentary Rock Formations

The students were just beginning a unit on rocks, after finishing one on flight. For the first five minutes the teacher led a discussion about the previous day's lesson, which had involved a paper airplane "fly-off". She then asked a student to share the library book he had brought in on the subject.

This lesson was taught as part of a unit on Earth's changes over time. The teacher had been to many workshops in her 20-year career, and had chosen pieces from several of them to create a study packet that she used instead of a textbook. This topic was in the state standards and the district course of study, and the teacher felt that it was important for students to know. The teacher indicated that while she usually preferred an active classroom, this group of students has had severe behavior problems, so she planned her lessons to be more structured for them.

To begin the lesson on Earth's changes, she asked students to brainstorm about the words "weather" and "weathering" and then transitioned to a discussion of the rocks that make up the Earth's crust. She then referred to the vocabulary words written on the board and focused on the term "sedimentary rock." She explained how the word "sediment" is embedded in the term, then explained the process of sedimentary rock formation. She showed a piece of sandstone and asked, "Guess what sandstone feels like?" Then she asked, "If you break something, what do you need to put it together? We don't have someone down there (in the ocean) squirting Elmer's." She explained how minerals in the water are "glued" together over thousands of years. Then she asked, "What else do you need? If you break a vase and Mom will be mad…" Students discussed the need to hold pieces together and apply pressure, and the teacher asked, "Where might the force come from?" Once the class had decided that the weight of water creates the necessary pressure, the teacher passed around the sandstone for students to examine. Next, she held up examples of different types of sedimentary rock, discussed their formation and where they could be found, and passed them around the room. Then students answered questions on a worksheet from the packet the teacher had created, as the teacher elaborated on the fill-in-the-blank questions. Finally, the teacher reviewed what had been learned that day, a student read vocabulary words from the worksheet, and the teacher gave the evening's assignment.

7th Grade: Ecology

This 7th grade class was just beginning a unit on ecology. Previously, the class had been studying evolution, geologic time scale, and fossils. Following the ecology unit, the class would move into a study of the growth and development of plants.

The teacher taught the concepts of ecology covered in the lesson because they were included in the state and city standards. The teacher used an old life science textbook she had acquired from a book depository downtown as a main resource to plan this lesson. This textbook included a glossary with many of the vocabulary words she posted on the front board during the lesson.

The teacher began the lesson by drawing students' attention to the new vocabulary words listed. She said, "You'll notice the vocabulary is here and the words in black are seven new words that I will speak to this week." She told students they would not have a quiz on their vocabulary words today but they needed to copy down the new words on the list. The teacher launched into the lesson by asking the class: "Ladies and gentlemen, number one, who will answer this? I have three words, biosphere, ecosystem, and environment; how many before yesterday had heard of them?" One student indicated familiarity with the terms. The teacher asked the question again. Another student replied, "I have heard of ecosystem." "What did you think it meant?" the teacher asked. The student didn't respond. The teacher next started a discussion of the biosphere.

This pattern of teacher/student interaction continued with vocabulary-based discussions of the five kingdoms; producers versus consumers; photosynthesis; and examples of living, dead, and non-living things that occurred in all ecosystems. Each time the teacher began a new topic, she wrote various vocabulary words and their definitions on poster paper attached to the front board. The teacher concluded the lesson by explaining the homework assignments: study the vocabulary for a possible quiz the next day, and write a paragraph using five words the teacher had written on the board—producer, consumer, chlorophyll, animals, plants.

7th Grade: Erosion

The teacher indicated that this 90-minute class was generally split between science and social studies. This lesson, however, focused almost exclusively on science. The class had just finished a chapter on weathering the previous week. The day's topic, erosion, was chosen because it came next in the school's syllabus for the course and because all the 7th grade science teachers had decided to stay together so that they could give a common quarterly exam.

The lesson began with students copying 14 vocabulary words off the board to do as homework. The teacher then did a brief oral review of the chapter on weather, asking the students questions like, "How many forms of weathering are there?" He related weathering to the new topic, erosion, by asking, "Does weathering take a long time or overnight?" When the students answered that it took a long time, the teacher stated, "Erosion is fast-paced weathering" and gave the Grand Canyon as an example of a place where erosion is happening quickly. Next, he had the students copy a title for their "lab report" from the board and then directed them to the page in their textbook where erosion was defined. He wrote the definition on the board and had the students copy it in their notebooks. The teacher then asked students to draw two diagrams in their notebooks. One was an overhead view of the stream channel he created on the stream table, the other was a blank space where they would redesign the stream channel. The teacher said, "Here's our question: What exactly does erosion do? What problems does it cause?" A student responded that erosion "carves through rocks." The teacher then proceeded with a demonstration using a stream table that had been set up with potting soil. At the conclusion of the demonstration, the teacher asked students to return to their seats to work in pairs to redesign the "river basin" to minimize erosion. With about 20 minutes to go in the lesson, the teacher wrote four questions on the board from the teacher's edition of the text and told students to answer them for homework.

7th Grade: Fossils and Radiocarbon Dating

Students in this 7th grade earth science class had been studying fossils and had already done some hands-on activities like making casts. The teacher indicated that this lesson would teach students about radiocarbon dating and would also give them practice in graphing skills. Part of the lesson (a review of the kinds of fossils) was taken from a "book" the students had made on fossils, an idea the teacher had gotten at a recent NSTA conference. The hands-on activity was modified from one in the textbook.

The lesson began with a lively discussion between the teacher and students summarizing what the students had learned so far about fossils. Standing in front of the class, the teacher opened one of the little booklets that students had been creating on fossils and reviewed the main topics. She started by asking the class, "What are the five ways fossils form? Name one and explain." She waited for them to answer, and almost all of the students eagerly raised their hands. She called on different students, each of whom came up with a part of the answer. One student was having difficulty explaining how molds and casts form, and the teacher gently helped him by providing a series of "fill in the blank" type questions. "The water left the minerals in the _____________." Using this strategy she elicited from the students all five paths to fossilization that they had been studying.

The review led naturally to a mini-lecture about how scientists date fossils. The teacher then led the class through the process of creating a radiocarbon dating curve used to measure the age of a fossil, and each student created his or her own curve. This was followed by a hands-on activity in which students, working in pairs, dated "fossils" (with Carbon atoms represented by pennies in a plastic bag). Each "head" on a penny stood for a C14 atom, which students replaced with a paper clip, representing N14. Students then dated their "fossils" in thousands of years, using the standard curve they had created. Students who finished the task early were asked to create the corresponding standard N14 curve.

7th Grade: Liquids and Gases

This 7th grade class was working on the last section in a chapter on states of matter and energy transformations. Prior to this lesson, they learned about solids and did a mini-lab on cohesion and surface tension. In this lesson, the students focused on the specific characteristics of liquids in terms of density and buoyancy, and next they would move on to the properties of gases.

The teacher indicated that she taught this lesson largely because she believed it would be a focus area on the state test in February. She skipped over several chapters to get to this one because she wanted to be sure she had covered this material and because she had already taught the content in the skipped chapters to about half of these students the previous year.

The lesson began with a focus activity in which students read a paragraph about the buoyancy of submarines from a "section focus transparency" and spent a few minutes answering questions about it. The teacher then introduced the day's lesson by reminding students that they had been studying the states of matter and that today they would work on liquids and gases. She asked, "Does anyone remember about ice and liquid water, and why ice floats?" A student explained the concept, and the teacher asked, "What term did we use? It started with the letter D." A student replied "evaporation," and the teacher said, "D? Density—remember the discussion on density. What did I say about the density of an object in terms of whether or not it floats? More or less dense than water?" Once they had reviewed the density of water, they moved on to discuss the example of a submarine. The teacher asked, "What about this taking in water would make it sink?…What's your weight on the moon? It's going to feel different in water, because of a subject we're going to talk about today called buoyancy." The teacher continued her lecture on density and buoyancy, including a variety of student questions in her presentation. She then played an eight-minute audiocassette which summarized the book chapter. After the cassette had finished, the students spent the remaining 20 minutes of the class period filling out a worksheet on the behavior of liquids and gases.

7th Grade: Physical and Chemical Changes

This 7th grade class was in the middle of the Matter and Energy chapter of their textbook. They had just completed a study of atoms, molecules, and changes in matter. This day's lesson was a review of physical and chemical changes, as well as the branches of science. The following day the class would start learning about molecules and chemical symbols. The teacher reported that the district standards indicated where they have to be in the textbook by certain points in the school year and that she followed these standards and the textbook to develop her lessons. The teacher used the textbook as a guide and as a reference, but said that students did not actually read it too often because the wording was difficult for them. Also, the teacher said that the textbook was missing a lot of supplementary materials (e.g., worksheets), so she has to find things like that on her own, as she had done for this day's lesson.

The class began with students working to complete a worksheet on physical and chemical changes. They worked on this individually for several minutes, and then the teacher called on students to read their answers aloud. The worksheet had a list of 23 changes, and the students had to mark each with a "P" or "C." For example: etching glass with acid; fertilizing a lawn; crushing ice in a blender; and slicing a block of cheese. If an answer was called out incorrectly, the teacher or another student corrected it, with little explanation. For example, a student answered that baking bread was a physical change. The teacher quickly said that it was a chemical change because "when you bake bread it rises, so it is different."

Next, the class went over the previous night's homework, which was a worksheet in which they had to categorize types of science as life, earth, or physical science (e.g., cosmology, biology, meteorology, ornithology, and physics). The teacher asked students for their answers, and students called out answers to the various questions. After the teacher collected the homework, she gave each pair of students a newspaper and asked them to find one article that dealt with life science and one that dealt with physical science. As students worked on the assignment, the teacher walked around the room answering questions and asking students to pick their trash up off of the floor. The class ended with the teacher asking students to fold up their newspapers and to put their names on the back of the articles.

8^{th} Grade: Inheritance of Traits

This 8^{th} grade science lesson focused on the inheritance of traits using an imaginary scenario of marshmallow creature reproduction. The related concepts of meiosis and mitosis were part of the state and district standards and appeared in the textbook designated for the class. The marshmallow activity seemed to the teacher like a fun way to give the students concrete experiences with these concepts, and she believed hands-on activities to be important in concept development. The activity also provided an opportunity to integrate science with mathematics through the Punnett Square component and to tie genetics to the similarities and differences that exist among individual human beings.

The lesson began with students responding independently to two "Questions of the Day" asking them how many chromosomes there are in a human daughter cell after mitosis and to explain the stages of the cell cycle. While students wrote their responses, the teacher passed back papers and helped some students with their answers. The teacher then introduced the primary activity for the day, which involved the sexual reproduction of imaginary marshmallow creatures. Students were to use toothpicks and marshmallows to create baby creatures based on the inheritable traits of the parent creatures. In groups of about four, students randomly selected strips of paper representing chromosomes of the parents, determined the phenotype of their baby, and constructed a physical model of it. When the babies were completed, the teacher asked for a reporter from each group to describe the baby their group had constructed. The teacher provided a brief introduction to Punnett Squares on the chalkboard, and in the final two minutes of class, students responded independently to worksheet questions related to the marshmallow babies.

8th Grade: Periodic Table

This 8th grade lesson focused on the periodic table. The state standards call for an integrated approach to the teaching of physics and chemistry. This teacher, however, strictly followed the textbook, which started with physics and ended with chemistry. This study of the periodic table was near the beginning of the second chemistry unit, which dealt with the structure of matter and chemical properties.

The teacher began the lesson with a warm-up activity, asking students to list the six steps of the scientific method. The teacher also offered two bonus questions: "What was the caliber of the gun used in the San Diego school shooting?" and "How many days of school are left?" A student quipped, "I'm going to put down too damn many." The teacher told him that he could do that but that he might not get credit for that answer. Many students were talking throughout this part of the lesson.

After the warm-up activity, the teacher showed a video entitled "The Periodic Table," asking students to take notes. Besides presenting the periodic table and showing pictures of different elements, the video discussed the structure of the atom, including the definition of isotopes and the relationship between electron levels and the periodic table. After the video, the teacher passed out a copy of the periodic table and asked students to take notes from a lecture to be presented by one of the students from the class. The student presented the information from one cell of the periodic table (atomic number, symbol, and atomic mass). The teacher asked the student presenter, "What does atomic number mean?" The student did not know, so the teacher asked the student to sit back down. The teacher said, "You didn't do much preparation time. I'm kind of disappointed."

Next the teacher asked several questions about elements in the periodic table. The table that the students were reviewing differed somewhat from the one the teacher had, which caused some confusion. Finally, the teacher asked students to use their books to explain how the groups in the periodic table were different from each other. Nearly half the students in the class did not have their book, and so he had them copy definitions from a dictionary as part of the review for the final exam, which was two months away.

8th Grade: Projectile Motion

This 8th grade lesson was in a unit on motion, forces, and energy and dealt specifically with projectile motion. Prior to this lesson, the students had read the section of the book on projectile motion, gone over questions from the book, and outlined the material. This lesson on projectile motion was taught for three main reasons. First, the teacher indicated that the topic was in the state standards and that she followed the standards. Second, the teacher was piloting a new textbook for the district, and thus was working her way through the textbook very methodically. Third, the teacher thought the students needed practice with their measurement skills.

This lesson began with the teacher reviewing lab procedures and using the overhead projector to remind students how to properly use a ruler and a protractor. The teacher demonstrated measuring one distance and one angle before asking students to open their textbooks to the lab activity. The teacher asked students to read the procedures twice (the lab was to use a spoon to catapult marshmallows, launching at various angles and measuring how far they went). When students finished reading, she reminded them to measure their distance from the catapult to where the marshmallow hit the ground, not to where it rolled. She then assigned students to groups of three and had one person from each group collect the materials needed for the lab.

Next, the students went outside to the quad to conduct the experiment. Students experienced some difficulty in correctly completing the activity, making errors in measuring both distances and angles (e.g., when they launched a marshmallow that went over a 2 foot wall, they draped the measuring tape over the wall instead of just measuring the horizontal distance; the students were not using the protractor correctly as they did not understand how to line up the base of their catapult with the crosshairs at the base of the protractor). Some groups were not really doing the lab and were just trying to launch their marshmallow at certain targets ("Let's try to get it over the bush.")

Near the end of the period, the teacher called the students back into the classroom and had them work individually on writing their lab reports. Most students spent the time writing out the lab procedure and copying a data table from the textbook and then filling it in. As the students worked, the teacher circulated through the room asking questions.

8th Grade: Water Cycle

Students in this 8th grade class had been working on a unit on weather for the past week. The class alternated between units on earth science and units on life science. This lesson was taught because the teacher enjoyed the topic of weather and felt the concepts she covered were important ones that build upon one another. In addition, the content was included in the course of study the teacher followed and would likely appear on the end-of-grade exam. The teacher took her lesson objectives from the designated textbook and used worksheets from its associated resources. Wanting to include content on the atmosphere's composition and importance (which was not specifically covered in the textbook), the teacher opted to also make use of worksheets from an older textbook.

