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ABSTRACT

This study was conducted to examine teachers' knowledge of teaching mathematics and writing to diverse learners, and knowledge changes that occur over time, particularly during and after formal teacher education programs. Commonplaces of teaching were articulated as subject matter, learners, learning, and context. Three measurement instruments were designed: (1) a self-administered questionnaire which explores teachers' beliefs about the commonplaces of teaching as well as procedural and propositional knowledge of mathematics and writing; (2) a structured interview built around scenarios describing various classroom situations; and (3) an observation guide to collect information on teachers' knowledge and dispositions to act in particular situations. Records of teachers' responses were recorded at three points: prior to entering a formal education program; at graduation; and at 1 year following graduation. Results of the study point out shortcomings of the research approach, particularly with respect to the thinness of data for the kinds of descriptive profiles of learners originally envisioned. The problems seem to point less to the conceptual framework of teacher reasoning and more to flaws in the research design and instruments.
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NCRTE

National Center for Research on Teacher Education

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THE TEACHER EDUCATION AND LEARNING TO TEACH STUDY: AN OCCASION FOR DEVELOPING A CONCEPTION OF TEACHER KNOWLEDGE

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National Center for Research on Teacher Learning

The National Center for Research on Teacher Learning (NCRTL)[1] was founded at Michigan State University in 1985 with a grant from the Office of Educational Research and Improvement, U.S. Department of Education.

The NCRTL is committed to research that will contribute to the improvement of teacher education and teacher learning. To further its mission, the NCRTL publishes research reports, issue papers, technical series, conference proceedings, and special reports on contemporary issues in teacher education. For more information about the NCRTL or to be placed on its mailing list, please write to the Editor, National Center for Research on Teacher Learning, 116 Erickson Hall, Michigan State University, East Lansing, Michigan 48824-1034.

Many papers published by the NCRTL are based on the Teacher Education and Learning to Teach Study (TELT), a single multisite longitudinal study. The researchers who have contributed to this study are listed below:

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[1]Formerly known as the National Center for Research on Teacher Education (1985-1990), the Center was renamed in 1991.

Abstract

How does teachers' knowledge of teaching mathematics and writing to diverse learners change over time, particularly during and after formal teacher education programs? To address this question, researchers at the National Center for Research on Teacher Education (NCRTE) had, first, to develop and articulate a conception of teacher knowledge and, subsequently, devise ways of tapping such knowledge.

Recognizing that knowledge of what Schwab called the "commonplaces of teaching"—subject matter, learners, learning, and context—is a static formulation, the authors argue that the core activity of teaching and, hence, the proper object of study is pedagogical reasoning. In thinking about a specific activity or task, such as planning or responding to pupils' questions, teachers weave together their understandings of the various commonplaces in figuring out what is going on and what they should do. To track changes in teachers' knowledge involves examining changes in both how their understandings of the individual commonplaces change and how they bring these together in responding to instructional situations.

Using this framework for teachers' knowledge, NCRTE researchers developed three types of instruments: a self-administered questionnaire, a structured interview, and an observation guide. The instruments are distinctive because the teaching and learning of mathematics and writing are the context for most items. Using subject matter as context derives from the premise that teaching means teaching *something* to someone. The questionnaire, consisting principally of conventional Likert-scale and forced-choice items, is designed to tap teachers' beliefs about the commonplaces as well as their procedural and propositional knowledge of mathematics and writing. Scenarios built around tasks teachers commonly undertake in their mathematics and writing classes—such as responding to pupils' novel ideas, writing, and seatwork—constitute the interview. By examining how teachers respond to various scenarios across the entire interview as well as across time allows the researchers to discern patterns in teachers' reasoning and how these do or don't change over time. The observation, finally, is intended to collect information on aspects of teachers' knowledge to which the questionnaire and interview are not particularly sensitive: teachers' dispositions to act in particular situations such as ways of treating differences among learners and how they manage to "pull it all together" in the classroom.

The authors point out the shortcomings of their approach: the thinness of their data for the kinds of rich descriptive profiles of learners originally envisioned as a primary product; the struggle to develop credible ways of tapping participants' views of differences and the role of such differences in teaching and learning; the strictures imposed by the longitudinal design; and the difficulties of untangling the individual strands of teachers' understandings, given the intertwined, confounded nature of teacher reasoning. These shortcomings seem to point less to problems with their conceptual framework of teaching reasoning and more to flaws in the research design and instruments.

THE TEACHER EDUCATION AND LEARNING TO TEACH STUDY: AN OCCASION FOR DEVELOPING A CONCEPTION OF TEACHER KNOWLEDGE

G. Williamson McDiarmid and Deborah Loewenberg Ball[1]

In 1986, researchers at the National Center for Research on Teacher Education (NCRTE) embarked on a new research agenda: to investigate the relative impact of different approaches to teacher education on teachers' knowledge, skills, and dispositions. In preparation for this ambitious investigation, the research staff faced the task of devising ways to track changes in teachers.[2] Conceptualizing and developing instruments was difficult because experts do not agree about what teachers need to know and, thus, about what should be the focus of instruments designed to track teacher change. Some argue that teachers should learn a set of routines and skills applicable in just about any situation, irrespective of the subject matter or the learners' backgrounds. Others contend that teachers need to understand a particular theory of learning. Still others insist that teachers need to know the values, normative social behaviors, and preferred communication styles of the pupils they teach. And some feel a good liberal arts education is really all teachers need.

The particular challenge for the NCRTE researchers was to devise instruments that would track changes in teachers along a wide range of dimensions of teacher knowledge and also be sensitive to a wide variety of conceptions of what teachers need to know. This was critically important for the Center's research because the teacher education programs chosen for the Teacher Education and Learning to Teach Study were selected precisely on the basis of their differences. The programs represented varied perspectives on what teachers need to know and how they can learn those things. For instance, one of the programs immersed students in process-product research on teaching. Another required all students to take a three-course sequence in mathematics to ensure that the students themselves have a good grasp of the ideas and concepts that underlie the mathematical procedures that constitute the conventional curriculum. A third focused on teachers' ideas about how pupils make sense of mathematics.

