WHY STAYING ONE CHAPTER AHEAD DOESN'T REALLY WORK: SUBJECT-SPECIFIC PEDAGOGY[1]

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When most prospective teachers enter formal teacher education, they view the teacher's role as telling pupils what they need to know and giving them practice in it.[3] They tend to assume that learning means accruing information and that the teacher's main task is to "motivate" pupils and to get them to pay attention. Toward that end, prospective teachers tend to focus on making learning fun (Ball, 1988a). Prospective teachers also tend to assume that, to find out if pupils have learned, teachers need only ask them to restate or perform what they have been taught (Feiman-Nemser, McDiarmid, Melnick, and Parker, 1987). That prospective teachers hold these images of teaching, learning, and the teacher's role is not surprising. While other views have been around for some time and while a few teachers have held and acted on these alternative views, telling and accruing information have dominated U.S. classrooms from the inception of the common school (Cohen, in press; Cuban,

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[3]Throughout this paper, the term "pupils" is used for learners in kindergarten through 12th grade and the term "students" for those in college.

1984; Jackson, 1986;). Still, this approach to teaching encourages pupils to rely on memorization and does not help them develop a flexible understanding of subject matter (Anderson and Smith, 1987; Nickerson, 1985).

A recently hired university faculty member might face, for the first time, the task of teaching a methods course--in mathematics, or social studies, or science--to preservice teacher education students. The goal is to prepare teachers who will break out of this conventional pattern of teaching and help their pupils develop deep and flexible understandings of subject matter. The instructor knows that to teach in this way requires particular disciplinary knowledge as well as changes in conviction and commitment. While acknowledging the possibility of drawing from methods textbooks that describe "neat" activities for teaching her subject, the instructor is uneasy about this approach. Such activities may simply reinforce her students' assumptions about teaching and learning. What is essential for students to learn to be prepared to help pupils develop flexible understanding of the subject matter? To pursue this question, we will follow the course of the methods instructor's thinking--from her goal to her means of accomplishing that goal.

The Goal: Teaching for "Flexible Subject Matter Understanding"

Flexible understanding of a subject entails the ability to draw relationships within the subject as well as across disciplinary fields and to make connections to the world outside of school. In mathematics, for example, it means knowing how fractions and division are related conceptually as well as historically. It means being able to identify quantities in everyday life that are best represented by negative numbers.

Flexible understanding also involves knowing *about* the discipline: What experts in the field do, how knowledge evolves, what the standards of evidence are. For example, what activities, processes, and conventions do scientists use to investigate the physical and biological world? How are historical accounts constructed? Finally, flexible understanding means knowing a subject well enough to increase one's understanding of and thereby power within one's environment. Such an understanding of history, for instance, enables one to take a critical perspective on the "facts" and to see them as interpretations rather than as absolutes--to question why women figure so narrowly in history or to challenge the portrayal of Native Americans in accounts of early America.

Many students do not develop an adequately flexible understanding of subject matter in school, in part because the traditional teaching-learning model of telling and accruing ignores the ideas and beliefs that pupils bring with them to the learning situation. No matter how clearly teachers present material in class, pupils understand that material based on their prior assumptions and understandings. If pupils are to develop flexible understanding of disciplinary knowledge, teachers cannot merely tell them information and expect them to know it. In teaching for subject matter understanding, the teacher's role is to connect children to the communities of the disciplines. To do so, teachers must be able to view the subject matter through the eyes of the learner, as well as interpreting the learner's comments, questions, and activities through the lenses of the subject (Dewey, 1916/1964a; Dewey 1916/1964b; Feiman-Nemser and Buchmann, 1986; Highet, 1966). Connecting pupils with subject matter entails weaving together ideas about how people learn and knowledge about particular pupils with a thorough understanding of the subject in ways that respect the integrity of each. The processes and products of this weaving are the focus of the remainder of this paper.

The Role of Representations in Teaching Subject Matter

Teaching involves a wide range of activities that relate more or less closely to the essential purpose of helping others understand. Teachers explain, ask questions, respond to pupils, develop and select tasks, and assess what pupils understand. These activities emerge from a bifocal consideration of subject matter and pupils, framed by the teachers' own understandings and beliefs about each and shaped further by their ideas about learning and their role in promoting learning as well as their understandings and assumptions about the content.

Melding these different domains of knowledge is at the heart of teaching. Shulman and his colleagues have labelled the *product* of this melding "pedagogical content knowledge" and study it as a domain of knowledge in its own right (Shulman, 1986; Wilson, 1988; Wilson, Shulman, & Richert, 1987). According to these scholars, pedagogical content knowledge consists of topic-level knowledge of learners, of learning, and of "the most useful forms of representation of [particular] ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations--in a word, the ways of representing and formulating the subject that make it comprehensible

to others" (Shulman, 1986, p.6).

In this paper we focus exclusively on these "forms of representation." We argue that whether or not they are aware of it, teachers are constantly engaged in a process of constructing and using *instructional representations* of subject matter knowledge. By instructional representations we mean a wide range of models that may convey something about the subject matter to the learner: activities, questions, examples, and analogies, for instance. We are *not* talking about representation as cognitive psychologists do--that is, as the *mental representations* that learners construct for themselves as they learn or that teachers have that shape their teaching (see Wilson, 1988). Some representations are provided to teachers in textbooks, worksheets, or other teaching materials. Other representations teachers construct themselves.

What Do Representations Represent?

