AGAINST THE ODDS: EXAMINING HIGH-QUALITY MATHEMATICS INSTRUCTION WITHIN HIGH-POVERTY SCHOOLS

by

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Paper presented at the meeting of the American Educational Research Association.
San Francisco, CA
April, 2006

Abstract

This paper examined practices of teachers who help children from low-income families succeed in mathematics. This researcher asked what these practices looked like and how they varied. Six case studies were selected from approximately 70 participants in a longitudinal study of 4^{th} and 5^{th} grade teachers. A key finding was that certain practices were pervasive while others differed according to perceived student ability. In general, successful teachers encouraged deep and principled understanding of concepts asked students to explain and justify answers. However, teachers of more accelerated students were most aligned with reform-oriented ideas. Those who taught students in regular classrooms varied greatly in their practices, although both tended to manifest excitement about learning mathematics. Teachers of struggling students tended to adjust instruction to the developmental needs of their students.

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Perhaps more than ever, improving the quality of mathematics instruction in the United States has become a public concern (NRC, 2001). At least three reasons exist for this amplified public interest: international comparisons, achievement gaps, and widely publicized federal mandates. Specifically, international comparisons of mathematics instruction have indicated that American classrooms lack the rich connections and emphasis on deep understanding that exist in countries with higher achievement rates (Ma, 1999; Stigler & Hiebert, 1999). Within the United States, significant achievement gaps have remained between various groups of students despite reform efforts and some improvements (Lubienski, 2001). For better or for worse, *No Child Left Behind* has been implemented in response to these lingering gaps, calling for teachers to be “highly qualified” in their subject area (NCLB, 2001).

While evidence exists that teacher quality is a critical factor in student learning (Rice, 2003), the practices that define such quality may not be the same for all groups of students. In order for educational research to inform the public’s concern about quality instruction for *all* students, more needs to be known about what high quality instruction looks like in classrooms of students who are economically disadvantaged (Boaler, 2002). Does high quality instruction exist in this context? What does it look like? How does it vary among teachers and their particular groups of students? Using case studies of teachers selected for their pedagogical success, this paper attempted to explore such questions. The purpose of this inquiry was to contribute to knowledge necessary for the preparation of “highly qualified” mathematics teachers.

Perspectives

This paper is grounded in two distinct but complementary bodies of literature. First, it draws heavily from the literature on psychological perspectives of learners. Specifically, Alexander and Murphy (1998) described five principles associated with effective learning and teaching that emerged from a comprehensive review of the psychological literature. These learner-centered principles include: knowledge, strategic processing, development, motivation, and context or situation. They suggest that teachers need to impart a deep understanding of the subject knowledge, encourage reasoning and strategic thought, attend to developmental and individual differences, motivate and affirm student efforts, and create a welcoming, caring environment that encourages an effective use of resources. These principles are not specific to mathematics and therefore provided a broad perspective of teaching and learning in which to frame the study. They were also used as part of the coding scheme described later.

Second, this study draws heavily on the literature on effective mathematics instruction. This literature suggests that it is not enough for students to passively learn procedures and definitions. Rather, students need to be actively engaged in dialogue about mathematics (NCTM, 2000; NRC, 2001; Reynolds & Muijs, 1999; Stipek, 2002). Students need to explain their thinking, link concepts and procedures, make connections to experiences outside of school, consider alternative solution methods, and learn to reason through novel problems. These tenets of effective mathematics teaching provided a domain-specific perspective on teaching and learning in which to frame the study. Like the learner-centered principles, these distinctive features of mathematics instruction were used as part of the coding scheme described later.

Six case studies were examined through both the broader psychological perspectives as well as the domain-specific teaching practices suggested by the mathematics education community. Quantitative data and student achievement data were used to support the findings, and these data helped answer two additional questions. First, how do these teachers compare to the rest of the teachers in the longitudinal study from which they were selected? Second, how might the particular teaching practices exemplified by these case-study teachers relate to student achievement in mathematics?

Research Methods

Participants

This examination of teaching practices was part of a longitudinal study of 4^{th} and 5^{th} grade teachers from a large, diverse school district.[1] Teachers in the larger study were invited to participate because they taught in schools whose students performed higher than would be predicted on standardized tests, based on their demographics. All the schools had moderate to high poverty levels. There were approximately 70 such teachers from 15 schools, and the study was conducted over a four year period (2001-2005). Participants were generally observed teaching mathematics and reading, but for the purposes of this paper, only mathematics instruction is considered.

Teachers in the larger study were observed in mathematics an average of six times throughout each school year. Based on ratings from the observations, teachers were identified and considered for case studies. Student achievement was also considered for case study nomination. Finally, observers made recommendations based on a variety of

[1] The work reported herein was supported by the Interdisciplinary Educational Research Initiative (IERI # 0115389), a combined effort of the National Science Foundation, the U.S. Department of Education, and the National Institutes of Health. The opinions expressed in this manuscript are our own and do not reflect the positions and policy of the National Science Foundation, the U.S. Department of Education, or the National Institutes of Health.

exemplary practices. Of the teachers considered for case studies, nine were chosen in such a way as to represent a variety of these practices. The chosen teachers agreed to participate and were audio-taped during their next observation, and they participated in an unstructured interview immediately followed the lesson.