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[2]For a fuller and more detailed description of the Teacher Education and Learning to Teach (TELT) Study of the National Center for Research on Teacher Education, see NCRTE, 1988.

Regardless of one's view of what teachers need to know, all conceptions of teaching include teaching *something* to someone. The Teacher Education and Learning to Teach Study focused on learning to teach academic subject matter to diverse learners, and, in order to make the study design as sharp as possible, we chose mathematics and writing as the particular academic subject matter on which we would focus. We reasoned that these subjects were taught throughout the K-12 curriculum and were often difficult for pupils. Modal instructional practice in these subjects, moreover, frequently differs from that suggested by recent research. Thus, we speculated, these were subjects on which teacher education might aim to have an effect. By selecting specific subject areas, we were also able to create focused questions that would enable us to examine and track changes in teachers' ideas and ways of thinking.

As a consequence, a central focus of the Teacher Education and Learning to Teach Study has been prospective and practicing teachers' understanding of the subject matter they teach. This does not mean, however, that we assumed that a thorough grounding in subject matter is, in and of itself, sufficient for teaching mathematics and writing. Rather, we took the position that teachers cannot teach what they themselves do not know and understand.

Dimensions of Teachers' Knowledge

Because we were interested in teachers' knowledge and how that knowledge changes while and after they are involved in formal teacher education programs, we needed to articulate a conception of such knowledge to guide our instruments and data collection. What are the ingredients of teacher knowledge? The conceptual framework that we developed to guide our inquiry was constructed around Schwab's (1973/1978b) four commonplaces of teaching: subject matter, teachers, learners, and milieu.

What aspects of *subject matter* figure in teacher knowledge? Knowledge of subject matter includes not only the ideas, theories, and frameworks of a field but also the ways of knowing that are characteristic of that field: understanding how knowledge is discovered, organized, and tested, major debates in the field, the principal perspectives or "schools" in the field, how the field has developed over time, and who has contributed to its development. Examples of the knowledge of subject matter, which we term "substantive knowledge" of a field, include area and perimeter in mathematics, the causes of the Civil War and the responsibilities of local government in social studies, and ways of organizing ideas in writing. Examples of knowledge of the "syntax" of a discipline (Schwab, 1961/1978a) include, in history, appreciating how different interpretations of the same event can be made and supported, or, in mathematics, testing the viability of a conjecture. While

substantive knowledge of subject matter is considered adequate according to some views of teaching, other views of teaching emphasize the importance of the syntactic aspects of subject matter. Knowledge of subject matter also includes knowledge of the school curriculum: Conventionally, when—that is, at what grade level and in what sequence—are various ideas, topics, propositions, and procedures in a given field taught?

Ideas about *learners* constitute another dimension of teachers' knowledge. In organizing learning activities, teachers can cast learners in a variety of roles from passive recipients to active collaborators and various shades in between. As learners differ along a variety of dimensions—cultural and linguistic background, prior performance and experience in and out of school, individual preferences and proclivities, and so on—teachers identify those differences they believe salient and respond to them. Teachers may respond to differences in prior performance, for instance, by ability grouping or they may respond to differences in individual proclivities by individualizing learning opportunities.

Closely related to their understandings of learners are teachers' understandings of how *learning* occurs. Teachers may believe that pupils learn by accumulating information until they achieve understanding. Or they may believe that every child learns differently and, therefore, requires individualized instructional programs. Or they may believe that pupils make sense of new information or ideas on the basis of their prior understandings and that others in their environment play critical roles in this process. The reciprocal of ideas about learning is ideas about teaching—that is, their understandings of what teachers do to foster learning. Those who understand learning as an accumulation of information view teaching as ensuring that pupils learn the necessary information. Those who believe every child learns differently view their role as identifying pupils' preferred "learning modality" and managing their individual learning program accordingly. Those who understand learning as a process of making meaning based on prior understandings in cooperation with others view teaching as challenging pupils to examine and refine their prior understandings as they wrestle, in the company of peers, with problems, information, and ideas.

Teachers' knowledge includes, finally, understandings of the role of the social and cultural *context* of the classroom and community. Teachers may approve of the values fostered in most classrooms—self-denial, patience, obedience, and so on (Jackson, 1968). Teachers may try to foster other values in their classrooms. They may, for instance, attempt to change the relationships of power in the classroom by orchestrating instruction so that pupils, as a group, have the experience of deciding, in examining a problem or question, what are and aren't sensible solutions or ideas instead of relying solely on the teacher and

the textbook. In such a context, the understandings pupils develop of the content, themselves as learners, and the role that others can play in learning differ from the understandings pupils develop in classrooms in which children, working mostly alone, are enjoined to be quiet unless called upon and to remember and reproduce the information presented in textbooks and workbooks.

These dimensions of teachers' knowledge, then, provided a framework for assessing teachers' knowledge. We wanted to sample teachers' knowledge and understandings within each of these domains—and to gauge how these change over time. We know that teachers do not usually consider each of these dimensions—or "commonplaces of teaching" as Schwab (1973/1978b) called them—in a serial or linear fashion. The very flatness of the language that we and others use in discussing teachers' knowledge belies and misrepresents the dynamism of the process of thinking and reasoning.

