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CHAPTER TWO

Aligning Teacher Education with Contemporary K–12 Reform Visions

Magdalene Lampert and Deborah Loewenberg Ball

The current reform movement in education takes aim at the common assumptions about knowing and worthwhile knowledge that have dominated public schools for decades. If K–12 teaching is to adopt a different stance toward what it means to know and what is worth knowing, then teacher education will need to change in these ways as well. In this chapter we look at the knowledge demands of the reform vision—for students and for teachers. We explore how teacher education might be designed to help teachers prepare to teach and the potential of innovative uses of technology to support the preparation of teachers. We use the subject of mathematics to illustrate our argument because it is a subject we are deeply familiar with, as both teachers and teacher educators. Nevertheless, the arguments we make are intended to apply to all K–12 subjects.

KNOWING IN SCHOOL: AN EXAMPLE FROM MATHEMATICS

Consider the problem of adding three-fourths to two-fourths. Should a teacher settle for the answer "five-fourths," or its mixed number equivalent, "one-and-one-fourth"? Or should we take a more ambitious view that would have students

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asking questions like: "Three-fourths of what?" "Two-fourths of what?" and "Why do you want to add them?" "What do you mean by three-fourths? or two-fourths? and what do you mean by adding them?" This latter way of thinking about the problem may seem esoteric and quibbling. Nevertheless, asking these kinds of questions in school mathematics lessons is fundamental to the current reform movement in education, which identifies knowing a school subject with the practices associated with intellectual and practical work. Why might we want K–12 learners and teachers to worry about the kind of quantity to which these numbers refer?

Someone doing mathematical work might argue that adding three-fourths to two-fourths results in five-eighths or simply note that the total is less than two but greater than one. Traditionally in school, teachers and textbooks would label these assertions incorrect or not accurate enough. But what if we were to look more deeply into the reasoning behind these assertions, as educators are now exhorted to do? We might find out that in the first instance, the student was referring to an experience with athletic competitions: "two-fourths" refers to winning two out of four games in the first half of the soccer season, and "three-fourths" refers to winning three out of four games in the second half of the season. We would then agree that the team had won a total of five out of eight, or five-eighths of its total games.

Another person, basing his reasoning on experience with a different kind of mathematical work, might be trying to find out how much butter is needed altogether if a cake calls for three-fourths of a cup of butter and the frosting for two-fourths. Since the store sells butter by the pound, the baker would need to buy two pounds of butter altogether. Still a third person, responsible for the neighborhood swimming pool, notices that in one case of chlorine (containing four one-gallon jugs), three are full, and in another case, two are full, and concludes that she has the necessary five gallons for balancing the pool's chemicals. Her friend might say it is one and a quarter cases, and they would agree on how much there is left.

In our ideal classroom, students with experiences like these (figuring out soccer team records, buying butter, and figuring out how much chlorine is left for the swimming pool) would engage in a discussion with their teacher and reflect on the conditions under which each of the different ways of thinking about adding two-fourths and three-fourths makes sense. They would invent and learn about how to represent the additions in mathematical symbols, and they would talk about other scenarios that fit each model of "fractions" and "addition." In the process of such talking, the teacher might suggest that they could more easily relate all of these different phenomena in mathematical ways if they agree to call the number that comes first (or "on top") in the fraction the *numerator* (because it tells the number of parts to the whole), and the number that comes second ("or on the bottom") in the fraction the *denominator* (because it tells

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the name of the kinds of parts you are working with). The teacher would suggest that students with their different examples consider the benefits and disadvantages of a rule like this one: "When the denominators are the same, add by adding the numerators and keep the same denominator." After doing this sort of work, the students might be asked to use what they had learned from their investigation of "three-fourths plus two-fourths" to consider a problem like how to measure the sum of one-eighth of a teaspoon of sugar and three-fourths of a cup of sugar when combining two recipes. They would come to know that there is a rule for adding fractions with unlike denominators, but they would also understand when and when not to apply it. Fundamentally they would begin to appreciate the importance of the unit in talking about quantities.

These students could be said to know how to do both the practical and the intellectual work of mathematics, as well as how to communicate about why the solutions to various kinds of problems make sense. Would we agree that they know how to add fractions? Would we agree that the student who insists that three-fourths plus two-fourths must always be five-fourths knows how to add fractions? The examples force us, and the students and teachers who are trying to effect the reforms we have in mind, to ask: What does it mean to know how to add fractions? To know anything in mathematics? More than a vast set of algorithms and rules, mathematical knowing entails considering the specifics of the context and using resources of abstraction and pattern to gain control and perspective. Specific problems cannot be fully anticipated. Enmeshed in a mathematical or real-world context, knowers choose, apply, and invent ways of making sense.