The lesson began as students entered the classroom. The teacher reminded students to update their temperature chart and do their temperature conversions for the daily weather chart that was posted on the front board. After calling roll, the teacher directed students to take out their worksheet on the content of the atmosphere. The teacher began the review by asking questions such as: "What is the atmosphere?" "What is it composed of?" "What is one importance of our atmosphere?" She then proceeded to go over the answers to the worksheet by calling on different students to provide the answer for each of the questions. The teacher next moved to a handout on the water cycle. On the overhead projector, the teacher had a diagram of the water cycle with various processes listed. Students were asked to draw their own diagram and write a paragraph explaining the cycle. As a check for the class, the teacher asked students to go to the board to write the various processes of the water cycle, such as transpiration and condensation, and then define the terms. The teacher next placed notes on the overhead entitled, "What is Weather?" Students copied the notes while the teacher discussed various points. Near the end of the lesson, the teacher reminded students to fill out the atmospheric gases handout, to work on their independent library research assignment, and to study their notes.

Ratings of Lesson Components

The design of middle school science lessons is rated most highly for the contribution of available resources to accomplishing the purpose of the instruction and for reflecting careful planning and organization. Lessons are rated somewhat less highly in their attention to student backgrounds and prior experience and in their encouragement of collaboration and investigation. On average, the lessons are weakest at providing adequate time and structure for sense-making or wrap-up. The relatively low ratings in these areas may account for the low synthesis ratings of more than two-thirds of middle school science lessons and high ratings of less than ten percent.

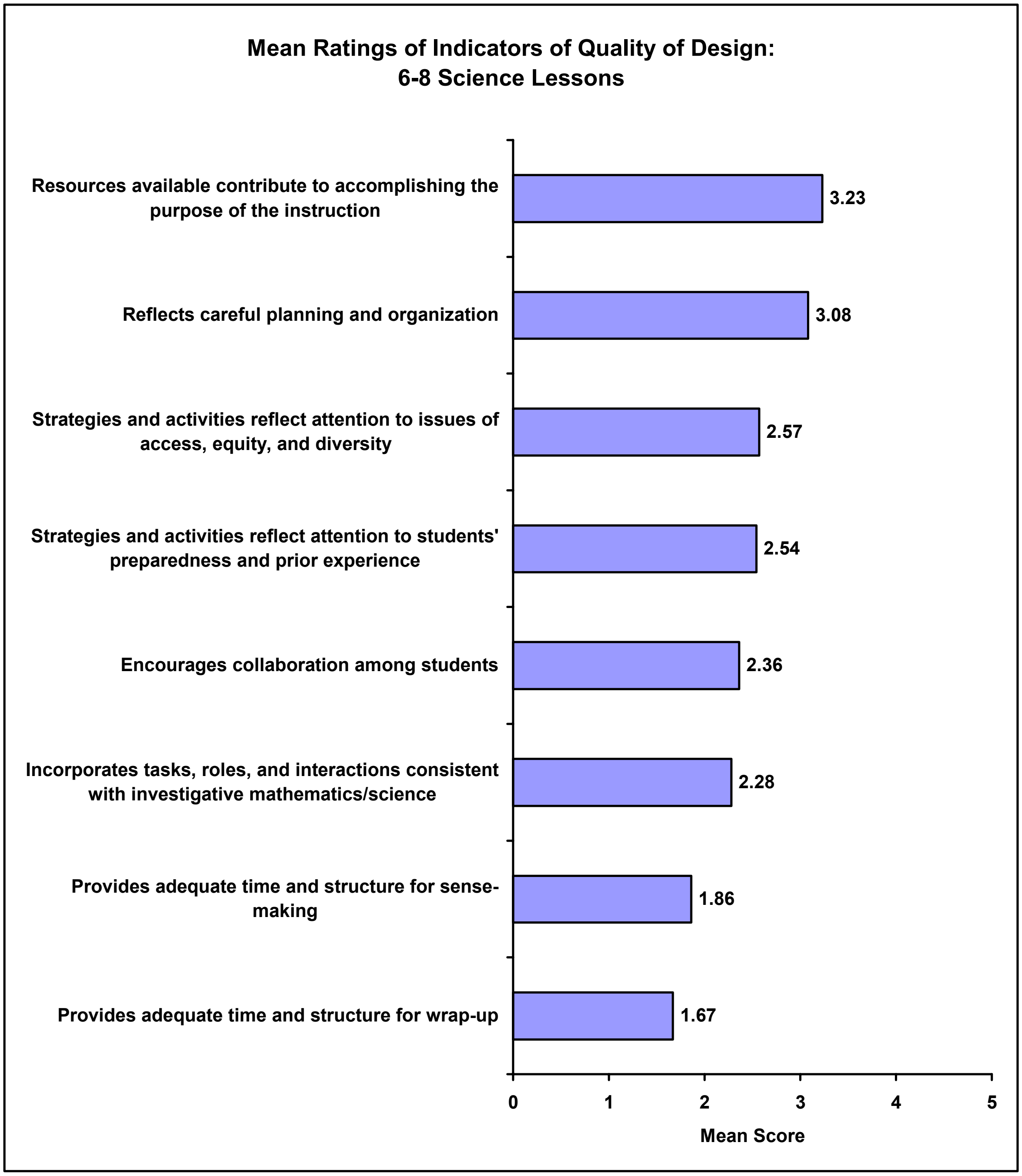

Mean Ratings of Indicators of Quality of Design:
6-8 Science Lessons
Resources available contribute to accomplishing the purpose of the instruction
3.23
Reflects careful planning and organization
3.08
Strategies and activities reflect attention to issues of access, equity, and diversity
2.57
Strategies and activities reflect attention to students' preparedness and prior experience
2.54
Encourages collaboration among students
2.36
Incorporates tasks, roles, and interactions consistent with investigative mathematics/science
2.28
Provides adequate time and structure for sense-making
1.86
Provides adequate time and structure for wrap-up
1.67
0
1
2
3
4
5
Mean Score

Figure G-1

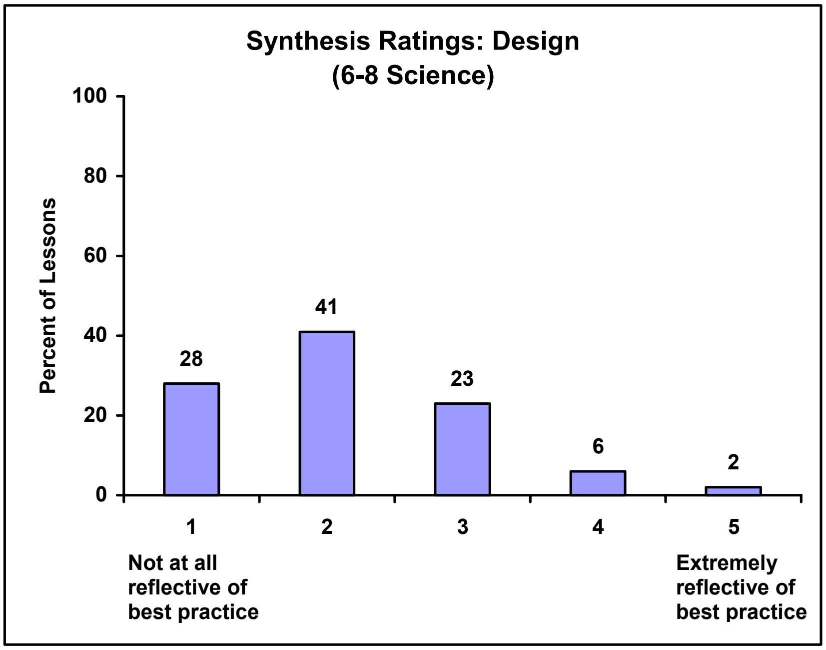


Figure G-2

The implementation of middle school science lessons receives the highest implementation ratings, on average, for teacher confidence and classroom management ability. Ratings are lowest for teachers' ability to adjust instruction according to student understanding, and to ask questions that enhance student learning. Overall, only eight percent of middle school science lessons are given high synthesis ratings for implementation and 16 percent receive medium ratings. Low ratings are given to 76 percent of lessons.

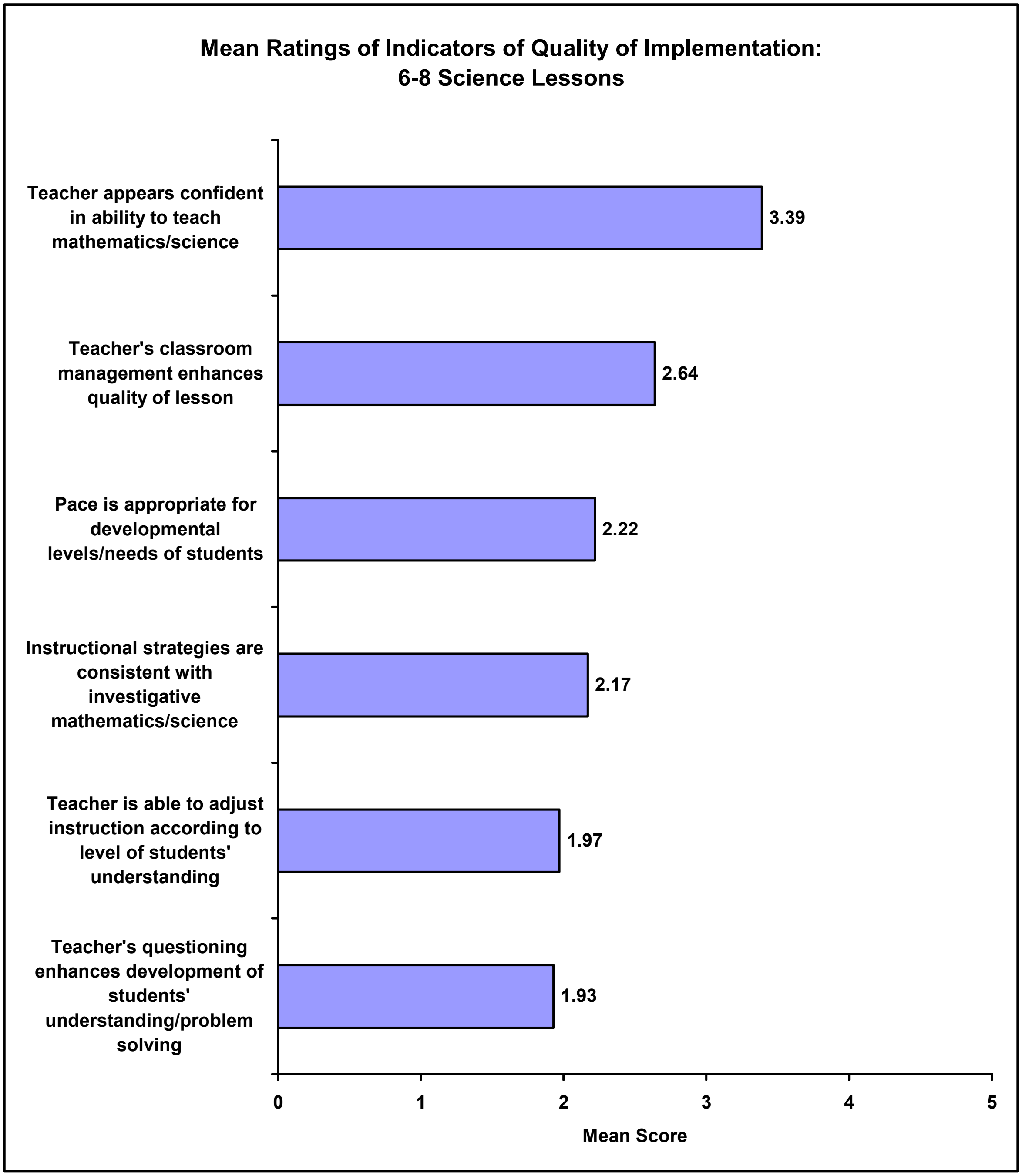

Mean Ratings of Indicators of Quality of Implementation:
6-8 Science Lessons
Teacher appears confident in ability to teach mathematics/science
3.39
Teacher's classroom management enhances quality of lesson
2.64
Pace is appropriate for developmental levels/needs of students
2.22
Instructional strategies are consistent with investigative mathematics/science
2.17
Teacher is able to adjust instruction according to level of students' understanding
1.97
Teacher's questioning enhances development of students' understanding/problem solving
1.93
0
1
2
3
4
5
Mean Score

Figure G-3

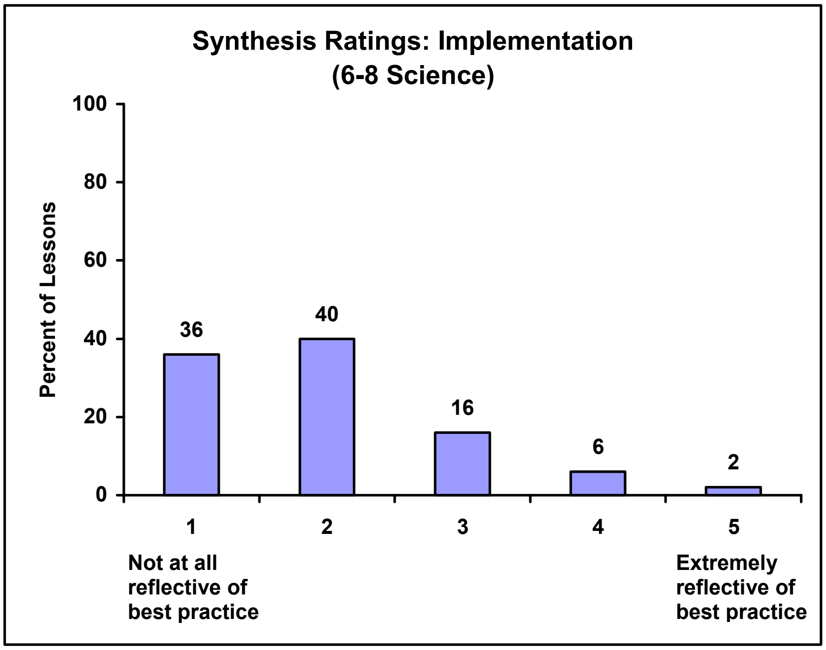


Figure G-4

The content of middle school science lessons is generally rated highly for being accurate, significant, and developmentally appropriate. Lessons are less strong in terms of including connections to other disciplines or elements of abstraction. The lowest ratings are given for the portrayal of science as a dynamic body of knowledge, intellectual engagement of students, and appropriate sense-making. These weaknesses are reflected in the synthesis ratings; only 8 percent of lessons receive a high synthesis rating for content, whereas 28 percent receive a medium rating and 64 percent receive a low rating.