As teachers consider any one dimension, they do so in the context of other dimensions (Kerr, 1981). Hence, thinking about useful ways to represent operations with negative numbers is not merely a matter of understanding the content and its embodiment in the school curriculum but also involves considering who the students are, what kinds of problems the content is likely to pose for them, and what role the teacher will play in pupils' encounters with the content. Teachers' understandings, like everyone's, develop unevenly. Understandings of cognitive processes may develop well in advance of understandings of learners themselves: What interests third graders? When and why do antipathies between boys and girls develop and how do you deal with them in the classroom? How much and what kind of homework is appropriate for fifth graders in mathematics? Prospective teachers who may possess a sophisticated understanding of the differences between Skinner and Piaget may be baffled by these and many other questions about learners.

Pedagogical Reasoning: The Focus of Study

As teachers' consideration of the commonplaces of teaching is dynamic and contextualized and develops unevenly, we attempted to gauge not merely teachers' knowledge of each of the dimensions but their capacity for balancing and accommodating the various considerations. While we were interested in what teachers know and understand about the content they teach, our focus was on how teachers call on that knowledge and weave together the various threads of their thinking—their subject matter understandings with their knowledge of learners, learning, and the context. This reasoning process occurs around specific instructional situations in which teachers perform certain pedagogical

activities or tasks. This pedagogical reasoning process thus was the focus of our interview protocols.

At the same time, we wanted to be able to measure change in prospective and practicing teachers' beliefs about and understandings of the individual commonplaces: subject matter, learners, learning and teaching, and context. This was important because knowing something of their knowledge and understandings of each of these in and of itself would help us understand the differences we found among teachers. The self-administered questionnaire was designed to register changes in understanding of the individual dimensions of teachers' knowledge. Our intention was to use the data that we collected on the questionnaire to help understand what we got from the interviews—and vice versa.

Studying Pedagogical Reasoning: Conceptual Frame

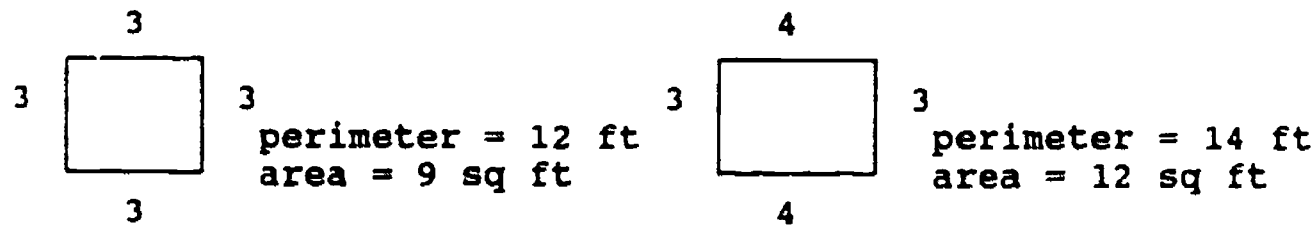
How, then, does pedagogical reasoning manifest itself so that we can tap it? Where do we look for evidence of teachers' pedagogical reasoning? All teachers, regardless of their pedagogical purposes, undertake certain instructional tasks such as planning lessons and instructional units, responding to pupils' written work, asking questions, responding to pupils' questions and assertions, selecting and adapting curricular materials, and so on. In carrying out any of these tasks, teachers act on certain considerations—of their role and responsibilities, the content, learning, learners, and the context. These considerations and the decisions teachers reach reflect their knowledge and assumptions as well as the relative emphases that they give to different concerns.

For instance, in planning a mathematics activity, a teacher may consider what is to be learned about the mathematics (content), how the topic articulates with previous and future topics (content and curriculum), what she wants her students to learn about the mathematics being presented (learning and content), how appropriate the activity is for her particular group of pupils (learners), the kinds of problems they are likely to encounter in the activity (content, learning, and learners), and how she will find out what her pupils do and don't understand (learning and pedagogy). The plan she generates embodies her idea of her role and responsibility as well as her notions about the moral and political context. A teacher could, for instance, allow her pupils to determine the length of time spent on the activity or she could determine this herself ahead of time. She could choose an activity and organize it in such a way that most interactions occur between her and her pupils. Different understandings of learning, the teacher's and the pupils' roles, and the moral and political context would produce an activity organized to promote interactions *among* pupils around the content.

To gain some understanding of teachers' pedagogical reasoning requires that one observe teachers as they carry out instructional tasks. Watching a teacher engage, define, and manage these various tasks of teaching provides a window onto the teacher's pedagogical reasoning. By observing a teacher across a number of tasks, one may be able to see a pattern in her reasoning (Wilson, 1988) as well as to develop a partial inventory of the understandings and assumptions that underlie her actions. In explaining why they do what they do, teachers reveal which considerations come into play in any particular activity or decision—as well as their understandings of these considerations and their relative salience (Ball, 1988).

Normally, teachers do not provide a running commentary on their actions. Researchers on teachers' thinking often have to rely on commentaries that teachers provide after the fact (Clark & Yinger, 1979). Teachers asked to explain past actions do so in light of present understandings. Their explanations tend, consequently, to reflect not so much their thinking at the time but rather the understandings they have reached subsequently. And hindsight, as the saying goes, is always 20-20.

While fraught with problems of its own, an approach we adopted in attempting to examine teachers' pedagogical reasoning was to interview teachers about scenarios that describe typical teaching tasks. For instance, we asked those in our sample how they would respond to a student who came up with a hypothesis about the relationship between the area and perimeter of a closed figure:

> Imagine that one of your students comes to class very excited. She tells you that she has figured out a theory that you never told the class. She explains that she has discovered that as the perimeter of a closed figure increases, the area also increases. She shows you this picture to prove what she is doing:
>
> 
>
>
> How would you respond to this student?

In responding to this scenario, prospective and practicing teachers attend to various aspects of the situation. Here are what three first-year teachers, completing an induction program in our sample, chose to address:

Teacher #1: I would be positive about it, you know, have her explain what she's found because that's what's neat about math . . . is finally saying, "Hey, this looks like it works." I'd encourage it. I wouldn't say, "Oh, you're absolutely right" . . . unless I was sure it was a theory.