Through the representations they select and the ways they use them, teachers convey messages to their pupils about both the *substance* and *nature* of the subjects they teach. Representation is a fact of life in teaching, not an inherent good. In teaching for subject matter understanding, the aim is to represent the discipline appropriately. We do not mean to imply that students necessarily draw the conclusions we suggest. Instead, we are arguing that the instructional representations that students encounter define their formal opportunities for learning about the subject matter--the possible, not the inevitable.

Talking about teaching in terms of instructional representations is intended to focus attention not just on the activities of teachers and pupils in classrooms but on the relationship between these activities and the knowledge and activities of the discipline being taught as well. Using such a lens, we discover that many classroom activities and materials represent disciplinary knowledge poorly; that is, they promote conceptions or encourage patterns of thought and action in pupils that do not correspond to the ways of thinking and knowing in history, mathematics, literature, or science. Representations take different forms in different subjects (see Dewey, 1916/1964a). In mathematics, for instance, an idea may be represented verbally, symbolically, graphically, or concretely. A representation may connect one mathematical idea with another, link a concept or procedure with an

idea in another subject, or connect to something in the world around us. Finally, instructional representations of mathematics, individually and cumulatively, portray what *doing* mathematics means. For example, the concept of slope may be connected within mathematics to the derivative or to the idea of covariance more generally. Slope may be represented as

$$\frac{\text{rise}}{\text{run}}$$

or

$$\frac{\text{change in y}}{\text{change in x}}$$

or

$$\frac{y_2 - y_1}{x_2 - x_1}$$

Slope may be represented in words, such as "the ratio of the amount of change in the dependent variable to the amount of change in the independent variable," or, more colloquially, "the relationship between how fast one thing is changing compared to another." One might use representations such as the relationship between distance run and calories burned, between miles driven and gallons of gas used, between lemonade sold and profit earned, for instance. Using graphs, slope can be connected to the derivative by examining curvilinear relationships such as the relationship between human age and running speed or by exploring instantaneous velocity as an object is rolled down inclines of different steepness.

While teachers of literature must also find ways to enable diverse pupils to connect with the text material, the forms and kinds of representation differ from those of mathematics. The teacher may compare characters, events, or themes in a text with those in other texts or in other spheres, such as films, television, or real life. Themes in texts may be represented by verbal definitions, analogies, or dramatizations. In teaching writing, teachers must choose activities, tasks, and patterns of interaction that help pupils learn to express their own ideas in ways that communicate effectively with different audiences for different purposes. Teachers of writing face the

need to represent appropriately the interaction of individual and community, the relationship between speech and print as well as between convention and creativity in writing.

Science teachers face still other decisions and considerations. Sometimes they introduce their pupils to real objects or systems, such as plants and animals or electric circuits. At other times they must work with representations of those objects and systems, such as pictures, circuit diagrams, or graphs and tables. Science teachers must also develop and use representations of concepts and processes that are not directly observable by pupils, such as current and voltage, photosynthesis, or acceleration. How can such concepts be represented in ways that pupils understand and connect with their experiences in the real world?

History teachers work with representation along other dimensions. Events, people, and places, as well as themes and movements, can be represented by verbal exposition, analogies involving the past and present, dramatizations, graphics, and analysis of primary documents. Modes of representation in various subjects do, of course, overlap. Analogies, simulations, and diagrams are used in teaching mathematics, history, English, and physics, for instance.

In learning to teach, however, representation cannot be approached generically. Simply knowing that metaphor can be a useful pedagogical tool, for instance, does not go far in helping beginning teachers select helpful and appropriate metaphors for teaching specific topics such as division, story structure, multiple causation, or electricity. The belief that academic content should be connected to the real world is not sufficient to enable beginning teachers to relate key dimensions of a topic to real situations that will make sense to their pupils. What are the key elements of studying the causes of the Civil War? What familiar events or story would validly represent the complexity of the Civil War and, at the same time, seem reasonable and compelling to a particular group of pupils? What would pupils of a particular age already know or assume that might affect the teacher's deliberations? Learning to represent subject matter in ways that will help pupils learn depends on the subject. Beginning teachers need to start by learning what representation entails in the particular subjects they teach. Later, as they acquire experience, they may develop generalized knowledge about representations.

Consequently, prospective teachers need to work on representations that are appropriate for specific subject

matter topics. For instance, does it make sense to talk about photosynthesis as the way plants "eat"? Although this seems intuitively appealing, Roth's work (1985) on pupils' misconceptions about photosynthesis makes one realize that another analogy might be a better choice. Each alternative must be evaluated carefully, however. What about describing plants as "factories" that make food from raw material? What does the chemical formula for photosynthesis represent for scientists? Would it have the same meaning for middle school pupils? Knowing that analogies can be useful pedagogical devices does not help the beginning teacher answer these questions, nor does the solution to one problem of representation lend itself to the next.

Still, problems of representation in subject matter teaching cannot be adequately addressed simply by treating each course as a succession of topics for which representations must be developed. Beyond representing the *substanc*e of a subject, teachers also represent its *nature*. For example, are scientists concerned mainly with strange and obscure phenomena, or are they trying to explain the everyday world around us? What does it mean to "do" mathematics? Are ideas in mathematics subject to interpretation and argument or are they clearly true or false? How do historians decide what is or isn't a fact? How do writers improve their work? In all disciplines, these questions involve learning about the relationships between individuals and the community of the disciplines (Schwab, 1976), relationships that play out in the classroom community as well.

