Leadership Content Knowledge: A Construct for Illuminating New Forms of Instructional Leadership [1]

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Background

Over the last few years, there has been a renewed interest in school and district administrators as instructional leaders (Rowan, 1995; Spillane & Halverson, 1998; Stein & D'Amico, 2000). Concomitant with this shift has been an increasing recognition that administration needs to be more connected to the work of schools—that is, to learning and teaching—and that instructional leadership needs to be more closely tied to subject-matter knowledge (Hallinger, Leithwood, & Murphy, 1993; Murphy, 1999; Nelson & Sassi, 2000 a, in press; Rowan, 1995; Stein & D'Amico, 2000; Stein & Nelson, in press). This interest in reconceptualizing instructional leadership has been spurred, in large part, by the move toward

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standards-based instruction in mathematics and science (e.g. NCTM 1989, 1991, 2000; National Research Council, 1996). It has been shown that students who do mathematics in their classes — who work on complex mathematical problems; consider, reconsider, and discuss mathematical ideas; make mistakes and work through them; and invent solutions to problems, all the while learning basic mathematical facts and procedures — learn problem-solving and complex reasoning as well as factual recall and computation (cf. Carpenter et al, 1989; Fennema et al 1993; Silver, Smith & George, in press; Stein & Lane, 1996). Such instruction is quite different from that with which most administrators are familiar.

The issue of what school and district administrators need to know in order to function well as instructional leaders in standards-based educational environments is beginning to be addressed, both conceptually and empirically. The construct of "Leadership Content Knowledge," (LCK) recently introduced by Stein & D'Amico (2000) and elaborated by Stein and Nelson (in press), adapts Shulman's construct of pedagogical content knowledge (Shulman, 1986) to the administrative domain. Work is underway to specify what such Leadership Content Knowledge entails. Several scholars have suggested that the cognitive revolution in psychology and ancillary changes in pedagogy essentially represent a transformation of the "core technology" of schooling (Elmore, 1996) — a transformation of ideas about the nature of knowledge; students' role in learning; how ideas about knowledge and learning are manifested in teaching and classwork; the structural arrangements of schools; the relationships between administrators and teachers; and so on. In this line of argument, administrators need to update their knowledge of the core technology (Elmore, 1996; Nelson, 1999; Rowan, 1995; Spillane, 2000; Stein & D'Amico, 2000). However, to date there has been little systematic work to elaborate the nature of Leadership Content Knowledge and how such knowledge plays out in administrators' practice.

For the study described here we focused on Leadership Content Knowledge in the domain of elementary school mathematics. We have characterized Leadership Content Knowledge for mathematics along two dimensions: (1) knowledge of mathematics, and (2) beliefs about mathematics learning and teaching. Strong mathematics knowledge is quite complex, consisting of strong conceptual understanding of mathematical ideas interwoven with knowledge of algorithms, mastery of computational procedures and mathematical facts, and mathematical "habits of mind," or ways of approaching mathematical problems, including skill at choosing representations for numerical situations, mathematical reasoning, problem-solving, and proof (Cuoco et. al. 1996; Kilpatrick, et. al, 2001; NCTM, 1989, 2000). In the best case, all of these are tightly interwoven and inform each other. However, the strands of people's mathematics knowledge may not be so tightly integrated and some elements may be more developed than others. For example, we have learned from our prior research on principals' Leadership Content Knowledge that elementary and middle school principals vary in their knowledge of mathematics, from having conceptual understanding at about the fourth or fifth grade level and largely algorithmic or procedural knowledge beyond that to having highly developed conceptual understanding, algorithmic skills, and mathematical habits of mind.

The second dimension of Leadership Content Knowledge is also complex, since knowledge about learning and teaching is evolving and currently contains elements that derive from several intellectual perspectives. One viable view with deep historical roots holds that knowledge is the organized accumulation of facts, ideas, and skills. In this view learning is a matter of acquiring these ideas and skills through sequentially arranged learning tasks and opportunities to absorb ideas and facts and practice procedures and skills (Greeno, et. al, 1996). A different, but equally viable view is that knowledge is a process of individual (and collective) human construction, learning is the process of active sense-making, and teaching is the process of providing social and material contexts that present students with grist for the work of learning (Bransford, et. al, 1999). Most people's views of learning and teaching are a mix of these two. Our prior work indicates that many elementary and middle school principals view mathematics instruction as largely a matter of providing (and absorbing) information about mathematics facts and practicing procedures (Romberg, 1983). Others see teaching and learning as a matter of providing opportunities for students to construct conceptual understanding of mathematical ideas, as well as mastery of facts and procedures (Lampert, 1990, 2001). Many principals have views of mathematics teaching and learning that entail a mixture of these orientations.

<u>Scope of this paper</u>

In this paper we will describe a small study of elementary principals' Leadership Content Knowledge for Mathematics. First we will describe the study, then we will describe our instruments for measuring principals' mathematics content knowledge and present some preliminary findings. Following this we will describe our instruments for measuring principals' mathematics epistemology and present preliminary findings. Finally we will describe four principals with distinctly different Leadership Content Knowledge profiles, as the beginning of a discussion of what Leadership Content Knowledge is and how it may affect administrative practice. The conclusion will summarize our findings and lay out important questions for future research.

The Study

This is a small, exploratory study of the Leadership Content Knowledge for mathematics of a number of elementary school principals, and the relationship between that Leadership Content Knowledge and their practice of classroom observation and teacher supervision in mathematics. Our research questions are:

> 1. *What ideas about mathematics, children's learning, and elementary mathematics instruction inform what principals attend to when observing elementary mathematics classrooms?*
>
> *2. How do these ideas inform their judgments about the quality of the instruction they observe and what they decide to talk with teachers about in post-observation conferences?*
>
> *3. How does this content knowledge shape their leadership concerns in the actual practice of classroom observation and teacher supervision?*

While Leadership Content Knowledge may affect administrators' instructional leadership in a number of different domains — recruiting and hiring teachers, choosing professional development programs, choosing instructional materials, developing staffing policies, etc. — we have situated this research in the administrative practice of classroom observation and teacher supervision in elementary mathematics. We have chosen this focus because it offers the most direct access to the connection between Leadership Content Knowledge, instruction, and student learning. All elementary principals do classroom observation and teacher supervision — they are the arbiters of instructional quality in their schools. In visiting classrooms and talking with teachers, principals come into direct contact with instruction, judge its adequacy, and decide what kind of help and support a teacher may need.

The first stage of this research, on which we report here, addresses the "content knowledge" aspect of Leadership Content Knowledge by looking at 20 principals' knowledge of mathematics and their ideas about the nature of mathematics learning and elementary mathematics instruction. Data collection has involved administering a battery of three instruments: a biographical information form to gather information about principals' prior work and professional development, an assessment of mathematics content knowledge, and an assessment of beliefs about mathematics learning and teaching (we call this a mathematics epistemology instrument). The latter two instruments were developed for use with teachers and have been adapted and piloted for use with administrators. (No such instruments designed for use with administrators currently exist.) The mathematics content knowledge instrument is a psychometrically constructed, quick-score instrument that measures conceptual mathematics knowledge in two strands: 1) number and operations, and 2) patterns, functions, and algebra.[2] We have added a section assessing algorithmic knowledge in each of these strands. The mathematics epistemology instrument contains a quick-score Likert instrument measuring beliefs about mathematics learning and teaching, an open response section in which principals interpret a short description of an elementary mathematics class, and a third section in which principals rank order four teachers on the basis of the teachers' stated philosophies of mathematics instruction.

We have administered Leadership Content Knowledge surveys to all of the principals in our sample and are currently analyzing the results. This paper is a preliminary discussion of what we are finding, with an emphasis on what the data are telling us about the construct of Leadership Content Knowledge itself. Our current sample is too small to enable us to characterize principals' Leadership Content Knowledge more generally.[3]

In the second stage of this research we will collect data on what these principals attend to and think significant, and what they would talk with the teacher about, when viewing three different videotapes of elementary mathematics

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[2] Instructional measures copyright 2001. Study of Instructional Improvement (SII)/Consortium for Policy Research in Education (CPRE); development supported by NSF grant REC-9979873, and DOE/OERI subcontract to CPRE (R308A960003). We have permission from the authors of this instrument (Hill, Ball, Rowan) to use it in our research on administrators.