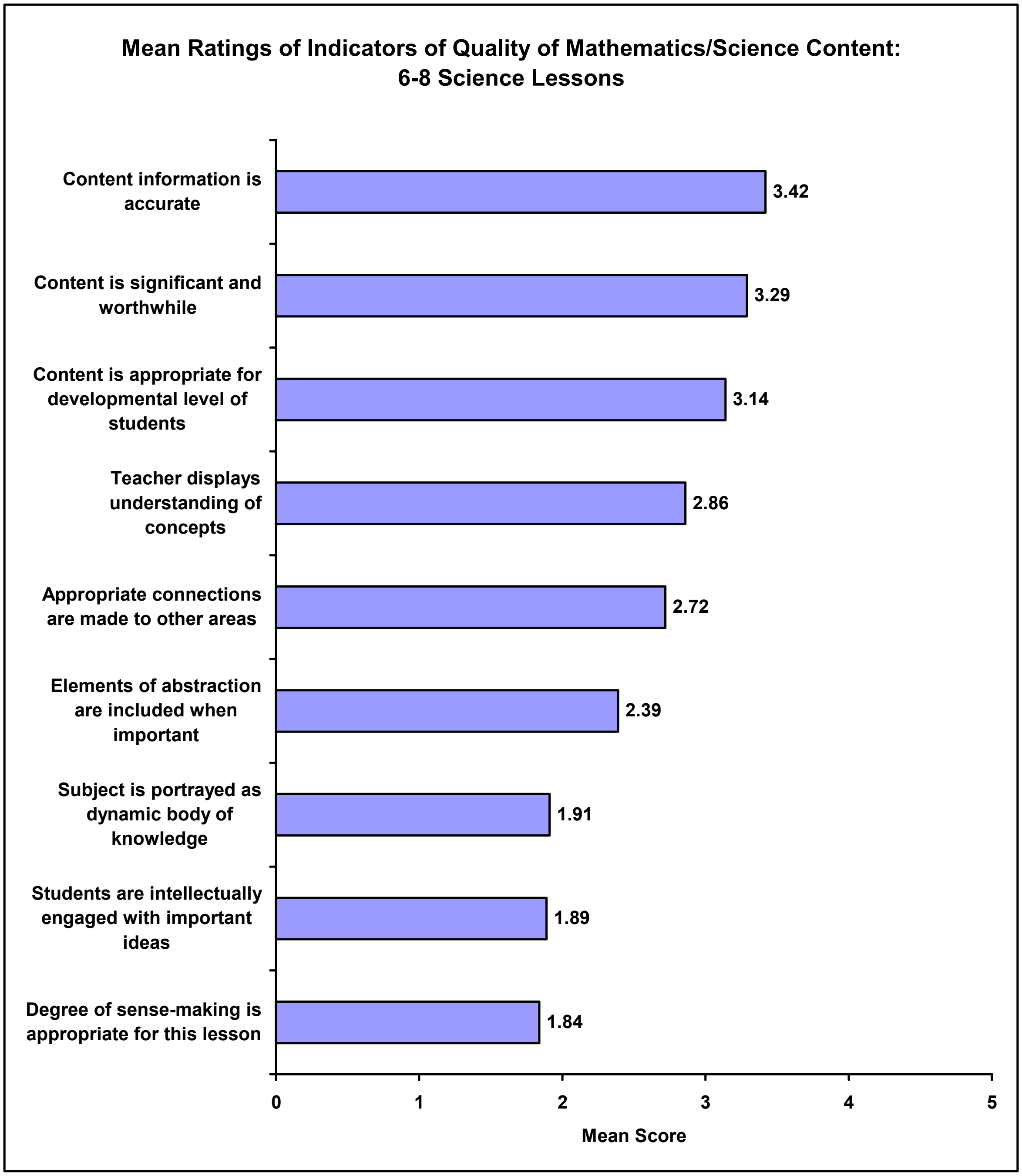

Mean Ratings of Indicators of Quality of Mathematics/Science Content:
6-8 Science Lessons
Content information is accurate
3.42
Content is significant and worthwhile
3.29
Content is appropriate for developmental level of students
3.14
Teacher displays understanding of concepts
2.86
Appropriate connections are made to other areas
2.72
Elements of abstraction are included when important
2.39
Subject is portrayed as dynamic body of knowledge
1.91
Students are intellectually engaged with important ideas
1.89
Degree of sense-making is appropriate for this lesson
1.84
0
1
2
3
4
5
Mean Score

Figure G-5

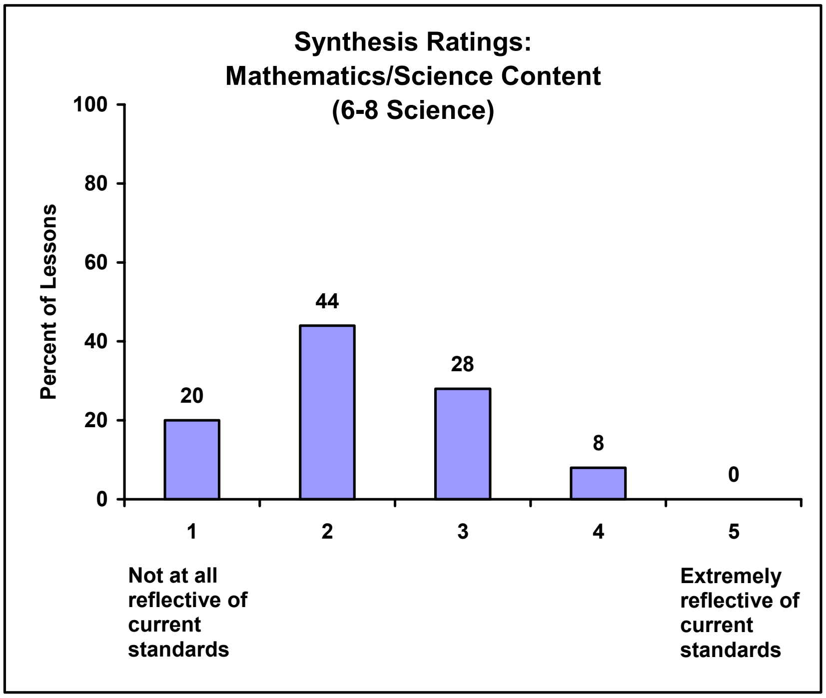


Figure G-6

The culture of middle school science lessons is rated highest on average for being respectful of students' ideas, questions, and contributions, and for encouraging active participation. The lessons are weaker with regard to encouraging student ideas and questions, and the lowest ratings are given for intellectual rigor. The synthesis ratings for classroom culture reflect these indicators with 13 percent receiving a high rating, 20 percent receiving a medium rating, and 67 percent receiving a low rating.

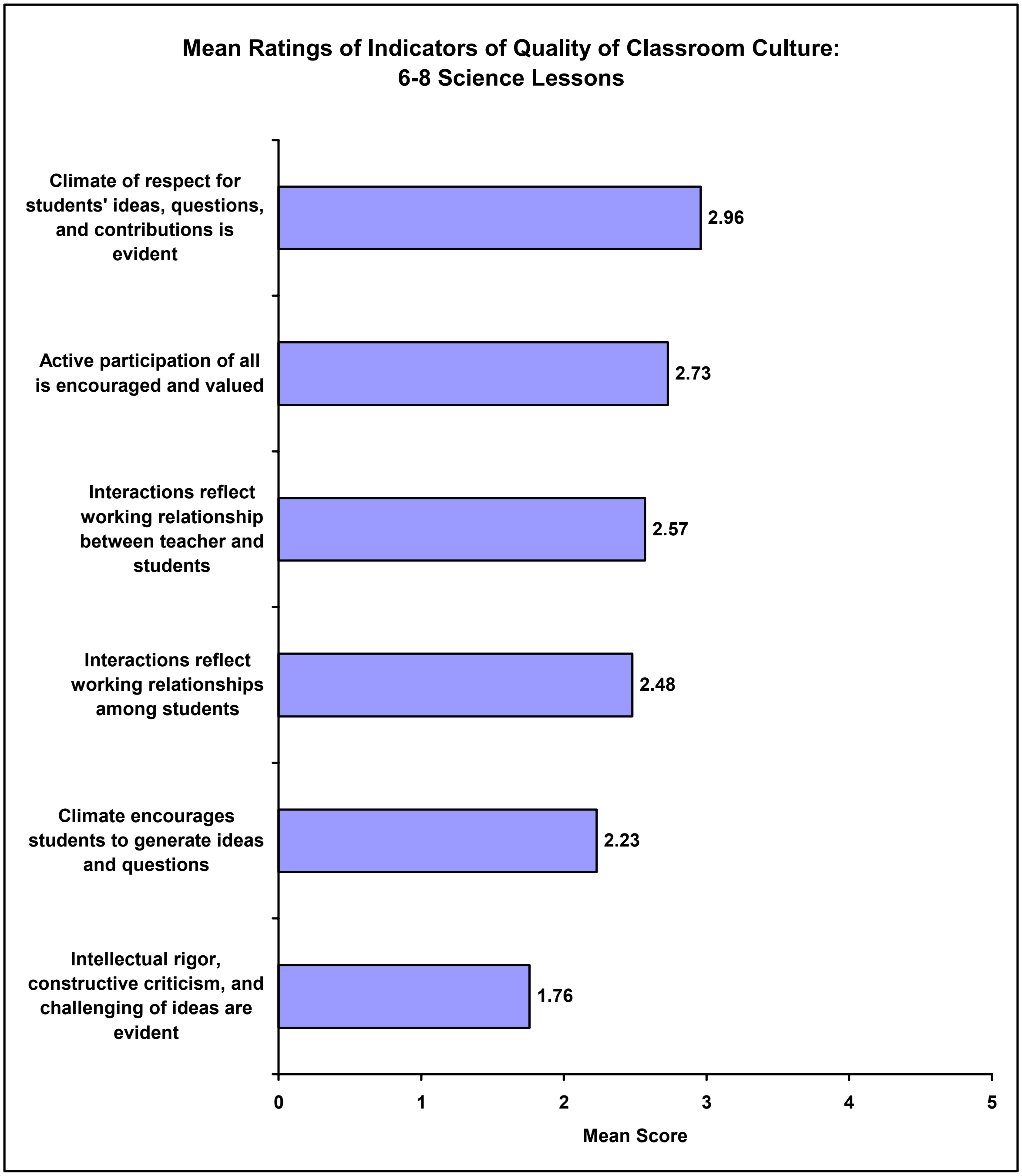

Mean Ratings of Indicators of Quality of Classroom Culture:
6-8 Science Lessons
Climate of respect for students' ideas, questions, and contributions is evident
2.96
Active participation of all is encouraged and valued
2.73
Interactions reflect working relationship between teacher and students
2.57
Interactions reflect working relationships among students
2.48
Climate encourages students to generate ideas and questions
2.23
Intellectual rigor, constructive criticism, and challenging of ideas are evident
1.76
0
1
2
3
4
5
Mean Score

Figure G-7

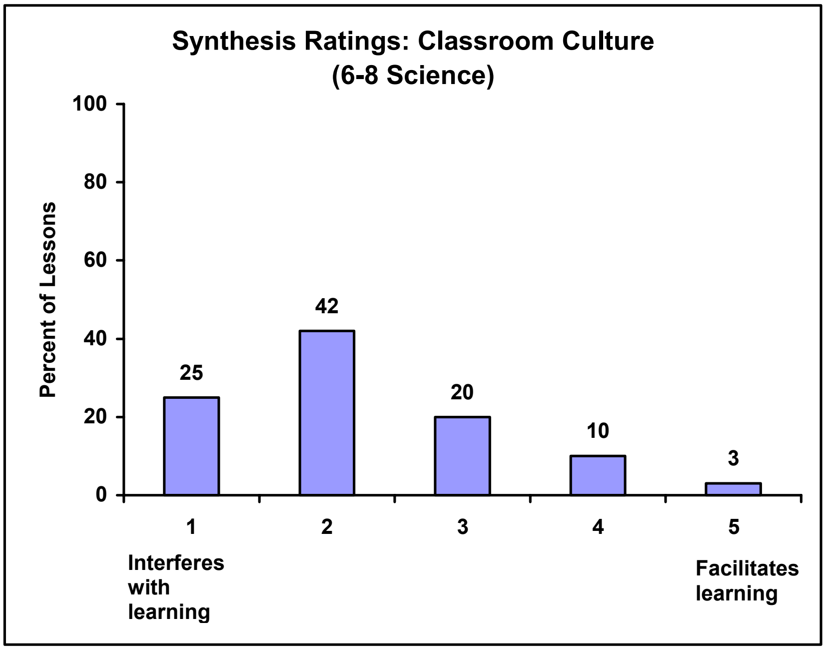

Synthesis Ratings: Classroom Culture
(6-8 Science)
100
80
60
40
20
0
Percent of Lessons
25
42
20
10
3
1
2
3
4
5
Interferes
with
learning
Facilitates
learning

Figure G-8

Overall Lesson Quality

Following the ratings of the individual components of the lesson, the researcher was asked to consider the likely impacts of the lesson as a whole. Just under a quarter of the lessons are judged to have a positive effect on student content knowledge, ability to generalize skills and concepts, and interest in science. In about one-third of lessons students' interest in science is judged to be negatively affected. (See Table G-1.)

Table G-1
Likely Impact of the Lesson: 6–8 Science

	Percent of Lessons		
	Negative Effect	Mixed or Neutral Effect	Positive Effect
Students' understanding of important mathematics/science concepts	19	57	24
Students' ability to apply or generalize skills and concepts to other areas of mathematics/science, other disciplines, and/or real-life situations	11	65	23
Students' interest in and/or appreciation for the discipline	33	45	22
Students' capacity to carry out their own inquiries	17	67	16
Students' understanding of mathematics/science as a dynamic body of knowledge generated and enriched by investigation	28	58	14
Students' self-confidence in doing mathematics/science	22	65	13

Figure G-9 shows the percentage of 6th–8th grade science lessons in the nation rated at each of a number of levels. (See page 9 of the Observation and Analytic Protocol in Appendix A for a description of these levels.) Seventy-eight percent of middle school science lessons are rated as low in quality on the capsule rating, 16 percent are rated as medium in quality, and 7 percent are rated as high in quality.