Teacher #2: The thing is, if I was going to be teaching about perimeter and area, I would look it up before. So, let's say I hadn't, for some strange reason. I guess I would say, you know, I need to look up how you would find out perimeter and area before I could answer that question.

Teacher #3: Well, I would probably give her a lot of encouragement that she was coming up with independent sorts of ideas and approaches to this kind of problem solving to math and encourage her to try and test it in as many ways as possible with many different types of figures, to maybe even take it over into some other form or something and try to show why she thought it held.

Teacher #1 addresses the pupil's effort. Because she herself seems unsure whether or not the pupil's conjecture is correct, her response is confined to encouraging this kind of behavior. At the same time, she also wishes to convey a positive view of mathematics. Teacher #2, like Teacher #1, doesn't seem to know whether or not the pupil's idea is accurate. She is preoccupied, however, with her own lack of knowledge, not with encouraging pupils to venture hypotheses. In both instances, these teachers' responses are circumscribed by their limited understanding of mathematics—both in general and this specific issue.

Teacher #3, like Teacher #1, is inclined to encourage pupils to think independently about the content. This teacher's understanding of mathematics, appears to be, however, qualitatively different from that of the other two. Notice that her response is to "encourage her to try and test it in as many ways as possible with many different types of figures." Teacher #3 appears to attend immediately to the issue of proof in mathematics, to the pupil's apparent assumption that one example would "prove" her conjecture. Teacher #3 reveals a sophisticated notion of what constitutes understanding in proposing that the pupil write a justification for her conjecture. This suggests that the teacher realizes that a measure of genuine understanding is the capacity to represent an idea or relationship in more than one way.

Finally, Teacher #3 is inclined to encourage the pupil to determine for herself the validity of her idea. Some teachers in our sample suggested this because they had no idea about the soundness of the pupil's conjecture. In this case, other evidence suggests that this teacher's notion about how pupils learn and about the importance of pupils deciding for themselves the correctness of their responses predispose the teacher to encourage pupils to test

their ideas. That she is inclined to promote such testing further suggests something about the teacher's understanding of the nature of mathematics as a field of inquiry: Mathematics is a subject in which students can decide for themselves what does and doesn't make sense.

As these examples illustrate, responses to the scenarios allow us to see to what teachers attend. Their inclination to attend to different features of a scenario are, in turn, strongly influenced by their knowledge and understandings of the subject matter, learners, learning, their role and responsibilities, and the context. Looking at teachers' responses to a variety of scenarios across the interview enables us to search for patterns in their reasoning. Teacher #1, for instance, appears to attend principally to pupils' emotional responses and rarely to pupils' subject matter understandings. This is evident in her response to another scenario in the interview describing three first graders and the individual tasks they have been assigned. The tasks represent quite different opportunities to learn: Vikki is matching geometric shapes, James is tracing letters, and Brian is dictating a story into a tape recorder to be played back to the whole class. Asked how she thought the first-grade teacher in the scenario was responding to differences, Teacher #1 replied:

> I think individualizing work is okay, but you need to think about how kids react. Like the shy girl, she might always be shy because she's always working by herself and if you can encourage her to work with other kids . . . sometimes it's intuition about a child, or just maybe trying something and if it didn't work you could try something else.
>
> I would make sure that [Brian wanted to dictate his story], maybe give the responsibility to him to explain what he thought the book was about and then have him play it to the class so there's no forcing him to do it. I think with James, the one that's really active, I know that this is something I know pretty well, not calling attention to him. I did it a lot of times and it doesn't help. Maybe more nonverbal communication or writing him a note that says he's doing really well. Like she says, "I like the way James is working quietly today." That's positive but she's addressing it out loud to the whole class and it singles him out as, you know, "You're usually noisy and today. . . ." I did it [i.e., corrected pupils' behavior in front of the class] (laughing) and . . . what I've seen is it makes it worse. The rowdy child has always attention called to him. Maybe he wants attention but the only way he's gotten it has been by being rude and it's negative attention but he's still getting attention. You've got to at least try different ways to approach him.

Compare this to Teacher #3's response to the same scenario:

> It seems to me that in a lot of ways she's exacerbating the differences in the particular problems that these students have. . . . For one thing, Vikki, a lot of

her problem is being shy and not having social skills and not knowing how to relate to other students and for her to sit there by herself working on anything, I don't see that as a real valuable. I mean she can learn the skills but she lacks these other communication skills that would help her a lot. I think that she'd be better off in a small *group* working on geometric patterns where they can talk about what they're doing and they can help each other and she can contribute, maybe, if she's good at that, and apparently she is because she keeps adding more challenging shapes for her to do. She could help other students with that particular content area while helping herself with confidence and with social interaction.

Brian is competitive and so she has him, by himself, producing a product that's going to be presented to the other students for judging, basically, and in a natural way it will be judged, whereas I think that he would be better off in some cooperative team effort where he learns how to.... Although some of the sports involves teamwork I think that in *academics* he would be better off in a situation where he's working with other students doing maybe even the same project but something where he's giving. And the fact that his father moves often would probably be indicative that he would have a hard time with social skills and with cooperation with other kids.

And then James: She's kind of bouncing him around to keep him away from other students because she sees him as disrupting. He's trying to make some connection. His disruption is trying to make some interaction with other students and so she just isolates him, which isn't going to help him develop social skills either. And she's giving him some sort of mechanical task, which is going to disenchant him with the education process and the school and not teach him anything about interacting with other children. And her sort of comments there are just sort of automatic, knee-jerk comments that I don't see will have a really big effect on him because what he's doing doesn't have any inherent reward. And then—"Don't lean back on your chair, James." I hate that. I'm always getting after my own kids for leaning back in their chairs and now I realize I do that myself too.