[3] We are currently in the early stages of a large-scale, national study of elementary and middle school principals' Leadership Content Knowledge for mathematics under the auspices of a RETA grant (a Research, Evaluation, and Technical Assistance grant related to the NSF's Mathematics and Science Partnerships Program) funded by the NSF (Grant No. HER-0335384). This work will allow us to make more general characterizations of elementary and middle school principals' Leadership Content Knowledge for mathematics.

classrooms chosen to illustrate different views of mathematics knowledge and pedagogy. As the result of the first two stages of data collection we will be able to analyze the relation between these principals' ideas about mathematics, learning and teaching, what they notice and think significant in the elementary classrooms on videotape, and what they would talk with the teacher on the videotape about. After analyzing this data we will select a sample of 8 principals to participate in Stage 3 research, in which we will address the "leadership" aspect of Leadership Content Knowledge by looking at what elementary principals attend to and think significant when conducting observations of elementary mathematics lessons in their own schools. We will collect data on these 8 principals doing classroom observations in elementary mathematics and having pre-and post-observation conferences with teachers in their own schools. We will identify what each principal attends to and thinks significant in a real-world observation and will collect data on the judgments that each makes about the classroom and the interventions he/she makes in the post-observation conference with the teacher. By comparing what these principals see and would want to talk with the teacher about in videotaped classrooms with what they see and talk with the teacher about in real classrooms, we will be able to analyze how principals' perceptions of contextual considerations affect how they engage in observation and supervision for elementary mathematics classrooms for which they have leadership responsibility.

Sample. This project is designed to have a sample of 20 elementary principals in the first stage of the work. To date we have studied 14. This group is typical of elementary school principals in many ways. Most are in their fifties, were elementary school teachers for between five and fifteen years, and have been principals for between ten and twenty years. A few have been principals for less than ten years. Six are principals in a large urban district, the rest work in small towns, small cities, or suburban areas. Three have Ed.D degrees, the rest masters degrees. All but one took some form of mathematics in college. For half of the group these were mathematics methods courses or mathematics for teachers. The other half took one or more of statistics, calculus, linear algebra, or geometry. Five took mathematics in graduate school, usually one statistics course. Atypically, one passed the PhD qualifying exam in statistics.

Data Analysis. To date we have analyzed the data from the mathematics content knowledge instrument and the mathematics epistemology instrument for all 14 elementary school principals. While the mathematics content knowledge instrument and two sections of the epistemology instrument contain quick-score items, one section of the epistemology instrument contains three open-response items for which a coding scheme was developed. Four researchers analyzed these qualitative data and discussed their interpretations until consensus was reached. In order to standardize the epistemology scores, different parts of which had different numbers of items, we calculated z-scores for the epistemology data. In order to keep the epistemology and mathematics scores on the same scale on our graphs, we calculated z scores for the mathematics assessment as well (see footnote on p. 23).

Mathematics Content Knowledge

Overview of Items. Our mathematics assessment included a total of 31 items (6 computation items and 13 conceptual problems, some with multiple items). Early in the development of the project we spent a significant amount of time thinking about how we could measure the mathematics content knowledge of the principals participating in our study. We looked at many existing instruments, some designed for use by teachers and others for students, and we considered developing our own instruments. We decided to use assessments designed by Ball, et. al. as part of the *Study for Instructional Improvement (SII),* which developed and administered mathematics content items to elementary school teachers. This collection of items was designed to measure mathematics "knowledge for teaching" -- content knowledge that is specific to the mathematics that elementary teachers teach and use in their teaching as opposed to the mathematics used by accountants, engineers, or members of other professions. These items assess conceptual understanding of elementary number concepts and operations, as well as problem solving (patterns, functions, and algebra). Many of the items are couched in the context of student learning.

It is important to point out that this assessment is not designed to be an absolute measure of mathematical knowledge. It is used as a method of comparison within or between groups of how teachers (and, in our case, principals) think about fundamental mathematical concepts and procedures and can also be used to mark growth in content knowledge over time. One of the reasons we chose to use items from the *SII* is that the items are very well constructed and "get at" important concepts of elementary mathematics. They also have been field tested and analyzed for validity and reliability. For more information on the development and analysis of the original items, see Ball, Hill, & Bass (2002) and Hill, Schilling, & Ball (2003).

To avoid having the items become too widely known, and therefore less effective for measuring content knowledge for teaching, a limited number of sample items are made publicly available by the *SII* instrument developers to share in articles such as this. We display some below in order to illustrate the unique style of the items.[4] (Readers may wish simply to browse through these samples at this point. We will refer to Sample 1 in greater detail later in this paper.)

Sample 1

Imagine that you are working with a class on multiplying large numbers. Among the students' papers, you notice that some have displayed their work in the following ways:

Student A	Student B	Student C
35 ×25 125 +75 875	35 ×25 175 +700 875	35 ×25 25 150 100 +600 875

Which of these students is using a method that could be used to multiply any two whole numbers?

	Method would work for all whole numbers	Method would NOT work for all whole numbers	I'm not sure
a) Method A	1	2	3
b) Method B	1	2	3
c) Method C	1	2	3

Sample 1 illustrates three valid methods of using the distributive property to expand the product (30+5) x (20+5).

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[4] **Measures copyright 2002 Study of Instructional Improvement/Learning Mathematics for Teaching Project.**
Please do not duplicate or use without permission of these projects. Measures development supported by NSF grant REC-9979873, NSF grant REC-0233456, and by a subcontract to CPRE on Department of Education (DOE), Office of Educational Research and Improvement (OERI) award #R308A960003. Additional released items from SII can be found at http://www.sii.soe.umich.edu/.

Sample 2

Ms. Dominguez was working with a new textbook and she noticed that it gave more attention to the number 0 than her old book. She came across a page that asked students to determine if a few statements about 0 were true or false. Intrigued, she showed them to her sister who is also a teacher, and asked her what she thought.

Which statement(s) should the sisters select as being true? (Mark YES, NO, or I'M NOT SURE for each item below.)

	Yes	No	I'm not sure
a) 0 is an even number.	1	2	3
b) 0 is not really a number. It is a placeholder in writing big numbers.	1	2	3
c) The number 8 can be written as 008.	1	2	3

In Sample 2, participants are asked to analyze three statements about 0 and determine which are correct.

Sample 3

Which of the following story problems could be used to illustrate $1\frac{1}{4}$ divided by $\frac{1}{2}$? Circle 1, 2, or 3 (YES, NO, or I'M NOT SURE) for each possibility.)

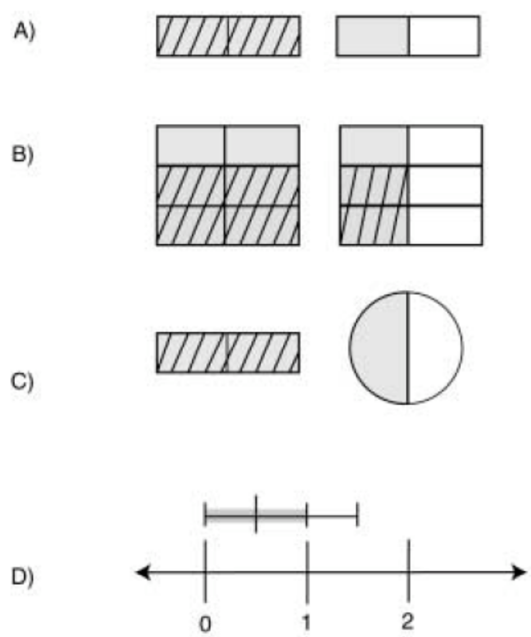
	Yes	No	I'm not sure
a) You want to split $1\frac{1}{4}$ pies evenly between two families. How much should each family get?	1	2	3
b) You have $1.25 and may soon double your money. How much money would you end up with?	1	2	3
c) You are making some homemade taffy and the recipe calls for $1\frac{1}{4}$cups of butter. How many sticks of butter (each stick = $\frac{1}{2}$cup) will you need?	1	2	3

Sample 3 provides participants with three story problems and asks them to determine whether any of them models 1 1/4 divided by 1/2.

Sample 4

At a professional development workshop, teachers were learning about different ways to represent multiplication of fractions problems. The leader also helped them to become aware of examples that do not represent multiplication of fractions appropriately.

Which model below cannot be used to show that $1\frac{1}{2} \times \frac{2}{3} = 1$? (Mark ONE answer.)



In this problem, participants are asked to determine which of the four visual models represents the equation 1 1/2 x 2/3 = 1.

Many of the items we chose to use were designed to assess conceptual understanding of various number concepts and operations, as opposed to problem solving.

During piloting we realized that if a principal had difficulty with a conceptual problem we would not know if he or she could correctly perform the underlying operation. We wanted know if a principal who, for example, had difficulty determining which of the alternative algorithms given in a problem like Sample 1 are correct actually could compute the product of the same set of numbers. Conversely, we wondered whether participants' difficulty with computing something like the quotient of fractions might affect their ability to correctly answer a question like Sample 3 concerning which of the given story problems correctly modeled the given quotient. To avoid making unwarranted assumptions, and to satisfy our curiosity, we added six strictly computational problems at the beginning of the content assessment. A description of these items is given below[5], but the specific problems are not given in order to maintain item security (we will be using the assessments in several large scale projects in the future).