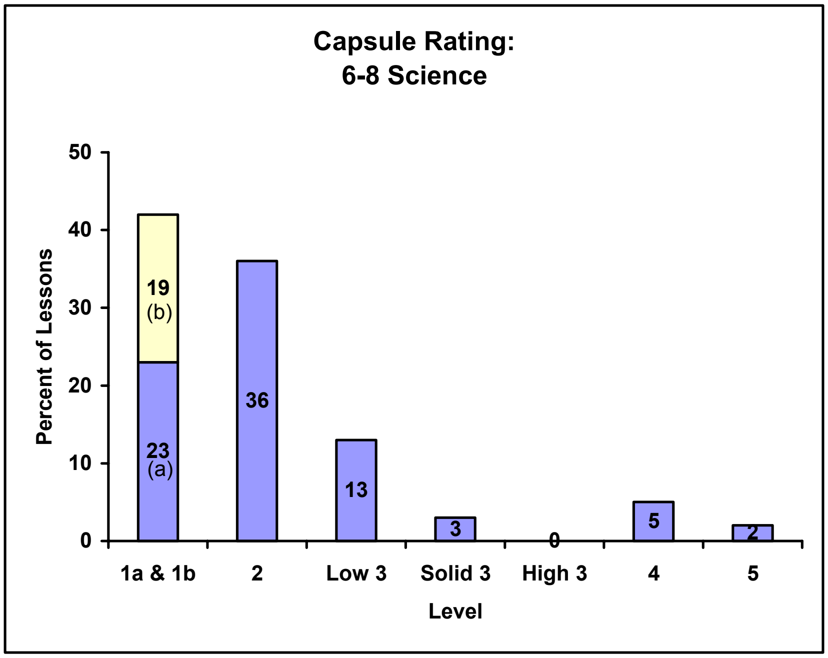


Figure G-9

The following illustrate lesson descriptions that were rated low, medium, and high in quality.

Sample Low Quality Lesson: Passive "Learning"

This 6th grade class was starting the last section of a unit on matter. Prior to this lesson they had studied the atom and characteristics of elements, and now they were beginning to study compounds.

The teacher conducted a review of the earlier material by asking a series of questions: "Can anybody tell me what a compound is? What is a mixture? Can anyone give an example? How about a non-uniform mixture?" Students raised their hands to answer the questions, and gave examples of each term (e.g., sand and water for a mixture, water for a compound, blood for a non-uniform mixture).

The teacher then began going over a worksheet the students had completed for homework, stating that "if you didn't get it correct, you need to erase it. We're going to fill it in together." He read through the worksheet aloud and asked for answers, which the students called out. The teacher confirmed whether the answers were correct, and the students corrected their papers. Several students did not have their worksheets in front of them, and when the teacher questioned one, he replied that he couldn't find it. The teacher accepted this answer and simply went on with the lesson, calling only on students who volunteered.

When they had finished with the worksheet, the teacher instructed students to put it in their notebook. Students asked whether it should be placed in the homework section or the classwork section, and the teacher told them it was homework.

Before the teacher moved on, a student asked, "In H_2O, what's the 2?", and the teacher opened the question up to the class, asking, "Does anybody know?" Another student replied, "It's two elements." The first student asked, "So why isn't it H_2O_1?", and the teacher said "It's understood."

The teacher then introduced the next worksheet. He drew a diagram of an atom and asked questions such as: "Can anyone tell me the negative charged part? How about the positive charged part? What about the part with no charge? What about the part right there located in the center of the atom?" Students raised their hands to answer these questions. The teacher then passed out the review sheet, clarifying that it was part of classwork, which counts for 15 percent of the final grade. A student asked, "Are we working together?" and the teacher replied, "No, I want you working on your own so you can prepare for the test next week."

Students worked individually on the worksheets for the remainder of the class period, with the teacher circulating to help. As students finished the worksheet, they either took out books to read or put their heads down on their desks to sleep.

This lesson was very passive in nature. The teacher's heavy reliance on worksheets with low-level questions, and the lack of engagement of most students throughout the lesson, made it unlikely that this lesson would enhance students' understanding of compounds.

Sample Low Quality Lesson: "Activity for Activity's Sake"

The students in this 6th grade class have been studying weights and measurement in mathematics and Roman architecture in social studies. To integrate these topics with physics, the teacher decided to have a bridge building competition in which the students acted as groups of engineers. The lesson began with a student reading the bridge challenge to the class, after which the teacher reviewed the terms compression and tension. The teacher then explained the procedures for the competition and listed the materials that each group would receive (35 straws, 10 rubber bands, 1 foot masking tape, and 10 paper clips). Next, the students arranged themselves in groups of 3–6 to build the bridges, and the teacher handed out materials. The teacher stated that the groups that worked diligently together would receive extra materials. The students built different components of the bridge by cutting or inserting straws or assembling pre-made structures into the bridge. Once the groups were finished, the teacher put the bridge across a span of 1 foot and asked students to gather around. The students placed the weights on the bridges to test their strength, but no standard weight was used for all of the groups. The students went to lunch immediately after these trials.

During the bridge building and competition most of the students were engaged in the process of constructing or observing. The students worked well together, and the teacher recognized the student work by providing the groups with more materials for the bridge. However, none of the groups discussed the type of bridge they should build, nor did any design a bridge before building it. Although the students came up with some interesting ways to provide support for the bridge, all groups used a similar span design. No time was provided for reflection on the physics or engineering concepts behind their designs, nor was there any discussion of why the different bridges supported different amounts of weight. The students seemed to enjoy the activity, but no clear connection was made to either the mathematics or social studies content that the lesson was intended to integrate. The lesson was essentially an activity for activity's sake, with no science content save for a brief introduction by the teacher on compression and tension.

The bridge project was grade appropriate, but the science content was limited. Although some students may have gained some confidence in their ability to do science, they neither furthered their understanding of tension and compression, nor learned about the role of controls and experimentation in science.

Sample Medium Quality Lesson: Beginning Stages of Effective Instruction

This lesson came in the latter part of a unit on plant growth and development and was divided into two major sections. For the first part of the class, students worked on finishing a lab activity on plant development; the second part of the class consisted mainly of a lecture on the structure and functions of leaves.

The class began by students finishing a two-week lab activity in which they grew different types of seeds in a beaker (with wet paper towels) and made daily observations about the plants' growth and development (root systems, stems, and leaves). As this was the final day, students took their plants from the beakers and made final measurements of the root system, stem, and leaves. The students were quite engaged in the activity, as evidenced by the questions they asked of the teacher and their conversations with classmates. For example, one group was excited to discover a type of nodule on one of their plants and asked the teacher what it was. The teacher told them what it was called and what function it served.

The students recorded their observations and answered questions on a lab worksheet (e.g., "Do all seeds planted at the same time germinate at the same time?" "Compare the growth rate of different seedlings.") which called for the students to use their data to support their answers. This was the weakest aspect of the lesson as the teacher ended up doing most of the intellectual work. By leading them through the questions, the teacher didn't give students much of a chance to draw conclusions from their data.

Next, the teacher distributed a worksheet with a diagram of a leaf cross-section and had students take out paper for notes. The teacher lectured about the parts and functions of a leaf, and the students took notes and labeled the parts of the leaf on their worksheet. The lecture was interesting, as the teacher drew upon several videodisc images to illustrate parts of the leaf, and his examples used plants commonly found in the local area. The teacher also mixed in questions that drew upon students' prior knowledge about plant parts and functions, though these tended to be factual/recall types of questions (e.g., "What is the outermost layer of a cell?" "What do we call this?").

The lesson engaged the students in important science content and processes, in both the lab and lecture portions. However, the teacher's short-circuiting of the data analysis from the lab activity and the predominant use of recall-type questions in the lecture tended to limit the effectiveness of an otherwise well-designed and well-implemented lesson.

Sample High Quality Lesson: Traditional Instruction

This 8th grade lesson focused on probability, genetics, and the Punnett square. It came near the end of a multiple-week unit on cell structure, function, and processes that included “mitosis, meiosis, and a little bit on genetics.” The lesson followed a hands-on activity in which two imaginary marshmallow creatures reproduced sexually, and students were asked to construct marshmallow babies based on the genetics of the parents. Today’s lesson began with students writing answers to two “Questions of the Day” pertaining to the marshmallow activity: “Describe two phenotypes that your marshmallow baby had (what did it look like?)” and “How many ‘daughter’ cells are produced from 1 human cell during mitosis and how many chromosomes do the ‘daughter’ cells have?” These questions were posted on the board prior to students’ arrival. When students were finished answering the questions, the teacher led a whole-class discussion about them and then transitioned into a brief interactive lecture about meiosis, X-chromosomes, and Y-chromosomes. During this lecture, the teacher involved students by asking them questions about their parents, elaborating on one student’s reference to a movie, and asking students what sex chromosome (X or Y) they’d received from their fathers.

Following the lecture, the teacher supplied each student with a one-page passage about probability and genetics and a related worksheet, both from their textbook. The worksheet required students to complete Punnett squares for heterozygous matings and to infer the genotypes of the parents given specified offspring genotypes. In addition, there was a matching section related to vocabulary from the reading selection. The teacher gave students the option of reading the selection as a whole class, but they chose to read independently instead. Most students had just begun the worksheet when the teacher asked who was confused about the Punnett squares on the worksheet. When many students raised their hands, the teacher led a whole-class, interactive tutorial about how Punnett squares work. Students then returned to the worksheets for a few more minutes. During the period of independent work the teacher circulated to ask questions, provide encouragement, and offer assistance. Once students had finished the worksheet they discussed it as a class, with students volunteering their answers and the teacher writing them on an overhead. Finally, the teacher distributed blank Punnett squares and announced two crosses for students to complete. Students again worked alone, and when they were finished the teacher called on volunteers to share their answers with the class.

This lesson included a variety of instructional strategies that all appeared to be appropriate for the students in the class. The teacher asked questions that engaged the students, and she probed further at appropriate times. She also changed her instruction when it was clear that students were not following. The intellectual rigor during the entire period was high, and the level of difficulty seemed to require most students to stretch, but never to a point of frustration. In addition, the content was worthwhile, had relevance to students’ real world, and included a cross-disciplinary connection to mathematics. Although the lesson was fast-paced, students remained engaged and motivated. Overall, this lesson seemed very well suited to the students in the room and was likely to have helped deepen their understanding of genetics concepts.

Sample High Quality Lesson: Reform-Oriented Instruction

This 7th grade class was studying a unit on human anatomy that included the structure and function of body systems. The focus of today's lesson was an introduction to the digestive system. The teacher began the lesson by asking students if they knew "which organ performed 500 different functions for their bodies?" This got the students' attention and the class moved into the study. After materials were dispensed, a student was asked to read aloud from the text describing the organs of the digestive system. The class was then asked to look at the expanded diagram of the digestive system, find specific structures, and color them in.

As each structure was colored, the teacher led a discussion linking the form of each structure in the digestive system to its function. The teacher used an interactive, conversational style in which he would ask a question and the class would put together the concept in their responses. To enhance the discussion, he used both interesting examples and models that he had built before class. For example, a corrugated plastic hose was used to model the cartilaginous support in the trachea, and a bicycle inner tube was placed against the trachea to represent the position of the esophagus. To illustrate enzymatic digestion, the teacher cut a piece of paper into tiny pieces. He then visually demonstrated how the epiglottis folds back so food can go down the esophagus and not the trachea. The class period ended with students chewing soda crackers, holding them on their tongue until they could taste sugar in order to reinforce the idea that starch is converted to sugar by enzymes of the digestive system. Students were then reminded of their assignment: to write an essay entitled "As the Stomach Churns" which would describe what happens to food in the stomach.

This lesson was well planned, with every minute allocated to instruction. The teacher used multiple pedagogical strategies to introduce the digestive system and to conceptually link structure with function. The teacher emphasized the student reading of the textbook for content, but amplified the student understanding with many activities and concrete models. His method of alternating discussion to explain, coloring to reinforce the form of the system, and models to describe the function was an effective way of helping students understand the digestive system.

Appendix H

Grades 9–12 Science

Typical Lessons

Ratings of Lesson Components

Overall Lesson Quality

Typical Lessons

The following lesson descriptions are based on a random sample of 9th–12th grade science lessons.

9th Grade Biology: Review for End-of-Grade Exam

The 9th grade class has been working on a review for the end-of-grade, district-wide common exam in biology. Prior to beginning this review, which was scheduled to last two weeks, the class was working through the different kingdoms of living things. The teacher developed the lesson using two textbooks, which were not designated by the district, but that he believed were better suited to the reading levels of the students.

The lesson had two parts. In the first 20 minutes of the class, the teacher gave detailed directions for completing a class assignment to make a model of a plant or animal cell out of materials of their choice. For the remainder of the lesson, the teacher outlined the requirements to pass biology and conducted a question and answer session on topics that would be on the end-of-grade test: osmosis, diffusion, classification. A typical exchange was as follows: The teacher asked the class to turn to page 83 in their text which had a picture of ink drops being put in water until equilibrium was reached. He asked a student to read the caption under the picture which explained what was happening. When she finished the teacher asked, "Who wants to define equilibrium?" Another student raised her hand and read the definition from the book. The teacher gave the example of spraying perfume on one side of the room to illustrate diffusion. He also used the example of dye to color eggs at Easter. The teacher told the class, "I guarantee that there will be a question on the test about osmosis and diffusion. If you see passive transport on the test you know it is diffusion." Similar exchanges occurred with the other topics being reviewed. The lesson ended with the teacher giving students tips on taking tests.

9th Grade Earth and Environmental Sciences: Analyzing Nutrients in Soils

This 9th grade lesson came near the beginning of a unit on soil and water testing. It focused on analyzing nutrients in soil from the local community, in many cases from students' gardens. The teacher indicated that soil was a key link between earth and environmental science, and that this lab gave students the chance to see how science is applicable to their lives (by testing soil from their own homes and figuring out what types of plants they could grow).

The lesson began with the students taking a short quiz on background reading from the night before, focusing on the effects of the various soil nutrients on plant growth and development. After taking the quiz, students swapped and graded the quiz as the class reviewed the answers. Next, the teacher distributed the lab instructions and spent about 15 minutes giving students some hints on how to complete the lab (such as making sure they used the correct scoop when measuring the chemicals as there were two that looked the same but held different amounts).

The class spent the remainder of the period working on the soil tests, measuring the pH, and the concentrations of nitrogen, phosphorous, and potassium. Because of the amount of time needed to complete all four tests, the teacher planned for students to complete half of the tests during this lesson and finish the remaining ones the next day. The students were engaged with the activity and were concentrating on carrying out the procedures correctly. During the lab work, students discussed the proper procedures (e.g., how long they had to wait for the mixtures to settle, how much indicator they had to add). While the groups were working, the teacher circulated and assisted students when necessary, answering questions about the procedures. Most groups finished 2 of the 4 tests (as the teacher planned), though some completed 3. The teacher wrapped up the lesson by telling the students they would finish the tests the next day and then analyze and discuss the data.

9th Grade Physical Science: Atomic Models

This lesson was an introduction to atomic structure. After taking attendance, the teacher handed back the students' tests from the previous chapter so that students could see their grades. The teacher then collected the tests and told them that they were going to start on Chapter 5. He said, "Chapter 5 is on atomic structure, so the first thing we'll do is look at models." After briefly explaining models, he instructed students to use their textbooks to take 3–4 sentences of notes on each of the six models: Greek model, Dalton's model, Thomson's model, Rutherford model, Bohr model, and the Wave model. He said, "Just go through your book and give me 2, 3, or 4 sentence descriptions of these models." Further, he told students that he would be out the next two school days so this was just an introduction. The teacher said, "Basically what I'm trying to accomplish is to get the idea in your head. Then on Monday we'll basically start over, knowing you will forget this in two days, I'm sure. I'll try to line you up for a video when I'm gone."