To specify the implications of these aspects of knowing for teaching, learning, and assessment in K–12 education, David Perkins and Howard Gardner have developed something they call the "performance perspective" on understanding (Boix Mansilla and Gardner, 1998). In Perkins's terms,

> In brief, this performance perspective says that understanding a topic of study is a matter of being able to perform in a variety of thoughtful ways with the topic, for instance, to: explain, muster evidence, find examples, generalize, apply concepts, analogize, represent in a new way, and so on. . . . Understanding something is a matter of being able to carry out a variety of "performances" concerning the topic . . . that show one's understanding, and at the same time, advance it by encompassing new situations. We call such performances "understanding performances" or "performances of understanding" [Perkins, 1993, p. 7].

A classroom in which performance understanding is the norm reflects an ambitious vision of K–12 education. Helping students develop such understanding goes considerably beyond what has been expected heretofore of students and teachers in public schools. Whether this vision should be the one we embrace

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as a society is not an issue that we take up here. We consider instead what the vision implies for the practice of teaching and, consequently, for the education of teachers.

KNOWING IN TEACHING: AN EXAMPLE FROM A DIVERSE CLASSROOM

Consider the problem of the teacher faced with a class of thirty students, five of whom have their hands raised and presumably want to speak. Of those five, two are girls, three are African American, one has not yet volunteered to speak since the beginning of the school year, and one raises his hand at every opportunity and almost always has something interesting to say. Who is to have the floor? This is both a practical problem, since the teacher does need to call on somebody, and an intellectual problem, because the act of giving students the floor needs to be understood in relation to a host of other problems and their solutions. Should we accept the idea that a teacher who has had the appropriate kind of preparation can know which of these students to call on first? This way of thinking about knowledge is as common in traditional teacher education as the notion that the correct answer to three-fourths plus two-fourths is five-fourths is in traditional mathematics education.

In this example, a teacher faces a class in which five diverse students want to speak at the same time. What does the teacher need to know in this situation in order to manage it? A host of general considerations about the particular students comes to mind: race, gender, class, achievement levels of particular students, past mathematical experience in school. There are theories that can inform the teacher's decision—theories about engaging minority students, about girls, power, and discourse. There are also aspects of the subject matter that may be useful to the teacher in making a decision about whom to call on. What all these kinds of understanding have in common is that they are constituted out of something already known before the problem arises in the situation at hand. It assumes that in the situation, the teacher can, in split-second fashion, draw on her repertoire of understanding and ideas and attempt to apply them.

Researchers have learned a great deal about what sort of knowledge teachers need to bring to teaching. For example, the work initiated by Lee Shulman and his colleagues (Shulman, 1986, 1987) has moved knowledge of subject matter to center stage. Shulman advanced a conception of content knowledge combined with understandings of learning and learners, and lobbied it as the kind of knowledge of content that teachers needed. "Pedagogical content knowledge," or knowledge of the best and most useful representations, of what topics students are likely to be interested in, and of the kinds of difficulties students

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are likely to have with specific academic concepts and procedures, drew attention to the special ways in which teachers needed to understand content. It also made more visible the ways in which the knowledge teachers need is both varied and interactive. The framework of pedagogical content knowledge made plain that teaching children to add fractions sensibly, as in our example, would depend on the teacher's own understanding of key ideas about number as well as her understanding of what helps children develop their knowledge of fractions. This perspective shaped our ideas about what teachers need to know in order to teach well. It also raised a set of complicated questions about how teachers could develop such ways of knowing content. In addition to this work on subject matter, researchers have recently explored other domains of knowledge essential to teaching, such as knowledge of students and knowledge of students' cultures and contexts.[1]

Still, knowing teaching is more than applying prior understandings. It also depends fundamentally on being able to know things in the situation: to know things that one cannot know in advance of any particular encounter. Let us return to the teacher who faces a class of thirty students, five of whom have their hands raised to speak. In the situation, this teacher needs to know things she could not know when the school year began, the day before, or even minutes before. Looking for various cues, she must know who is vying to speak. She must know who has not spoken recently, and it helps to know what different students have been working on, so that she has a sense of who might say what if called on. She might know which children are engaged at the moment and who is drifting off. She might seek to have a sense of the dynamics among the students this morning. But students are not all she needs to know. She needs to have a sense of where the class is in their exploration of the problem. How is the mathematics developing? Are there key ideas that might be highlighted here? Are any misunderstandings developing? Would a rediversion of the question help? We could keep elaborating this list of things that the teacher needs to know in the situation. From moment to moment, the teacher must observe, infer, interpret, conjecture. Her conclusions, although tentative, are knowledge claims to herself. The assertions she makes to herself function as knowledge. She knows them the best she can in the moment, and must act, treating what she knows as both reasonably reliable and also provisional.