Computation problem descriptions

3-digit whole number subtraction*	product of mixed number and proper fraction
2-digit whole number product*	quotient of mixed number and proper fraction*
product of proper fractions*	quotient of decimal numbers

* these problems had corresponding conceptual problems in the assessment

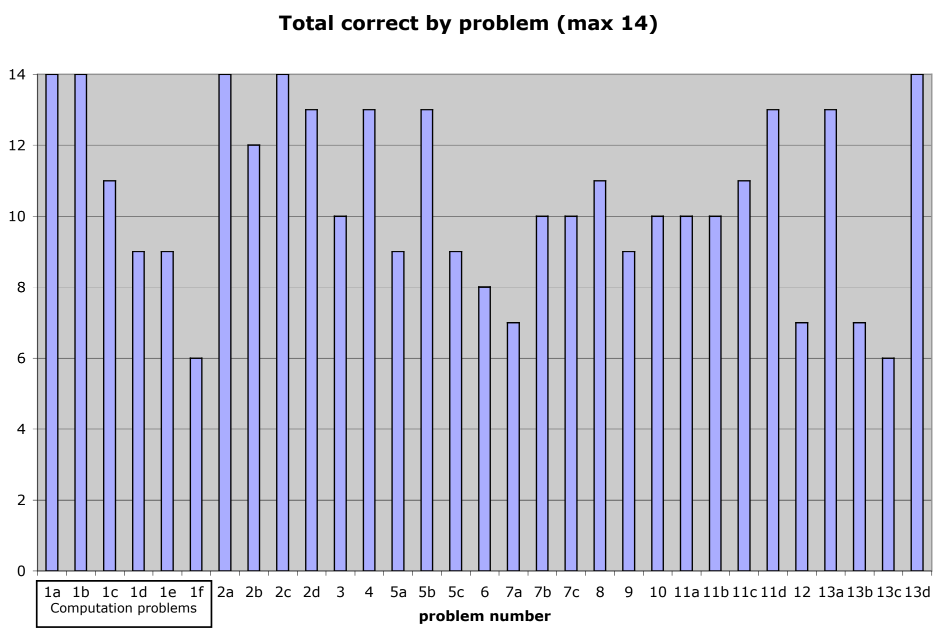
In the next three sections we will discuss the preliminary findings of this assessment, analyze overall data on the relation between principals' computational ability and conceptual understanding, and do an analysis of three pairs of items in which the computation and conceptual understanding problems were related.

Preliminary Findings. The following table shows the raw scores from the mathematics content assessment for each of the 14 study participants (the computation score is the total from the 6 computational problems described above, the conceptual score is for the 13 problems chosen from the *SII* [a total of 25 items], and the total score represents the sum of the computation and conceptual scores):

[5] Space was given for participants to show their work on this part of the assessment and each part was graded holistically with full credit awarded only if the answer and the accompanying work were correct (1/2 credit was awarded for "minor" errors).

Participant #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Computation score	6	5.5	2	5	3	5.5	5.5	3.5	6	5.5	6	6	4	3
Conceptual score	21	22	11	18	15	20	22	12	23	23	24	21	16	15
Total score	27	27.5	13	23	18	25.5	27.5	15.5	29	28.5	30	27	20	18
% correct (out of 31)	87	89	42	74	58	82	89	50	94	92	97	87	65	58

There is a reasonable range of scores among these principals, with no ceiling or floor effects (no one got every item wrong, no one got every item right).[6] At first glance it appears that higher computation scores correspond to higher conceptual scores (more on this later). There was also was a spread of difficulty among the items on the assessment, as illustrated by the following chart showing the number of correct answers on each of the 31 items.

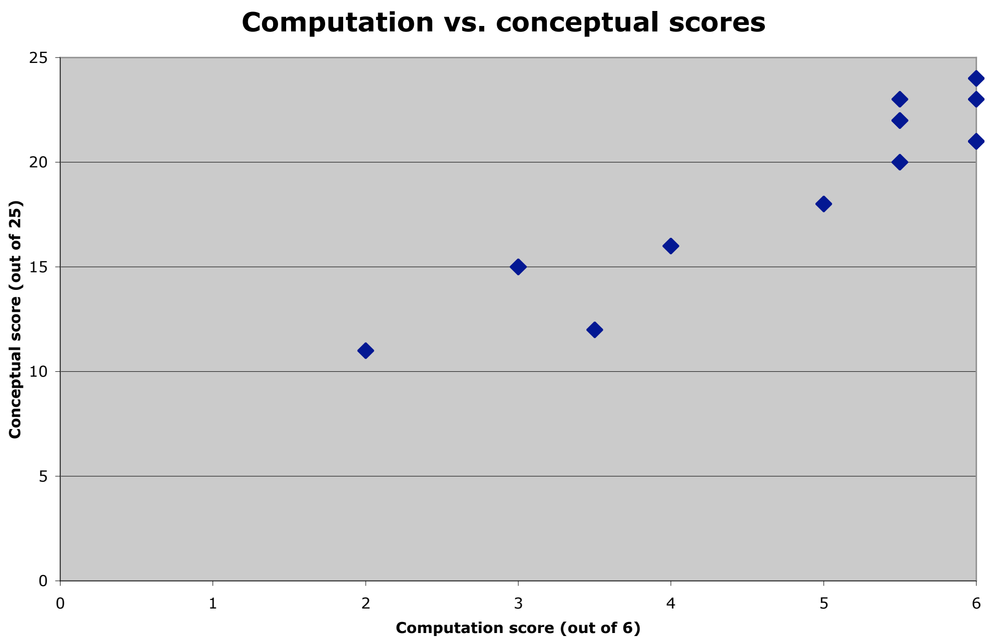


[6] The mean and median of the total scores were 23.54 and 26.25, respectively (conceptual mean and median:18.79 and 20.5; computation mean and median: 4.75 and 5.5). The 1st quartile scores were 18.5 for the total scores, 15.25 for the conceptual scores, and 3.625 for the computation scores, while the 3rd quartiles were 27.5 (total), 22 (conceptual), and 5.875 (computation).

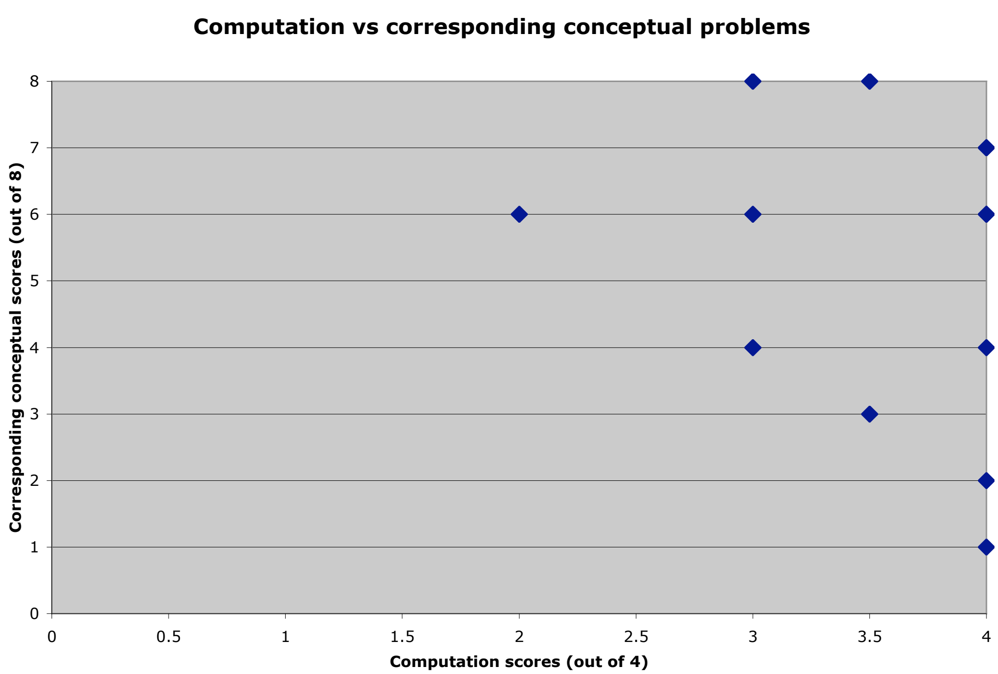
On any given item, at least 6 participants correctly responded and all participants correctly answered two of the computation problems (problems 1a and 1b) and 3 of the conceptual problems (problems 2b, 2c, and 13d).

Of the 14 principals who completed this assessment, all correctly completed the subtraction and multiplication computation problems, which was not surprising since whole number operations are not as problematic as multiplication and division of fractions and decimals. Eleven participants correctly computed the product of proper fractions, 9 correctly computed the product and quotient problems involving a mixed number and a proper fraction, but only 6 participants got the decimal division problem correct. Thus, our sample of principals, like the general population of students and adults, also has difficulty with division of decimals and fractions.