For the purposes of this paper, only the six case study teachers from year 3 are discussed. Including teachers only from the same year made it easier to compare the teachers to the overall group. Comparing teachers over time would necessitate a consideration of the many policy changes occurring during the years of the larger study. A consideration of policy implications are reported elsewhere (Valli, Croninger, & Buese, 2006). Year 3 was chosen because there it was the year when most of the case studies were conducted. Also, there were two teachers each of struggling students, regular students, and accelerated students. Although this configuration was not intentional, it made possible an exploration of how teaching practices might vary across student ability levels. An overview of each participant is subsequently described.

Ms. Keller

Ms. Keller had been teaching for 34 years. Her class was a special education class consisting of six 5th graders. Ms. Keller was the students' only mathematics teacher. Two-thirds of the students in the class qualified for Free and Reduced-Price Meal Services (FARMS). Half were also English Speakers of other Languages (ESOL). The case study lesson was on conversions between units of measure, and it took place in the second half of the spring semester.

Ms. Shepard

Ms. Shepard had been teaching for 40 years. She taught an intervention class to ten 5th graders. All but one qualified for FARMS. The class was in addition to their regular math class, and it lasted 30 minutes a day. At times, Ms. Shepard liked to preview what students would later learn in their regular mathematics class. Other times, she reviewed topics with which she knew they needed extra help. The case study lesson was on perimeter, and it took place early in the spring semester.

Mr. Forrest

Mr. Forrest was in his third year of teaching. He described his class as low in ability. It was a 5th grade class consisting of 13 students, but he stated that only four of the students are really on grade level. About half were either ESOL or were recently. About half qualified for FARMS. The case study lesson was on equivalent measurements, and it took place late in the spring semester.

Mr. DiLoretto

Mr. DiLoretto was in his 16th year of teaching. He described the students as low to average in ability. There were 23 students in the class, and about one-fifth was FARMS. The case study lesson was on volume of a rectangular prism, and it took place late in the spring semester. It was a 5th grade class.

Ms. Lauffer

Ms. Lauffer was in her fifth year of teaching. She taught accelerated fourth graders, meaning that they covered both fourth and fifth grade curriculum. There were 20 students in the class, almost half of which were FARMS. The case study lesson was about solving equations, and she used the Hands on Equations materials. It took place near the end of the school year.

Ms. Fulton

Ms. Fulton was also in her fifth year of teaching. Her class was a combination class consisting of advanced 4th graders and average ability 5th graders. About one-fourth of the 4th graders and one-third of the 5th graders were FARMS. There were 22 students in the class. She taught using the Everyday Math curriculum. The case study lesson was about sample size, and it took place in the middle of the spring semester.

Data Sources

Observers in the larger study were trained on standardized protocols to code teacher practices every three minutes. The eight time-sampled codes included: teacher and student activity, the content and context of the lesson, the organization of the class and attention of the teacher, classroom behavior, and use of technology. This instrument was designed to reflect both reform-oriented and traditional practices (Chambliss & Graeber, 2003), and it has been consistently reliable across the years of the study. Using correlations, reliability scores for mathematics have been consistently around .76.

At the end of the lesson, observers also completed a teacher attribution form. The observed lesson was scored for evidence of five dimensions of effective pedagogical practice (Alexander & Murphy, 1998). Those five dimensions dealt with the learner-centered principles: knowledge, strategic processing, development, motivation, and context or situation. Each of these dimensions was examined using four specific instructional behaviors and rated on their centrality to the teachers' performance during the observed lesson. For example, the knowledge dimension assessed whether the teacher: promoted principled understanding, activated prior knowledge, manifested a deep understanding of the content, and illustrated the value or utility of the lesson. After all five dimensions were coded on a 4-point continuum ranging from not evident to pervasive, the lesson was rated for overall quality with 1 representing low quality and 4 indicating high quality. These quality ratings helped determine who was subsequently chosen for a case study.

The transcribed case study lessons were coded for evidence of the five dimensions of learning, as well as five distinctive features of high quality mathematics instruction. Those features included a subset of the time-sampling codes: connections to prior lessons, other content areas, or to life outside of school; requests for students to explain or justify solutions; requests or allowances for alternative methods; linking procedures to their related concepts; and posing of high-level tasks or questions with appropriate scaffolding. The results reported in this paper are primarily based on these case study lessons. However, quantitative data from the observation instruments were also examined to substantiate and extend the patterns documented in the case analyses. Performance on the nationally-normed portion of the state assessments was used to suggest which teaching practices might be positively related to student achievement.

Results

For the case study lessons, some general findings for both the learning dimensions and the distinctive features will be reported. Then, each teacher will be discussed in detail. Finally, the case study teachers will be compared to the larger sample of teachers using quantitative data.

Case Study Lessons

With regard to the five learning dimensions, knowledge was a primary focal point of these teachers' pedagogical activities. For five of the six teachers, behaviors associated with the knowledge dimension were seen as pervasive elements. In particular, their lessons tended to be principled and deep, and they tended to activate prior knowledge. The strategic processing dimension was identified as pervasive for four of the teachers. The development and individual differences was seen as pervasive for three of the teachers, as was the motivation dimension. Context and situation dimension was pervasive for only one of the teachers. Although a focus on knowledge and strategic processing was most prevalent, most teachers' attended to all five dimensions of learning to some degree.