What are some recurrent themes in this kind of knowing in teaching? Making no attempt to be comprehensive, we offer some illustrations. Our claim is that teaching is more than the application of knowledge, and it is more than a site for thoughtful reasoning and reflection. In practice, we argue, teachers know things; they make claims to themselves based on what they can see, hear, sense. An unexplored and underappreciated area of teacher knowledge, knowing in teaching is critical to both teaching and teacher learning. One theme in this kind of knowing is knowing who is engaged. Teachers work with groups of students

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and are responsible for keeping them involved in experiences and activities aimed at helping them learn. Teachers must continually appraise who is paying attention and who is disengaged. Visual clues are not always reliable. Students can paste attentive looks on quiet faces, and lively, fidgety, chatterers may be following the flow. Teachers must do their best to keep track of who is in and who is tuning out. Another example of this knowing in teaching is knowing what particular students understand. Basic to their work, knowing who is "getting it" is critical. Are students getting a sense of the importance of the "unit" in fractions? What do they think it means for two fractions to be equivalent? How do they think fractions, with like denominators and with unlike denominators, are added? Just as with figuring out who is paying attention, determining what students understand is far from straightforward. Students produce correct answers with incomplete or incorrect reasons; incorrect answers can also mask sound understandings and reasoning. Across two or three dozen students and with these endemic uncertainties, teachers must make ongoing, usable assertions about what students know.

Teachers must know if something they are doing is working. They must know when to move on and when to spend more time on an idea. They must know what a student's comment means, and they must know what a student's silence means. Each of these themes could be elaborated and linked to a set of questions the teacher needs to know the answers to as she works.

Calling these judgments "knowledge" highlights the sense in which teachers observe, interpret, reach conclusions, and act based on what they know in the situation. The knowledge is uncertain, provisional, evolving. Yet in the moment, teachers' assertions have the epistemological status of knowledge and must function as such (Scheffler, 1965). Teachers make decisions and design moves based on what they know. What they must know is much more than what they can know in advance; they must know in the context of practice.

PREPARING TEACHERS TO KNOW

Traditional beginning teacher education courses and in-service workshops for practicing teachers have been organized to help educators acquire the knowledge and skill thought to be crucial to teaching. In courses and workshops, educators learn theories and methods of teaching, and in classroom settings, they practice using what they have been taught. The assumption, held by instructors and learners at the university as well as by teachers, field supervisors, and learners in classrooms, is that knowledge is acquired in course work and applied in practice (Feiman-Nemser and Buchman, 1986).

This divide between theory and practice, however, has left a critical gap unattended (Dewey, 1964). Student teachers are often in the end most influenced

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by what they see their cooperating teachers do or by their own memories from school. The effect of teacher education is often small. Although they collect ideas, learn theories, and develop some strategies, beginning teachers often report that their professional preparation was of little use or practicality (Feiman-Nemser, 1983; Lortie, 1975; Tabachnik, Popkewitz, and Zeichner, 1979–1980). The first years of teaching are often characterized as a period of sink or swim, during which novices cope with the many demands of the job, borrowing and inventing ideas as they go. It is during those years that teachers think they "learn to teach," by themselves, from experience, or by picking up tips from fellow practitioners. In-service workshops are usually required by school districts and not highly valued as sources of knowledge about improving instruction.

A second gap in teacher education lies between reform visions of teaching and the traditional pedagogy of teacher education. Prospective and practicing teachers learn about constructivist theories of learning, communities of learners, and authentic tasks, but often the courses and workshops in which they hear about these ideas are taught in ways that do not make use of the very same ideas. With little or no firsthand experience with learning of the kind that reformers advocate, neither beginning nor experienced teachers have adequate images of what these ideas mean, what it might mean to draw on them in practice, and the complications they raise for teaching and learning.

If teacher education is going to prepare teachers for the kind of ambitious teaching that reformers envision, then reformers of teacher education will need to look carefully at what it means to know something in teaching, just as the architects of the K–12 reform have looked at what it means to know something in school subjects. Teacher education will have to be designed to help prospective teachers develop flexible understandings and ways of knowing in and about teaching. This means being prepared to teach. It also means being prepared to know in teaching. Teachers need to be prepared for the more predictable parts of practice: teaching a song, helping children learn addition facts, discussing the weather. And they will also have to be prepared for the unpredictable: what to do or say when a child gives a solution that the teacher does not understand, how to assess the momentum of a discussion, talking with parents.

Because what there is to be known in teaching cannot be known entirely in advance, an essential part of the practitioner's role is to figure out what is right practice in the situation, as opposed to looking only to experts to identify which strategies to apply. Still, although the answer to what is right practice is not standardized, neither is it entirely an idiosyncratic matter of personal style, where anything goes. Making decisions about right practice is not relativistic, but responsible within a community of practice.

So what might it mean to orient teacher education courses and workshops in such a way that teachers would be better prepared to meet the challenges of knowing that they will face as teachers? These goals for the reform of teacher

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education parallel the goals of the school reform vision. The National Council of Teachers of Mathematics, for example, argues for all K–12 students to be engaged—not only in acquiring, but also in building and communicating about—mathematical knowledge:

> Goals such as learning to make conjectures, to argue about mathematics using mathematical evidence, to formulate and solve problems and to make sense of mathematical ideas are not just for some group thought to be "bright" or "mathematically able." Every student can—and should—learn to reason and solve problems, to make connections across a rich web of topics and experiences, and to communicate mathematical ideas [National Council of Teachers of Mathematics, 1991].