Through selection and use of representations, teachers convey to their pupils implicit messages about the answers to the above questions, messages about what Schwab (1961/
1978a) calls the "syntactic structures" of a discipline. What are the aspects or properties of a subject that distinguish it as a discipline? What are the ways of knowing and pursuing knowledge? In the context of schools, the nature of a subject matter is portrayed to pupils through the activities in which they and their teachers engage, the questions and problems they examine, the ways in which answers are sought and validated, what counts as an "answer" and on what basis. In these ways pupils learn what it means to *do* mathematics, science, history, or to write (Doyle, 1986).

Sources of Representations in Teaching

Teachers' instructional representations derive from two primary sources, one outside themselves and the

other within. Because of the central role that representations play in enabling pupils to understand subject matter, teacher educators must help beginning teachers develop good representations and judge the appropriateness of existing ones. Outside sources of representations include curricular materials, courses or workshops for teachers as well as their own academic studies, colleagues, and the environment. Curricular materials--textbooks and teachers' guides, kits, computer software, filmstrips, and videos--are themselves representations of the disciplines. Both the topics or ideas included and the way they are presented represent the substance and the nature of the subject matter to pupils.

In many math textbooks, for instance, doing mathematics seems to mean performing computations. In most history textbooks, history is portrayed as an actual record of past events. History as an interpretation of the past remains, for the most part, hidden. Besides tacitly representing the subject, accompanying teachers' guides also explicitly suggest activities, questions, and ways of explaining the content. For example, one high school algebra text offers the following: "There are several models that may help illustrate the definition of slope: the pitch of a roof, the grade of a hill; the rise/run of a stairway or a ramp" (Dolciani, Wooton, and Beckenbach, 1980, p. T56).

Teachers' direct personal experiences may also suggest other ways of representing the subject matter: A methods instructor from college may have advocated the use of base-10 blocks for teaching place value; a colleague may pass along an analogy for explaining photosynthesis; a college English professor may have used a particular approach to literary analysis; or a high school history teacher may have made a memorable comparison between the domestic debate during the Mexican-American and Vietnamese wars. Through a variety of sources, teachers collect both tangible and intangible "stuff" for representing subject matter. In addition to adopting representations from others, teachers also invent their own, fashioning representations from their own understandings, knowledge, experience, and imagination. They create units of instruction, make worksheets, design activities, develop explanations, think of questions, and respond to pupils. Sometimes these are modifications of ideas gathered elsewhere; sometimes they are original inventions.

Over time, teachers develop a repertoire of subject matter representations from outside sources and from

their own ingenuity. As these representational repertoires develop, teachers have more options for connecting pupils with subject matter (Putnam, 1987; Putnam and Leinhardt, 1986; Shulman, 1987; Wilson, 1988; Wilson, Shulman, and Richert, 1987). This is an important part of learning to teach and something that takes many years. We cannot provide beginning teachers with ready-made repertoires that will suit all the possible contexts in which they could teach.

Providing beginning teachers with ready-made repertoires would not ensure that they could effectively connect their pupils with subject matter. Teachers must be able to appraise the pedagogical potential of an available representation and determine how well it fits the context. What makes a representation good? Is money a good model for helping fifth graders understand decimals? Can classroom elections help teach junior high pupils about democracy and the electoral process? Would today's high school seniors find useful a comparison between Thoreau's *Civil Disobedience* and resistance to the draft during the Vietnamese war? To answer questions such as these, beginning teachers must develop standards by which they can judge the validity and usefulness of representations.

Judging the Appropriateness of Representations

Teachers are faced with the complicated task of judging the appropriateness of available representations. This includes evaluating the approach used by the school's textbook, appraising activities passed on by colleagues, considering the relative value of particular questions, and analyzing models or pictorial representations. Teachers' judgments are based on their ideas about how people learn, about learners at different ages, about their particular pupils, about the subject matter itself, as well as about the context.

Instructional representations are woven from four domains of knowledge central to pedagogy: subject matter knowledge, knowledge about learning, knowledge of pupils, and knowledge about the context (see Schwab, 1973/1978b). And, stated succinctly, good instructional representations (a) correctly and appropriately represent the substance and the nature of the subject being taught, (b) are comprehensible to the particular pupils being taught, (c) contribute helpfully to learning, and (d) are reasonable and appropriate in the context (Ball, 1988a).

Although these standards seem obvious, they are anything but straightforward and easy to apply. Pupils are diverse, subject matter experts disagree among themselves about the nature and substance of their disciplines, and representations that work well for one purpose may be inadequate in others.

For example, a mathematician might argue that money is an inappropriate model for place value because nothing inherently requires you to "trade up" when you have 10 of any coin: "What's `wrong,' for example, with having 16 dollars, 22 dimes, and 14 pennies?" (Schoenfeld, 1986, p. 235). Furthermore, except for gas prices (i.e., $.97^9$ per gallon,) money does not model the number system beyond hundredths. A cognitive psychologist, on the other hand, might point out that since 10-year-olds are both familiar and competent with money, it serves as a useful link to understanding decimal numeration. Knowing that 100 pennies are equal to a dollar and that $.01 represents a penny may help pupils to understand the number "one hundredth" and its notation. A teacher might point out that fifth graders *like* money, and that using money might increase their attention to the lesson.

Similarly, subject matter experts, psychologists, and teachers might disagree on the appropriateness of classroom voting. A political scientist might argue that most classroom voting trivializes the democratic process by failing to structure the occasion around a genuine controversy. Furthermore, by failing to set up complicated alternatives in such a way that none is wholly satisfactory to any individual voter, pupils may not see the complexity involved in making choices. The lessons learned may ultimately disappoint pupils when they confront real electoral decisions. Yet others might respond that planting the seeds of fundamental concepts requires small beginnings (see Bruner, 1960). What may seem misleading at first can be elaborated over time as children's understandings develop.