Several consistent teaching practices have been identified among these successful teachers. Of the distinctive features coded in the transcribed lessons, requesting student explanations and making connections were common. Requesting students to explain or justify their solutions was pervasive for four of the teachers. Connecting mathematical ideas to experiences outside of school was common (but not pervasive) for half of the teachers, but only occasionally were connections made to other mathematics or content areas. Linking procedures to their related concepts was pervasive for three teachers. Two teachers asked for alternate methods of solving problems, and only one teacher consistently engaged the students in high-level tasks. In this case, high-level tasks were those that the student was not given a method for solving. Instead, they had to create a solution based on prior knowledge of the topic.

Two of the six teachers chosen for case studies taught students who were severely struggling in mathematics, two taught in regular classrooms, and two had students who were judged as more advanced in mathematics. As such, these teachers were grouped for comparative analysis in order to ascertain whether there were distinguishable patterns in their teaching practices that might be linked to students' perceived mathematical ability.

Several noteworthy patterns were found. First, two of the three teachers who consistently illustrated the development and individual differences dimension were Ms. Keller and Ms. Shepard, the teachers whose students struggled in mathematics. They seemed to understand developmental needs and adjust their instruction accordingly. They were also two of the four who showed evidence of the strategic processing principle. In other words, these teachers emphasized strategies and reasoning, but they did so at an appropriate level for their students.

The teachers of advanced students (Ms. Lauffer and Ms. Fulton) were two of the most frequent users of connections to outside experiences. They also consistently requested explanations from students. The teachers in the regular classrooms both tended to be strong on the motivation dimension of learning but quite varied in other ways.

Teachers of Struggling Students

Ms. Keller and Ms. Shepard both taught students who were struggling academically and these teachers were alike in many ways. Besides the fact that they had both taught for more than 35 years, their teaching practices were also similar. Not surprisingly, these teachers were the most attentive to the developmental needs of their students. They were knowledgeable of the mathematical difficulties with which students struggle, and they provided appropriate scaffolding for their students. These teachers stuck a balance between guidance and discovery. They wanted the students to figure out how the mathematics worked, but they provided the needed assistance for the students to make these discoveries.

Both teachers were abundantly patient. When students responded in unusual ways, they did not show frustration. When students struggled with fundamental concepts, these teachers took the time to promote a deeper understanding, even when it was not the primary goal of the lesson. For example, Ms. Shepard helped her students forge links between addition and counting, while Ms. Keller helped her students forge links between multiplication and repeated addition. In neither case was the lesson about operations per se.

Ms. Keller. During a lesson on converting between measurements, there were several moments when the students needed to multiply in order to convert from one measurement to another. Each time, the students opted to add the same number repeated rather than multiply. Instead of insisting that the students use multiplication, Ms. Keller allowed the students to proceed (at first) with the method that made sense to them. When it became apparent that their method was inefficient, she still did not tell them they needed to multiply. Instead, Ms. Keller asked the students if they knew of a more efficient method. In this way, she encouraged the students to make connections between multiplication and repeated addition and to understand when multiplication was appropriate for solving problems. The following example illustrates this process:

Ms. Keller posed a problem from the book. She read, “Rochelle bought eight pounds of apples for pies. If each apple weighs four ounces, how many apples did she buy?” After discussing the relevant information in the story, Ms. Keller asked for a suggestion for tackling the problem.

One student suggested that they “put the rule down.” Ms. Keller responded to this suggestion by stating that “sixteen ounces equals one pound.” A student then suggested counting by fours and said that the answer would be in ounces. “Okay,” said Ms. Keller. “You’re going four, plus four, plus four.” The student took over at this point. “Now plus four one more time,” he said.

“So how many apples is that?” asked Ms. Keller. “Four,” said the student. “Okay,” said Ms. Keller, “that’s four apples.” She drew apples on the board as she said, “There’s an apple, there’s an apple, there’s an apple, there’s an apple. So if I get four apples together that equals 16 ounces and that’s the same as?” A student responded that sixteen ounces was a pound, and Ms. Keller reiterated that it took four apples to create that pound.

A student then insisted that Ms. Keller draw another four apples to get two pounds, and she responded by drawing four more apples. “Keep doing it until you get eight pounds,” he said. At this point, Ms. Keller said they could do that but suggested there was not enough room on the board. “Anyone got a shortcut…?” she asked.

“You could go eight times four,” suggested a student. Ms. Keller elaborated on the student’s suggestion. “Because I’m going to do this eight times. I’ve got four in each row. And eight times four equals?” Several students gave 32 as the product. “Thirty-two what?” asked Ms. Keller. “Apples,” said several of the students.

Ms. Shepard. During a lesson on perimeter, Ms. Shepard used contexts and models to help students understand why adding each side of a rectangle would give the distance around its outside edge. After the students calculated the area of a rectangle, Ms. Shepard asked a question suggesting perimeter:

> Now, look at my rectangle that I’ve sketched. Suppose this was a garden and I have a lot of carrots in that garden. And rabbits came and ate my carrots so I decided to put up a fence around my garden because the rabbits come in and the deer come in at night. What part of that rectangle would I take to fence?

