THE SUBJECT MATTER PREPARATION OF TEACHERS[1]

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> If anything is to be regarded as a specific preparation for teaching, priority must be given to a thorough grounding in something to teach. (Peters, 1977, p. 151).

That subject matter is an essential component of teacher knowledge is neither a new nor a controversial assertion. After all, if teaching entails helping others learn, then understanding what is to be taught is a central requirement of teaching. The myriad tasks of teaching, such as selecting worthwhile learning activities, giving helpful explanations, asking productive questions, and evaluating students' learning, all depend on the teacher's understanding of what it is that students are to learn. As Buchmann (1984) points out,

> It would be odd to expect a teacher to plan a lesson on, for instance, writing reports in science and to evaluate related student assignments, if that teacher is ignorant about writing and about science, and does not understand what student progress in writing science reports might mean. (p. 32)

Although subject matter knowledge is widely acknowledged as a central component of what teachers need to know, research on teacher education has not, in the main, focused on the development of teachers' subject matter knowledge. Researchers specifically interested in how teachers develop and change have focused on other aspects of teaching and learning to teach: for example, changes in teachers' role conceptions, their beliefs about their work; their knowledge of students, curriculum, or of teaching strategies. Yet to ignore the development of teachers' subject matter knowledge seems to belie its importance in teaching and in learning to teach.

The focus of this paper is the subject matter preparation of teachers: what subject matter preparation entails, where and when it occurs, and with what outcomes. Since research on teachers' learning of subject matter is a relatively new domain of inquiry in teacher education, the literature is scant. The purpose of this paper, therefore, is to offer a framework that can contribute to future research in this area. To lay a foundation for the argument, the first section of

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the paper examines the concept of subject matter knowledge, for, although the claim that teachers must know what they are teaching appears self-evident, agreement does not exist about what is included in the idea of knowing subject matter for teaching. The second section offers a framework for the sources and outcomes of teachers' subject matter learning. In the third section, this framework is used to consider extant evidence about teachers' subject matter preparation. The paper concludes with a discussion of issues raised in earlier sections that suggest directions for future work on the subject matter preparation of teachers.

The Role of Subject Matter Knowledge in Teaching

Helping students learn subject matter involves more than the delivery of facts and information. The goal of teaching is to assist students in developing intellectual resources to enable them to participate in, not merely to know about, the major domains of human thought and inquiry. These include the past and its relation to the present; the natural world; the ideas, beliefs, and values of our own and other peoples; the dimensions of space and quantity; aesthetics and representation; and so on. Understanding entails being able to use intellectual ideas and skills as tools to gain control over everyday, real-world problems. Students should see themselves, either alone or in cooperation with others, as capable of figuring things out--of using mathematics to define and reason through a problem; of tracking down the origins of current social policy; of interpreting a poem or story, of understanding how physical forces operate; of recreating in writing a feeling, idea, or experience. They should both be able and inclined to challenge the claims in a politician's speech, to make sense of and criticize presentations of statistical information, and to write an effective letter to the editor. A conceptual mastery of subject matter and the capacity to be critical of knowledge itself can empower students to be effective actors in their environment.

Philosophical arguments as well as common sense support the conviction that teachers' own subject matter knowledge influences their efforts to help students learn subject matter. Conant (1963) wrote that "if a teacher is largely ignorant or uniformed he can do much harm" (p. 93). When teachers possess inaccurate information or conceive of knowledge in narrow ways, they may pass on these ideas to their students. They may fail to challenge students' misconceptions; they may use texts uncritically or may alter them inappropriately. Subtly, teachers' conceptions of knowledge shape their practice--the kinds of questions they ask, the ideas they reinforce, the sorts of tasks they assign.

Although early attempts to validate these ideas, to demonstrate empirically the role of teachers' subject matter knowledge, were unsuccessful (e.g., Begle, 1979), recent research on teaching and on teacher knowledge is revealing ways in which teachers' understandings affect their students' opportunities to learn (e.g., Ball, in press a; Grossman, 1988; Lampert, 1986; Leinhardt and Smith, 1985; Roth and Anderson, in press; Shroyer, 1981; Wilson, 1988; Wineburg and Wilson, 1988). This research is proving fruitful, in part, because of the researchers' conceptual work on dimensions of subject matter knowledge, work that is moving the field beyond the counting of course credits as a measure of teacher knowledge. Shulman's (1986) three categories of content knowledge--subject matter content knowledge, pedagogical content knowledge, and curricular content knowledge--are at the heart of much of the current inquiry. This paper focuses on the first, on what Shulman (1986) calls *subject matter content knowledge.*