Even with explicit standards for what makes a good representation, however, no instructional representation is perfect. In teaching, competing considerations come into play. Teachers cannot completely resolve all these considerations at once (Buchmann, 1988; Lampert, 1985). Furthermore, Lampert (1985) reminds us that this juggling is not *abstract*: Teachers' reasoning takes place in concrete, dynamic situations, inherently fraught with dilemmas. In working with beginning teachers, therefore, teacher educators need to involve prospective teachers in the kind of reasoning entailed in determining the relative appropriateness of representations

in teaching as well as helping them acquire the kinds of knowledge required to do so.

Why "Representation"--Instead of "Method" or "Strategy"?

Educators have traditionally thought about subject matter teaching in terms of "methods" or "strategies." How does the notion of instructional representations differ? We suggest three points that make this shift significant. The idea of teaching as representation focuses on subject matter by highlighting the fact that the so-called strategies themselves may "teach"--both intentionally and unintentionally. A class discussion about two pupils' differing interpretations of a short story can represent literary interpretation as it is enacted within a community of literary critics: Justifying one's understanding by referring to specifics in the text and challenging the frames of reference and assumptions of others. A worksheet of 28 long-division exercises, surrounded by cute pictures, may convey that performing calculations is at the heart of doing mathematics.

The concept of instructional representations tightens the connection between subject matter and method--and between what teachers know and what they do. Methods are not generic (Dewey, 1916/1964a). While it is true that teachers ask questions, hold discussions, give explanations, and use metaphors in all subjects, these play out in different ways, with different issues, in different subjects. Discussions in an English class may require different considerations from those in a mathematics class; using analogies appropriately demands much specific knowledge.

Using the notion of representation also connects the inventive work of teaching--making worksheets, tests, and designing activities--with the more routine tasks, such as using textbooks. Conceptually these have similar features, both in teaching and in learning to teach. Given this way of thinking about representations, all, whether invented, selected, or adapted, are subject to similar standards for their pedagogical usefulness and appropriateness. Emphasizing representations and standards by which to judge them offers a means for avoiding the "do your own thing" and "be creative" approach that often tends to threaten the integrity of subject matter teaching, especially with beginning teachers. Standards for developing and judging instructional representations are based on knowledge, not personal preference.

The Means: Implications for Teacher Education in Subject-Specific Pedagogy

Assuming an understanding of the critical role that representations of disciplinary knowledge play in teaching subject matter, what should the new methods instructor, discussed at the beginning of this paper, work on with his or her prospective teachers? What do beginning teachers need to know in order to develop, select, and use appropriate representations? We suggested above that beginning teachers need to develop an appropriate repertoire of representations for the subjects they teach; they also need to develop standards by which they can evaluate the appropriateness of subject matter representations. These tasks are not only difficult but inescapable. They are inescapable because teachers must use representations to help build bridges for their pupils. Every explanation, every worksheet, every computer program necessarily represents something about the substance and the nature of subject matter knowledge to pupils.

These tasks are difficult because to develop, select and use appropriate representations, teachers must understand the content they are representing, the ways of thinking and knowing associated with this content, and the pupils they are teaching. Such flexibility in creating access to knowledge, in turn, demands a much deeper and more critical understanding of subject matter than that needed simply to tell pupils what they ought to know. For example, a teacher whose understanding of the origins of the Civil War extends no further than being able to list "slavery, states' rights, and Southerners' wish to preserve their lifestyles" may have little to draw on to help her pupils understand the complexity and subtlety of historical causation or concepts such as "states' rights." Such a teacher would be unlikely to relate this idea to more contemporary events--say, school prayer, AIDS legislation, abortion, or Southern opposition to black civil rights--or to create activities, such as getting pupils to write a Bill of Rights for their school that would provide occasions for her pupils to confront, discuss, and think about the "reserved-powers" amendment. The greater this teacher's knowledge of U.S. history and historical concepts such as causation, the greater his or her repertoire and capacity to invent or select representations that fit the context and provide multiple opportunities for pupils from diverse backgrounds to understand. In the teaching-for-flexible-understanding model, teacher educators must therefore focus on the understandings of subject matter that

prospective teachers can call on to help diverse pupils understand.

Knowledge of Subject Matter Essential to Teaching for Subject Matter Understanding

Recent research highlights the critical influence of teachers' subject matter understanding on their pedagogical orientations and decisions (e.g., Ball, in press; Ball and Feiman-Nemser, 1988; Grossman, 1987; Gudmundsdottir, 1987; Hashweh, 1987; Kuhs, 1980; Leinhardt and Smith, 1985; Shroyer, 1981; Steinberg, Haymore and Marks, 1985; Thompson, 1984; Wilson, 1988; Wilson and Wineburg, 1988). Teachers' capacity to pose questions, select tasks, evaluate their pupils' understanding, and make curricular choices all depend on how they themselves understand the subject matter. Beginning teachers must develop a flexible, thoughtful, and conceptual understanding of their subject matter if they are to create or choose representations that enable pupils who bring a diversity of knowledge, experience, expectation, and values to develop similar understandings.