A student offered that the fence should go “around the whole thing.” Ms. Shepard asked the students to use a red pen to illustrate the fence using the sketch on their papers.

After contrasting the outside edge of the rectangle with the number of squares, Ms. Shepard asked the students to make a rectangle using ten tiles. She asked what the perimeter would be, but rather than accepting answers immediately, Ms. Shepard asked the students to talk with someone about the problem. Meanwhile, she observed what the students were doing and made suggestions to guide them. One student looked confused, and Ms. Shepard suggested that she did not "have to add, subtract, multiply or divide." She said, "Just do something and tell me what the outside edge is."

One student suggested they could measure the rectangle, but Ms. Shepard suggested they did not have anything to measure it with. She asked the students what they could do if they had to find the length without measuring. Shortly after, Ms. Shepard gained the classes' attention. "Okay, everybody watch up here….I want you to watch. I'm not going to add. I'm not going to subtract. I'm not going to multiply. I'm not going to divide." She began to point to each segment along the outside of the rectangle and said, "One, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen. What did I do?"

A student suggested that the teacher had just counted. Ms. Shepard reiterated this point and restated the total. "Fourteen. I got fourteen….Can I do anything mathematically with these numbers and come up with 14? Can I add, subtract, multiply or divide and come up with 14?" A student suggested that the sides could be added.

Ms. Shepard continued with a few more examples, telling the students, "I have to check out this adding the sides thing because I'm not sure. I think that was a good idea but I have to be sure. I got to check out. I have to experiment more than once." After the students finished counting the segments around a 4 × 3 rectangle, Ms. Shepard said, "Now, you told me before if I added up all four sides I would get the perimeter. What do we already know the perimeter is?" The students said the perimeter was 14. Then Ms. Shepard asked the students to add all the sides on paper. "I need to see your addition," she said. After a moment, she said, "Raise your hand and tell me, what sum did you get when you added up all four sides?" The students all got 14. "So do you think that worked?" The students agreed that it did.

Teachers of Students in Regular Classrooms

Mr. Forrest and Mr. DiLoretto both taught students in regular classrooms. For both of these teachers, the motivation dimension was pervasive, and the context and situation dimension was strong. Specifically, these teachers showed excitement about learning, incorporated student interests into the lesson, and promoted positive attributional beliefs among their students. They also tended to create a caring and affirming environment and welcome students' ideas. Finally, both teachers tended to make connections between the mathematics and life outside of school in order to help students understand new or difficult concepts.

The teachers differed significantly in several ways. Mr. Forrest He had been teaching for three years, while Mr. DiLoretto had been teaching for 16 years. Mr. Forrest linked concepts and procedures and asked students to explain their thinking. The strategic processing dimension of learning was also pervasive in his lesson. Specifically, he engaged the students in problem-solving and encouraged reasoning and reflection on learning. Finally, Mr. Forrest used context more pervasively in his lesson, not just when the students were struggling with a new concept.

Mr. DiLoretto. During a lesson on volume of rectangular prism, Mr. DiLoretto wrote $V = l \times w \times h$ on the board and began to explain how to use the formula to find volume. Almost immediately, he noticed that the students were confused, and he began to talk about the meaning of volume.

"I am looking out there and I'm not even sure people know what volume is," said Mr. DiLoretto. "What is volume? Is it the button you press on the tape recorder to turn up the music? Isn't that volume? When we are talking about volume in math, what are we referring to?"

Mr. DiLoretto praised the students who were paying attention and then continued. "We don't really know what volume is, do we? Just like we didn't know what attributes were last Thursday." He assured them it was okay and that they would know the definition before they left the class. Mr. DiLoretto gave a formal definition and wrote it on the board as he spoke. "Volume is the amount of space a solid figure occupies." He then acknowledged that the students may not understand it yet. "We put a lot of words on the chalkboard, but what does it mean? Look at where you are sitting right now. Your desk. Does that have a volume? Is it a solid figure? Is it taking up space?"

Mr. DiLoretto gave another example. "How about this book? Solid figure? Takes up space?" He stated that they could find the volume by measuring its length, width, and height and multiplying them together. Then Mr. DiLoretto asked the students to give some examples of their own. One student suggested that a door would have volume. "Absolutely. That's good, Shelise…A door definitely would have volume." Other students suggested a fan, bulletin board, binder and computer as objects with volume. After Mr. DiLoretto felt that the students were beginning to understand the concept of volume, he asked them to use the formula to calculate it.

Mr. Forrest. Like Mr. DiLoretto, Mr. Forrest used connections to the real world to help students understand a concept, but even more so. He also engaged the students in solving problems without providing a particular way to solve them. To prepare them for it, Mr. Forrest spent the beginning of class discussing strategies. He walked to the chalkboard at the front of the room and wrote "Strategy." He then asked a student, "What does it mean to use a strategy? It could be reading or math or anything else. When people use the word strategy, what do they mean?" A student responded with "ways to help them." Another student suggested it was "something you already know." Mr. Forrest asked for clarification. "Something you know already, like background knowledge?"