What teachers need to know about the subject matter they teach extends beyond the specific topics of their curriculum. Shulman (1986) argues that "teachers must not only "teachers must not only be capable of defining for students the accepted truths in a domain. They must also be able to explain why a particular proposition is deemed warranted, why it is worth knowing, and how it relates to other propositions" (p. 9). This kind of understanding encompasses an understanding of the intellectual fabric and essence of the subject matter itself. For example, while English teachers need to know about particular authors and their works, about literary genres and styles, they also needs to know about interpretation and criticism (Grossman, in press). A history teacher needs detailed knowledge about events and people of the past but must also understand what history is: the nature of historical knowledge and what it means to find out or know something about the past. Scheffler (1973) writes that this kind of subject matter understanding "strengthens the teacher's powers and, in so doing, heightens the possibilities of his art" (p. 89).

Lampert (in press), writing about her own teaching of fifth-grade mathematics, provides a vivid picture of the role that this kind of subject matter knowledge plays in teaching. She describes a series of lessons in which her students were learning to compare numbers written as decimal fractions: Which is greater--.0089 or .89? Or are they equal? While part of her goal was for her students to develop conceptual understanding of place value with decimal numbers, she had another aim as well:

> My wish [was] to present mathematics as a subject in which legitimate conclusions are based on reasoning, rather than on acquiescing to teacherly authority. . . . I wanted to enable the students themselves to question their own assertions and test their reasonability within a mathematical framework. (p. 24)

Concretely, this means that Lampert chose not to teach her fifth graders the familiar algorithm:

"Add zeroes after the digits to the right of the decimal points until the numbers you are comparing have the same number of decimal places. Now ignore the decimal point and see which of the numbers is larger" (p. 4). This common approach--"line up the places and add zeroes"--is not essentially mathematical: Students arrive at an answer "through a combination of trust in authority, memory, and mechanical skill" (p. 5).

Lampert's own understanding of the substance of mathematics as well as its nature and epistemology shape what she is trying to help her students learn. When a student in her class asserted that .0089 is a negative number, for example, Lampert interpreted his claim as a conjecture whose validity could be judged by the classroom mathematical community rather than as a misconception that she should correct. Because she conceives of mathematics as a system of human thought rather than as a fixed body of procedures, she believes that students must have experience in developing and pursuing mathematical hunches and learning to make mathematical arguments for their ideas within the context of a discourse community. Orchestrating this in a fifth-grade classroom requires that the teacher draw simultaneously on her substantive understanding of mathematics--in this case, place value and decimal numeration--and her knowledge about the discourse, activities, and epistemology of mathematics. This knowledge of mathematics is necessary but not sufficient. Good teaching demands that teachers know a lot of other things--for example, about learning, about their students, and about the cultural, social, and political contexts within which they work.

That teachers may hold such goals for student learning that grow out of their study of subject matter does not, however, dictate a particular pedagogy. In helping students develop such understandings, teachers may play a variety of roles and draw on a variety of knowledge and skills. Teaching styles and the manner in which teachers organize their classrooms may also vary. Wineburg and Wilson (1988) describe two very different but equally excellent high school history teachers, Mr. Price and Ms. Jensen, teaching their students about the American Revolution:

> The juxtaposition of Price and Jensen offers a study in contrasts. Watching Price, we see what Cuban has called "persistent instruction"--whole-group recitation with teacher at the center, leading discussions, calling on students, and writing key phrases on the chalkboard. Jensen's classroom, on the other hand, departs from the traditional: Cooperative small groups replace whole-group instruction; student debate and presentation overshadow teacher recitation; and the teacher's voice, issuing instructions and dispensing information, is largely mute. (p. 56)

Despite differences in their pedagogy, these teachers conceive of history and of what is important for students to learn about history in similar ways. Both want their students to understand that history is fundamentally interpretive: Learning history means studying accounts of the past that have already been constructed as well as learning about alternative accounts of the same phenomenon and how such accounts are constructed. In Scheffler's (1973) terms, these teachers' knowledge of history underlies their power and strength as pedagogues.