As we saw in her response to the perimeter-area question, Teacher #3 attends not merely to the social and emotional dimensions of tasks but to their intellectual content and potential for stimulating further learning as well. She recognizes the relative vacuity of the tasks that the teacher has assigned Vikki and James and understands the potential impact of such "busy work": "She's giving him some sort of mechanical task, which is going to disenchant him with the education process and the school." Attending almost exclusively to the behavioral management issues raised in the scenario, Teacher #1 seems oblivious to the differences in opportunity to learn each of the tasks offers.

Over several items of this type, patterns emerge that indicate not only what teachers consider in reasoning about instructional tasks but the relative emphasis they place on different considerations and how they fold in these various considerations in their reasoning. A major limitation is, of course, that teachers are telling us hypothetically what they would do in a given situation; we are not observing them in these situations, doing the tasks we set for them in the scenarios. While Teacher #3 told us that she would have the student in the perimeter-area scenario try out her idea on several other geometric shapes, we do not know what she would actually do when faced with a similar situation in her classroom. As part of the TELT Study, we did observe the focal teachers in their classrooms. We saw, however, most teachers no more than once or twice, leaving us at the mercy of what the teacher happened to be doing on those occasions.

Studying Changes in Teachers' Pedagogical Reasoning Over Time

Overview of the Instruments

Tracking changes in teachers' pedagogical reasoning over time is a distinguishing feature of the TELT Study. We designed our instruments so that we could detect changes in practicing and prospective teachers' knowledge within individual dimensions and in the way they bring together their knowledge in responding to a specific instructional situation. This approach allows us to examine the relationship between changes in teachers' knowledge along a specific dimension—say, knowledge of subject matter—and their capacity to respond to instructional tasks.

To collect information on teachers' knowledge, we used three instruments: a self-administered questionnaire, a highly structured interview developed around instructional scenarios, and an observational guide. The questionnaire is our means for registering teachers' beliefs and understandings of the various commonplaces of teaching as well as their propositional and procedural knowledge of math and writing. For instance, we ask teachers what they think "being good" at math and writing means. Their responses help us understand what they think is the nature—or "essence"—of mathematics and writing. A person who thinks that "being good" at math means remembering formulas and procedures probably has a quite different view of the nature of mathematics—and of teaching and learning mathematics—than does someone who thinks that "being good" at math means being able to think flexibly.

We also include subject matter knowledge items to find out about their own substantive understandings of topics in math and writing. We ask them, for instance, to compare two

pieces of student writing and identify the criteria they use in evaluating writing. In math, we ask them, for example, to identify appropriate representations for a numerical expression.

Our second instrument for recording teacher knowledge—and the one described most fully in this article—is a structured interview. After a series of questions in which we ask teachers and prospective teachers about their experiences as learners of math and writing, we present them with a series of scenarios that describe typical instructional situations. We developed these scenarios around common teaching tasks such as deciding what to teach, responding to student errors, and determining what students have learned. In responding to these scenarios, teachers reveal how they weigh and blend their knowledge and understandings of the various dimensions of knowledge. One of the questions that follows these scenarios asks practicing and prospective teachers what they would do in the situation; we thereby get a glimpse of their dispositions—that is, how they are inclined to act in circumstances common to classrooms.

Finally, we observe the teachers teaching. Our observation is designed to gather information on areas of knowledge that neither the questionnaire nor the interview can capture. In seeing how they actually carry out teaching tasks, we can find out more about their dispositions. From interviews that precede and follow the observation as well as from the observation itself, we collect data on how teachers deal with learner diversity, represent the subject matters they teach, construe their role and that of their pupils in learning, and find out what students have learned.

Selecting Topics for Subject Matter Items

In developing items for both the questionnaire and the interview, we constructed, in cooperation with both university-based subject matter experts and practicing teachers, a list of topics in mathematics and writing. We used five criteria to guide our choice of topics. Reasoning that teachers need to be particularly well prepared for those topics that frequently prove difficult for students to understand, we chose topics of this type. Mathematics topics that met this criterion include subtraction with regrouping, ratio and proportion, fractions, and slope. In writing, topics that are perennially difficult for pupils include organizing a piece of writing, the use of apostrophes, subject-verb agreement, and revision.

Second, we chose topics that are often taught algorithmically but whose conceptual underpinnings are essential to genuine understanding. For example, subtraction with regrouping can be taught as a set of steps ("3 take away 5, can't do it, cross off the 6, put a 5 . . .") or as an operation that involves thinking about the place value of the numbers involved. While the first approach suggests helping pupils remember to keep the numbers "lined up," the

second could involve pupils in figuring out different ways to represent numbers with bundles of popsicle sticks or a number of coins.

The need to create instruments sensitive to changes across competing views of quality mathematics and writing instruction suggested a third criterion for topics: The topics should allow us to identify participants' views of good teaching and to detect changes over time in their orientations to teaching these subjects. Division, solving equations, and problem solving are examples of such areas; almost all of the other mathematics topics satisfy this criterion as well. In writing, topics we selected include organizing for writing, reporting direct speech, and criteria for judging written products.

A fourth criterion was that topics selected should, as much as possible, be ones that spiral through the K-12 curriculum and be critical at many grade levels. This criterion would help ensure that they would be important topics for all teachers to understand and be able to teach. Among the topics we have selected in mathematics are fractions and decimals, ratio and proportion, and geometry; in writing we included complete sentences, subject-verb agreement, and organization. These topics figure prominently in the elementary and secondary curriculum.