We might imagine that every teacher, not only professional leaders or teacher-researchers, would engage in learning to reason and solve pedagogical problems, to make connections across a rich web of topics and experiences, and to communicate pedagogical ideas. If assertions about who to call on in the scenario presented earlier were considered as conjectures—that is, as tentative judgments, open to revision in the course of thinking the problem through with other members of one's professional community—then teachers could take on a more direct responsibility for creating practical and intellectual knowledge that could be used in classrooms. If teachers and prospective teachers were encouraged to examine assumptions about what makes something good teaching or about how one event in the classroom is related to another, they would be more adequately prepared for the multifaceted problems they will face in their own classrooms from one minute to the next.

WHAT KIND OF TEACHER EDUCATION AIMS TOWARD THESE GOALS?

One possibility that we have been exploring in our work is to orient teacher education around the investigation of the practices of teaching and learning, rather than to center it solely on the provision of knowledge and skills to be applied in practice. Investigation is an appealing idea. In any field, conducting an investigation entails using the extant knowledge of the field and simultaneously constructing new frameworks. Investigation has also been part of the current reform in school subject matter instruction. Whether they are studying temperature or democracy, poetry or probability, students are to learn from investigating ideas, that is, from working on problems, talking with others about potential solutions, building on their own ways of thinking about concepts, and

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engaging with big disciplinary ideas. In mathematics lessons, for example, students would be expected to investigate situations in which probabilistic events occur, construct ways of representing mathematical patterns, and debate the applicability of classic strategies for finding needed information. Working in parallel, we have been exploring what this kind of pedagogy might offer to the way we teach beginning teachers about teaching (Lampert and Ball, 1998).

Although *investigation* could describe a teacher's private inquiry into his or her own practice, we focus our discussion here on investigations conducted in common using some set of materials representing practice: videotapes, children's work, teacher notes and reflections, curriculum materials, and guidelines. The focus here is on the idea of a group of teachers using a common set of materials drawn directly from practice—the same classroom and the same set of students—to pursue different questions important to learning about teaching and learning. Since such investigations are unusual, at least in the United States, the participants in this kind of teacher education would also need to be developing terms and rules of discourse for talking about practice.[2]

Imagine a teacher education class in which students are intently watching a short video segment from a whole class discussion in a third-grade class. On the video, the children are disagreeing about whether 4/4 is equivalent to 5/5. A number of children are arguing vigorously that 5/5 is "more" because there are more pieces. Several others argue that 4/4 and 5/5 are the "same amount." The teacher on the video asks clarifying questions, and guides the turns taken by children in the discussion, but she does not step in and explain equivalent fractions. A number of the children on the video do not say anything in the discussion, some seeming to write or draw in their notebooks.[3]

The teacher education students are quiet, riveted on the screen. Occasionally they chuckle at a child's comment or point at and whisper about something in the video. At the conclusion of the segment, the instructor flips on the lights and asks the students to write for a few moments in their notebooks, jotting down what stood out to them, what puzzled them, what confused them, what they wondered. A few pore over a paper transcript as they write. After a few minutes, the instructor asks for comments and questions. The comments pour out.

"She should have told them that 5/5 is the same! I was so frustrated with the discussion going on and on!"

"I was impressed with that little girl's—is her name Mei?—ability to explain her thinking."

"I was amazed at how comfortable the children seemed. I never would have gone to the board like that when I was that age. In fact, I wouldn't do it now!"

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"Yeah, how did the teacher get the kids to talk like that, and to talk to one another so much? In my math classes, the teacher could never get anyone to talk."

"I wondered what the kids had done before about fractions. Had they used manipulatives to see how two fractions can be equivalent?"

"A lot of children seemed to be bored."

"I didn't think they were bored. Did you see how that one boy who never talked was leaning toward whoever was speaking, and how he reacted to different things the other kids said?"

"What did the teacher do next?"

"What should kids know about equivalent fractions at this age?"

"Why were so few boys talking? Is that always the case in this classroom?"

The instructor does not comment and records the students' questions on the board. After about ten minutes of this, she flips an overhead with this list of other information:

children's writing from their notebooks

fraction quizzes

third-grade math textbook and goals and objectives for third grade in this state

teacher's journal

videotapes from previous and subsequent class sessions

She begins, "Here is a list of other materials I am making available for you today. I want you to spend a few minutes thinking about the questions, inferences, and assertions we have up here on the board and select something you'd like to pursue using something on this list." A low hum of talk can be heard in the class as the teacher education students bend over their notebooks, glance up at the board, and comment to others nearby. The instructor then invites students to share what they are thinking of doing. This time she offers suggestions or connects each idea to something that someone else has already volunteered. After about twenty more minutes, the students are set off to pursue their issue using the materials.

Like the elementary mathematics students in the vignette at the beginning of this chapter who investigated the sum of three-fourths and two-fourths by drawing on their experiences with mathematical work, these teacher education students draw on their own experiences with learning and teaching to try to make sense of the phenomenon they are investigating. They also draw on re-

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search they have read in various academic fields like philosophy, sociology, psychology, and anthropology. And they draw on their knowledge of the mathematical content: fractions. By participating with others, they will be exposed to a variety of interpretations of what is going on and what is important. By using other representations of the practices of teaching and learning gathered from the same classroom, they will develop a richer, more complete sense of the teacher and students in the lesson on the tape and develop the capacity to understand their actions and ways of thinking.