The teacher lectured briefly on the six models before assigning a worksheet involving the use of their textbook to find factual information on atomic models. After the students completed the worksheet, the teacher called out the answers and then collected the worksheets. The teacher then did another mini-lecture, reviewing what had been covered on the worksheet. This was followed by the teacher talking about diagramming atoms. At one point, he drew a lithium atom on the board, told students the atomic number was 3 and mass number 7, and asked them how many protons were contained in the atom. After a number of attempts, the students finally offered 3, as an answer, but were unable to answer when the teacher asked how many neutrons were in the atom, so he provided the answer, 4. After several similar exchanges, the teacher ended the lesson by just stopping, and students sat talking for the last 10 minutes of the class.

9^{th} Grade Physical Science: Demonstrations of Wave Phenomena

This 9^{th} grade physical science class had just finished two chapters—on sound waves, and colors and light—in their state-adopted textbook. The teacher indicated that he usually provided some sort of lab/demonstration activity at the conclusion of a chapter from the textbook, in this case, at the conclusion of two chapters. The teacher had prepared a series of demonstrations of mechanical waves, polarized light, and colored light.

At the beginning of this 55-minute lesson, students were told to take notes in their notebooks as they watched the demonstrations. The first demo involved a long spring stretched along the central area of the room. He used the spring to demonstrate horizontal and vertical waves, nodes, pulses, interference, and compression waves, one right after the other. This was followed by a series of demonstrations involving light waves. The teacher drew a picture on the board of light waves, blocked in one direction by a horizontal slit and asked students questions about the diagram: "This is called polarization....Is it possible to polarize light? How?" This type of questioning continued with the next demonstration of polarization using sunglasses placed on an overhead projector and a small square of Polaroid filter. The teacher then moved quickly on to show how certain minerals naturally polarize light using a crystal of Iceland spar and then mica placed on the overhead projector sandwiched between two sheets of Polaroid film. He asked the students to predict what would happen if he rotated the top piece of film and then showed them that only the center remained light. The teacher next showed on the overhead how polarized light could be used to find stresses in materials, like plastic, using X-rays. The topic for the demos once again shifted, this time to sound. The teacher rapidly performed demos showing how the vibrations from one tuning fork can make another tuning fork vibrate, but only when both are "playing the same note." The last ten minutes of class were spent on several demonstrations with different colors of light. Again using the overhead, the teacher reviewed how different colored filters could be used to combine magenta, cyan, and yellow to all of the other colors. The class ended with a reminder that they had two days remaining to prepare their projects for the science olympics.

9^{th}–10^{th} Grade Biology: Evolution

This was the final lesson in a unit on evolution. The students had previously learned about fossils and the geologic time scale, as well as Lamarck's and Darwin's theories of species change.

The teacher began the lesson with a review, asking a series of questions such as: "What was the first piece of evidence for evolution? Who remembers what epoch we live in? What was Lamarck's theory of evolution? Why did Darwin say [giraffes'] necks get long?" Next, the teacher told students to open their texts to the appropriate page, and placed an outline on the overhead projector. For the next thirty minutes she lectured based on that outline. She gave five modern pieces of evidence for evolution by natural selection: analogous structures, homologous structures, vestigial organs, similarities of embryos, and macromolecules. She provided examples for each (from the textbook) and asked questions throughout, such as "What do you notice about these diagrams (of arm bones of different mammals)?" "Can anyone think of an organ inside the body that today is not used?" and "What does a nucleotide consist of?" When directly called to do so, students answered questions, but otherwise spent most of their time copying the teacher's outline into their notes. The teacher next turned her lecture to the subject of evolutionary patterns listing three types: coevolution, convergent evolution, and divergent evolution. She drew diagrams and gave examples for each.

9th–12th Grade Environmental Science: Alternative Energy Sources

This lesson was a review of previous discussions and lectures, focusing on alternative energy sources. The teacher reported that for this course, he is required to follow the district's Earth Science standards because there are no environmental science standards. Also, he said that he is required by the district to use the textbook and resource materials provided for the course.

At the start of the lesson, the teacher reviewed the previous day's activity (measuring soccer/football fields and bleachers). He did this by asking students to call out their measurements and then wrote the correct measurements on the board. The teacher told students to bring gardening gloves for the next class for they would be doing work on the school grounds.

The remainder of the lesson consisted of students calling out answers to a five-page packet, where each page was a section review for a particular section of Chapter 17 in their text. For example, the first page of the packet consisted of seven questions such as: "People burn fossil fuels and use both wind and water to generate electrical power. Explain how the energy in all of these sources originates from the sun's energy." and "What is active solar heating? Provide some examples." The questions in the other section reviews covered hydroelectric power, wind energy, and geothermal energy. The last page of the handout was titled "Vocabulary Review" and required students to use a dictionary to write definitions for words used throughout these sections (e.g., solar energy, photovoltaic cell, geothermal energy).

Near the end of the lesson the teacher said, "I guess this will be the last one we'll do" and then called on a student. The student started answering the question, but the announcements came on, so she stopped and everyone packed up and left the room.

10th Grade Biology: Natural Selection and Adaptation

Students in this 10th grade biology course had been studying evolution. They had recently watched a video about speciation in finches and had discussed the classic example of adaptation—the industrial melanism in peppered moths in Manchester, England. The class period started with the students working on a "warm-up" activity. They worked individually at their desks to write down the answers to five questions written on an overhead. Examples included: Paleontologists: scientists who study______. Punctuated gradualism: a model of evolution in which periods of ____ change are separated by periods of little or no change. After five minutes the teacher went over the questions with the whole class by reading each question aloud and then calling on a student to give the word to fill in the blank.

Next, the students worked on a lab activity (Peppered Moth Survey) that was designed to simulate the adaptation of peppered moths to industrial melanism. A lab handout directed students to simulate the predator-prey relationship by picking a mixture of two colors of paper discs (white and newspaper) off of two different colors of background paper (white and newspaper). They had 30 seconds to pick up the discs; they were to work in pairs, with one person serving as the timekeeper and the other as the predator. Students graphed the data designated on the lab handout and answered some questions about the two activities. Several students finished early and started working on their homework for this class—answering questions in the textbook.

10th Grade Biology: Protein Synthesis

This lesson came near the end of a required 10th grade trimester biology course focusing on cells and molecular biology. The class had already covered cell processes like photosynthesis, respiration, mitosis, meiosis, and this lesson was an introduction to how genes code for proteins. This topic, according to the teacher, is important for students in this course and is consistent with the required state curriculum.

The twelve students in the class were assembled around a collection of lab desks positioned "conference-style" in the center of a large classroom. Two "Essential Questions" were written on the board for students to copy into their notebooks: (1) "What makes you who you are?" and (2) "How do genes code for proteins?" After everyone had copied the questions, the teacher began an interactive lecture related to those questions. The atmosphere was very informal and relaxed as the teacher, who was sitting at the conference table with the students, described how DNA from within a nucleus codes for the synthesis of particular proteins elsewhere in a cell. During the lecture, the teacher frequently posed questions (e.g., "Do you remember what Mendel found out with his pea plants?"), sometimes making connections between the lesson and students' lives (e.g., "What kind of codes do you encounter in your everyday lives?"—to which a discussion of musical sheet music ensued). The lesson ended with an activity where students acted out the process of protein synthesis using laminated cardboard manipulatives representing DNA, mRNA, and tRNA. The activity to physically model the process came from a colleague a few years prior, and the teacher felt that this activity helped students remember the process because it got them up and out of their seats. At the conclusion of the class period, the teacher indicated that these same essential questions would be addressed in the following lesson as well.

10^{th}–12^{th} Grade Physics: Electrostatics, An Introduction to Electricity

This lesson on electrostatics was the first in a unit on electricity. Although the teacher indicated that the content of this unit is in the district curriculum and on the end-of-level test, the primary purpose of this initial lesson was to introduce the topic through inquiry, exploration, and discussion.

The class began with a "bell quiz," asking students to define the words electrostatics, conductor, and insulator. After reminding students that electrostatics phenomena are familiar to them (the shock you get after scuffing your shoes, your hair sticks out when rubbed with a ballon), the teacher distributed a "Guide Sheet on Electricity," containing the objectives for the upcoming unit as well as lists of the vocabulary, activities, and assignments.

The teacher introduced the day's activity with a brief discussion of charge and then moved the class to a large central open meeting area at the school for an exploration of static electricity using a Van de Graaf generator, Tesla coil, and fluorescent light tube. The teacher explained how each worked and arranged a set of experiments, using students in the class to demonstrate (sometimes a bit painfully) what happens when electrons are pulled from one source to another. During the demonstrations, the teacher explained in a general way what was happening as they tried different arrangements of students and apparatus and watched the "shocking" results. After the initial demonstrations and "zappings," students started to ask a series of "what if…" questions, e.g., "What if I turned it off while holding it?" to which the teacher responded, "What would you predict?" The student came back with, "I'd get a shock!" and the teacher asked, "Why?" The teacher also allowed the students to do some of their own experiments. For example, at their own request, the students made a human chain and all become involved as their hair began to rise and they felt the tingle. The student on the end was the only one who got a shock.

The teacher moderated a whole-class discussion back in the physics classroom of phenomena observed through the explorations and demonstrations. A discussion ensued after several students asked why the spark from the ball was blue but the spark from the coil was purple and what the color of lightning was. The teacher concluded the lesson by telling students what to expect in their study of electricity and by relating what they would be learning to local concerns.

11th Grade Advanced Chemistry: History and Development of the Periodic Table

The class has just finished a study of electron configurations related to the placement of elements in the Periodic Table. This lesson was the first on the history and development of the Periodic Table, a topic specified in the district's curriculum that would be assessed on an end-of-quarter, district-wide test.

The session began with about 10 minutes of non-instructional activity—the teacher taking care of paperwork and the students "getting ready for a pop quiz" (mostly just talking). The pop quiz consisted of five questions designed to see which students had read the chapter, an assignment given the previous day by a substitute teacher. The teacher collected the papers, commenting, "If more than half the class fails the quiz, then we won't count it, but the next one will." The teacher went over the questions, with students calling out the answers.

The next component of the lesson was essentially that of the teacher reading through and elaborating on an outline of facts in the chapter (names, contributions, vocabulary) that had been typed on a transparency, while the students took notes. About halfway through the class period, the teacher stopped the note-taking and passed out section review sheets that students had completed the previous day. Students graded each others' papers, with the teacher giving the instruction, "Mark it wrong if they miss it, but don't correct it. They can look it up, might learn something." The teacher asked for answers to each of the questions on the worksheets which consisted of multiple choice and short answer items.

For the remainder of the lesson, the teacher instructed the class to work on questions 1–30 in their Chapter 5 study guide.

11^{th}–12^{th} Grade AP Chemistry: Buffers and LeChatelier's Principle

This lesson was the first in a unit on equilibrium and was meant to have the students apply their prior knowledge of pH and equilibrium to buffers and salts. As a part of the unit, the teacher planned lessons on buffers and titration, including pH and LeChatalier's principle, concepts the teacher indicated students need to learn in order to do well on the AP test and for further study of chemistry in college.

The lesson began with the teacher distributing a handout (an outline and some sample problems) and asking students to solve the first problem as a review (calculating the pH of 3.0 M $HC_2H_3O_2$ with Ka = 1.8E–5). The teacher then reviewed the solution, asking students to tell her how to determine the pH. She then asked the students to apply LeChatelier's Principle and how adding acetate to the system would affect the pH. Most of the remainder of the lesson was spent with the teacher lecturing on buffers, asking the class questions such as "What are the products of dissociation [of acetic acid]?" "What would happen [to the equilibrium of this reaction] if we added tons of acetate?" "What happens to an acid or base when you add it to a buffer?" and doing sample problems (calculating the pH of acetic acid). Towards the end of the class, the teacher assigned homework and asked the students to begin it in the time remaining.

11th–12th Grade Zoology: Cnidarians (Jellyfish)

The students had just completed a unit test on cnidarians and were ready to begin a review for their upcoming semester exam. The lesson consisted of two main components: a PowerPoint presentation on cnidarians and a lab in which students studied a living cnidarian.

The teacher began the lesson by congratulating the students on a job well done on their test on cnidarians. She informed the class that after today's lesson they would begin preparing for their semester exam. The teacher then presented a PowerPoint presentation on cnidarians and informed the class that it was a review of material from their previous unit test. The students sat quietly and listened as the teacher talked through numerous professional quality, colorful slides for about an hour.

At the conclusion of the presentation, the teacher passed out a hand-written worksheet and told the students to work in pairs to observe a live jellyfish, the Gonionemus. Students were instructed to each answer the four questions on the worksheet and draw and label the parts of their specimen on the back of the worksheet. Students moved efficiently to their lab stations while the teacher passed out the specimens in wet petri dishes, and within a few minutes, students were "oohing" and "ahhing" over their jellyfish. Students were actively observing, but did little writing and recording. When the bell rang, the teacher told the students to finish the worksheet for homework.

Ratings of Lesson Components

The designs of high school science lessons are, on average, rated most highly for the contribution of available resources to accomplishing the lessons' goals and for careful planning and organization. Somewhat fewer lesson designs take students' preparedness into account. The lessons are weakest in providing adequate time and structure for wrap-up. Synthesis ratings for design are low for 60 percent of lessons, medium for 29 percent, and high for 11 percent.