A final criterion, closely related to the third, was that the selected topics should reflect ideas that are central to both the substance and the syntax of each discipline (Schwab, 1961/1978a). Underlying this criterion is the idea that teachers' curricular decisions are based on their ideas about fundamental structures of the subject matter (McDiarmid, Ball, & Anderson, 1989). Teachers, when teaching students to write, make assumptions about differences between narrative and expository text; they have ideas about the purposes each genre serves as well as the textual conventions that characterize each. Mathematics teachers' responses to students are grounded not only in their understandings of the particular topic at hand but also in their ideas about what constitutes proof, about what the purposes and nature of mathematical activity and discourse are.

These criteria guided us in making sensible choices from the many topics within each subject matter. We also chose topics that satisfy more than one criterion. We developed some items to measure mathematics and writing knowledge that could be used with both elementary and secondary teachers and prospective teachers. This would allow us to compare the understandings of teachers at these two levels. In addition, some items were geared specifically to secondary teachers to allow us to examine these teachers' understanding of topics typically found in the high school mathematics and composition curricula.

Data Collecti .1 Strategies: Strengths and Weaknesses

Each of three data collection strategies—observations, interviews, and questionnaires—on which we relied has its own strengths and weaknesses. Using the three data collection approaches in concert was intended to compensate for the weaknesses of each.

Classroom observations enable us to learn what teachers or prospective teachers are able and inclined to do in the context of actual classrooms. We are, of course, limited by what we happen to see. We may observe an elementary teacher reviewing grammar, or we may see him launching his pupils into a writing project. We may see a high school geometry teacher going over a proof, or we may see her seize a teachable moment to connect algebra to fundamental ideas in calculus. To generalize about teachers' capabilities and dispositions from limited observations is problematic.

Too, some important tasks of teaching cannot be observed. For example, we are interested in how teachers and prospective teachers plan, make curricular decisions, and appraise student work. We must probe teacher thinking about such tasks, for these are areas in which important changes may occur over time and in which differences among participants in various programs may appear. Classroom observations, at the same time, provide unique opportunities. They are the primary method by which we can gather data on teachers' skills, and the only way to see how teachers "pull it all together" in actual teaching.

A **questionnaire** presents all respondents with identical items and options affording a high level of control and facilitating comparisons. The closed-ended format of questionnaires does, however, restrict respondents' latitude for expressing their ideas. Making inferences from the data can be problematic, however, for what respondents mean by their answers is sometimes difficult to determine. For example, an "agree-disagree" Likert item on a pilot questionnaire stated, "I have always been anxious about mathematics in school." During a follow-up interview with a mathematics major who had agreed with the statement, the respondent explained that he had always been *eager* to go to math class. The pilot testing helped us discover words and phrases that have unanticipated connotations, and in subsequent revisions, we replaced such terms. This does not, however, eliminate the inherent ambiguity of questionnaire responses.

Another limitation of Likert-scale items is the ambiguity of midscale responses. A respondent choosing the midpoint on the scale may mean any of the following: (1) "I don't know what I think," (2) "I have no opinion," or (3) "This is a very complicated matter and depends on the circumstances." Given our interest in teacher learning, the difference is critical between not knowing, having no particular opinion, and interpreting a statement as highly

complex. Such differences may indicate important developmental variation or program differences or both.

Yet a questionnaire has many advantages as well. It can be used to gather data from all participants. Furthermore, it can be administered to a large number of students and teachers, and thus enables us to obtain more stable estimates of population differences (e.g., between preservice and experienced teachers or between teacher education and liberal arts students). The most controlled method of collecting data, questionnaires present all respondents at all points in time with identical questions.

Interviews offer some of the advantages of questionnaires (e.g., standardization) as well as some of the advantages of observation (e.g., seeing how teachers integrate different kinds of knowledge and skill together with dispositions). However, while we can simulate actual teaching situations in an interview, such inquiry remains hypothetical. We do not learn whether respondents are actually inclined to do what they describe, nor how competently they could carry out their plans. These are important for us to track in a study of teacher learning.

An interview can present respondents with carefully selected teaching scenarios or tasks and ask questions designed to uncover both *what* they think about and *how* they think. An interview also provides a unique opportunity to learn *why* teachers and prospective teachers respond as they do.

Below, we describe in greater detail each of our instruments, specifying what we hoped to learn from each.

The Questionnaire

The questionnaire is designed to measure respondents' ideas--their attitudes as well as what they believe and know—about teaching and learning, about learners, about the nature of knowledge, and about learning to teach. We ask their thoughts in particular about mathematics and writing, in addition to other more general questions. The questionnaire is also used to gather demographic data about the respondents and to explore their views of formal and informal teacher education.

Topical outline and rationale. The questionnaire begins with a set of demographic questions, including respondents' high school and college background, age, and experience with children. The second and third sections of the questionnaire contains items designed to elicit respondents' ideas about teaching and learning mathematics and writing. The fourth section contains general questions about teaching and questions about formal and informal teacher education. Below we discuss six areas of knowledge and belief examined in the questionnaire.

Knowledge of writing and mathematics. Indisputably, teachers must know the content they are teaching. As discussed earlier, we are interested both in our participants' personal knowledge of and about mathematics and writing, as well as their pedagogical knowledge of these subjects. The questionnaire is best suited for tapping their conceptions and personal understandings of these subjects. In the area of personal knowledge of mathematics, for example, our data revealed that 26 percent of the respondents thought that 7 divided by 0 was equal to 0, rather than being undefined, and only 29 percent were able to correctly identify an expression to represent a simple proportional relationship. Our questionnaire includes items designed to measure respondents' understanding of the focal mathematics and writing areas as well as their ideas about the nature of these subjects.