The teacher educator in this situation would prompt the students to examine the assumptions behind their assertions and look for evidence in the materials representing practice to elaborate their understanding. She would encourage them to examine and articulate the relationships among multiple aspects of the teaching and learning they have observed. She might introduce the term *registers* for talking about talk to help her students distinguish between formal mathematical talk and ordinary talk about quantitative relationships. She might have them consider the wisdom of pedagogical truisms like, "Only those students who verbally participate are engaged." Together the teacher educator and her students would search for ways to represent and communicate about what they know and try to interpret the representations and communications of others. They would revise and refine their questions. They would be producing what Perkins and Gardner call "performances of understanding" (Boix Mansilla and Gardner, 1998).

Using the idea of investigation to orient work in teacher education centers the focus on inquiring into concrete phenomena of practice. What are these children understanding about fractions? How can one decipher the children's writing and drawings, and how can one learn to listen well enough to figure out what they think and what they know, across boundaries of age, culture, and understanding? What are the elements of fraction knowledge to listen and look for in their talk, drawing, and writing? Investigations begin with something that is unknown and puzzling. The teacher education student might have a general pedagogical question with which she or he is absorbed, such as, "What do manipulatives contribute to learning?" or "How does the teacher decide when to follow the children and when to make insertions or sharply focus or turn the children's work?" Investigations can also be rooted in the specifics of the setting, such as, "Is Michael getting it?" or "What are the qualities of this classroom's culture, and how have they developed?" or "Who seems to be participating?" Investigation is a stance as well as an approach. Rooted in a tradition of inquiry-based teacher education, investigations approach teaching as complex, intriguing, and uncertain. Although they are focused, they must take account of the complexities of the context.

In an investigation, teacher education students pursue questions. These may be their own puzzlements and curiosities, or they may be questions that an

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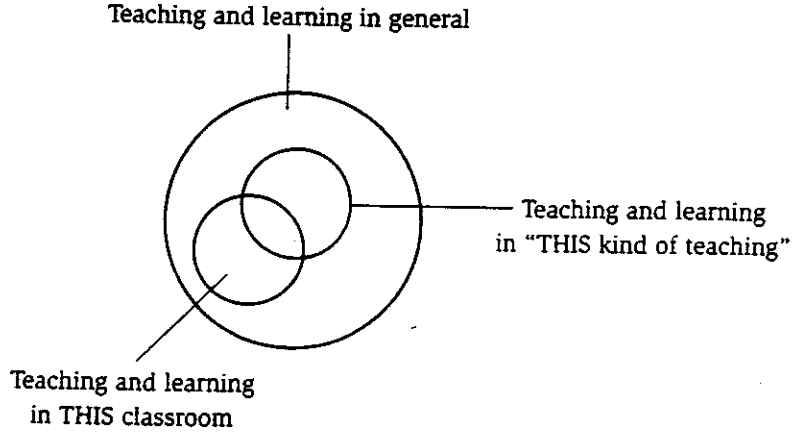
instructor frames. The focal questions of investigation are rooted in practice and are at once specific and general. A question about a particular child is a question about both that child and children more broadly, about children's understandings of this particular content, and about the general challenge of what it means to know children. A question about a particular teacher's decision is a means both to understanding a single lesson and to learning the workings of a specific classroom. But it is also more broadly about teacher role and teacher thinking. A question about what children learned about a particular problem is also a question about that kind of problem and the attendant possibilities and pitfalls. Figure 2.1 illustrates the interrelationships of the concrete and the general in pursuing investigations of teaching.

Investigations draw on but are not restricted to current theories and formal knowledge about teaching and learning in general or a particular kind of teaching and learning. Instructors help teacher education students access and use ideas of the field, and they also encourage students to make novel conjectures and advance possible novel interpretations. Engaging with situated questions of practice can support a context for the intertwining of knowledge use and knowledge construction.

Investigations rarely reach definitive conclusions; rarely are they complete. As one group of teachers with whom we worked exclaimed, "We just keep discovering more questions!" Instead of questions leading to answers, questions tend to multiply. In trying to understand what a particular child meant in a specific context, other questions arise about that child, other children, the problem

Figure 2.1. Interconnections Between the Particular and the General in Investigating Particular Phenomena of Practice.



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at hand, and the classroom environment. The subject matter itself often becomes more complex and worthy of a more careful examination. Just as knowledge in teaching is virtually always incomplete, tentative, and connected, so is the knowledge developed in investigating teaching. The big questions—"How do manipulatives contribute to students' understandings of fractions?" or "When does the teacher tell, and when does she hold back and press the students?" or "What is being covered in a curriculum where children do fewer problems but do them more thoroughly?"—are never concluded once and for all. Investigations help to uncover both the connectedness and the uncertainties of knowing in teaching.