Relationship between Computation Ability and Conceptual Understanding. When comparing each principal's computation score with his or her conceptual score, a cursory analysis seems to imply a possible relationship between the two measures, as illustrated in the chart below, which shows that, while there is not a strong correlation, in general as principals' computation scores increase, their conceptual scores also increase. (Note that the data points (3,15), (5.5, 22), and (6,21) each represent two participants).



However, a more careful analysis reveals something quite different. The figure below shows the relationship between the number of computation problems that a principal got correct and the number of conceptual problems using the same mathematics that he or she got correct.



(Note that data point (4,6) represents two principals and data point (4,7) represents three.) Since our sample size is small we cannot draw far-reaching conclusions, but it seems clear that among the principals in our sample computational fluency is not a sufficient condition for conceptual understanding, at least as measured by the problems we chose. That is, for each of three numbers of computation problems correct (3, 3.5, and 4) there is a considerable range of conceptual problems correct. In order to explore this phenomenon further, we did an analysis of three of the sets of problems in which the computation was the same as that required for the conceptual problem.

Item Analysis. It has already been noted that all of the principals participating in the study were able to correctly compute a two-digit whole number product. However, participants had significantly more difficulty with the corresponding conceptual problem. (This was a problem similar to Sample 1, where three different algorithms were used to solve a two-digit multiplication problem and participants were asked to say which methods would work for any two whole numbers.). Six principals (42%) got this problem completely correct, recognizing the standard algorithm and both non-standard algorithms as valid ways to solve the problem. Six principals recognized the standard algorithm and one of the two non-standard algorithms as correct, One recognized that the standard algorithm was correct but was not sure about the other two. Disconcertingly, one of the 14 principals in our study was able to correctly compute the product using the standard algorithm in the computation part of the assessment but failed to recognize that the standard algorithm was a correct method for computing the product in the context of the conceptual problem.

	Yes	No	I don't know
Non-standard algorithm 1	9	2	3
Standard algorithm	13	0	1
Non-standard algorithm 2	9	1	4

Recognizing what is going on in this problem involves using the distributive property to take the two-digit numbers apart in different ways each time, and then multiplying the component parts and adding the results. While the limitations of multiple choice instruments for illuminating what participants understand about the mathematics being examined are well known and make it difficult for us to say how any single participant in our sample actually thought about the mathematics, it is striking that fewer than half were able to work through this conceptual problem in its entirety. The inability of the others to use the standard algorithm's underlying principles to solve the problem in novel ways raises doubts about the degree to which they understand how the standard algorithm works.

Another conceptual problem we administered showed several methods for computing the difference of two 3-digit whole numbers. The particular calculation had been given as one of the computation problems we added to the assessment. Principals were asked whether only the first, only the second, only the first and second, only the second and third, or all three methods were correct.

Only first method correct	**0**
Only second correct	2
1st and 2nd correct	1
2nd and 3rd correct	2
All 3 correct (correct response)	9

All of our principals were able to correctly compute the difference on the computation portion of the assessment, but only 9 of the 14 were able to correctly answer the corresponding conceptual question. As in the earlier case of two-digit multiplication, this problem required participants to understand how three-digit subtraction worked sufficiently well that they could analyze the validity of novel ways that students might use to solve the problem (starting with the subtrahend and successively adding a series of single, double, and triple digit numbers until the minuend is reached; decomposing the subtrahend and doing successive subtractions, beginning with the minuend; and subtracting a given number from the subtrahend and adding it to the minuend to make "friendlier" numbers to subtract). Slightly more principals than in the case of multiplication (9) were able to do this completely correctly; all could do it to some extent.

Our final example concerns a problem which, like Sample 3, asks principals to determine which story problem is solved by computing a specific quotient involving a mixed number and a unit fraction. The results are given in the table below. (The only correct answer is the problem described in part (c). Part (a) models dividing the mixed number by the reciprocal of the fraction and part (b) models multiplication by the reciprocal of the fraction, which is a method for accomplishing division by the fraction, but the problem does *not* illustrate the given calculation):

	Yes	**No**	**I don't know**
Part (a)	7	7	0
Part (b)	3	10	1
Part (c)	10	4	0

Note that there were fewer "I don't know" answers as compared to the results of sample problem 1, but more mistakes (especially on part (a)). This error will likely not surprise those who have thought about this question before, since this is similar to a problem Liping Ma presented to elementary teachers and wrote about in Ma (1999).

Our mathematics assessment, while not an absolute measure of mathematical knowledge, does provide us with evidence of relative mathematical knowledge within a group, allowing us to make distinctions among our participants and leading us to a number of questions concerning the depth of their understanding. As has been shown to be the case among students and teachers, among these principals knowledge of how to compute algorithms does not imply sufficient conceptual understanding of number and operations for many principals to be able to reason their way through novel ways to solve these problems (though some can). While it seems clear that *teachers* need such flexible conceptual understanding in order to work with students' mathematical thinking in their classrooms, it would seem that principals, too, would need such understanding if they are to knowledgeably attend to what is happening in standards-based classrooms and evaluate the effectiveness of the instruction. The analysis of the matched computational and conceptual items on the mathematics knowledge instrument piques our interest in what these principals will see in the second stage of our research, when they observe videotaped classrooms in which different amounts and kinds of student thinking are encouraged.

Mathematics Epistemology

The instrument. The mathematics epistemology instrument consisted of three sections that assessed beliefs about mathematics teaching and learning. The first was a section of nineteen likert items that asked participants to reply to statements about mathematics teaching and learning on a seven-point scale from strongly agree to strongly disagree.[7] The second was an open response section, consisting of a classroom scenario showing interactions between a teacher and her students during a math lesson. Three of the teacher's statements or questions were underlined and participants were asked to write what they thought the teacher was doing, whether or not it was a good teaching move, and why they thought so. This item was scored using a 5-point rubric, "5" representing a constructivist approach to teaching and learning and "1" representing a direct instruction approach to teaching and learning. The third section entailed rank ordering four teachers from most to least successful in helping students learn math.[8] There was a brief statement of each teacher's philosophy of mathematics instruction and based on these principals made their judgments. For the purposes of this paper we decided not to include this section as part of principals' overall epistemology score. The scores on this section of the instrument were anomalous and we are conducting additional studies to try to understand what is going on when principals perform this rank order exercise.

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[7] This section of our instrument was adapted from an instrument created for the Teacher Education and Learning to Teach study conducted by the National Center for Research on Teacher Education, Michigan State University, 1985.

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Once each item on the epistemology instrument was scored on a 1 to 7 or 1 to 5 scale, we took the participants' responses and standardized them to produce z-scores,[9] which are the data discussed in this paper.

Preliminary Findings. We found several areas of interest in this data, which will be the object of future study. We list these first and then discuss each.

- Most of the principals in our sample agreed with instructional methods that support constructivist learning such as group work, discussions, and the use of manipulatives. There was more variability in their responses about items that considered how mathematical concepts are learned and taught.

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9 Z-scores take the average response to a given item by all participants and then determine how far a given participant's response is from the mean. That result is then divided by the standard deviation to determine how many standard deviations above or below the mean a given participant's response on that item is. We took an average z-score for all likert items, added that to the z-score for the open response, then divided by two to get an average epistemology z-score, i.e. we weighted likerts and open-response sections equally. Similarly, for the math content portion of the survey we took the z-score of the number of problems each participant answered correctly. In order to avoid negative judgments about principals' achievements on the mathematics and epistemology instruments, for the graphs in this paper we added "2" to all z-scores so that the graphs would begin at "0" and scores below the mean on either axis would not be expressed as negative scores.

Technically,z-scores are to be used when there is reason to believe that the data will be normally distributed. With our small sample we could not make that assumption, but decided to use z-scores as a provisional technique in order to be able to compute composite epistemology scores and display them with mathematics content knowledge scores on the same scale on a graph. When we have equivalent data from the much larger sample in our new study we will merge the data from this study with that one and recompute the z scores.

- Principals' ideas about the role of student confusion and teachers' deviation from the planned lesson tended to serve as markers for their epistemological position.

- Some principals who had a higher level of mathematical content understanding were attuned to listening for the mathematical ideas in a classroom, but others were not. However, principals with low math content knowledge were less likely to look for it or see it in classrooms.

Attending to form vs. function. The first observation above (that most principals agreed with "standards-based" or reform-oriented instructional methods but that there was disagreement about how mathematics concepts are learned and taught) at first seems contradictory. However earlier research by Nelson and Sassi (2000b) and Spillane (2000) provides two different, but complementary explanations for this phenomenon, one based on the history of administrator training for classroom observation, the other based on administrators' views of the nature of mathematics instruction itself.