"Flexible" implies that teachers need to know how a given phenomenon or event is related to other phenomena or events both within their field and outside of it. Knowledge of such relationships enables teachers to represent ideas, information, or procedures. "Thoughtful" means that teachers must understand how knowledge in the field is generated and verified and be aware of competing ideas that have been advanced to explain observed relationships. "Conceptual" implies that the teacher comprehends the fundamental ideas and relationships that underlie interpretations of particular phenomena or events. Since pupils sometimes pick up on subtle messages embodied in instructional representations, teachers need to know as much as possible about the subject matter they are teaching in order to represent it well. Grossman, Wilson, and Shulman (in press) discuss in detail the kinds of knowledge of subject matter that teachers need.

Consistent with our contention that standards for judging the appropriateness of representations as well as the representations themselves differ from subject to subject, we offer examples from science, mathematics, history, and English. For instance, in physical science, teachers themselves may need to understand the nature of an electrical current if they are to help pupils understand it. They may need to know why electricity flows in currents as well as how electrical currents are generated and how such currents are transformed into other forms of energy. Preservice teachers could be involved in discussions of how the flow of electrons is similar to and different from

other types of particles--say, those in water--and how electricity relates to other forms of energy. In short, being able to define electricity and describe its properties is necessary but not sufficient knowledge. Teachers may also need to know how it relates to other physical phenomena and events.

Mathematics teachers need to know a great deal more about slope than the phrase "rise over run." They may need to think about the relationship between slope as a mathematical device and slope as a phenomenon of every day life if they are to represent the concept in a way that makes sense to pupils. In addition, they need to think about slope as a way of understanding relationships within mathematics--for instance, as a way of representing the covariance of two variables. They may need to see that this concept and related concepts have application in many other fields, from engineering to sociology to economics and business.

In history, preservice teachers should be able to view a study of the causes of the U.S. Civil War as an opportunity to think about and explore the notion of causation in human affairs and what doing history means. Where does the idea that slavery and the plantation system "caused" the Civil War come from? On what basis can a single set of social phenomena be said to cause other phenomena? What constitutes valid evidence for such a claim? What role should the perceptions of participants in historical events play in our contemporary efforts to understand the past? Teachers need to understand that the causes of the Civil War have not been definitively established. Historians are continually sifting through historical records. Their views of the significance of events, organizations, people and so on is shaped by the preoccupations of the present moment. Accounts of the causes of the Civil War represent a process of assessing, reconfiguring, and interpreting the historical record.

In English classes, teachers often portray writing as a technical process involving knowledge of the conventions of grammar, punctuation, text organization, syntax, tone, and word usage. Yet in order to teach for flexible understanding and competence with writing, teachers need to understand writing as a way to manifest, develop, refine, and communicate ideas. As most writing is ultimately a form of social intercourse, teachers need to think also of the processes of developing ideas and composing as social activities. If teachers understand writing only as "knowledge-telling" (Scardamalia and Bereiter, 1986), they are unlikely to help pupils develop into competent writers.

These kinds of understandings of subject matter are the sine qua non of teaching. Teachers have a better chance of being able to help their pupils develop flexible understandings of subject matter if they understand their subject matter well. Moreover, such understandings enable teachers to come up with a variety of ways of representing their understanding for their pupils who, we argue in the next section, bring very different experiences and knowledge with them.

Unfortunately, considerable evidence suggests that many prospective teachers, both elementary and secondary, do not understand their subjects in depth. Consider an example in mathematics: Ball (1988a) interviewed 19 undergraduate teacher education students, 9 of whom were majoring or minoring in mathematics intending to become high school math teachers and 10 of whom were preparing to teach at the elementary level. Of the 19 teacher candidates, only 5 were able to provide and explain the correct solution for $7 \div 0$. Twelve prospective teachers stated it as a rule ("You just *can't* divide by 0") and, of those 12, 5 gave an incorrect rule (the most frequently mentioned was "anything divided by 0 is 0"). Two teacher candidates said they did not know what $7 \div 0$ produced.

Among a larger sample of college students ($n = 318$), only 31% were able to identify from among four choices the mathematically correct representation of a division of fractions statement (Ball, 1988b). And, on another interview task, only 5 out of 19 prospective teachers could explain why the partial products in a multiplication problem "move over." As one prospective teacher said, "I know how to do it, but I don't know the ideas behind it." Examining their knowledge *about* mathematics produced results that were no more encouraging: Few thought of mathematics as a field of human endeavor in which people argued about and discussed interpretations, problems, methods, and solutions. Mathematics was, for the most part, conceived to be "cut and dried," a set of rules and procedures. Similar studies in other disciplines, such as physics (Clement, 1982) and history (Wilson 1988), also reveal wide gaps in college students' subject matter understanding.

In spite of this, teachers' understanding of subject matter rarely figures prominently in preparing teachers. Constrained by the limits of time, teacher educators tend to take prospective teachers' subject matter knowledge for granted, focusing instead on pedagogical knowledge and skills (Ball and Feiman-Nemser, 1988). At the same

time, many prospective elementary teachers assume that "common sense and memories of their own schooling will supply the subject matter needed to teach young children" (Feiman-Nemser and Buchmann, 1986, p. 245). And secondary teacher candidates do not accord much attention to their own subject matter knowledge either, although for a different reason: They feel they *understand* the content they will teach (Rosaen, Roth, and Lanier, 1988). After all, it is "just" high school material, and it was easy enough when they studied it as high school students. While beyond the reach of any single course, subject matter understanding is an issue our methods instructor cannot ignore. Helping prospective teachers acquire more flexible, thoughtful, and conceptual understanding of subject matter is critical to preparing them to teach for understanding.