Whether or not they intend to, teachers in all subjects influence students through their own engagement in ideas and processes. Teachers' intellectual resources and dispositions largely determine their capacity to engage students' minds and hearts in learning. For instance, Lampert's deep interest in numbers and their patterns is contagious. And her understanding of mathematics as an active domain of human interest and inquiry leads her to orchestrate opportunities for learning that differ from those found in many mathematics classes (Ball, in press a; Stodolsky, 1988).

Similarly, describing his decision to challenge the conventional wisdom that students must be of high school age to tackle Shakespearean tragedy, Herbert Kohl (1984) writes of his own involvement with the play that he later staged with the 45 elementary and middle school students who attended his summer school:

> During the winter I thought about Macbeth occasionally, but it wasn't until I encountered an ad in the *New York Times* that read "Macbeth lives on in the story, but Cawdor Castle lives on in fact," and had a photo of Hugh Vaughn, sixth earl of Cawdor, posed in front of Macbeth's Cawdor Castle, that I began to work seriously on planning the play. The photo of the castle made Macbeth's world come alive for me as it did for my student actors during the summer. It gave a scale and shape to Macbeth's world. I began gathering resources as well as reading and rereading Shakespeare's play to prepare for writing my own shortened version. (p. 145)

In history, teachers who from time to time challenge the textbook's account of events demonstrate that history is not merely a matter of fact but also of interpretation; learning history involves developing the tools to assess various interpretations of the past. Wilson (1988), in her study of expert and novice history teachers, reports the description of a graduate seminar in history offered by one of her expert teachers: "It was a revelation to me. And this has always been reflected in my teaching. The idea, for instance, of the American Revolution as being two events: a war of independence and an internal revolution . . . " (p. 137) In explaining the emphasis he places on the interpretative nature of history in teaching, this teacher says:

> I have always put a heavy emphasis on interpretations in history. Not necessarily because I wanted to make them junior historians. But interpretations are useful to

> me because they help me create a frame of reference for kids in which they can realize their own frame of reference. I want them to understand that all of history is an interpretation. I want kids to confront their mindsets. . . . But most important on the high school level, interpretations show that different approaches yield different answers to the same problem. (p. 309)

This teacher's engagement with history as a way of making sense of our past is part of what he communicates to his students.

Sources and Outcomes of Teachers' Subject Matter Learning

Where Does "Subject Matter Preparation" Take Place?

Critics of teacher education tend to overlook the fact that prospective teachers take most of their courses not in much-maligned colleges of education but in liberal arts departments. The professional training they receive in colleges of education is also not centrally concerned with their subject matter knowledge. Elementary teachers take half or more of their courses in the liberal arts; recent policy initiatives--in states such as New Jersey, California, Illinois, Texas, and Virginia--have drastically curtailed or have eliminated the education courses that intending teachers can take. Secondary teachers have, for many years, taken as few as four or five teacher preparation courses in addition to student teaching. Yet, few critics or researchers concerned with teachers' ability to help their pupils learn subject matter knowledge have shown a broad philosophical interest in the liberal arts component of teacher education (see, for example, Bigelow, 1971).

While secondary teachers usually major in a discipline, elementary teachers take a range of survey and introductory courses in a variety of disciplines: history, English, sociology, biology, psychology, and art. What students actually learn about subject matter from their college and university liberal arts courses is both an open and a critical question. This paper, therefore, examines what is learned in university courses.

Yet, to limit the exploration of prospective teachers' subject matter preparation to their university education would be to miss the point. Teachers usually spend 13 years in school prior to entering college. During this period, they take English, mathematics, science, and social studies. What is the contribution of this precollegiate experience to teachers' subject matter understanding? A central premise of this paper is that teachers' understandings are shaped significantly through their experiences both in and outside of school and that a major portion of teachers' subject matter learning occurs prior to college. Consequently, this exploration of the subject matter preparation of teachers examines what children learn in school about science, mathematics, social studies, and writing, assuming that prospective teachers were once themselves such children.

While learning to teach begins long before formal teacher education, it also continues for years thereafter (Feiman-Nemser, 1983). Therefore, this paper looks to practice as an additional source of teachers' subject matter learning, for teachers may learn content from teaching it. Because of a student's question, a particular textbook activity, or an intense class discussion, teachers often report that, for the first time, they came to really understand an idea, a theme, or a problem that heretofore they had just known as information. How does this learning from practice contribute to the subject matter preparation of teachers?