After listing these ideas on the board, Mr. Forrest asked, "What does a strategy help you do?" A student suggested that "it helps you answer a question." Another responded that is helps make a task easier and another said it is something you do to help you figure something out. Mr. Forrest added these ideas to the list on the board and then asked how a strategy might be used outside of school. He paused and offered a scenario. "Okay, how about this? How about your mom or dad is driving somewhere and there's a huge accident. They come to an intersection and there's an accident. Everything's blocked off. What strategy might they use?" A student suggested they could go a different way.

Mr. Forrest offered another scenario. "How about if you need to buy clothing and you don't quite have enough money to buy what you really want, what strategy might you use?" A girl suggested buying something cheaper. "That's one strategy," said Mr. Forrest. Another student said to put the item on lay-away. Mr. Forrest was enthusiastic, "Good! That's another strategy; people use it all the time. Good. What else? What other strategies do people use? I might wait for what?" One student said to wait for a sale. "So these are all different things that we do," Mr. Forrest said, "It's not just reading and math and school, but it's everything we do all the time, is a strategy, okay?

This discussion about strategies was used to launch a lesson in which students had to either pair or order cards with different measurements on them. Mr. Forrest did not tell the students to find measurements that were equivalent, but he did encourage them to use any strategy they wanted. The tasks took 15 minutes to complete, and he assisted them very little during that time.

Before allowing the groups to present their solutions, Mr. Forrest asked the students to reflect on the task difficulty. “Hard activity? Easy activity? Medium activity?” The students’ answers varied and Mr. Forrest asked, “Why do we all have a different view on whether it’s easy or hard?” One student suggested they each have different knowledge. Another suggested, “We don’t know how to do things in the same way.” Other suggestions were that the activities might not be the same, some students may not be used to the topic, and that people think differently. Mr. Forrest seemed to like this response, replying, “We think differently. Our brains work differently. Good. And skills and strategies help us do things. In life, in math, in traffic, at our jobs, in college, when we go shopping, everything we do.”

When students presented their solutions, Mr. Forrest asked them to explain their thinking. Most groups had completed the task the way the Mr. Forrest had anticipated they would. However, one group used various attributes (e.g., square units) to pair their items. Mr. Forrest told the students that they had not paired the cards as he expected, but “every single [pairing] made sense to me because you explained it correctly.”

Teachers of accelerated students

Ms. Lauffer and Ms. Fulton were similar in many ways. They both had been teaching for five years, and they both taught accelerated students. They both made connections to the real world, and both asked students to explain their thinking. As such, the knowledge dimension of learning was pervasive for both teachers. Specifically, both lessons were principled and deep, and both teachers activated students’ prior knowledge during the lesson.

Ms. Fulton. Ms. Fulton's lesson was an investigation about samples. Rather than just defining a sample for the students, she ensured deep understanding by posing a high-level task for the students to complete. While she made some connections between concepts and procedures, it was not pervasive for this lesson because the lesson was mostly conceptual. She scaffolded the students appropriately, encouraging them to reason through problems but guiding them when necessary. The lesson began by motivating the need for an exploration. The following excerpts illustrate some of these points:

After gaining the students' attention with a bag of jelly beans, Ms. Fulton posed a question. "If I wanted to know – let's say my favorite jelly beans are the orange ones – if I wanted to know what percent of this bag of jelly beans are orange, how would I figure it out?" Rather than allowing the students to respond immediately, she asked them to talk about it for a few minutes with the students at their table. Discussions were brief but lively. After a very short time, Ms. Fulton asked, "All right, what are some ways we can figure out? How can I figure that out? Paris?" The student explained that she would find the total number of jelly beans and then count how many there were of each color. Ms. Fulton restated the student's response to make sure she understood the student's method and then asked for a different way.

A second student offered a similar approach but suggested that the colors be separated into piles for ease of counting. Ms. Fulton then asked if anyone had a method that did not require counting all the jelly beans, but no one offered one. She continued, "Have you ever heard things, like in the newspaper, they might say one in every four kids experiences bullying at some point. Have you ever heard of that? Did they ask you?" The class acknowledged that no one had asked them personally, and Ms. Fulton asked how the newspaper could make such a claim if it did not ask everyone. A student suggested that "they probably got a group of kids, like a group of four or something and they asked them if they were ever bullied and everyone present said that."

Ms. Fulton responded, "Okay, so maybe they got a group. How many did you think? They just got a group of four?" Students began suggesting larger numbers, ranging from 8 to 48. "What is that called?" asked Ms. Fulton. She asked again, this time elaborating:

> What is the word called when you take a small group to try to make some kind of general statement about a larger group? Because it's not possible to get to all the kids in the world to ask them a question. It takes a lot of time, a lot of work, money; it's not easy to do. What is it called….that group of people they use?

After a student offered "guinea pigs," Ms. Fulton wrote the word "sample" on the board, and the students responded by saying the word aloud. From here, Ms. Fulton launched the investigation, which involved estimating the percent of orange jelly beans using a very small sample and then pooling the small samples from each group to find an estimate with a large sample. Finally, the students counted the actual number of jelly beans and discussed which sample had been more accurate. The students were asked to write down which sample had been more accurate and why.