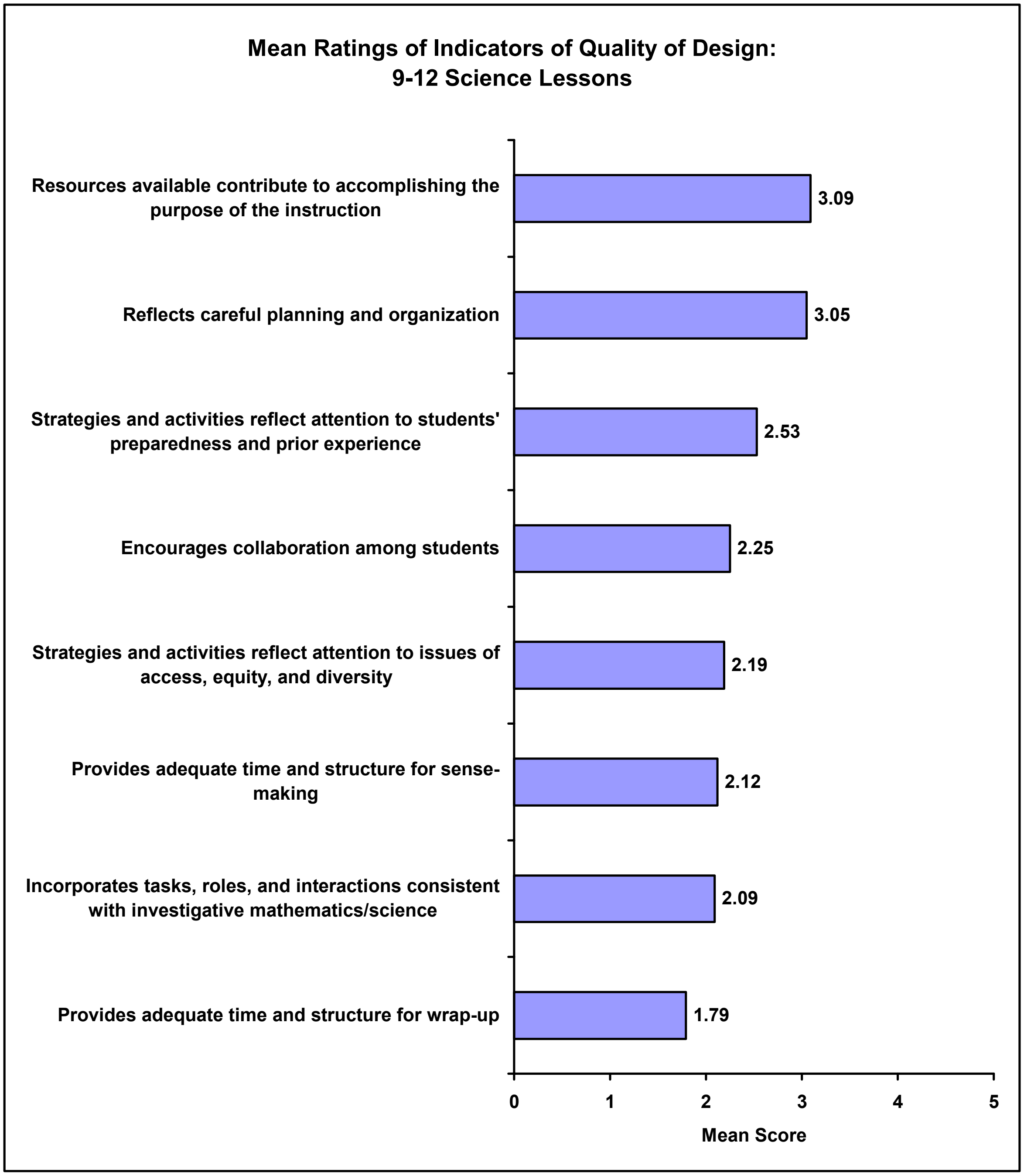

Mean Ratings of Indicators of Quality of Design:
9-12 Science Lessons
Resources available contribute to accomplishing the purpose of the instruction
3.09
Reflects careful planning and organization
3.05
Strategies and activities reflect attention to students' preparedness and prior experience
2.53
Encourages collaboration among students
2.25
Strategies and activities reflect attention to issues of access, equity, and diversity
2.19
Provides adequate time and structure for sense-making
2.12
Incorporates tasks, roles, and interactions consistent with investigative mathematics/science
2.09
Provides adequate time and structure for wrap-up
1.79
0
1
2
3
4
5
Mean Score

Figure H-1

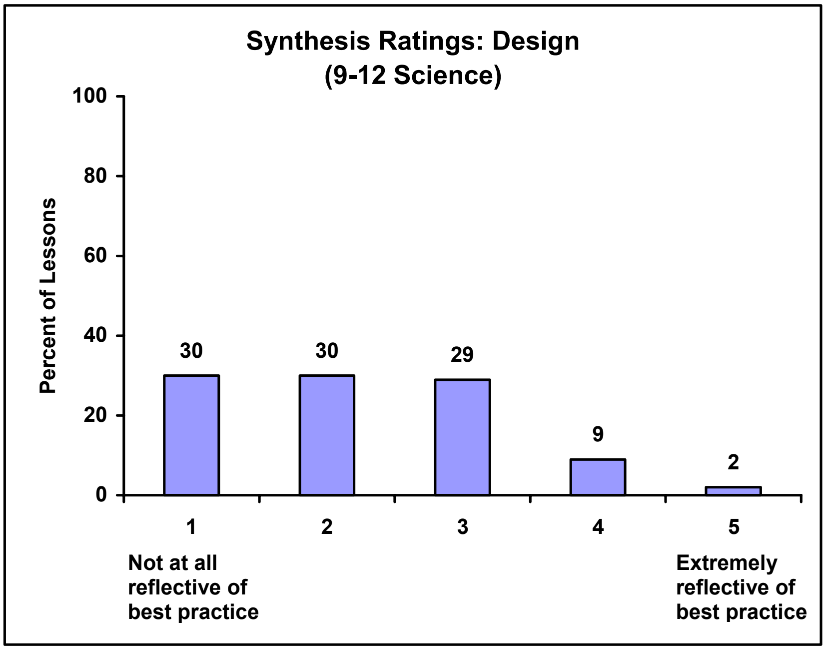


Figure H-2

Teacher confidence is, on average, the strongest aspect of high school science implementation. Teachers' classroom management is ranked somewhat less highly. The lowest-ranking aspects of implementation are the use of investigative instructional strategies and teacher questioning. The relatively low rankings in these areas may contribute to the low synthesis ratings of 74 percent of lessons. Twelve percent are ranked medium, and only 14 percent receive high ratings for implementation.

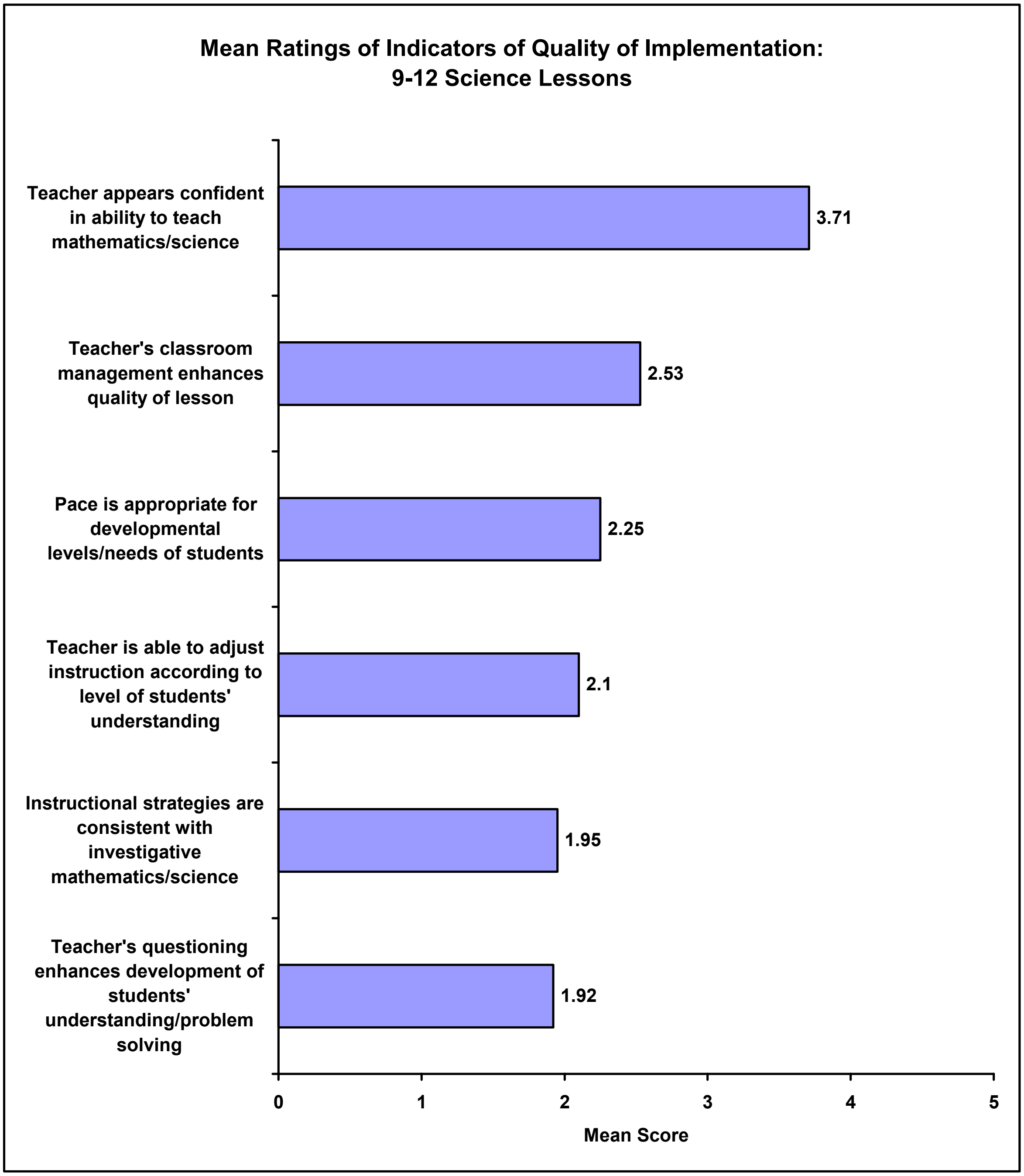

Mean Ratings of Indicators of Quality of Implementation:
9-12 Science Lessons
Teacher appears confident in ability to teach mathematics/science
3.71
Teacher's classroom management enhances quality of lesson
2.53
Pace is appropriate for developmental levels/needs of students
2.25
Teacher is able to adjust instruction according to level of students' understanding
2.1
Instructional strategies are consistent with investigative mathematics/science
1.95
Teacher's questioning enhances development of students' understanding/problem solving
1.92
0
1
2
3
4
5
Mean Score

Figure H-3

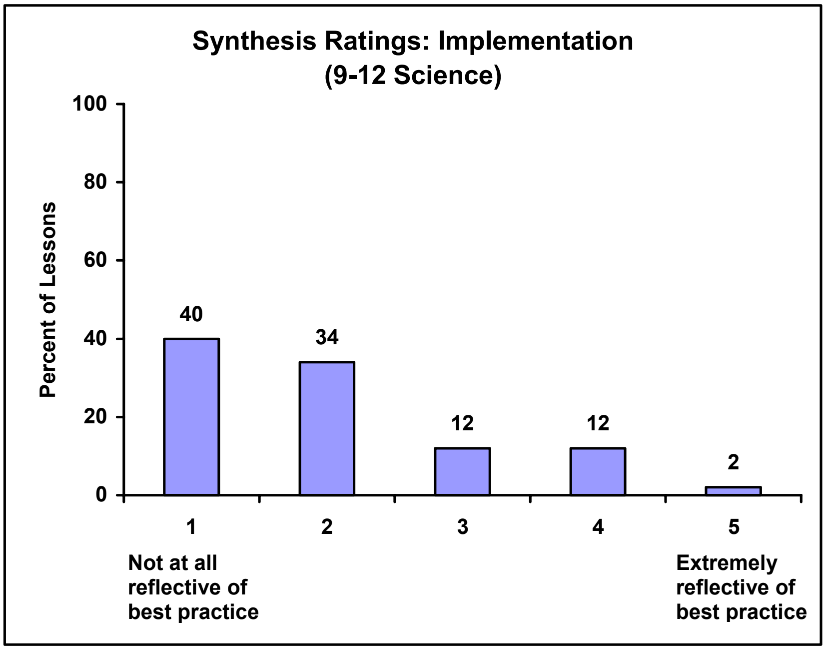


Figure H-4

High school science lessons are rated highly for significant, worthwhile, and developmentally appropriate content, as well as for teachers' clear grasp of the concepts being taught. Weaker points include a lack of intellectual engagement by students and a low degree of sense-making. In addition, lessons tend not to portray science as a dynamic body of knowledge. Synthesis ratings for content are low for 58 percent of lessons, medium for one-fourth, and high for 18 percent.

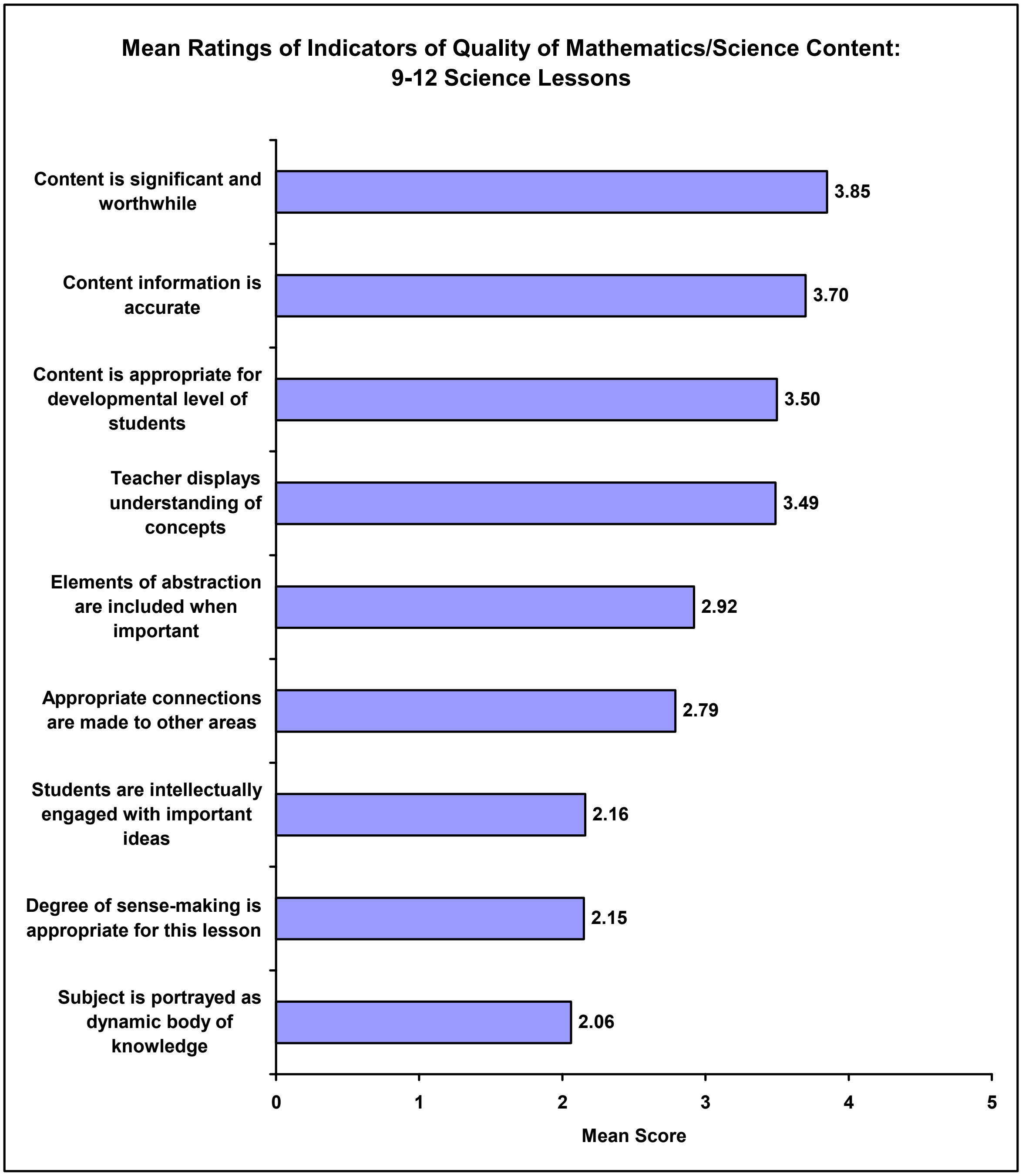

Mean Ratings of Indicators of Quality of Mathematics/Science Content:
9-12 Science Lessons
Content is significant and worthwhile
3.85
Content information is accurate
3.70
Content is appropriate for developmental level of students
3.50
Teacher displays understanding of concepts
3.49
Elements of abstraction are included when important
2.92
Appropriate connections are made to other areas
2.79
Students are intellectually engaged with important ideas
2.16
Degree of sense-making is appropriate for this lesson
2.15
Subject is portrayed as dynamic body of knowledge
2.06
0
1
2
3
4
5
Mean Score