Teaching mathematics and writing. In this category, we include participants' ideas about good teaching of math and writing and their beliefs about the purposes for teaching these subjects. The questionnaire presents statements which represent specific views on how writing or mathematics should be taught; respondents are asked whether they agree or disagree with these. We have learned that certain statements elicit strong reactions and enable us to discriminate clearly among respondents. For instance, an item which states, "Students should never leave mathematics class feeling confused or stuck," produced a split between mathematics majors (who strongly disagree) and other students (who tend to strongly agree). This section also includes short teaching scenarios in which respondents must evaluate the appropriateness of a student product and then indicate how they would respond to the pupil. Such items allow us to assess respondents' understanding of the subject in tandem with their ideas about teaching it.

Learning and knowing mathematics and writing. We include items which tap respondents' ideas about the nature of these two subjects and what it means to "do" math or writing well. These items also assess respondents' beliefs about how learning occurs and what promotes or inhibits it, including factors related to theories of learning and factors related to student differences. To elicit respondents' beliefs about who can learn what, we developed some novel items that mask the social desirability of certain responses. Our interest in teachers' preparation to teach diverse learners made this an important methodological issue.

The teacher's role and responsibilities. Items cover such topics as respondents' perceptions of themselves as learners of mathematics and as writers, their ideas about what the teacher's primary responsibilities are, and their notions about what a teacher of math or writing should do for or with pupils. Prospective teachers come to teacher education with many (sometimes resilient) ideas about these issues; these are also dimensions along which we expected to see change for they comprise areas of belief that programs may try to influence.

Classroom and community context. We ask a number of questions aimed at respondents' ideas about the organization of classrooms and the relationship between what goes on in school and what happens either at home or out in the community. Our interest in this area derives from our focus on teaching diverse learners. In addition, this is another area in which substantial differences are likely to appear among experienced teachers, prospective teachers, and nonteachers as well as to change over time. For instance, in our interviews, we have found that undergraduates rarely consider the classroom as a group context; they focus instead on individual pupils and seem to assume that they will interact with pupils one-on-one.

Learning to teach. We ask respondents what they feel they need to learn or do in order to get better at teaching. What participants say they need and what the programs in which they enroll emphasize may or may not be congruent—an issue we will examine when we analyze our data on the programs themselves. We also want to know whether participants' views of what they need to learn change, when this happens, and to what such change appears to be related.

The questionnaire elicits teachers' knowledge of mathematics and writing using "pedagogical frames." These items present teaching situations which have particular subject matter issues embedded in them. Respondents are asked directly for their reaction to these issues. For example, we present nonstandard, but mathematically reasonable, pupil answers and ask respondents whether these answers make sense mathematically; we ask them on a separate item how they would respond to a pupil who presents such an answer. Separating their appraisal of the mathematics from their ideas about teaching allows us to gather information about their own personal understanding of the content, while examining their knowledge in the context of its use.

The questionnaire also includes a number of 7-point Likert scale items. The 7-point scale was selected on the advice of survey experts, who recommended that, given our longitudinal design, the scale should be sufficiently wide to allow people to "move" in one direction or the other over time. Other item formats include scenario items followed by multiple choice options, and 2- or 3-point forced choice alternatives. We tried to balance innovative, and perhaps more interesting, formats with the conventional Likert scale items, to maintain respondents' interest, while avoiding an excessively complicated format that might result in high error or incompletion rates.

The Interview

Our interview is designed to elicit respondents' ideas and ways of thinking about teaching and learning mathematics and writing, with particular emphasis on the six conceptual frames described above. The interview format allows us to learn different kinds of things than we can

from the questionnaire. For instance, measuring teachers' pedagogical knowledge of subject matter using a multiple-choice format is difficult if not inconceivable. Although the questionnaire includes some items that tap particular dimensions of pedagogical content knowledge (e.g., participants' capacity to appraise the appropriateness of a model or representation), the interview is better suited to examining this dimension of teacher knowledge. We developed questions and tasks designed to explore our participants' repertoire of models, strategies, and analogies, as well as their knowledge of learners and learning in mathematics and writing. Other tasks were designed to elicit their capacity to think pedagogically in mathematics and writing, such as inventing appropriate explanations or, in a novel situation, developing a set of goals and the means to achieve them.

The interview includes questions and structured exercises. Questions have a basic stem and are followed by structured conditional probes. The structured exercises are grounded in tasks of teaching: planning, appraising curricular materials and tasks, responding to student comments and work, and evaluating student learning. By presenting participants with scenarios drawn from actual teaching situations, we can learn how they integrate different kinds of knowledge and, to some extent, skill and disposition. For example, teachers are asked to examine two students' papers written for a common assignment. The teachers' evaluations of the papers reveal what they focus on and what they believe to be important in learning to write as well as their ways of responding to students. This kind of pedagogical knowledge of writing, incorporating an understanding of writing with knowledge about learning and about pupils, is an area in which we are likely to see change over time. Tracking the relative impact of course work and experience on the development of this kind of pedagogical knowledge is of considerable interest. Our interview questions and exercises allow us to train our eyes closely on this and other similar important dimensions of teacher knowledge and skill as we follow our participants over time.

The Classroom Observation Guide

The classroom observation is the primary source of information about teachers' dispositions and interactive skills in teaching mathematics and writing. In addition, in watching what they do, we can make inferences about participants' knowledge and beliefs. We can compare these inferences with data collected on the questionnaire and interview.

The observation guide is grounded in the same overall conceptual framework as are the other teacher knowledge instruments. During each observation, we gather information related to core study variables, such as teaching diverse learners and pedagogical knowledge of mathematics and writing. We document how teachers and student teachers orchestrate the

physical and social/intellectual environment. For example, do pupils collaborate with one another? What role does the teacher play in helping students learn mathematics and writing? In what kinds of tasks are pupils and teachers engaged? We pay attention to the kinds of questions and explanations that teachers give and how they respond to diverse students. What conception of mathematics or of learning is implicit in the way the subject is presented to pupils? How teachers change may be subtle. In order to have accurate records of what they say to their students, how they pace their comments and questions, and so forth, we audiotape the classes we observe. The observer's responsibility is to fill out the record with the visual details that an audio recording cannot pick up.