Knowledge of Learners and Learning Essential to Teaching for Subject Matter Understanding

While obviously essential, a flexible understanding of subject matter is not enough for beginning teachers. They also need to know about learners-- both those in their own classes and learners in general--and about the learning process. As knowing about learners entails also knowing about learning--and vice versa-- we will discuss these together. Mounting evidence from cognitive science research shows that pupils' prior knowledge and beliefs powerfully influence the way they make sense of new ideas (see, for example, Anderson, 1984; Davis, 1983; diSessa, 1982; Posner, Strike, Hewson, and Gertzog, 1982; Schoenfeld, 1983). Research on reading, in particular, has produced the concept of schema. That is, children have their knowledge and experience of the world organized in particular ways. Their ability to understand what they are reading depends in part on the fit between the new information and ideas they encounter and the schemata they have developed to assess and organize new information or experience (Wittrock, 1981).

Research seems to demonstrate that children's understanding of subject matter is the product of an interaction between the ideas, information, and understandings they bring and the new ideas and information that they are presented. Wittrock (1986) reviews this research. In describing his own model of generative learning, Wittrock captures our view of the interaction between subject matter knowledge and students' prior experience and knowledge in learning:

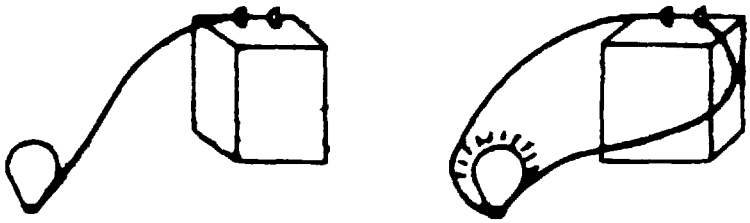
Learning with understanding includes . . . the generation of relations between previously acquired

> knowledge and the information to be learned, and between and among the parts . . . . Both learning with understanding and factual or other learning that need not lead to understanding involve learner generation of relations. However, the meaningful nature of relations differs because of the way the information relates to other information, to the learner's experience, and the learner's organized knowledge. (Wittrock, 1986, p. 306)

The process of constructing meaning from the social and physical world is not, however, a strictly individual, private affair. Rather, the interpretation of events and phenomena are mediated by the individual's enveloping social and cultural groups. In societies in which the sharing of game among hunters is the norm, for example, the concept of *equal*--as in "an equal share"--may mean a portion that meets the needs of the recipient rather than a portion that is the same in mass, quality, or quantity as all other portions. A child who comes to understand equal in this sense may find puzzling the notion of equal in arithmetic. (The first author observed this phenomenon as a teacher in a remote Yup'ik Eskimo community in Western Alaska.) Pupils' schemata for making sense out of the world are, thus, constructed from the meanings that events and people in their environment impart (McDiarmid, Kleinfeld and Parrett, 1988).

This perspective on learning as a constructive process makes learning theory especially relevant to the problems of teaching subject matter content. Returning to our example of teaching electricity, children see electrical circuits all around them. Before encountering the topic in school, they develop ideas about how circuits work. A common idea that children have about how circuits work is what Anderson (1980) refers to as the *source-consumer model*. Most children (and many adults) believe that batteries produce electric current and bulbs use it. The source-consumer model seems to make sense. People who assume this model might try to create light with a circuit like that shown in A in Figure 1. The light, of course, does not work in such an arrangement.

In contrast, physicists and electricians depend on a *circular flow model* of electric current when they are working with simple circuits. They believe that the current must flow out of one terminal of the battery and back into the other terminal. Someone who understands the circular flow model is more likely to construct the circuit shown in B. In this circuit, the light works.



A: Circuit based on source-consumer model

B: Circuit based on circular flow model

Figure 1. Two simple electrical circuits.

Thus, learning about simple circuits involves a complex process of *conceptual change* in which pupils must modify some of their beliefs about how circuits work while strengthening and reorganizing others. In this way, successful learners of science gradually reconstruct their understandings of the natural world. The interconnected and interdependent nature of our ideas about the world makes the process of learning science an arduous one for most pupils.

Some learning in all subjects requires major cognitive reorganization on the part of pupils. For instance, take the concept of causation in history. Pupils are often accustomed to linear causal explanation of events: "I didn't get a job that pays enough to buy the kind of car that girls want to be seen in, so that's why I couldn't get a date for the prom." Linear causal explanations are part of their everyday reality: "If you had *only* listened to us, your parents, this would never have happened." Pupils come to the study of history prepared for such explanations as "Slavery caused the Civil War." They are not prepared for the messy, distinctly nonlinear notion that the Civil War resulted from a confluence of events and developments that took place not only in the United States but elsewhere. Teachers need to help pupils understand their causal reasoning and their implicit standards of evidence.

In mathematics, pupils frequently develop the idea that math is "weird" or arbitrary, and therefore do not expect new ideas to make sense. When they encounter the concept of slope, they are prepared simply to memorize a formula and may resist a teacher's efforts to engage them in exploring the concept. Their ideas about what it

means to know something in mathematics shape their approach to learning and may pose difficulties for teachers who want to stress understanding. Furthermore, having progressed through school in this way, many pupils lack understanding of the prior concepts which are fundamental to understanding new ideas. In the case of slope, for example, pupils often have limited ideas about fractions that interfere with understanding the idea of slope as a ratio.

In English, pupils arrive with a variety of preformed ideas about the written word as well as ideas about themselves as thinkers and communicators. Some have little experience with text. For some, the written word symbolizes an alien world. For others, the written word is already an old friend. Needless to say, when the time to write rolls around, such experiences and attitudes dramatically influence how pupils come to understand writing as a process and a form of communication and themselves as composers of text. Teachers need to find out pupils' attitudes toward and experiences with text in devising or selecting representations.