Outcomes of Subject Matter Learning

What is learned through studying a subject, whether at the elementary, secondary, or college level? On one hand, this may seem an obvious question. Math classes teach students to add and subtract fractions, factor equations, construct deductive proofs, and solve story problems; social studies classes provide them with information about our nation's past, cultures different from their own, and world geography. In English, students learn to write the five-paragraph essay, to construct grammatical sentences, and to spell and punctuate correctly; in science they learn about electricity, gravity, and about the ecosystem. An abundance of evidence belies these easy assumptions about what students learn from subject matter study.

On the other hand, what is learned from studying a subject entails much more than what can be inferred from examining course syllabi or curriculum goals and objectives. Paradoxically, while students seem to learn less of the substance of the subject matter--the facts, concepts, procedures, information, and skills--than we often assume, they also learn more than the substance. Seldom the focus of research on student learning, these other outcomes contribute to students' ideas about the nature of the subject, their dispositions toward the subject, and their assumptions about the teaching and learning of the subject. Three dimensions of what students learn from subject matter study--substantive knowledge of the subject, knowledge about the subject, and dispositions toward the subject--are discussed below.

Substantive knowledge of the subject. The first dimension is what is conventionally thought of as subject matter knowledge. Every subject matter field, although continually changing and growing, includes specific information, ideas, and topics to be known. This information and these ideas and topics may be subject to disagreement and different interpretation based on competing perspectives within the field. Still, no conception of subject matter knowledge can exclude attention to substantive knowledge. The very stuff of the subject, its components and the terms used to classify it differ from one subject to another. Knowledge of mathematics includes specific concepts, definitions, conventions, and procedures (e.g., what a rectangle is, how to find the maximum value of a function). Historical knowledge focuses on differing accounts of people, societies, and events, and on explanations of factors that influence the course, sequence, and relationship of events (e.g., what contributed to the Great Depression or to the suffrage movement in the United States and in other countries). Biology includes knowledge of organisms, their functions and relationships (e.g., respiration and photosynthesis), and the nomenclature that signifies systemic differences. Knowledge of writing includes conceptual, propositional, and procedural knowledge about language, syntax, grammar, audience, and text genres (e.g., constructing a persuasive argument or a compelling narrative).

Knowledge about the subject. Substantive knowledge--knowledge of the ideas, facts, and theories of a subject--is but one aspect of subject matter knowledge. Subject matter knowledge also includes a host of understandings *about* the subject--for example, the relative validity and centrality of different ideas or perspectives, the major disagreements within the field (in the past as well as current), how claims are justified and validated, what is entailed in doing and engaging in the discourse of the field. Whether or not such understandings are explicit goals of instruction, students develop ideas about the subjects they study. Beers (1988) argues that while epistemological issues are rarely made explicit in classrooms, they are implicitly represented in the organization and content of curriculum, in the interaction between teachers and students, and in the nature of classroom activity and discourse.

The issues critical to knowledge about the subject vary. In mathematics, for example, a critical dimension of knowledge about the subject is the distinction between convention and logical construction. That positive numbers run to the right on the number line or that we use a base ten system of numeration is arbitrary. That division by zero is undefined or that any number to the zero power (e.g., 8^0) is equal to one is not. Critical knowledge about mathematics also includes relationships within and outside of the field--understanding the relationship among mathematical ideas and topics and knowing about the relationship between mathematics and other fields. Knowing the fundamental activities of the field--looking for patterns, making conjectures, justifying claims and validating solutions, and seeking generalizations, for example--is yet another aspect of knowledge about mathematics.

Knowledge about history has both parallels with and differences from knowledge about mathematics. Because history is fundamentally interpretive, distinguishing fact from conjecture is critical, just as distinguishing convention from construction is in mathematics. And, like mathematics, knowledge about discovery and discourse in the field--what is entailed in doing history--is an important aspect of knowledge about the field. In contrast, historical knowledge, as interpretation, grows out of alternative perspectives that evolve from different, sometimes conflicting, theoretical orientations.

Moreover, historians' different perspectives lead not only to different interpretations of the same phenomena but also to the pursuit of entirely different questions or about different phenomena. Wilson (1988) asserts that "historians . . . can tell qualitatively different stories about the same past, depending on the questions they find interesting and the frameworks they use to make sense of the world" (p. 216). Wilson (1988) points out that some historians, for instance, focus on issues of gender or power, others ask economic questions, and still others use sociological or psychological theories and constructs. While these perspectives are not wholly separable in seeking knowledge about the past, a historian's orientation shapes his or her account of particular phenomena.