By doing investigations like the one described, intending and practicing teachers have the opportunity to learn about the relationship between knowing and doing in teaching. They gather information from representations of practice that enable them to appreciate the teacher's construction of knowledge in the situation. They come up against evidence that knowledge is incomplete, uncertain, and context bound, and yet the teacher must act. As they develop an appreciation for a teacher and her students as people in a relationship over time, they have the opportunity to recognize that knowledge of facts and principles is used in connection with another kind of knowing, more moral or empathetic than cognitive. Yet they remain outsiders to that relationship, making them better able to look at it from multiple perspectives.

Investigations offer sites for exploring multiple interpretations. Looking at a set of student papers, prospective teachers will find that they do not always see the same things in the students' work. What looks to one person like a serious lack in a child's understanding can be seen as imaginative and clever by another. While one person sees a child as inattentive or frustrated, another person may see evidence that the child is listening intently. The inferences we make in teaching and learning are rooted in the evidence we apprehend and use, and the ways in which we interpret it. Discussing specific interpretations together with others reveals the multiplicity of perspectives that can be convincing around a single event or issue. Through such discussion, possibilities exist for teacher education students to develop multiple voices in their own heads. They can learn to generate for themselves alternative ways of hearing, seeing, and interpreting, and come to appreciate their initial interpretations as possible and not necessary.

How might a pedagogy of teacher education oriented around investigation restructure the relations of knowledge and practice? Table 2.1 offers one preliminary view of this restructuring, showing ways in which investigations might support the development of ways of knowing more consonant with the views of knowledge and learning that are fundamental to K–12 education, and the necessary teacher education. We see from the table that as new ways of knowing are acquired (italics), they must be integrated with more familiar approaches.

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Table 2.1. Restructuring Ways of Knowing in Teaching.

	Common Understandings About Knowing and Learning Encountered in Traditional K–12 and Teacher Education	Understandings of Knowledge Acquisition and Use That Are Consonant with Reformers' Visions of K–12 Education
Sources of knowledge	Textbooks Researchers/experts People with more experience	Textbooks Researchers/experts People with more experience *Self: not opinions but reasoned judgment* *Arguments with oneself and with others*
Nature of knowledge	Rules Definitions Facts Theories	Rules Definitions Facts Theories *Conjectures to be tested, discussed, and revised in the context of work on problems*
Connections between what you know and what you do	Remember Practice Apply	Remember Practice Apply *Manage dilemmas* *Empathize* *Consider multiple perspectives and possible interpretations*

HOW CAN NEW TECHNOLOGIES HELP?

In every field of endeavor, the capacity to collect and use information has been dramatically increased by new technologies. The introduction of investigations of practice as a method for studying teaching depends on having access to large collections of information about practice in the form of raw representations of the activities of teaching and learning. New hardware for putting representations into a computer and taking them out for viewing, new software for cataloguing these representations and annotating them, and new programming language for creating customized records of what users do with the information

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can be combined into an "investigator's working environment" for use by teacher educators and beginning and practicing teachers to learn the kind of knowing in teaching we have described above. We conclude this chapter by identifying three ways in which new technologies can support the access and use of such representations in teacher education settings:

- Increased capacity to document practice
- Improved potential to study practice outside of the time, space, and relational constraints of ongoing work in classrooms
- Added support for professional discourse

The hardware, software, and multimedia information together constitute an electronic environment in which teachers and teacher educators can investigate practice.[4] This environment does not replace the classroom, in which the teacher or student teacher learns by being a practitioner. Nor does it replace academic course work or focused workshops in which conceptual frameworks or specific pedagogical techniques are taught and learned. The kind of work that can be supported in this environment is unique, offering opportunities for learning not easily had through field experience or in classes or workshops.

In order to create an electronic environment in which teachers and teacher educators can investigate practice, the first task is to collect, file, and catalogue representations of practice that document the activities of teaching and learning and participants' perspectives on those activities. Improvements in tools for collecting information in multiple media, including miniaturization and easy translation between digital and analogue forms of storage, make it possible to capture high-quality representations of many different aspects of teaching and learning practices without significantly disrupting the ecology of the environment in which those practices occur. For example, scanning, together with database software, could save and catalogue children's daily work using a process no more complex than photocopying. Slides of the work on the chalkboard, taken automatically every five minutes by a digital camera, would provide an animated record of the graphic representations that accompanied talk in a lesson and could be electronically linked to an audiotape using time code.

The technology makes it increasingly possible to capture and make available aspects of what there is to see, hear, and know in practice. Examining raw materials from practice—videotape, for example—provides access to the less verbal and less analyzed texts of teaching: body movements and facial expressions, tone and timing, pattern and style, the unedited and uninterpreted expressions of children. Such opportunities are crucial in learning to teach, because so much of teaching entails hearing and seeing, as well as interpreting such information.