Ms. Lauffer. Ms. Lauffer introduced a lesson on solving equations by suggesting it was only a formal way of doing something they had already been doing. She also used concrete materials to help them understand why the same procedure must be carried out on both sides of the equation. While introducing the topic of the lesson, Ms. Lauffer stated:

> And what you're going to discover is, once we get started this morning, you had been doing this all year. We just didn't call it Hands on Equations. We have been solving for variables, if you go back and think to all the other units we've been doing it – every time you had one of those problems where you had to figure out – well, what was the height knowing what the perimeter is. And I know what the length is. What is the height? Right? Remember how you solved that – worked it out? You could have actually have set it up as an Algebraic equation. So, we've been doing this. Algebra is solving for an unknown.

Ms. Lauffer then placed a pawn on one side of a balance beam and some numbered cubes on the other. She asked the students if they knew the value of the pawn, and although they easily answered, she asked them to explain. She wanted them to verbalize that an equal sign was more than a signal to give an answer; it was a symbol suggesting balance. “Excellent, said Ms. Lauffer. “It was balance, right?” Again, she activated their prior knowledge:

> We've been doing this from the beginning of the school year. You did it last year. You've known it. If I asked you what – If I say that 3 + 2 is equal to 5, what have I told you about both sides of the equation? They're both equal to?

A student answered, “Five.” Ms. Lauffer agreed. “Five. Right. Five. And we know that the equal sign says that it is what? It's balanced.”

Ms. Lauffer then made connections to science. “Okay. Go back and think about 2nd grade. What was this piece on a balance called? It has a special name. What is the thing in the middle called?” A student suggested it was an equal sign. Ms. Lauffer agreed that it *represented* an equal sign, but asked again that they think about science. “Go back and think about 2nd grade when you've done all your balancing and science. And you had a scale or a balance and you were trying to make each side equal – what was that middle point called?” Ms. Lauffer wrote the word and asked the students to pronounce it. “Fulcrum,” they said. The students seemed to recognize the word, and Ms. Lauffer responded:

> Oh, yeah – I know that, right? Okay. And in science – in physics – what will happen is that if you have so much weight, remember, on one side and a weight on the other side and you can't change the amount of weight but you want to balance the beam out, what do you do?

At this point, the students discussed multiple ways to balance the sides, and Ms. Lauffer concluded:

> So, whatever we do on one side has to be equal to whatever's happening on the other side. And that's one of the basic rules with Hands on Equations you've got to remember. That this white piece right here – the Fulcrum – is like an equal sign here. All right. Whatever I do to this side, I'm going to have to end up doing it to this side at all times. All right?

Ms. Lauffer proceeded to ask give a variety of examples, with increasing difficulty. Throughout the lesson, she continued to emphasize the need for balance and how manipulations to the equation had to maintain this balance.

Comparisons to Larger Sample

Time-Sampled Data

Because these teachers were part of the larger study described earlier, data existed that could be used to compare these case study teachers to the rest of the sample. Recall that time-sampled data was collected for all teachers in the larger study. As described earlier, this data was collected every three minutes of an observed class and included codes to capture teacher activity, student activity, content, use of context, organization of the class, attention of the teacher, classroom behavior, and use of technology. For this study, I was particularly interested in high-level teacher activity, high-level student activity, use of context, use of small groups, and the content of the lesson.

High-level teacher activity included requests for: students to reflect on their learning, alternate methods or strategies, self-assessment, elaboration of a response, and attention to a response or idea. It also included posing or elaborating on a high-level task or question. High-level student activity included responding with a conjecture, explanation or justification, or alternative method. It also included working on a high-level task or extended writing. Use of context included connections to the real world, to other mathematics, or to other content areas. Use of small groups included when part or all of the class was working with other students. Conceptual focus, procedural focus, and a focus on linking procedures to their related concepts were all reported for content.

When comparing the six case study teachers to the larger sample, several general findings were of note. First, all six case study teachers were above the mean for high-level teacher activity. On the other hand, almost no one was above the mean for use of small groups. The one exception was Ms. Fulton, who also spent the most time engaging her students in high-level activities. She was the only case study teacher who taught from a reform-oriented textbook, which could explain why her students spent nearly 40% of the time working in small groups and engaged in high-level tasks. For all teachers, there tended to be much variability from lesson to lesson, as can be seen by the standard deviations. The means and standard deviations are reported in Table 1.

With regard to student ability level, the quantitative data for the case study teachers mirrored the audio-taped lessons for those teachers. Specifically, the teachers of low ability students were similar and teachers of accelerated students were similar, but teachers in regular classrooms were dissimilar. In fact, Mr. Forrest more closely resembled the teachers of accelerated students, scoring above the mean on high-level student activity, use of context, and time spent linking procedures to concepts. One exception was with the time they spent on conceptual content (i.e., meanings and definitions). Mr. DiLoretto and Mr. Forrest spent approximately twice as much time on conceptual content than teachers in the larger study, and they both spent more time on this content than procedural and linking content combined.

In contrast, only teachers of struggling students (Ms. Keller and Ms. Lauffer) were at or above the mean for the proportion of time spent on procedures *not* linked to concepts. These teachers were also at or below the mean on linking, small groups, and context. However, high-level student activity tended to occur more often (and more consistently) in Ms. Shepard's class.