In each of the examples above we have tried to demonstrate how pupils pre-instructional understanding of and experience with the subject matters shape their understanding of the ideas and information presented in classrooms. All significant learning, while not necessarily a matter of changing deeply rooted naive ideas, still occurs via connections between what learners bring and what they are taught. Teachers must help their pupils learn new and more powerful ways of understanding the world; they cannot simply *tell* their pupils what they should know and expect them to understand.

What Can the Methods Instructor Try?

Have we been able to suggest anything to a new methods instructor that would help her in designing a course to enable beginning teachers to teach for flexible understanding of her or her subject? Below we expand upon suggestions implicit in this paper:[4]

1. **Teacher Education Students' Conceptions of Teaching and Learning**

Helping teacher education students develop their own understanding of the subject matter they will teach

[4]For more discussion of the issues raised in this paper, please consult the annotated bibliography in the appendix.

involves challenging their fundamental conceptions of teaching and learning. Students typically begin their teacher education programs with the view that teaching is telling and learning is accruing information. Years of the "apprenticeship of observation" (Lortie, 1975) and of watching the public behaviors of teachers have led them to believe that they understand what is required for teaching.

Teacher educators, on the other hand, may view teaching and learning quite differently. Many of them recognize that children do not enter classrooms as blank slates but rather as individuals who bring with them a variety of experiences with and understandings of the subject matter, schools, classrooms, and teachers. Unless teacher educators address teacher education students' initial conceptions of what it means to teach and learn subject matter, to challenge the prevailing view that teaching means telling and learning means remembering, we are likely to see the perpetuation of the telling-accrual model of teaching that has dominated schools in the United States since their inception (Cohen, in press; Cuban, 1985; Goodlad, 1985).

2. **Prospective Teachers' Understanding of Subject Matter**

If methods instructors want to prepare teachers to teach for subject matter understanding and not merely for accruing information, they need first to help teachers develop their own understanding of subject matter. Methods instructors may select two or three topics that are critical to their field--such as electricity or experimentation in science, fractions or argument and proof in mathematics, causation or interpretation in history, audience or argument in writing--and help prospective teachers in developing their own subject matter understanding. This may involve having preservice teachers generate all the examples, analogies, graphics and so on that they have in their repertoires for representing a particular topic or idea. Others in the class could react to the representations, commenting on their usefulness and appropriateness. Such work will help prospective teachers to deepen their notions about *understanding* as well as to acquire ideas about how to help pupils develop such understanding.

In addition to focusing on substantive knowledge and understanding, methods instructors might also give explicit consideration to raising their students' awareness of how aspects of subject matter knowledge relate to the *nature* of the subject. Course activities could be designed to provide students with experiences that would help to

challenge and develop their ideas about sources of knowledge, nature of activity, and the role of community in the respective disciplines.

3. **Learning to Learn About Pupils in Relation to Specific Subject Matter**

Methods instructors may also want to work with their students on creating opportunities inside and outside the classroom to learn more about the knowledge, attitudes, and experiences that their pupils will bring to the study of specific subject matter. Attention to pupils' prior knowledge tends to be limited, in most methods classes, to advocating the use of paper-and-pencil pretests. Preservice teachers need a chance to see and think about other ways of finding out what pupils know and understand, particularly ways that allow them to explore the dynamics of the process by which pupils make sense out of the world. What knowledge and understandings do pupils already have? How do various materials--textbooks, workbooks, audiovisual, laboratory units, and so on--take these understandings into account, if they do at all?

4. **Evaluating Representations of Subject Matter**

Methods instructors could help prospective teachers develop skill in evaluating representations, such as textbooks, curricular materials, models, graphics, metaphors, activities, and explanations. Prospective teachers need opportunities to examine existing representations and develop a subject-specific framework for judging their appropriateness.

5. **Generating Representations of Subject Matter**

Finally, methods instructors could model the process of creating multiple instructional representations for ideas. Rather than trying to cover a great deal of subject matter, instructors could concentrate on developing a wide range of representations for a limited number of topics or ideas, focusing on the kinds of considerations involved in generating defensible representations. Students could become involved in developing both the representations and the criteria by which those representations should be judged for appropriateness. Through discussions, they could identify and grapple with the dilemmas entailed in representing subject matter well in teaching.

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APPENDIX

Annotated Bibliography

The following is a list of readings that might be helpful to teacher educators interested in helping beginning teachers acquire knowledge, skill, and dispositions essential for learning to teach subject matter well. In addition to general works, we suggest readings in specific subject areas to highlight some of the unique issues entailed in the pedagogy of each area. Some readings offer frameworks that might prove helpful in working with prospective teachers. Others provide descriptions of different teachers' alternative representations of the same or similar content; these might be useful to beginning teachers as cases for analysis and appraisal.

Anderson, C. W., and Smith, E. L. (1987). Teaching science. In V. Richardson-Koehler (Ed.), Educators' handbook: A research perspective (pp. 84-111). New York: Longman.

This chapter reviews both large-scale national studies of student achievement and studies focusing on the design of science instruction for conceptual change learning. Recommendations for science teachers, teacher educators, and administrators are developed.

Atwell, N. (1981). Writing and reading from the inside out. Language Arts, 58, 913-918.

This article focuses on the connections between reading and writing and argues that instruction must emphasize these connections.

Ball, D. L., and Feiman-Nemser, S. (1988). Using textbooks and teachers' guides: A dilemma for beginning teachers and teacher educators. Curriculum Inquiry, 18, 401- 423.