Given our interest in program impact, we are especially interested to examine how the particular emphases of the programs play out in teachers' and student teachers' practices. In addition to gathering information on our core variables, we have tailored our observation guide for each site to focus on specific program emphases. For instance, one of our inservice programs stresses the importance of teachers not leading students to answers while one of our preservice programs emphasizes knowledge based on findings from research on teaching. We wanted to learn how participants made sense of such program emphases and whether and how they act on them when they teach.

Between the Conception and the Realization . . .

Up to this point, we have discussed our conceptions of teacher knowledge and of our design for tapping changes in that knowledge in the most sanguine of terms. In this section, we discuss problems that we have encountered as we analyze the data that we have collected over the past three years. Some of these have implications for our original conceptions of knowledge, but most are comments on the shortcomings of our instruments as instantiations of our original understandings of pedagogical reasoning.

One product that we hoped would come out of the study would be a series of profiles of participants in teacher education programs that would reveal the changes that take place in their thinking over the course of the program. Such profiles, rich in details, would, we hoped, help us in interpreting the data we gathered with the self-administered questionnaire. While to some degree true, we have found, however, that despite a vast amount of data across all programs, the data on students in preservice programs is too thin for the kinds of profiles we had originally envisioned. As we typically interview participants only three times (at one site, four times), a lot of time elapses between these interviews and researchers feel they have, at best, a tenuous sense of their students' development and its sources. Even though we asked participants to fill us in on significant developments in their lives between visits, the type of

profiles we had hoped to draw would have required closer and more frequent contacts with students.

A second major difficulty has been developing items that tap teachers' and prospective teachers' views of student diversity. From the beginning, we were aware of how social response bias skews responses to questions about people's racial attitudes. When we were disappointed with a question that directly asked teachers what pupil differences matter in teaching, we developed a scenario designed to gauge how teachers treated "neutral" generalizations about groups of pupils. Because we were also interested in the interconnections among learning tasks, teachers' perceptions of pupils culturally and socially different from themselves, and approaches to addressing perceived differences in teaching, we also developed a scenario intended to raise these issues. Finally, we asked teachers and student teachers to explain to us, in the interview, their responses to an item from the questionnaire intended to register their beliefs about ability grouping and tracking. In short, in important ways, our study of teachers' knowledge of how to respond to pupil diversity became a study of how to tap credibly teachers' underlying beliefs and understanding. Along the way, we may also have learned some things about how teachers' thinking about and understanding of the learning process, subject matter, and the classroom context interact with their thinking about diverse learners (McDiarmid, 1989).

This raises yet another issue that is not peculiar to this study but is probably characteristic of longitudinal studies in general; that is, we got smarter about what we were studying as we went along—yet, we were committed to a set of instruments for the duration of the study. Changing the metric along the way would have meant that no one could trust our results at the end. So, the problems, oversights, and omissions that we kicked up as we used our instruments in the field and began to analyze the data grew and yapped incessantly at our heels over the four years of data collection.

Finally, the teachers' responses to our scenarios do not readily and easily lend themselves to analyses of the various dimensions of teacher knowledge. We have difficulty drawing lines between teachers' understanding of the subject matter per se and their understanding of the subject matter as a school subject, of learning, of learners, and so on. Teachers' understandings are a web; attempting to extract an individual strand from the web is nigh impossible. Even if one could do so, the strand is only fully comprehensible as part of the web of understanding and beliefs. Analysis of individual dimensions of teacher knowledge—our initial plan—on the bases of responses to the scenarios is, consequently, problematic.

Conclusion

Different views of good teaching entail different conceptions of what teachers need to know. Our particular challenge has been to devise instruments that would enable us to measure changes in prospective and practicing teachers' knowledge regardless of the view emphasized in the formal program they attended. Starting from the premise that teaching means teaching *something* to somebody, we chose the teaching of two contrasting subject matters—mathematics and writing—as the somethings about which we would track the development of teachers' knowledge.

We also recognized that in teaching, teachers interweave their understandings of the commonplaces of teaching—subject matter, learners, learning, and the context—in reasoning about classroom situations. Hence, we devised scenarios around common classroom situations that arise in teaching mathematics and writing—and asked the prospective and practicing teachers in our sample to respond to the scenarios. By looking at their reasoning across several of these scenarios we hoped to discern patterns in their thinking and understandings. More conventionally, we asked—once again, in the context of mathematics and writing—these teachers about their beliefs about learning, learners, teaching, and the role of context. We also included questions designed to gauge their knowledge of the substance of mathematics and writing—in part, to tease out the relationship between this kind of subject matter knowledge and their capacity to reason pedagogically. While we are interested in how teachers' think about teaching mathematics and writing to diverse learners at any given point in time, we have been primarily concerned with how their knowledge changes. This led us to record our teachers' responses to the items at three points in time—before their programs, at the end, and a year later.

This design has meant, however, that we were wedded to our original conceptions and instruments. In an area such as understandings of the role of learner diversity—an area that has proved difficult to gauge validly—we had to sacrifice tracking change to refining our approaches to measuring teachers' knowledge. In other areas, such as subject matter knowledge, discriminating changes in one dimension as distinct from other dimensions proved problematic. While partially attributable to flaws in our instruments, the confounded character of teachers' knowledge and understandings exemplified in our data seems to bespeak the nature of such knowledge. Rather than individual dimensions of pedagogical knowledge, teachers' understandings of subject matter, curriculum, learners, learning, and the context might more accurately be thought of as strands of a web. In teacher thinking, these strands are interdependent and mutually supportive. The reasoning that is the product of this web of understandings is the heart of teaching—and the object of our study.

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