Table 1

Summary of Teaching Practices

Mean Proportion of Time Spent on Teaching Practices during Class

	Teacher Hi Level	Student Hi Level	Use of Context	Small/Mixed Groups	Linking Content	Conceptual Content	Procedural Content
Keller (n=9)							
M	.18	.17	.01	.02	.10	.23	.54
SD	.12	.15	.04	.07	.11	.16	.25
Shepard (n=8)							
M	.18	.22	.03	.17	.14	.28	.42
SD	.13	.08	.06	.17	.10	.26	.26
DiLoretto (n=8)							
M	.21	.19	.03	.01	.12	.38	.25
SD	.13	.13	.07	.02	.14	.26	.20
Forrest (n=8)							
M	.25	.28	.12	.14	.23	.48	.11
SD	.15	.14	.17	.14	.26	.26	.08
Fulton (n=8)							
M	.15	.39	.08	.38	.29	.19	.27
SD	.12	.26	.11	.34	.27	.18	.19
Lauffer (n=9)							
M	.18	.21	.09	.10	.20	.34	.28
SD	.07	.14	.09	.18	.14	.17	.15
ALL (N= 606)							
M	.11	.17	.04	.17	.13	.23	.41
SD	.10	.15	.08	.14	.16	.21	.24

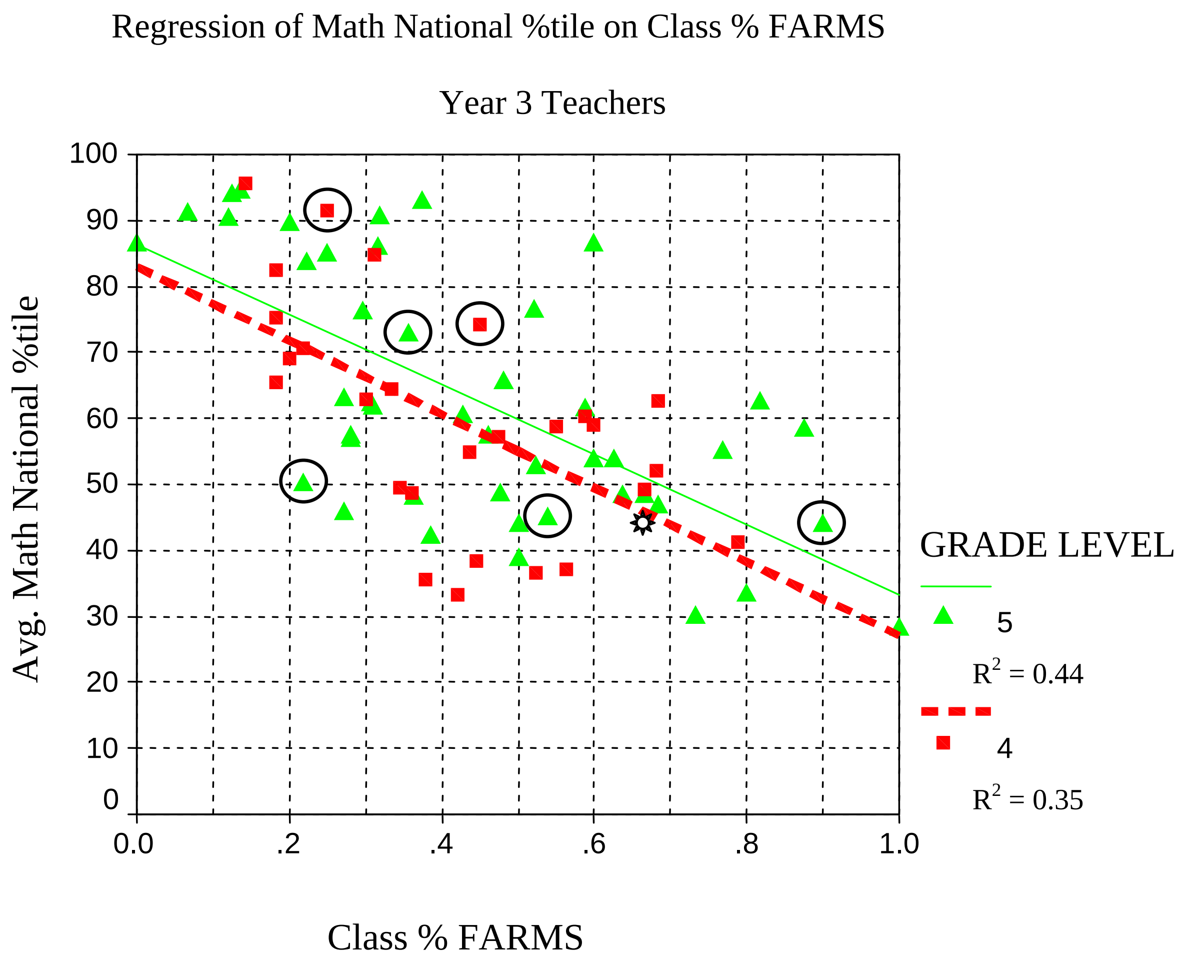
Student Achievement Data

Part of the state test was nationally-normed, and results from that part of the test are presented here. Not surprisingly, accelerated students had the highest national percentile rankings. The fourth graders in Ms. Fulton's class scored better than 91% of fourth graders in the nation, and Ms. Lauffer's fourth graders scored better than 74% of other fourth graders. Although Ms. Fulton's fifth graders were taught with accelerated students, they were still learning fifth grade material. However, Ms. Fulton described them as strong students, and they experienced the same instruction as did the accelerated students. These fifth graders scored higher that 73% of fifth graders, whereas students of Mr. DiLoretto and Mr. Forrest scored higher than 50% and 45% of other fifth graders, respectively. Ms. Keller's and Ms. Shepard's struggling fifth graders both scored at the 44^{th} national percentile.