In a study of administrators' supervisory practices, Nelson and Sassi reported that, deriving from process-product research on teaching that emphasized teacher behaviors, many principals have been trained to attend to the behavioral features of classrooms such as wait time and objectively observable indicators of student engagement. Principals typically do not attend to the mathematical thinking that is going on. When they observe standards-based mathematics classes they tend to continue focusing on behavioral features of the class but substitute a new set of behaviors for the old. Now they look for the presence of manipulatives, small group discussion, students explaining their problem-solving strategies, etc. These features tend to be easily observable, generic features that are independent of the mathematical thinking going on in the class. Such principals have not shifted their observation practices to look for how teachers' use of these pedagogical tools gives their students the opportunity to do the hard work of making sense of the mathematical ideas at play in their classroom. It is only as principals' views of how children learn mathematics move toward a constructivist position that they begin to consider how teachers' pedagogical moves might influence the development of students' ideas.

In his study of district leaders (including principals) who have recently participated in mathematics education reforms, Spillane (2000) found that district leaders tended to focus on the *form* of the reform rather than the *function* of the reform (the function being the development of conceptual understanding of mathematics in addition to procedural knowledge). When focusing on the instructional *forms* of classrooms, principals tend to see the use of manipulatives, group work, student discussion, and real-life story problems and they miss deeper aspects of what mathematical thinking the students are doing. Spillane goes on to say that, "…these forms of instruction were understood chiefly in terms of modal pedagogical functions, that is, as instructional strategies that preserve the conventional view of mathematics as teaching procedural knowledge" (p. 154).

District leaders easily shifted their focus from one kind of surface feature to another, but their deeper understanding of what mathematics means had not changed.

Our data shows that the principals in our sample seem to have accepted generic surface-level changes of classroom pedagogy, but are still grappling with some of the deeper level changes in how to think about the subject of mathematics. Our preliminary analysis of the likert items found the same trend as in the Nelson and Sassi, and Spillane research. Of the nineteen likert item statements, there were five statements that the principals in our study agreed with more strongly than any of the others: students discussing ideas, working together on tasks, using models and visual aids, and assuming girls are as capable in mathematics than boys. Not only was there a high level of agreement on these items, but the average responses were high on the constructivist scale, all were above a 6.464 (7 is the most constructivist position).[10] These data suggest that these principals look for and agree upon certain features of classrooms that they can easily see and check off, and that these are considered to be good instructional practices. We speculate that these principals are looking at the behavioral aspects, or forms, of classrooms much as they always have. They are simply looking for different instructional forms.

However, many of our participants seem to be at a point of change, at a mixed position. While they attend to, agree upon, and easily see the surface features of a classroom associated with standards-based math, many of them are beginning to see deeper level features as well. We found nine likert items that represent areas

[10] Their average answers ranged from a 6.464 to a 6.714 on a 7-point scale from traditionsl to high constructivist. The standard deviations for these five items range from 0.497 to 0.76.

where there is a great deal of variance among our participants. These are related to how teachers and schools navigate individual students' mathematical thinking. They include items about how teachers should structure student learning -- for example, the role of confusion in learning, whether computation needs to be mastered before moving into problem-solving, how to best serve students who are having difficulty, when might students be ready to consider new ideas, and the role of students' explaining their thinking. How a principal responds to such items relates to his or her beliefs about how students learn math. Do principals view students as building their conceptual understandings each day, filling in more pieces, making more linkages? Or do they view students as layering one piece of knowledge on top of another, and without a strong foundation, nothing more can be built? These items suggest areas where principals may be reconceptualizing what it means to teach and learn math. They show the areas in which principals are taking the next steps toward merging constructivist teaching practices with their concept of what it means to learn mathematics.

Markers of epistemological positions. While the examination of the likert items allowed us to make some general statements about principals' views and identify those principals with mixed views, the open response section provided us a more textured understanding of these principals' beliefs about teaching and learning. The open response section presented principals with a classroom scenario of a fourth grade mathematics class. In this lesson the class is working on division problems. A comment by Jason, one of the students, prompts the teacher to deviate from the planned lesson and explore his related idea. There is a good deal of student discussion and student thinking shown in the scenario.[11]

The open response was scored on a 5-point scale. A “5” is a response that demonstrates a socio-constructivist view of learning that integrates a conceptual understanding of mathematics with these beliefs. Principals in this category consider it the teacher’s job to listen to children’s mathematical ideas, make teaching decisions based upon those ideas, and ask questions or pose tasks that are mathematically specific. They comment on the mathematical appropriateness of the teacher’s instructional moves. The next category, a “4”, is a socio-constructivist view of learning but without reference to subject-specific understanding. This position looks similar to “5” but is generic -- principals do not comment on mathematical appropriateness. A score of “3” is a mixed position. About half of our principals fell into this category. These principals often wrote about the surface features of a standards-based teacher’s pedagogical practice and used language such as “inquiry” and “discovery-based,” but they do not go beyond mentioning such classroom features as group work, discussion, and manipulatives to discuss student ideas. A score of “2” represents responses in which principals see the teacher’s role as setting up situations in which students can discover the skills or ideas important to a given lesson, but there is no attention to student thinking, and listening for students’ ideas is not a method of guiding instruction. A score of “1” represents principals who look for direct instruction and are only focused on what the teacher does, not on student thinking.

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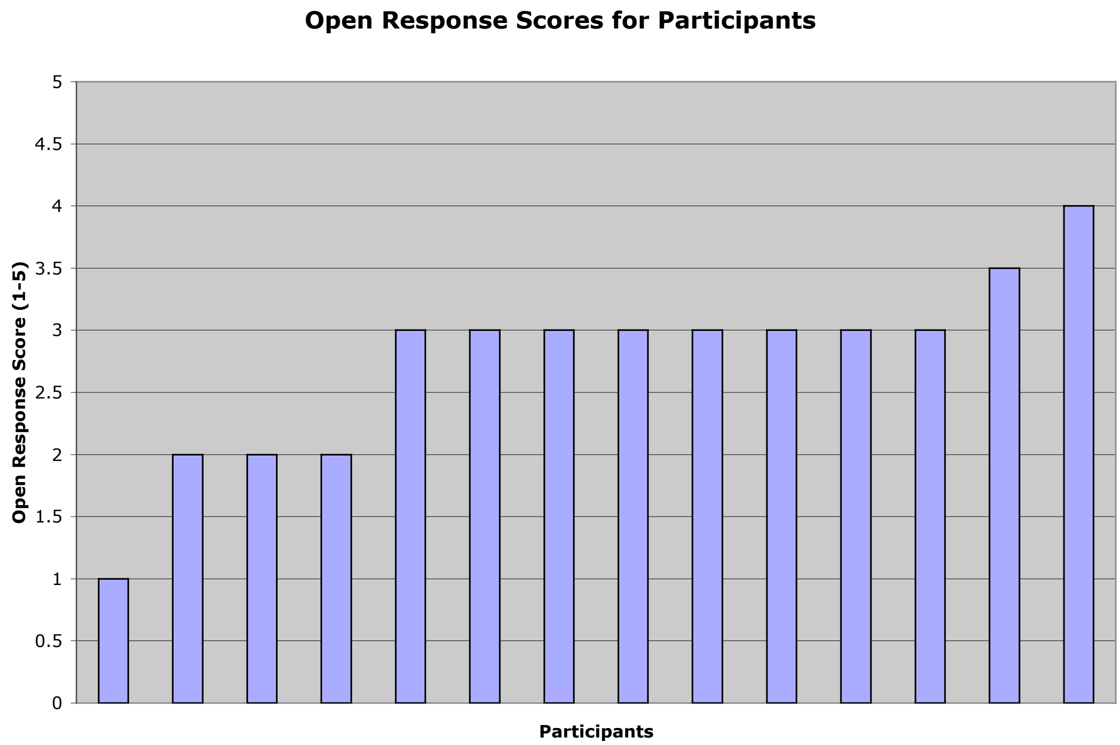
[11] The names of teacher and students, and the names of objects in the mathematics problem have been changed for this paper.

As can be seen on the chart below, most of the principals in our sample were scored as “3” – in the mixed or transitional position. Only one was a four, clearly constructivist. Three were scored as 2’s and one as a 1, advocating direct instruction.