Figure H-5

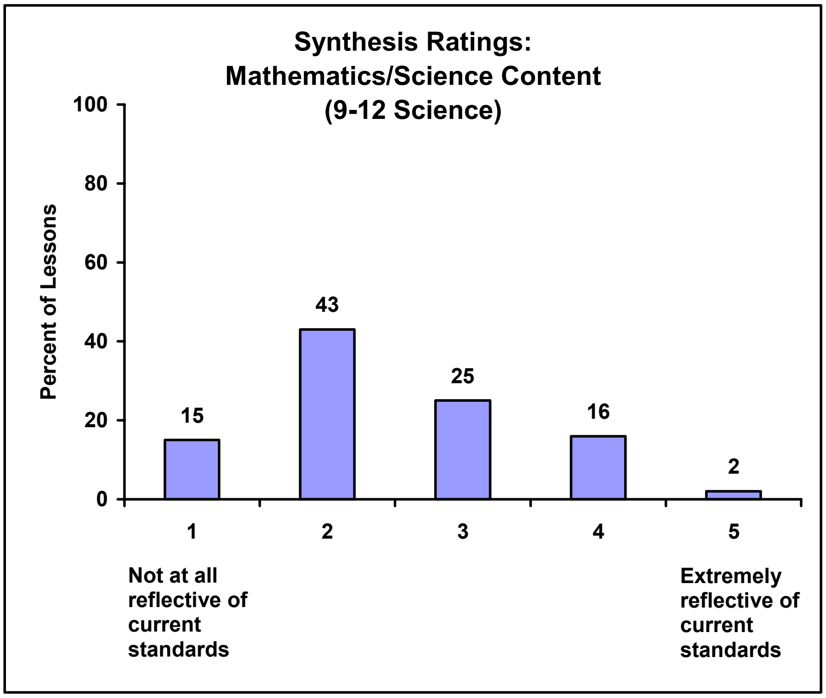


Figure H-6

On average, high school science lessons are rated higher for including a climate of respect than for other aspects of culture. Lessons tend to be weak in encouraging students to generate ideas and questions, and intellectual rigor is not often evident. These limitations may contribute to the low percentage of lessons receiving high synthesis ratings (13 percent, compared to 21 percent medium and 65 percent low).

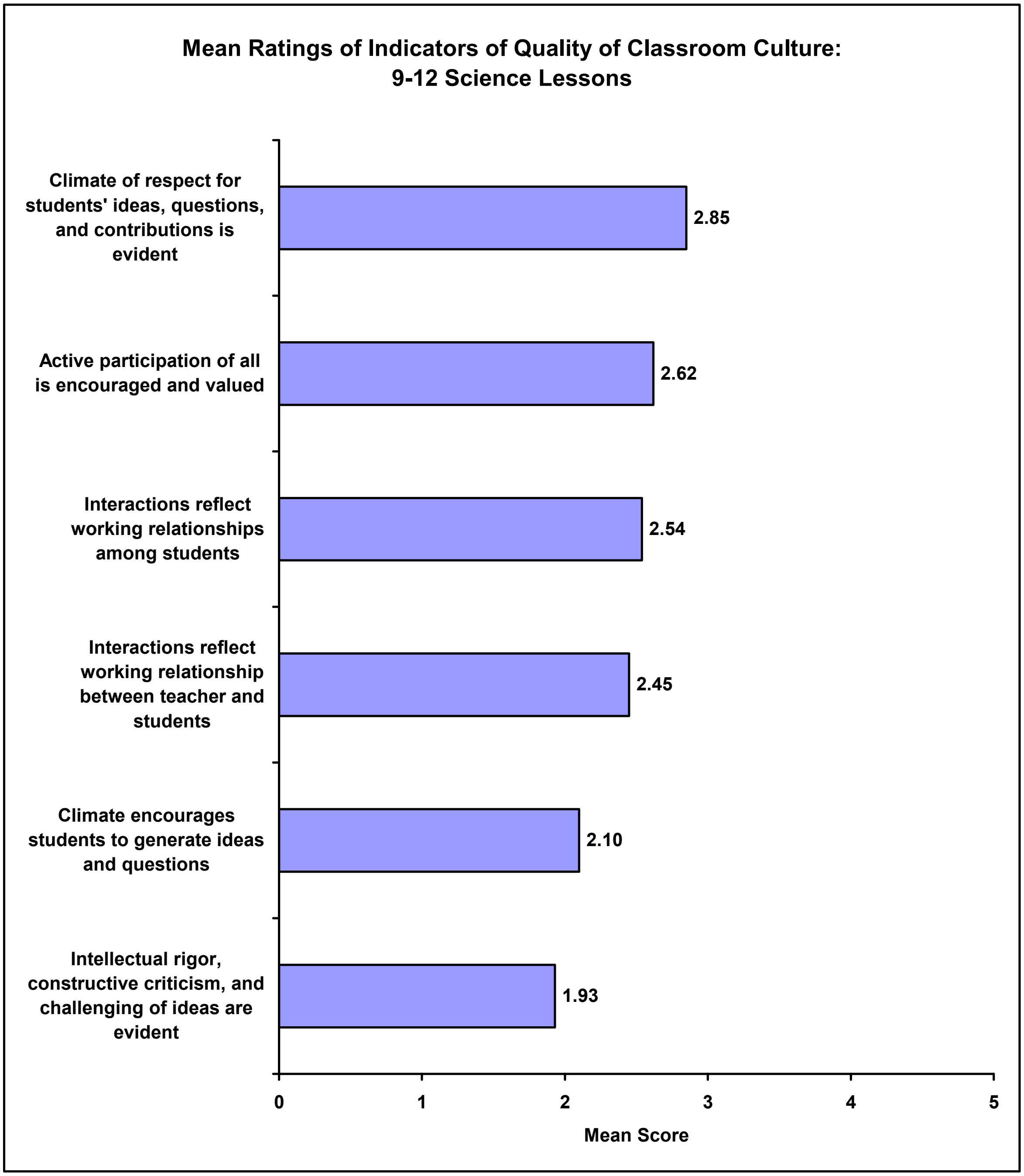

Mean Ratings of Indicators of Quality of Classroom Culture:
9-12 Science Lessons
Climate of respect for students' ideas, questions, and contributions is evident
2.85
Active participation of all is encouraged and valued
2.62
Interactions reflect working relationships among students
2.54
Interactions reflect working relationship between teacher and students
2.45
Climate encourages students to generate ideas and questions
2.10
Intellectual rigor, constructive criticism, and challenging of ideas are evident
1.93
0
1
2
3
4
5
Mean Score

Figure H-7

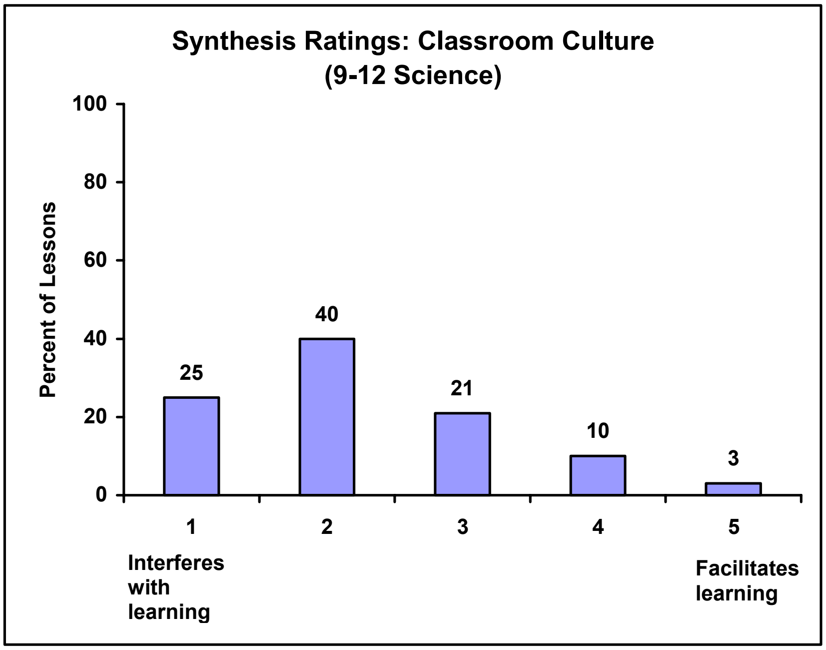

Synthesis Ratings: Classroom Culture
(9-12 Science)
Percent of Lessons
100
80
60
40
20
0
25
40
21
10
3
1
2
3
4
5
Interferes with learning
Facilitates learning

Figure H-8

Overall Lesson Quality

Following the ratings of the individual components of the lesson, the researcher was asked to consider the likely impacts of the lesson as a whole. Thirty-eight percent of lessons have a positive effect on students' content knowledge, and less than one-fourth of lessons are judged to have a positive effect on other aspects of student learning. Thirty-seven percent of lessons negatively affect students' interest in science. (See Table H-1.)

Table H-1
Likely Ratings of the Lesson: Science 9–12

	Percent of Lessons		
	Negative Effect	Mixed or Neutral Effect	Positive Effect
Students' understanding of important mathematics/science concepts	14	48	38
Students' ability to apply or generalize skills and concepts to other areas of mathematics/science, other disciplines, and/or real-life situations	14	63	23
Students' self-confidence in doing mathematics/science	24	60	16
Students' interest in and/or appreciation for the discipline	37	47	16
Students' capacity to carry out their own inquiries	18	69	14
Students' understanding of mathematics/science as a dynamic body of knowledge generated and enriched by investigation	33	55	12

Figure H-9 shows the percentage of 9^{th}–12^{th} grade science lessons in the nation rated at each of a number of levels. (See page 9 of the Observation and Analytic Protocol in Appendix A for a description of these levels.) Sixty-six percent of high school science lessons are rated as low in quality on the capsule rating, 22 percent are rated as medium in quality, and 12 percent are rated as high in quality.

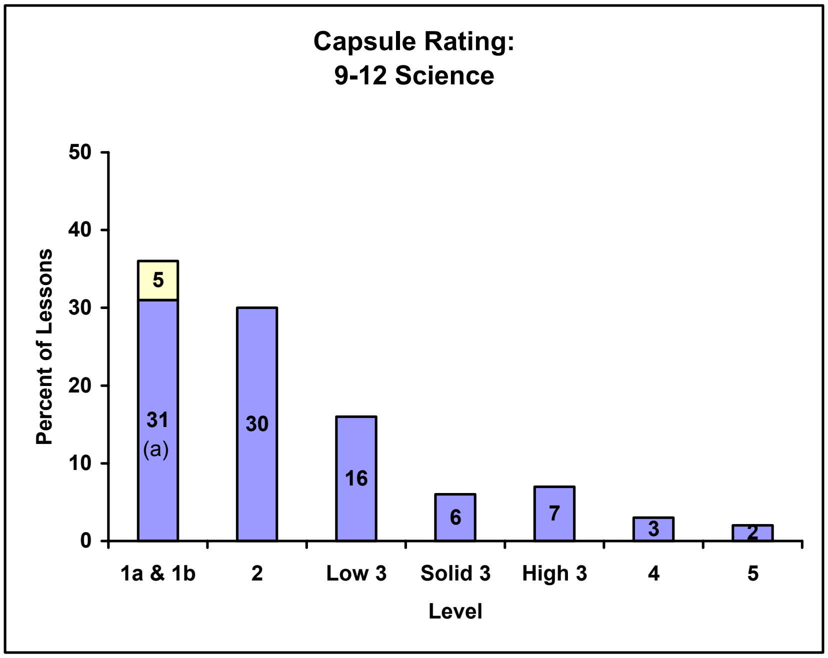


Figure H-9

The following illustrate lesson descriptions that were rated low, medium, and high in quality.

Sample Low Quality Lesson: Passive "Learning"

This 9th grade Biology class was near the end of a unit on evolution. The students had previously studied the formation of the solar system, bacteria and cellular evolution, and changes in the atmosphere over time. After this lesson they would briefly study human evolution, then take a test.

The lesson began with students individually filling out a worksheet on which facts from the chapter were written. Without looking in the book, students had to decide whether the statements were true or false and correct the false ones. The true/false statements included: "Eubacteria was the first bacteria formed." "Multicellular organisms evolved from protists." and "Arthropods invaded land first." Once they had finished working individually, students were instructed to check their work in the book, working in small groups to come to a consensus on the answers, and to document on what page and paragraph they found the answer.

When they had finished the worksheet, the students copied from the board a timeline of evolution that focused on bacteria. Then the teacher announced the answers to the worksheet questions. About half the class did not try to answer the questions in the time allotted but instead waited until the teacher gave out the answers. Some students raised their hands and asked about items they did not understand, in which case the teacher would ask the class to explain the answer, but he rarely gave them time to speak before answering himself. Once students had asked their questions, the teacher read through each worksheet problem one more time and asked students to identify the page and paragraph in which they had found the answer.

The teacher then gave a lecture based on the chapter students had just read. He began by asking students to look at the inside of the textbook's back cover, which showed a chart of the evolution of all life and when each life form was found. He told students that this chart summarized the material they were about to cover. The rest of the lecture consisted of a series of names of organisms and time frames of their existence. The focus was on lists of facts taken from the book; at several points, the teacher read straight out of the textbook or asked students to do so. He introduced new topics by saying, "Next they start talking about continental drift" or "Then it starts talking about sharks." Students followed along in the book. The teacher instructed them to take notes in a two-column format in which one column was titled "Main Themes" and the other was "Detail." Only a few students followed this format, and the teacher never followed through or helped to identify the "Main Themes."