For example, Eric Foner (1988) views black officeholders in the South after the Civil War as thoughtful, independent politicians who sought, partially through their alliance with so-called carpetbaggers from the North, to improve the lot of their people. His account of Reconstruction, as a consequence, differs markedly from those of earlier historians. Foner's account is different less because of his reliance on previously unexamined evidence than on the weight he gives to certain types of evidence and his orientation to black history: He rejects as biased the view that postbellum Southern black politicians were, by definition, passive, ignorant, and pliable.

Knowledge about science and knowledge about writing complement substantive knowledge in mathematics and history. What do scientists do? What is the interplay between theory and empiricism in scientific inquiry (Kuhn, 1962; Phillips, 1985; Popper, 1958; Schwab, 1960/1978)? How does this vary with the focus and nature of particular scientific inquiry? And, as in mathematics and history, understanding the nature of particular knowledge--fact or theory--is essential.

Writing, in many ways a different kind of field, nevertheless embodies critical epistemological issues. For example, writers, like historians, construct their texts according to their purposes and orientations. Writing mysteries differs substantially from sports journalism, personal letters, or persuasive essays. Within and across kinds of writing, what standards govern the use of language and mechanics and how do conventions interplay with style? How does audience influence text design and construction?

Some of the ideas that students develop about the subjects they study may not accord with the ways in which scholars who work in these fields think about their subjects. For example, students may come to view history as a factual account of the past or mathematics as a domain of clearly right and wrong answers. Students' beliefs about the nature of the subjects they study constitute a critical element of their subject matter knowledge that influences their substantive understandings as well. A student who thinks that poems must rhyme and that good writing is signalled by mechanical correctness is unlikely to appreciate or understand Ezra Pound or e. e. cummings. A student who believes that the meaning of history is a matter of debate is more likely to interrogate accounts of the past.

Dispositions toward the subject. In addition to understandings of the substance and nature of the subjects they study, students also develop dispositions toward those subjects. They acquire tastes and distastes for particular topics and activities, propensities to pursue certain questions and kinds of study and to avoid others. Students develop conceptions of themselves as good at particular subjects and not at others. For example, 65 percent of third graders think they are good at mathematics; by the end of high school this proportion has dropped to roughly half (Dossey, Mullis, Lindquist, and Chambers, 1987). And, college students tend to juxtapose being good at mathematics with being good at writing (Ball, 1988). Such dispositions towards subject matter, while well known, are often overlooked in considering what students learn from studying subject matter.

The Precollege Curriculum and Teachers' Subject Matter Preparation

Prospective teachers have been studying mathematics, science, social studies, and writing long before they enter a university. Their precollege education forms a much bigger chunk of their formal education than does the relatively brief period of college study. Not only is the precollege phase of subject matter study longer than the college period, but the content studied in elementary and high school classes is also often closer to that which prospective teachers will actually teach.

The subject matter preparation of English teachers reveals perhaps the closest correspondence between what is studied in college and what teachers teach in elementary and high school. High school English teachers study literature in their college courses; the works they read and what they learn about literary interpretation may contribute to the understandings upon which they draw in teaching. Still, high school English teachers teach grammar, spelling, and writing as well, topics rarely explicitly central to the college major. Thus, English teachers often must draw ultimately on what they learned when they were in school themselves.

The centrality of the teacher's own precollege education is clearer yet in the case of mathematics teachers. High school mathematics teachers teach about exponents, division, slope--

topics that they will not have revisited since high school themselves. Thus, their own understanding of these ideas is the product of their own high school mathematics experience, an experience that is likely to have been focused on an algorithmic approach to mathematics (Davis and Hersh, 1981; Goodlad, 1984; Madsen-Nason and Lanier, 1986; Wheeler, 1980) and unlikely to have contributed to conceptual understanding (Ball, in press b). In a longitudinal study of undergraduate teacher education candidates at five institutions, researchers at the National Center for Research on Teacher Education explored the understandings of mathematics held by 252 prospective elementary and secondary mathematics teachers. Concepts on the questionnaire and interviews included place value, slope, multiplication and division, zero, and perimeter and area.