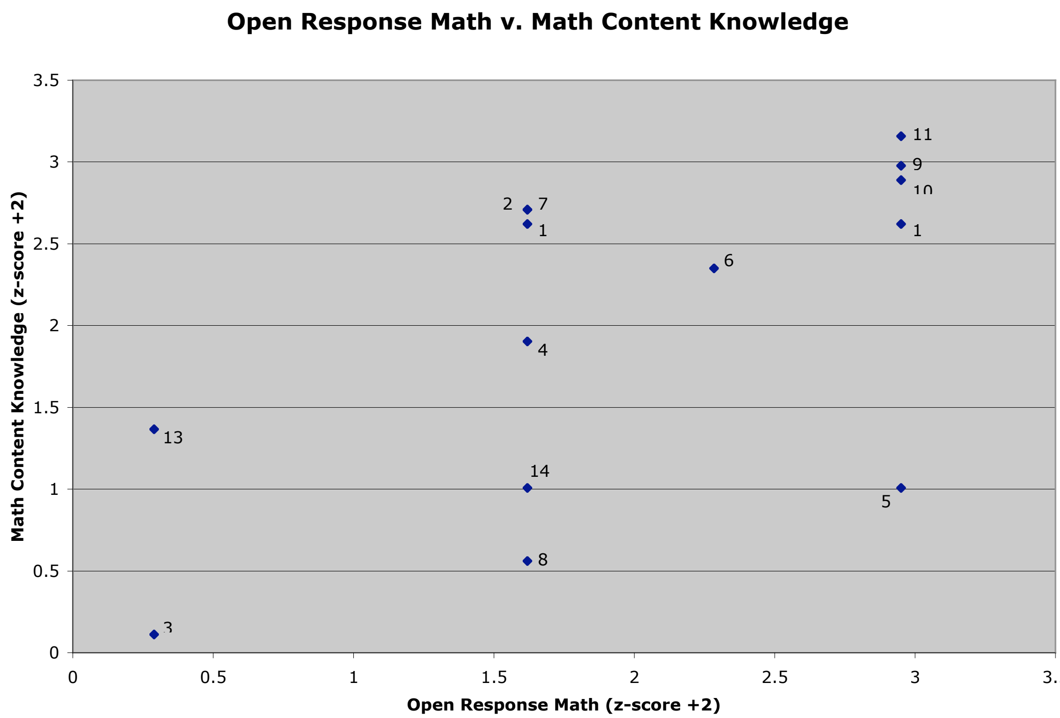
In examining the ways principals wrote about this classroom episode we noticed several markers that distinguished these categories from each other -- how principals dealt with the teacher’s deviation from the planned lesson and how they interpreted any confusion that the students exhibited. Principals with a more constructivist viewpoint were not particularly concerned about the teacher losing the focus of the lesson by following one student’s thinking. These principals were more willing than others to see the teacher’s deviation from the lesson plan as a purposeful and thoughtful choice in response to student thinking and interest. These principals were also more accepting of conceptual confusion in a mathematics classroom. They did not see confusion as something that the teacher was to avoid, but rather something that students could learn from. At the traditional end of the spectrum deviations and student confusion were things to avoid.

Principals' interpretations of deviations and student confusion seem to vary systematically from one category to the next.[12] How principals interpret the function of student confusion and the effects of deviations from the day's lesson plan are areas for us to continue to examine. We would like to see if they hold up as category markers in a larger sample of principals. We also will search for other such markers.

Using one's mathematics knowledge when interpreting classroom scenarios. In addition to the scoring system described above for the open response section of the epistemology assessment, we also looked at participants' open responses in terms of the quality and quantity of observations they made about the mathematical content of the lesson. Participants' responses were again coded on a 5-point scale, with a "5" representing a sophisticated understanding of not only the mathematics involved, but also an understanding of how students were conceptualizing the mathematics. A score of "1" represents a response that did not include any discussion of the mathematics in the classroom episode at all. The graph below plots principals' scores on the mathematics content knowledge instrument on the y-axis and the

[12] The likert item which addressed the topic of confusion had an average score of 4.857 with a standard deviation of 1.703 (the second highest standard deviation of all the likert items)

nature of principals' mathematical comments about the classroom scenario on the x-axis.



In the upper right are four principals (1, 10, 9, 11) with strong mathematics knowledge, as measured on the mathematics content knowledge assessment, who exhibited a more sophisticated understanding of the mathematics in the classroom scenario. However, having a strong mathematics background did not necessarily mean that principals used their math knowledge when looking at the classroom mathematics lesson, as can be seen from participants who scored high on the mathematics content knowledge instrument but were ranked mid-way on the degree to which they commented on the mathematics in the scenario (participants 2, 7, 1). An explanation for this may be found in Ball (2000) who argues that teachers need to know mathematical content in ways that allow them to hear the mathematical meaning when students struggle to explain often half-formed ideas, represent mathematical ideas in many different ways, and think about mathematical content in ways other than their own. The ability to do this rests on the ability to open up their own, adult, mathematical understanding and unpack its constituent elements so that they can recognize the elements of, say division of fractions, in a student's thinking (Cohen, in preparation, as quoted in Ball, 2000). It may be that the principals in our sample whose mathematics content knowledge was strong but who did not seem to use it in interpreting a classroom scenario were not using their mathematics knowledge in this subtle way. Further, these principals may have been trained to do classroom observations in ways that did not entail attending in much detail to the mathematics content of the lesson (Nelson & Sassi, 2000). We speculate that they would have to learn how to use their mathematics knowledge differently in order to integrate it into their observations. This is an area that merits further investigation.

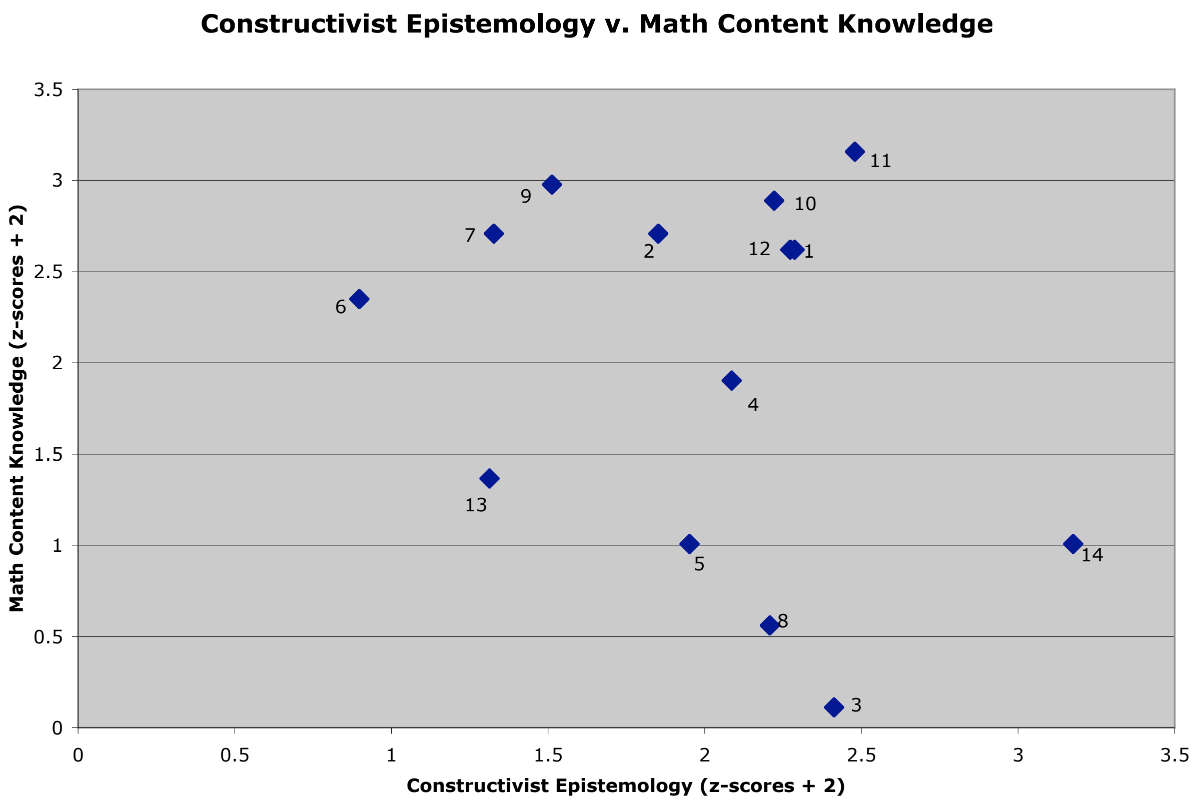
Finally, participants who scored low on the math content portion of the survey (participants 13 & 3) were less likely to have written about the math in their open response (only one principal, number 5, received a low math content score and a high math observation score on the open response). It seems logical that principals with low math content understanding are less likely to see and be able to discuss the mathematics going on in classrooms with specificity, depth and conceptual understanding. Further, an actual misunderstanding of the math, as in the case of participant 13 who thought that division of a smaller whole number by a larger one would lead to a negative number, can throw off the entire observation. He says,

> This is difficult to comment upon depending on Ms. R's goals. If she was intent on just a focus on positive #s, she should not have introduced this

possibility for discussion. If she was looking for students to understand the possibility of negative #s, then it would have been a good teaching move. (*underlines in original)*

Profiles of Leadership Content Knowledge for Mathematics

In this final section of the paper we combine principals' scores on the mathematics content knowledge instrument with their scores on the mathematics epistemology instrument to get a profile of Leadership Content Knowledge for each. The profiles for the entire sample are displayed on the following graph, where mathematics content knowledge is plotted on the y-axis and mathematics epistemology on the x-axis.