This article deals with the problems faced by beginning teachers whether they use or avoid textbooks (in elementary reading, math, and social studies instruction). The authors argue that beginning teachers need to learn to use textbooks critically as well as to learn from such curricular materials.

Dewey, J. (1964). The nature of method. In R. Archambault (Ed.), John Dewey on education (pp. 387-403). Chicago: University of Chicago Press. (Original work published 1916)

In this essay, Dewey argues that teaching method is intrinsically tied up with the subject that is being taught. The methods that are used shape what students learn; moreover, its pedagogical method should be the method of inquiry followed in a particular subject.

Driver, R., Guesne, E., and Tiberghien, A. (1985). Children's ideas in science. Philadelphia: Keynes.

This book includes chapters on student conceptions of a variety of scientific topics, including light, heat, force, motion, conservation of matter, and kinetic molecular theory.

Dunn, S. (in preparation). Hidden competencies in children's writing abilities: Dialogue journals in a resource room setting. Unpublished doctoral dissertation, Michigan State University.

This work focuses on the ways in which a particular form--the dialogue journal--represents the process of writing to elementary age children who have typically been unsuccessful with writing in school. The author examines and describes its contributions to pupils' writing and their understanding of the writing process.

Dunn, S., Florio-Ruane, S., and Clark, C. M. (1987). Response and revision: Teacher as respondent to the high school writer. In S. Freedman (Ed.), The acquisition of written language, (pp. 33-50). Norwood, NJ: Ablex.

This chapter presents a case of a high school English teacher teaching a unit on haiku. The case makes vivid what one very good teacher takes into account in planning and devising ways to represent the process of writing to high
school students.

Fitzgerald, F. (1979). America revised: History schoolbooks in the twentieth century. Boston: Little Brown and Company.

The author discusses the multiple influences on history and social studies textbook publishers that shape the content that is included and the ways in which it is presented. She argues persuasively that American history as it is portrayed in most school textbooks is revised to meet the perspectives and biases of states and groups with power.

Florio-Ruane, S. (1987). Teaching as response: The problem of writing conferences Unpublished manuscript. Institute for Research on Teaching, Michigan State University, East Lansing.

This paper places the dialogue of writing conferences in the larger social context of classroom discourse, arguing that enacting writing conferences as they are ideally conceived is complicated by this larger picture. The author gives an illustration of a student teacher attempting to work with a pupil and having difficulty using conferencing to represent and help the pupil engage in the writing process.

Grossman, P. L. (1987). A tale of two teachers: The role of subject matter orientation in teaching (Knowledge Growth in a Profession Series). Stanford,CA: Stanford University, School of Education.

This paper presents case studies of two teachers with different perspectives on interpretation of text. The cases highlight different ways in which two teachers represented interpretation to high school students.

Kreest, J. (1984). Dialogue writing--bridging the gap between talk and essay writing. Language Arts, 61(2), 141-150.

This article addresses the issue of helping students move from oral to written language and argues that dialogue writing appropriately represents a bridge between the two modes of discourse.

Lampert, M. (in press). Choosing and using mathematical tools in classroom discourse. In J. Brophy (Ed.), Advances in research on teaching: Teaching for meaningful understanding (Vol. 1). Greenwich, CT: JAI Press; Lampert, M. (1986). Knowing, doing, and teaching multiplication. Cognition and Instruction, 3, 305-342; Schoenfeld, A. (1986). On having and using geometric knowledge. In J. Hiebert (Ed.), Conceptual and procedural knowledge: The case of mathematics (pp. 225-264). Hillsdale, NJ: Erlbaum.

These three readings provide vivid portrayals of the complicated process of representing mathematics in ways that are intellectually appropriate and valid--from the point of view of the subject matter, of the students, as well as of the context of real classrooms. All three pieces discuss representation and the considerations that underlie the selection and generation of representations in teaching mathematics.

Roth, K. J., and Anderson, C.W. (1988). Promoting conceptual change learning from science texts. In P. Ramsden (Ed.), Improving learning: New perspectives. London: Routledge and Kegan Paul.

This chapter presents case studies of two teachers teaching science from science textbooks. The authors suggest ways of using science textbooks to promote conceptual change learning. Underlying these suggestions is research in which student learning from an experimental science text has been compared with student learning from two major traditional science texts. Different reading strategies were identified. The chapter highlights some subject-specific problems with learning from science textbooks.

Wilson, S. M., Shulman, L. S., and Richert, A. (1987). "150 different ways of knowing":

Representations of knowledge in teaching. In J. Calderhead (Ed.), Exploring teacher thinking (pp. 104-124). Sussex: Holt, Rinehart and Winston.

This chapter outlines a framework for the domains of knowledge from which teachers must draw: knowledge of subject matter, pedagogical content knowledge, knowledge of other content; knowledge of curriculum, learners, and educational aims, as well as general pedagogical knowledge. The authors also propose a beginning model for the process, which they call "pedagogical reasoning," by which teachers transform their own subject matter knowledge in order to help students learn it.

Wineburg, S. S., and Wilson, S. M. (in press). The subject matter knowledge in the teaching of history. In J. Brophy (Ed.), Advances in research on teaching (Vol. 2). Greenwich, CT: JAI Press.

This chapter presents cases of two history teachers and illustrates the way in which subject matter knowledge comes together with other considerations in representing history to students. Both teachers have similar understanding of the material they are teaching (the American Revolution), but choose to represent it to students in different ways both of which the authors describe as exemplary.