Researchers found that both elementary and secondary majors had difficulty remembering particular ideas and procedures. Moreover, many were unable to make conceptual sense of the mathematics they had learned to perform. In seeking to explain "particular mathematical concepts, procedures, or even terms, the prospective teachers typically found loose fragments--rules, tricks, and definitions. Most did not find meaningful understanding." (Ball, in press b).

Other studies that examine prospective teachers' understandings of school mathematics content have yielded similar findings. More research has focused on elementary teacher candidates' subject matter knowledge (e.g., Graeber, Tirosh, and Glover, 1986; Mansfield, 1985) than on the understandings of students intending to teach high school. A notable exception is Even's (1989) cross-institutional study of mathematics majors' understandings of functions. Although the concept of function is central both to mathematics and to the high school curriculum, many students had limited and inaccurate knowledge of functions.

Science and social studies teachers face a common problem unlike that faced by English or mathematics teachers. Because of the way in which school subjects are organized, the courses these teachers become responsible to teach are frequently well beyond the scope of their college disciplinary specialization. Science teachers teach earth science, physical science, biology, health; social studies teachers teach civics, geography, economics, sociology, and history. Yet, as university students, prospective science and social studies teachers major in a single science--chemistry, physics, or biology, for example--or a single social science, such as anthropology, political science, sociology, or history. As teachers, what they understand about topics outside their area of specialization is likely based on what they remember from elementary and high school classes.

For example, Hashweh (1987) compared the subject matter knowledge of science teachers, focusing on topics from physics and biology. He found that teachers, not surprisingly, had more detailed knowledge of topics and were able to make more connections to higher order principles and unifying disciplinary concepts within their area of specialization. Outside this area, their knowledge was often inaccurate and thin. Two of the biology teachers, for example, held commonsense notions about work and force; similarly, some of the physics teachers misunderstood cellular respiration.

Research conducted by Wilson and Wineburg (1988) suggests that, in the case of social studies teachers' background knowledge, the issues may be subtler still. They suggest that the perspectives developed as a result of their college disciplinary specialization may dominate--inappropriately--their representation of other areas:

> What is interesting about our findings is the way in which our teachers' undergraduate training influenced their teaching. The curriculum they were given and the courses they subsequently taught were shaped by what they did and didn't know. Thus Fred's U.S. history course became the study of political science . . . organized around [political] themes. . . . In much the same way, Cathy used her knowledge of the structures of anthropology and archaeology to make sense of the social sciences she was simultaneously learning and teaching. (Wilson and Wineburg, 1988, pp. 534-535)

The authors argue that these teachers' "disciplinary lenses" at times skewed and misrepresented the content they were teaching. Failing, for example, to appreciate the role of context in interpreting events of the past, nonhistory majors overgeneralized across distinctly different periods in time.

While the outcomes of college study are relatively undocumented, what students learn in elementary and high school classes is a question more commonly explored; inferences about the outcomes of prospective teachers' precollege studies are possible based on these data. In mathematics, for example, data from the most recent National Assessment of Education Progress (Dossey, Mullis, Lindquist, and Chambers, 1987) show that while students are able to perform routine arithmetic calculations, many have difficulty with moderately complex procedures and reasoning. Only about half the 17-year-olds were successful with problems such as calculating the area of a 6 x 4 cm rectangle or solving a simple algebraic equation. Most high school seniors (94%) were unable to solve multistep problems: "Suppose you have 10 coins and have at least one each of a quarter, a dime, a nickel, and a penny. What is the *least* amount of money you could have?" Based on these data which suggest that students leave high school with little more than basic whole number computational skills, Dossey at al. (1987) argue that many students "are unlikely to be able to match mathematical tools to the demands of various problem situations that permeate life and work" (p. 41).

Data on what students learn in their science and social studies classes, on what they learn about writing, reveals a similar, although possibly more variable, picture. Furthermore, students also acquire ideas about the meaning of knowledge and of knowing in their elementary and secondary classes. When mathematics consists of memorizing rules and formulas, history means knowing dates and names; science means reading a text or carrying out scripted laboratory experiments; and writing consists of spelling, grammar, and the five-paragraph essay, students are not likely to think of knowledge as constructed, as uncertain, or of themselves as bona fide participants in these domains. Evidence abounds, too, that the representations of knowledge embodied in many classrooms is jointly negotiated between teachers and students. Cusick (1983) studied the relationships among students, teachers, and administrators in urban high schools and found that, in the effort to keep students in school, the subject matter of the curriculum was often transformed or even abandoned.