There is a good deal of variability in this sample, though we had few principals with extremely traditional epistemology (only 1, #6, was scored "1" on the open response items) and none with an extremely constructivist orientation (no principal was scored "5" and only one was scored "4" on the open response items). Principals' average answers on the likert items tended towards the constructivist viewpoint, ranging from 4.972 to a 6.663 out of 7 possible points. The mathematics content scores varied widely

For the purpose of illuminating the construct of Leadership Content Knowledge, we will examine in some detail four of the principals in this sample, chosen because they provide interestingly different views of the nature of Leadership Content Knowledge. We will look at a principal (14) who had weak mathematics knowledge but was quite constructivist in her orientation toward learning and teaching. We will look at two principals (7 and 9) who had high math content scores and two of the most traditional epistemology scores (second and fourth highest math scores and third and fourth most traditional epistemology). Finally, we will look at one principal (11) who had the highest math content score, and a transitional epistemology score.

As noted earlier, none of the principals in our sample was scored as category 5 in epistemology. which represents a socio-constructivist position with sophisticated understanding of mathematics fully integrated. However, when we were doing validity studies for this research we asked a number of mathematics education experts to take the same instruments, so that we could calibrate the category scheme. Here, offered as a point of reference, is an excerpt from the open response section of the instrument, written by one of these experts.

> I think the teacher was taking advantage of this child's miswording (which might or might not have had as part of it a more conceptual confusion) to look at a form of division not generally taught in fourth grade. If the original problem of [35÷4] had had a word problem as part of it … it would have been natural, and helpful, to ask the children to make up a word problem for [the misworded problem]. If not, then it might have been helpful at this point to … have the children make up word problems for both. … It might be interesting to pair [some of these problems] as a set. Comparing the numeric answers when you switch the dividend and the divisor makes for an interesting pattern, just as switching the subtrahend and minuend does in subtraction.

This mathematics educator is focused on the children's mathematical thinking and is creative at generating mathematics problems that could give the children further opportunity to explore the ideas at hand. Her orientation toward the teacher is that it is the teachers' job to do the kinds of problem generation that she has just done herself. We do not expect that many elementary principals would be in the position to react to this class the way this mathematics educator did, though some might. However, we have included this data so that readers will have a sense of what a category 5 response would be like.

Now to look at the Leadership Content Knowledge profiles of some of the principals in our sample. First we will look at the profile of a principal with low mathematics content knowledge and a quite constructivist orientation toward learning and teaching (number 14).

Low Math Content Knowledge. High Constructivist Epistemology.

Participant 14 has been an urban principal for over ten years, she has a strong professional background. She has attended a number of recent workshops and institutes related to standards-based math curricula and school improvement and accountability. Over the past several years her district has implemented a standards-based math curriculum. She had trigonometry in high school and math for elementary teachers in college. Participant 14 is constructivist in her orientation toward learning and teaching, but low in math knowledge. Her likert score was the highest of all participants (an average of 6.625 out of 7) and her open response was scored as a "4", the highest score any participant received. A score of "4" is a response that demonstrates a socio-constructivist view of teaching and learning but without mathematics specific content. In spite of the mathematics courses she has taken, she answered 56% of the problems on the math content portion of the instrument correctly, which is the third lowest of all participants.

In order to better understand what leadership content knowledge looks like based on this profile, we will examine some of this principal's comments in the open response section. In her open response, she saw the teacher's first move, pointing out Jason's misstatement of the division problem, as an opportunity to probe students' understanding of division. She found value in the teacher's trying to elicit students' thinking and in trying to understand their misconceptions, as when the teacher generalized the topic by asking "Is it true you can't divide a smaller number by a larger one?" Participant 14 wrote in response to this move:

> The teacher was trying to elicit the thinking of the group. She was also challenging the generalization made by Michelle. She didn't say, 'That's wrong'. Instead, she asked a question that made them think.

Participant 14 showed that she values student discussion as a tool for the teacher to elicit information from students and plan her next moves:

> She was probing their current mathematical knowledge. Most of the class, from their answers, thought it was impossible to divide a smaller number by a larger number. By the discourse she was able to discern the confusion and it gave her clues about where to go next with students. … She … can use her next question set to clear up the misunderstanding and teach an important concept in mathematics.

Participant 14 saw the teacher's last move, introducing the idea of dividing one cake among 4 people, as a great way to guide their thinking about dividing a smaller number by a larger number and move them to expand their concept of division to include fractional parts. However, while her response demonstrates an understanding of constructivist learning, her answer does not reflect mathematical subject-specific understanding.

> She was encouraging mathematical discourse to expand her students thinking about the problem. She was guiding them into a different, deeper way to think about the problem. This is a good teaching move. She's created cognitive dissonance. Students can no longer make the generalization, because she's introduced a new way of thinking about the problem.

From a constructivist viewpoint on teaching and learning, a good teacher would challenge generalizations, elicit the thinking of the group, and ask questions that make students think in any subject. While the ideas of constructivism are there for principal 14, they are not specific to the mathematics content of the lesson.

Strong Math Content Knowledge. Traditional Epistemology. Participant 7 was a math specialist in elementary schools for 6 years, has been a principal for over 15 years and has done several recent professional development programs in math. She had high school calculus and a college math survey course in addition to math for educators. She is currently a principal in a small suburban town, which uses both a standards-based math curriculum and a very traditional text. Participant 9 has been a principal for about ten years and currently works in a suburb. He had calculus in high school and college but does not list any recent math professional development. His school uses a standards-based curriculum.

The open response answers these participants wrote were both scored a “2” -- responses that do not show participants listening for student ideas as a method of guiding instruction. Their responses are characteristic of participants in this category in that they are very concerned with the teacher staying with the lesson plan and minimizing student confusion. Participants 7 and 9 start out saying that the teacher was taking advantage of Jason’s comment to broaden the students’ thinking, but go on to say that it was not a good idea because it took the class off track for the day and only confused students more. In response to the teacher’s first move, participant 7 wrote

> [She was] trying to broaden her students’ knowledge and help them see why the problem was read wrong. She also wanted them to think about why these are two different problems. It was a good academic thinking experience however, it veered students off their learning objective for the day and might have confused some students more.

In response to that same move participant 9 wrote:

> I think the teacher was trying to take advantage of Jason’s reversal and make it into a teachable moment. Usually, I believe there is much to gain from doing this—however in this instance—in the middle of a division lesson/activity on division w/reminders it only served <u>to confuse</u> the students and bring them <u>further away from</u> [the] learning goal. *(underlines in original)*

Both of these principals considered the teacher’s last move, presenting the example of the cake, skilled and effective. They would have liked to see her take control of the discussion this way from the beginning. They are both looking for closure to the lesson and trying to see how the teacher frames the issue for the students so that they can understand it. Participant 9, wrote:

> The teacher is making a real life math connection for students here (which I believe is a good teaching move). In fact, this is how I would suggest that the teacher introduce this concept of dividing a small number by a large number. The students' discussion leads me to believe that they didn't think they could wrap their brain around this type of problem- & they'll continue to think so until they hear about 1 cake & 4 people -- something they're probably very familiar with.

Participant 7 wrote:

> She pretty deftly got them to consider a way into discussing parts, wholes, and fractions of things. The last comment brings the students pretty close to disproving the assertion that you can't divide a smaller number by a larger one. Again, was this the time, the place, the lesson in which to explore this unintended concept if today's skill was on dividing larger number by a smaller one, perhaps with remainders? I don't know—what came before, what follows?

While these principals use the phrases "teachable moment", "real life connection", and "broaden… students' knowledge" they do not seem comfortable with the teacher following a student's comment. They are looking for a lesson that shows more teacher control and guidance.

Finally, we examine the profile of a principal (number 11) with strong mathematics but a transitional epistemological position.

Strong Math Content Knowledge, Transitional Epistemology. With the highest math score in this sample (97% correct), Participant 11 had calculus in high school, calculus and statistics in college, and has done a significant amount of recent math professional development. He has been a principal for two years in an urban setting. His district has spent several years implementing a standards-based curriculum. His epistemology score was the second highest in our sample (his average likert score was 6.4 out of 7 and his open response was a 3).

In his open response, participant 11 demonstrates a "3" position. He is supportive of the teacher's encouraging dialogue in the classroom as a way of gathering information from the students, but does not offer a sense of how this information then guides the teacher's decision-making.

> The teacher is calling attention to the misread problem and gathering information from the students on their ability to recognize the difference between [the two equations] and what they are asking. This is a good move as it will result in a good dialogue about the nature of division and the division of part vs. whole.

This principal goes on to compliment the teacher on her excellent teaching move of introducing a real life example at the end of the scenario, the example of the cake. The principal also stresses that the teacher's priority is on student understanding rather than the correct answer alone.