Because I was particularly interested in instructional practices for teachers of high-poverty students, I wanted to examine student achievement as it related to poverty levels. For all fourth grade classes in the larger study, FARMS was strongly and negatively correlated with achievement (-.66, $p<.01$). For fifth grade classes, FARMS was also negatively correlated with achievement (-.59, $p<.01$). Figure 1 shows regression lines for both 4^{th} and 5^{th} grade, using FARMS to predict national percentile rank for classes with low numbers of special education students. Because Ms. Keller taught special education students, her class was not part of the regression. However, for ease of comparison I placed her class on the plot, denoting it with a ✡. The other case study teachers were circled.

Figure 1

Student Achievement and Poverty



Note: Includes only classes with less than 25% Special Ed.

Out of seven groups, four scored above the regression lines and three scored below them. While this result seemed to imply there was no pattern for these teachers, a more detailed examination was warranted. First, Ms. Keller taught special education students. Moreover, she had the highest percent of ESOL students (50%) of all fifth grade classes in year 3 of the larger study. Given these facts, it is impressive that her students scored as near as they did to the other fifth grade classes with a similar percent of FARMS students. The one exception was a class fifth graders who were 60% FARMS but scored better than 86% of other fifth graders. However, this was an accelerated group of fifth graders who were taught the sixth grade curriculum.

Mr. Forrest’s class also fell below the regression line. However, his class had the second highest percent of ESOL students (46%) of all fifth grade classes in year 3 of the larger study. The next highest percent ESOL for the 5^{th} grade teachers this year was 36%, and the mean was 15%. It was perhaps because of these demographics that Mr. Forrest chose to spend nearly half of his class time on conceptual content.

The teacher who was furthest below the regression line was Mr. DiLoretto, who described his students as low to average. His class also had low levels of FARMS and very low levels of special education or ESOL students. However, Mr. DiLoretto was the only teacher who had not pervasively illustrated the knowledge dimension of learning. He also was one of the teachers who did not show evidence of the strategic processing dimension. Although this teacher manifested excitement and was affirming of student ideas, he was markedly different than the other teachers with regard to the promotion of deep understanding and reasoning in his class. Although he focused often on concepts, the proportion of time he spent on linking concepts to procedures was average, as was the occurrence of high-level student activity.

Conclusions

In the past, researchers have not agreed on the effectiveness of reform ideas, such as those prescribed by the National Council of Teachers of Mathematics, for students of low socioeconomic status (Boaler, 2002). Boaler has suggested that more needed to be known about specific practices of teachers in low-income areas and how they related to success in mathematics. She found that teachers who were successful at creating equity were ones who asked their students to explain and justify solutions and who made connections to experiences in the lives of their particular students.

The present study supports Boaler's (2002) findings and extends them. As in her study, successful teachers in this study asked students to explain their thinking and made connections to the real world. These teachers also tended to link concepts and procedures (i.e., they helped students understand why procedures worked). In general, their lessons were principled and deep and provided opportunities for reasoning and problem-solving.

By examining teaching practices using the five dimensions of learning as well as the five distinctive features of effective mathematics instruction, this study provided both a broad perspective on quality teaching as well as a focused one. In this way, the relative frequency of specific practices could be measured, as well as the relative emphasis of things like motivation and knowledge. For the six teachers discussed in this study, the knowledge principle seemed to play the primary role in helping students achieve, whereas the other principles played a supporting role.

The inclusion of teachers who teach a range of ability levels offered a chance to explore the possibility that perhaps the practices of high-quality teachers vary even within a low socioeconomic context. Some differences were apparent among the six teachers in this study. For example, the two teachers of struggling students were more likely to focus on procedures and on scaffolding the students. The two teachers of regular classrooms were more likely to focus on concepts and getting the students excited about mathematics. The teachers of accelerated students tended to have the deepest lessons, and their practices were most like the ones suggested in the literature on effective mathematics instruction (NCTM, 2000; NRC, 2001; Reynolds & Muijs, 1999; Stipek, 2002). Namely, they expected students to explain their thinking, link concepts and procedures, and make connections to experiences outside of school.

By examining what works with students from a low socioeconomic background, this study contributes to the growing body of knowledge about high quality mathematics instruction. In a time where public concern for education and the achievement gaps has reached a peak, research on what *is* working will play a vital role in teacher preparation and training. While this study is limited in that it closely examines only six teachers, it suggests that many reform-oriented practices are effective in high-poverty schools. Unfortunately, these practices may be more prevalent among teachers whose students have higher perceived ability in mathematics.

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