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

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Looking Inside the Classroom

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by

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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.