Powell, Farrar, and Cohen (1985) report similar results in their five-year study of U.S. high schools. They describe student resistance to complex intellectual tasks and a widespread air of indifference. In response, they found, teachers seemed to negotiate implicitly with students, arriving at treaties that made classroom life more harmonious. As the researchers observed classes, they saw a predominance of so-called discussions that consisted of teachers asking convergent questions that demanded only one-word answers. Similarly, some teachers, despite their initial commitment to having students write regularly, gave up assigning writing in favor of fill-in-the-blank worksheets because of problems entailed in getting students to do the writing. These treaties between teachers and students about the nature of classroom activity and discourse served in many cases to narrow and distort the subject matter content and, consequently, to limit students' learning opportunities.

Whether prospective teachers' precollege learning has a greater influence on their subject matter understandings than do their subsequent formal college studies is an open and empirical question. Some evidence suggests that the formal period of preservice teacher education is a relatively weak influence on what teachers know and believe. While this has often been explained in terms of the powerful effect of the school culture once teachers begin teaching (e.g., Hoy & Rees, 1977; Zeichner and Tabachnik, 1981), the powerful effect of the school and wider cultures on prospective teachers before they enter a university seems an equally plausible explanation (Ball, 1988).

The College Curriculum and Teachers' Subject Matter Preparation

What about teachers' college study of subject matter? Two somewhat competing perspectives on the role of liberal arts courses in preparing to teach are evident in the literature. In the first, subject matter study is thought to provide the teacher with an understanding of the content he or she is to teach (e.g., Anderson, 1988). From this perspective, recommendations for the improvement of teachers' subject matter preparation tend to focus on which subject matter courses elementary and secondary teachers ought to take in order to be qualified to teach. Should the major for the prospective teacher include the same requirements as that for the future mathematician, physicist, or historian? What mathematics should prospective elementary teachers study? Number theory? Calculus? Algebra? What literature should they study? Shakespeare? Modern contemporary poets?

A second perspective conceives of liberal education itself as preparation for teaching (e.g., Buchmann, 1984; Dewey, 1904/1964; Kaysen, 1974; Peters, 1977; Scheffler, 1973; Wilson, 1975). A liberal education, according to this perspective, provides the intellectual resources, essential cultural capital, and knowledge. It fosters a spirit of inquiry as well as critical intellectual dispositions and skills. To engage and help students develop their minds, teachers must themselves be well-educated:

> Subjects should be taken to represent, not hard bounds of necessity which confine the teacher's training, but centers of intellectual capacity and interest, radiating outward without assignable limit. Anything that widens the context of the teacher's performance, whether it extends his mastery of related subject matter or, rather his grasp of the social and philosophical dimensions of his work has a potential contribution to make to his training. . . . We accordingly conceive of the education of teachers not simply as the development of a class of individual classroom performers, but as the development of a class of intellectuals vital to a free society. (Scheffler, 1973, pp. 89, 92).

A liberal education conceived of as preparation for teaching is, of course, in some ways a contradiction in terms. A liberal education, after all, is education not for any specific end but for its own sake. Still, since teachers' work is centrally involved with knowledge and the life of the mind, their own intellectual qualities are critical. Teachers must care about knowing and about inquiry. They must be able to grapple with fundamental questions about ideas and ways of knowing, to know the kinds of questions and problems on which different disciplines focus. Being liberally educated means, ideally, being a "veteran of encounters within the community of discourse" (King and Brownell, 1966, p. 121) of particular disciplines--having participated in critical analyses of literary texts, having compared and disputed competing accounts of historical phenomena, having constructed and defended an argument in support of a mathematical conjecture. In this way, liberal education marshalls against the "misleading dichotomy of the scholarship of a field or subject and the teaching and learning of the field" (King and Brownell, 1966, p. 68) and is, therefore, in spite of itself, ultimately practical as preparation for teaching.

Whether one assumes the first or second perspective on the contribution of liberal arts to teacher education, what students actually learn about subject matter from their college and university liberal arts courses remains a critical question. What do we know about what prospective teachers have an opportunity to learn in liberal arts courses? If one assumes that course descriptions and syllabi provide an adequate account of what is learned, we could claim to know a lot. If, however, we look at studies of what actually seems to be learned--instead of what faculty claim to teach--the picture that emerges is sketchy (Lanier, 1986) and, for those concerned about the education of teachers, worrisome.