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New programming languages for building complex and relational databases mean that access to multiple representations is fast and easy. Search strategies can be used that make it practical to keep a collection of representations in a relatively undigested form, meaning that teacher educators and teacher education students can go directly to instances of classroom teaching and learning and build their own links among them without having their view of those instances filtered through the conceptual frameworks of others. This is similar to the overwhelming volume of unprocessed "data" surrounding teachers in the moment-to-moment reality of teaching. At the same time, representations can be organized in multiple ways, drawing on conceptual frameworks of not only academic disciplines like psychology, sociology, and philosophy but also on perspectives of parents, children, subject matter specialists, and the like. Being able to link the raw data to such multiple perspectives can enhance teachers' capabilities to make sense of the flood of information in which they swim.

If a database of this sort has been collected and electronically filed and catalogued, new technologies make it possible to get access to it in ways that substantially enrich the study of teaching and learning. Multimedia workstations link computers with sources of textual, graphic, audio, and video information and make it possible for users to create and store information in all of those media as well. Even without computer control, video and audio can be used to stop in the middle of an activity to think, write, or talk about it; replay the activity over; and chunk activities together in different ways for different analytic purposes. Given a lesson video, for example, one can try to figure out where the important transitions between activities are from the teacher's point of view and then use the same tape to consider that question from the points of view of different students. With computer-controlled video and audio and the capacity to annotate these media electronically, one can make comments at various points and keep records of multiple streams of commentary on the same instance of practice. With software for capturing audio, video, and graphics, investigators can make scrapbooks of their journeys through the year as a case by pasting movies of lessons or excerpts from children's and teachers' work into a text processing, spreadsheet, or database application. All of these and other such capacities can support teachers in developing multiple perspectives and frames of reference with which to interpret information and make conjectures in practice. In these ways, the technology supports the possibilities of preparing beginning and practicing teachers to know in teaching.

The power of current computing technologies to process large amounts of information in multiple media—video, audio, graphics, and conventional text—means that representations of teaching and learning practices need not be limited to verbal, linear information. We can store what gets written on the chalkboard during a discussion, for example, and look at it alongside what students write in their notebooks and what participants say. Being able to replay

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and rearrange events of practice make possible a kind of analytic thinking crucial to skilled, constructive, and reflective practice.

In addition, the technology can facilitate communication about teaching. Nonverbal representations of the multiple ways in which those practices can be thought about can be produced. Color and graphics can be used to show maps of relationships among social and academic considerations in the teacher's choice of a problem for the class to work on, for example. This opens up many more channels for communication about practice, and makes those channels available for collaborative study outside the time and space constraints of the classroom. It also may support the development of teachers' communication skills and capacities. In talking with others, using novel and conventional modes of representing aspects of teaching and learning, teachers can develop language and shared referents for communicating about teaching.

Because computers have the capacity to store large amounts of information and relations between pieces of information, it is possible to consider an entire year of classroom lessons, together with teachers' and students' reflections on those lessons and relevant background information, as a "case" of teaching and learning. Given the nature of the K–12 reform vision, this capacity is central to improving the study of teaching, for unlike traditional instances of teaching and learning, which could be understood as discrete bits of communication between teacher and learner about discrete bits of subject matter, the reforms we envision focus on problems that touch on many interrelated subjects and extend over many days of work. Within this work organization, teachers are expected to assess students' performances of understanding that do not come in simple packages like standardized tests. The difference between what a teacher plans and what actually happens in lessons is much greater when teaching is expected to take account of how learners think about the topic at hand. And if we are to be responsive to the increasing diversity in our classrooms, simple mechanisms for describing what is taught and learned are inadequate. If we are to teach and learn in K–12 classrooms in the ways that reformers envision, we cannot adequately keep track of or try to understand what is happening by looking at a few lessons or a few curriculum units or a few pieces of children's work. A corpus of all of these pieces of information and more is needed to represent accurately the kind of practice we want beginning and experienced teachers to study.

The technologies we have described have the potential to support a rich analytic discourse about practice among professionals in the field of education. By representing teaching and learning in terms of the year in one classroom as a case, they would make it possible for teacher educators and intending and practicing teachers to get to know another teacher and the students in the class without intruding on the fragile relationship that underlies the work they do together. Looked at from the other side, this means that their understanding of what is happening in that setting is less intruded on by the need to create and

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maintain an identity and a set of relationships with the people in that setting. For example, beginning teachers need not worry about whether the children they are observing should call them by the first names. This may seem like a trivial matter, but from the perspective of a young teacher education student, trying on what it means to be a "grown-up," such a consideration can interfere with giving full attention to the myriad issues in the classroom around her.[5] In order to develop new capacities for the sort of knowing in teaching we are examining here, it is important to cut down on these kinds of interferences, especially at the beginning of learning teaching.

Using new technologies means that this personal yet detached way of knowing a teacher and a class can be shared among a group of investigators, giving them a common multimedia "text" on which to focus their conversation. Other ways of giving intending and practicing teachers access to classroom activities for analysis (like field placement or mentoring) have each participant in a class or workshop looking at different teachers and classes, or the same teachers and classes on different days, making it impossible to use common referents to build shared meaning for the terms of discourse. Having a common text to study promotes the possibility of education professionals developing as a community of inquirers in ways that are parallel to the communities of inquirers that reformers would like to see them create in K–12 schools.