> The latter simpler example was an excellent teaching move and one of the most students had experienced—with [cake]. These 3 opportunities all demonstrate the teacher's priority on understanding division vs. getting 35 ÷ 4 correct".

Participant 11's mathematics knowledge has allowed him to have a quite abstract view of the lesson, noting that it gave the teacher the opportunity to contrast two different equations; that the class could have a good discussion about the nature of division (not just the particular problem at issue); and that one of the examples was mathematically simpler than the other. He exhibits many of the values and beliefs we have associated with a standards-based approach to teaching mathematics. However, he did not take these to the next level (which we saw in Participant 14 who scored a “4”) of seeing how the teachers’ listening to students’ mathematical ideas guides teaching decisions that are designed to push student thinking forward.

These profiles of different kinds of Leadership Content Knowledge give us a glimpse into how principals’ knowledge of mathematics and ideas about mathematics learning and teaching come together to shape how they analyze a classroom scenerio. The lens that each brings to the classroom affects what they see in that class and therefore their interpretation of the teaching and learning that is happening there. Principals’ knowledge of mathematics affects how they see the lesson. Participant 13, for example, misunderstood the mathematics involved in the lesson and this misunderstanding colored his assessment of the rest of the teacher’s moves. Participant 14, using a developed constructivist lens, understood the teacher’s decisions in very different terms from participants 7 and 9, who are more traditional. What principals are attuned to seeing affects what they *do* see, as shown by these examples, in which all principals were looking at the same classroom scenario.

As we continue to develop these ideas and continue this research, hopefully these preliminary sketches will help form a basis upon which to build a deeper understanding of the construct of Leadership Content Knowledge.

Conclusions.

In this paper we have reported on a preliminary analysis from a study of a sample of 14 elementary principals’ leadership content knowledge for mathematics, in which we sought to illuminate the nature of the construct of leadership content knowledge itself. Our sample was too small to make any claims about the nature of leadership content knowledge in the population of principals more generally, though we expect to be able to do so in the future.

Our analysis of the data about these principals' content knowledge in mathematics (as measured by an adaptation of the SII instrument, which measures elementary teachers' mathematics knowledge for teaching from a conceptual point of view) shows that these principals did relatively well on this assessment, with some correlation between being computationally fluent and being able to solve conceptual problems. However, when we analyzed computational and conceptual versions of the same problem, we saw that for many principals in our sample it was likely that they did not have sufficient understanding of number and operations to understand why the standard algorithm worked, and therefore could not work with variants of it in novel problems.

We also analyzed the epistemological beliefs for mathematics among this sample of principals – how they thought children learn mathematics and how they thought it was best taught. This analysis indicated that many of these principals approved of methods of classroom instruction that would support a constructivist view of children's learning, such as group work, discussions, and the use of manipulatives. There was less agreement among our sample of principals about how mathematical concepts are learned and therefore best taught. We speculate that many of these principals are just beginning to develop the deeper understanding of what it means to learn mathematics that would lead them to look beyond the surface features of classrooms to the mathematical thinking that is occurring there. Further, just because principals had strong mathematical content knowledge did not mean that they used it when analyzing the classroom depicted in the scenario (though principals with low math content knowledge were even less likely to look for it or see it in the scenario). Here, we speculate that these principals have not been trained to look carefully at students' mathematical thinking and do not know how to use their mathematics knowledge in this way. Finally, we analyzed the mathematical and epistemological aspects of Leadership Content Knowledge in combination and provided preliminary analyses of four Leadership Content Knowledge profiles to illustrate what different combinations of mathematical and epistemological knowledge on the part of principals look like.

While this was a small and very preliminary study, it has both provided interesting preliminary results and raised a number of important questions for future study. We remain interested in learning more about how these principals (and others) think about mathematics, and are working to see if we can tease out more insight about principals' mathematical thinking from the items on the SII instrument. We would like to know if there are common patterns of conceptual understanding (and misunderstanding) in our sample of principals. We also would like to know if our preliminary findings hold up in studies of larger groups of principals. We are particularly interested in understanding better what is going on with those principals who have strong mathematics knowledge but don't appear to use it when interpreting a classroom scenario depicting mathematics instruction. Nelson and Sassi (in press) have proposed that such principals may not realize that they have to "unpack" their mathematics knowledge into its constituent elements in order to see what teachers and students are doing mathematically. This is a rich question for further study.

We are very interested in the range of epistemological beliefs that the principals in our study exhibited, and especially in teasing out distinctions among the principals in category “3” – those with very mixed views of mathematics learning and teaching. Finally, while we examined four different profiles of Leadership Content Knowledge in order to give a sense for the qualitatively different orientations toward mathematics learning and teaching that different profiles afford, our sample was small and we are not yet in the position to assess how robust those profiles are, how many distinctly different categories of profiles there might be, and the degree to which such Leadership Content Knowledge profiles are correlated with how principals do their administrative work. These issues will be the topic of future studies.

References

Ball, D. L., Hill, H. C., Bass, H. (2002) Developing Measures of Mathematics Knowledge for teaching. Ann Arbor, University of Michigan

Ball, D. L. (2000). Bridging practices: Intertwining content and pedagogy in teaching and learning to teach. Journal of Teacher Education, Vol 51, No. 3, pp 241-247.

Carpenter, T. P., Fennema, E., Peterson, P. L., Chiang, C., & Loef, M. (1989). Using knowledge of children's mathematical thinking in classroom teaching: An experimental study. American Educational Research Journal, 26, 499-532.

Elmore, R. F. (1996). Getting to scale with good educational practice. Harvard Educational Review, 66(1), 1-26.

Fennema, E., Franke, M. L., Carpenter, T. P. & Carey, D. (1993). Using children's mathematical knowledge in instruction. American Educational Research Journal, 30, 555-583

Hallinger, P., Leithwood, K. & Murphy, J. (Eds.) (1993). Cognitive perspectives on educational leadership. New York: Teachers College Press.

Hill, H.C., Schilling, S. G. & Ball, D. L. (2003) Developing Measures of Teachers' Content Knowledge for Teaching. Ann Arbor, University of Michigan.

Ma, Liping (1999) Knowing and Teaching Elementary Mathematics: Profound Understanding of Fundamental Mathematics in China and the United States. Lawrence Erlbaum Assoc.

Murphy, J. (1999). Reconnecting teaching and school administration: A call for a unified profession. Paper presented at the annual meeting of the American Educational Research Association, Montreal, Canada, April 1999.

National Council of Teachers of Mathematics. (1989). Curriculum and evaluation standards for school mathematics. Reston, VA: Authors.

National Council of Teachers of Mathematics. (1991). Professional standards for teaching mathematics. Reston, VA: Authors.

National Council of Teachers of Mathematics, (2000). Principles and standards for school mathematics. Reston, VA: Authors.

Nelson, B. S., (1999). Building new knowledge by thinking: How administrators can learn what they need to know about mathematics education reform. Newton, MA: Center for the Development of Teaching, Education Development Center.

Nelson, B. S. & Sassi, A. (in press). Instructional Leadership in Flux: How elementary principals' ideas about mathematics, learning, and teaching affect their practice. New York, NY: Teachers College Press.

Nelson, B. S. & Sassi, A. (2000a). Linking ideas to practice: How administrators connect new ideas about learning, teaching, and mathematics to the actions and decisions that constitute administrative practice. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Nelson, B. S. & Sassi, A. (2000b). Shifting approaches to supervision: The case of mathematics supervision. *Education Administration Quarterly,* 36(4). 553-583

Rowan, B. (1995). Learning, teaching, and educational administration: Toward a research agenda. Educational Administration Quarterly 31(3) 344-354.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher

Silver, E. A., Smith, M. S. & George, E. A., (in press). An analysis of key facets of one urban middle school's success in enhancing the quality of mathematics teaching and learning: Resource availability, resource utilization, and trouble shooting.

Spillane, J. (2000). Cognition and policy implementation: District policymakers and the reform of mathematics education. Cognition and Instruction 18(2), 141-179.

Spillane, J. P & Halverson, R. (1998). Local policy-makers' understandings of the mathematics reforms: Alignment and the progress of the mathematics reforms. Paper presented at the annual meeting of the American Educational Research Association. San Diego, CA.

Stein, M. K. & D'Amico, L. (2000). How subjects matter in school leadership. Paper presented at the Annual meeting of the American Educational Research Association, New Orleans, April 2000.

Stein, M. K. & Lane, S. (1996). Instructional tasks and the development of student capacity to think and reason: An analysis of the relationship between teaching and learning in a reform mathematics project. Educational Research and Evaluation, 2 (1), 50 – 80.

Stein, M. K. & Nelson, B. S. (in press). Leadership Content Knowledge. Educational Evaulation and Policy Analysis XXXXXXX