The teacher's questions rarely required higher order thinking, never drew on previous knowledge or real-world connections, and never offered enough wait time for students to consider an answer. Most questions required factual recall and encouraged students to hunt through the text. With fifteen minutes left in class, students were given time to work on homework.

The process of evolution is important and relevant content for 9th graders, and the evolutionary timeline is useful as an organizing context to tell the story of the history of life on Earth. However, in this lesson the information was presented as a series of disconnected facts with no underlying context or relevance to students' lives.

Sample Low Quality Lesson: "Activity for Activity's Sake"

Ninth graders at this school are required to take physical science, but this particular section was labeled as honors, and students had self-selected into it. The class was in the middle of a unit on chemical change, and they had completed a lab in the previous week involving a sulfur and iron reaction. Apparently, there had been complaints from other teachers about odors associated with the lab, and the principal had requested that the lab be discontinued in the future. At the beginning of class, the teacher informed the students about the complaints and a few students stated that they had thought the lab was useful. At that point the teacher set the entire class to the task of writing a "persuasive essay" to the school's principal in support of the lab. Students composed their letters independently using word processors, some spending in excess of 50 minutes on the task. When students had completed their letters, they printed them, submitted them to the teacher, and began work on a two-page, teacher-generated, multiple-choice test. If time permitted, students were to begin working on a laboratory activity designed by the teacher to investigate a chemical reaction that produces heat. Throughout the lesson the teacher engaged in informal and distracting conversations with a few of the students about how the school's athletic teams had been performing lately.

Students worked independently of one another throughout the period in this highly informal atmosphere. The teacher demonstrated respect for this particular class of students in asking them to write the essays and allowing them to pace themselves on each component of the lesson. Unfortunately, the students worked inefficiently on the writing task, and the teacher did very little to help move students forward.

The only science content that can be evaluated is what appeared on the multiple-choice test and on the lab handout. The test questions focused heavily on factual recall related to chemical reactions. The level of difficulty was roughly appropriate, however, and the content was accurate. The lab focused on the scientific process and on logical reasoning. The lab was interesting in that students were instructed to mix multiple reactants, note the generation of heat, and then devise their own experiment to determine which of the reactants were responsible for generating the heat. Given that only one student actually began the lab, however, and that she had only 10 minutes to get started on it, the lab turned out to be at most a modest component of the lesson. Overall, this lesson lacked focus and intellectual rigor.

Sample Medium Quality Lesson: Beginning Stages of Effective Instruction

This lesson came at the end of a unit on the circulatory and respiratory systems. The class had spent three class periods on the circulatory system and this was the third and final class on the respiratory system. (The school was on a block schedule and each class was 90 minutes long.) This lesson had several purposes: to inform students of the dangers of smoking; to discuss various respiratory diseases; to review the Bohr effect; and to discuss the function of the respiratory control center. It appeared that about half of the material was new to students and half was review. Much of the information, while presented in a real world context, was very factual in nature.

The teacher used a variety of instructional materials in this lesson. These included the use of a laserdisc to illustrate the parts of the lungs, an audio tape with the breathing of people with various respiratory diseases, and a laboratory activity and pre-test review worksheet from the textbook package.

The lesson began with the teacher reviewing the Bohr effect and the function of the respiratory control center and then moving into a presentation on different respiratory diseases (lung cancer, emphysema, etc.) and how these diseases worked (e.g., cancer was the out of control reproduction of cells) and the dangers of smoking. The portion on smoking was presented in a very sermon-like manner, with the teacher telling the students how stupid it is to smoke. This entire segment of the class consisted mostly of the teacher talking to the students, occasionally showing a laserdisc picture of the lungs.

After the lecture, the teacher played an audiotape of people with different respiratory diseases breathing, during which the teacher pointed out the associated diseases. This activity engaged most of the students, but it was difficult to differentiate the different sounds and the length of the activity turned this into “let’s laugh at the funny breathing sounds.” In addition, there was no mechanism (or expectation) for the students to record any observations or relationships between the various diseases and breathing sounds. While this activity was fun for the class, it did not add to the students’ understanding of the respiratory system or of respiratory diseases.

The class then completed a breathing rate lab to illustrate how the respiratory control center functioned. Each student measured his/her breathing rate at rest; the class then went to the gym to jump rope and measure their breathing rates after exercise. While the teacher dictated the procedures, the lab was still exploratory in that the students were discovering the relationship between the variables, not simply confirming information they previously learned in class. After collecting the data, the class returned to the classroom and completed the analysis questions on the lab worksheet (which combined concepts from a portion of the activity completed on a previous day regarding the chemical composition of inhaled and exhaled air with the breathing rate exercise). These questions were higher-order as they required students to analyze their data and combine concepts across the portions of the lab activity. However, instead of letting the students complete the worksheet by themselves, or collaboratively, the teacher led the class through the questions, either calling on one student very quickly to give the answer to the class or just giving the students the answers himself.

The teacher then reviewed what would be on the test the next day.

This lesson was rated a low 3, Beginning Stages of Effective Instruction. The teacher-presented information was accurate, but the level of student engagement was highly variable. There was no mechanism to help the students tie together the individual components, and the lesson seemed to jump from one topic to the next without giving students an opportunity to see how it all fit together.

Sample High Quality Lesson: Traditional Instruction

Prior to this lesson on acid-base equivalents, this high school chemistry class had been introduced to titration. The purpose of this lesson was to teach the concept of equivalence and to begin preparation for the titration lab they would encounter in a chemistry contest later in the year.

The 90-minute lesson began with a short review of acid-base reactions and how to create and balance a chemical equation describing such reactions. The class then had a quiz on this material, in which students solved acid-base reaction problems that required indicating the products of the reactions and balancing the chemical equations.

After the quiz, the teacher introduced the concepts of acid-base equivalencies and gram equivalent mass. In the lecture, the teacher gave examples of equivalencies and related the content back to material previously studied by the class, such as acid-base reactions, molarity, and normality. He wrote down definitions and examples on the board. At the end of the lecture, the teacher led the students through a few problems similar to what they had done in prior classes and on the quiz, but using the concept of equivalencies to solve them instead. The students were attentive and clearly engaged.

After the lecture, the class moved into the lab room next door to practice pipetting for the titration lab they were to begin next time they met. The teacher had introduced the lab in a previous lesson, so the students were familiar with the equipment and understood why they needed to practice this skill. The students had about 10 minutes to practice and then were asked to individually demonstrate mastery of this skill to the teacher by using the pipette effectively three times in a row.

This lesson successfully built on and reinforced prior concepts covered in this course, and likely helped deepen the students' understanding of acid-base reactions. The lesson design followed a traditional format (review prior knowledge, introduce new concepts, guided practice), with the students and teacher working together to make sense of the material throughout the lesson. The teacher provided the new concepts to the students and posed many of the problems, and the students worked at integrating the knowledge into their understanding of acid-base reactions. The students freely asked questions about the new material and participated actively in solving the practice problems posed by the teacher. They also asked questions about how the new material related to topics previously studied, such as how normality is related to molarity. The teacher provided a few simple problems in these cases to show students the connections. It was clear that students understood the concept of equivalencies and that they were able to relate this new knowledge to other topics. The students were also able to master the proper technique for using a pipette, increasing their capacity to carry out investigations in chemistry.

Sample High Quality Lesson: Reform-Oriented Instruction

This high school biology lesson was in the middle of a unit on cells. In the previous lesson, students had conducted a membrane lab in which they placed either starch or sugar solution in dialysis tubing and then submerged the tubing in a beaker of water with indicator. The purpose of today's lesson was to begin to draw together ideas about molecule size and transport across cell membranes.

The lesson began with the teacher asking the students, in their lab groups, to predict what they expected to have happened with their lab (i.e., whether the starch and/or sugar would have diffused across the membrane) and to use the concept of particle size to explain why. After they had made a prediction, the groups examined their data and discussed whether their prediction was right or wrong. The teacher then led the entire class in a discussion about what had happened in the experiment. Students suggested hypotheses, and the class discussed methods for testing them. As needed, the teacher chimed in with suggestions (e.g., using test tape to measure sugar content), but his role was primarily providing lab techniques that would enable the students to test their ideas and prodding the groups to make sure they conducted enough tests to fully explain what had happened. This segment of the lesson worked extremely well, with the students in charge of their investigations and doing the majority of the intellectual work. The teacher kept to his role of facilitator, questioning students and giving them suggestions for lab tests.

The teacher skillfully guided the students as they finished making observations and analyzing the data, asking questions that pushed students to examine their results 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 (the iodine indicator) reach an equilibrium?" and "How do you know?"

The teacher also introduced new vocabulary to the class as appropriate. For example, as the students were trying to explain what had happened to the sugar in their experiment, the teacher interjected to the whole class "I hear you discussing, let me introduce a term: equilibrium." Thus, the teacher was able to ease new content into the discussion in the context of the investigation.

After the groups had finished all of their tests, the teacher gave them an assignment to write a story about a paramecium that lived in the local freshwater river who decided to go see his girlfriend who lived in the ocean. The groups were instructed to write about his trip and what he would experience. The teacher supplied them with a list of eight vocabulary words related to transport across a membrane that they had to use in the story. The groups were told that the teacher would call on one group member to read and explain their story to the class the next day, so they all needed to understand the concepts they included. The students spent the remainder of the class period working on their stories. This activity provided a good opportunity for the students to bring together what they knew about transport across a membrane and apply it to organisms living in their local river. It was a critical component of the lesson as it allowed the class to make sense of the lab results.

This lesson was an example of high-quality, reform-oriented science teaching. All of the students were engaged in meaningful investigation of important science content, and the teacher did a masterful job of guiding the class. Students were generating and debating hypotheses, and were given the tools they needed to test their ideas. Writing a story about a paramecium's travel from fresh to salt water provided a perfect opportunity for the students to make sense of the data and conclusions drawn from the lab investigation. The classroom culture was superb—students had clearly taken ownership of their learning, and the teacher pushed and challenged all students to engage with the content. It is highly likely that this lesson enhanced students' understanding of the concept of transport across a cell membrane, as well as their capacity to carry out their own inquiries.

Appendix I

Frequency Distributions of Observation Protocol Indicators

Table I–1
Ratings of Key Indicators – Design: Extent to which Lesson Design Includes Each of the Following

	Percent of Lessons				
	1	2	3	4	5
	Not at all				To a great extent
The resources available in this lesson contributed to accomplishing the purposes of the instruction	4	18	32	36	11
The design of the lesson reflected careful planning and organization	6	20	29	34	11
The instructional strategies and activities used in this lesson reflected attention to students' experience, preparedness, prior knowledge, and/or learning styles	12	27	29	23	9
The design of the lesson encouraged a collaborative approach to learning among the students	29	23	21	20	7
The design of the lesson incorporated tasks, roles, and interactions consistent with investigative mathematics/science	25	25	24	20	6
The instructional strategies and activities reflected attention to issues of access, equity, and diversity for students (e.g., cooperative learning, language-appropriate strategies/materials)	17	22	33	23	5
Adequate time and structure were provided for 'sense making'	24	37	22	13	5
Adequate time and structure were provided for wrap-up	38	27	21	9	5

Table I–2
Ratings of Key Indicators – Implementation: Extent to which Lesson Implementation Includes Each of the Following

	Percent of Lessons				
	1	2	3	4	5
	Not at all				To a great extent
The teacher appeared confident in his/her ability to teach mathematics/science	4	12	20	38	25
The teacher's classroom management style/strategies enhanced the quality of the lesson	17	21	28	20	14
The pace of the lesson was appropriate for the developmental levels/needs of the students and the purposes of the lesson	19	30	28	17	7
The teacher was able to 'read' the students' level of understanding and adjusted instruction accordingly	27	28	25	13	6
The instructional strategies were consistent with investigative mathematics/science	29	28	22	15	5
The teacher's questioning strategies were likely to enhance the development of student conceptual understanding/problem solving (e.g., emphasized higher order questions, appropriately used 'wait time', identified prior conceptions and misconceptions)	39	27	18	10	5

Table I–3
Ratings of Key Indicators – Content: Extent to which the Mathematics/Science Content of Lessons Reflects Each of the Following

	Percent of Lessons				
	1	2	3	4	5
	Not at all				To a great extent
Teacher-provided content information was accurate	4	12	28	29	27
The mathematics/science content was significant and worthwhile	2	9	22	42	25
The teacher displayed an understanding of mathematics/science concepts (e.g., in his/her dialogue with students)	6	18	33	26	17
The mathematics/science content was appropriate for the developmental needs of the students in this class	4	14	33	34	14
Appropriate connections were made to other areas of mathematics/science, to other disciplines, and/or to real-world contexts	19	21	30	19	11
Elements of mathematical/science abstraction (e.g., symbolic representations, theory building) were included when it was important to do so	11	24	28	30	6
Students were intellectually engaged with important ideas relevant to the focus of the lesson	20	35	25	14	6
Mathematics/science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification	36	25	21	13	5
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	30	36	18	12	4

Table I–4
Ratings of Key Indicators – Classroom Culture: Extent to which Classroom Culture Includes Each of the Following

	Percent of Lessons				
	1	2	3	4	5
	Not at all				To a great extent
Active participation of all was encouraged and valued	13	16	24	32	15
There was a climate of respect for students' ideas, questions, and contributions	10	17	28	32	13
Interactions reflected collaborative working relationships between teacher and students	17	25	22	25	12
Interactions reflected collegial working relationships among students (e.g., students worked together, talked with each other about the lesson)	25	23	23	19	10
The climate of the lesson encouraged students to generate ideas, questions, conjectures, and/or propositions	32	26	20	15	8
Intellectual rigor, constructive criticism, and the challenging of ideas was evident	38	31	18	8	6

Table I–5
Ratings of Key Indicators: Synthesis Ratings

	Percent of Lessons				
	1	2	3	4	5
	Not at all reflective of best practices/ national standards				Extremely reflective of best practices/ national standards
Design	18	33	34	11	4
Implementation	25	35	24	11	5
Mathematics/Science Content	12	39	30	17	3
Classroom Culture	19	28	31	16	6

Table I–6
Ratings of Key Indicators: Overall Ratings of the Lesson

	Percent of Lessons				
	1	2	3	4	5
	Negative effect		Mixed or neutral effect		Positive effect
Students' understanding of important mathematics/science concepts	4	12	50	26	8
Students' understanding of mathematics/science as a dynamic body of knowledge generated and enriched by investigation	10	20	45	16	8
Students' interest in and/or appreciation for the discipline	11	16	41	25	7
Students' self-confidence in doing mathematics/science	5	15	50	23	7
Students' ability to apply or generalize skills and concepts to other areas of mathematics/science, other disciplines, and/or real-life situations	5	10	58	22	5
Students' capacity to carry out their own inquiries	5	16	55	21	3