As educators, we currently lack practical or theoretical language for communicating about classroom activity. Having opportunities to examine practice in the concreteness of its unedited and unanalyzed flow, and to talk about what one sees and hears, and how one interprets that, can support the development of language for communicating about practice. Developing language that is useful in the context of careful examination of practice can contribute to the professional discourse of teaching, to teachers' exchanges with one another. It can also contribute to the internal conversations teachers have with themselves as they watch, listen, and try to make sense.

With the increasing availability of telecommunications, the sort of multimedia environment for studying teaching that we have described can be expanded across time and geographical distance. With relational database programming, it is possible to imagine the expansion of discourse about practice beyond face-to-face, local professional groups to more public discourse in the profession as a whole, using the same raw representations of teaching and learning to develop a shared understanding of the reforms. If commentaries on the representations and ways of organizing the representations could become part of the database as well, discourse could be incorporated into the electronic environment. This would make it possible for groups meeting in different places at the same time or in the same place at different times, or even in different places at different times, to be part of the same professional conversation about teaching and learning. For example, the environment could include the information that

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groups in several teacher education settings were interested in the question, "How can teachers cover the curriculum if we are supposed to spend a day or even a week on one problem?" In different locations, investigators could use materials representing teaching and learning in one particular classroom across the year. They could take various paths into that material, annotating various pieces of information from the classroom and arranging collections of information for reflection. With powerful relational databases, it would be possible to communicate across time and distance, examining the history of use and annotation for particular instances of teaching and learning and their representations, thus expanding the shared referents for a language of practice beyond local conversations.

ON THE HORIZONS FOR TEACHER LEARNING: USING TECHNOLOGY TO ALIGN TEACHER EDUCATION WITH THE CONTEMPORARY REFORM VISIONS

Technology has the potential to create workspaces for teachers' and teacher educators' learning that differ in important ways from the kinds of opportunities that exist in current settings and relationships. We conclude by discussing three distinctive features of these new workspaces.

First is the content of practice and tools for working with that content. Technology makes it possible to access close, concrete, inside information about teaching and learning, teachers and students, subject matter and classrooms. Although this is the central material of practice, and thus of learning practice, such information is never available to prospective teachers and teacher educators. And in the classroom, information whizzes by even the practicing teacher. Developing skills to see more, hear more, interpret multiply does not automatically come with the opportunity. The having of teaching experience does not necessarily make it possible to learn in and from teaching. It is a paradox of learning to teach that the very material of practice is so rarely available to those who seek to learn it. Technology makes it possible to collect and explore concrete materials of practice and use such information to investigate and develop understandings of teaching and learning.

Second, technology makes it possible to manipulate such materials of practice in constructively imaginative ways. Videotape can be stopped, replayed, and played in slow motion; a child's presence in September can be arrayed for comparison next to her stance in May; patterns of teacher talk can be examined across time. Playing with the data not only allows purposive exploration; it also can allow space and tools for the pedagogical imagination to fly in ways that cannot be done in real time by either observers or teachers. Ideas,

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interpretations, questions, and ways of looking can be developed through such playful work.

Third is the possibility for supporting a kind of professional discourse and joint work and exchange that is often hampered for a host of complicated practical and cultural reasons. Although the work we are describing can certainly be done by individual teachers, groups of teachers can expand their opportunities for learning by the possibilities of coming together with others to talk about teaching and learning. That it need not be the practice of any of the participants can free the norms of niceness that often hinder critical discussion. That the objects of inquiry are stored for access rather than occurring in real time can free the geographic boundaries that divide and isolate teachers. That the material can be collectively accessed and investigated can increase interpretations, considerations, and conjectures, substantially expanding the opportunities for educators' learning, in this environment as well as in classrooms to which they can later take others' eyes, ears, and voices.

Technology offers both mechanical and conceptual tools for use in teacher education. It can improve our mechanical capacities because of the kinds of processes and interactions that it makes possible in the study of teaching. It can improve our conceptual capacities because it can support new ways to conduct inquiry teaching, new ways to think about sharing the results of that inquiry, and new ways to make use of knowledge constructed through that inquiry.

Notes

1. Books such as Reynolds (1989) enumerated and analyzed the understandings needed in order to teach.
2. This approach to teacher education is common in Japan and China, but can be found only in rare and special circumstances in the United States. See, for example, Lewis (1998) and Paine and Ma (1993) for descriptions of teacher investigations in Japan and China and Stein, Silver, and Smith (1998) for a U.S. example.
3. This episode is taken from a videotape from Deborah Ball's class. Both of us have used this particular videotape with prospective and practicing teachers as well as teacher educators; the vignette we use here is a composite from our experiences in using such tape.
4. We describe our work in building and using such an environment in teacher education in Lampert and Ball (1998).
5. Dewey ([1904] 1964) wrote about ways in which the concerns of beginning teachers interfered with the attention they could give to deeper issues of teaching and learning.

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