The two subject matter areas in which researchers have studied both what undergraduates are taught and what they actually learn are physics and mathematics. Those who teach undergraduate physics have been puzzled for years by recurring student misunderstandings about mechanics. Physics students--even those in their second physics course--persist in believing that motion implies a constant force in the face of numerous examples to the contrary; that is, for an object such as a pendulum to remain in motion, it must be acted upon by a constant force that causes the motion. Through interviews, researchers have determined that students tend to draw on their own experience of the physical world in developing an implicit theory about bodies in motion. Students are in good company: Aristotle, based on his experience of the world and commonsense, concluded similarly that motion implies a force. Until Newton, the few people who chose to think about such matters took Aristotle's word for it, as nothing in their experience contradicted this belief.

McDermott (1984) describes research on students' understanding of force and motion conducted by Laurence Viennot at the University of Paris that has led him to evolve a model of student conceptions. According to Viennot (1979), students may hold both Newtonian and non-Newtonian ideas of force; the pedagogical circumstances in which they confront representations of force determine which conception they draw upon to make sense of the situation. When instructors subsequently developed representations of motion, velocity, and acceleration that directly address students' naive conceptions, students could compare their implicit theories with physicists' understandings of motion and force (see McDermott, 1984, for a review of research on undergraduates' naive theories and common misconceptions in mechanics; see Champagne, Gunstone, and Klopfer, 1985, for an example of instruction that targets specific misunderstandings in mechanics.)

In mathematics, research on students' understanding has produced similar findings. A number of studies in this decade (Clement, Lochhead and Monk, 1981; Clement, 1982; Maestre, Gerace, and Lochhead, 1982; Maestre and Lochhead, 1983) have demonstrated the inability of undergraduates majoring in science and engineering to represent correctly a simple algebraic relationship between two variables--to wit, the famous "student-professor" problem:

> Write an equation using the variables *S* and *P* to represent the following statement: "There are six times as many students as professors at this university." Use *S* for the number of students and *P* for the number of professors. (Maestre and Lochhead, 1983, p. 24)

Typically, students who offer an incorrect equation reverse the variables: $6S = P$. Clement and his colleagues (1981) report that over one-third of the engineering students they tested and nearly 6 out of 10 nonscience majors could not offer an appropriate representation. It appears that many students, even when they have mastered the mechanics of the subject, fail to develop an understanding of the underlying meanings.

Ball (1988) reports that, whereas mathematics majors planning to teach produced more correct answers for division involving fractions, zero, and algebraic equations than did elementary education majors, the math majors frequently struggled in "making sense of division with fractions, connecting mathematics to the real world, and coming up with explanations that go beyond restatement of the rules" (p. 39). Schoenfeld (1985) reports on his undergraduates, most of whom had previously done well in college calculus as well as in secondary school geometry, and their efforts to solve fairly simple geometric problems. While the students, working as a whole group, could solve the problems, they struggled to explain why the solutions worked: "My class spent a week (at the college level) uncovering the reasons for two constructions that they had been able to produce from memory in less than two minutes" (p. 376).

In both physics and mathematics, evidence is mounting that all students, not just those intending to be teachers, can meet the expectations for satisfactory work without developing a conceptual understanding of the subject matter--the lack of which, we have argued, seriously inhibits teachers' capacities to help school pupils learn in ways that are meaningful. In other subject matter areas, particularly history and composition, researchers seem to have paid less attention to the difficulties that undergraduates have in understanding the conceptual foundations of these fields. The literature consists more often of exhortations about what should be included in the study of the subject based on the theoretical orientations of various schools within the field rather than on attention to learners and the understandings they bring with them. (For a review of research on writing, see Hillocks, 1986.) As Bartholomae (1980) has observed about students in basic college writing courses, "We know little about their performance as writers, beyond the bald fact that they fail to do what other, conventionally successful writers do" (p. 253).

In writing, exceptions exist, such as Coleman's (1984) ethnographic study of five undergraduates in her basic writing course. Through the use of specific pedagogical devices such as learning logs and peer response groups, she both documents and facilitates her students' evolution from writers who viewed revision as fixing mistakes to writers who conceived of revision as clarifying their meaning. Drawing on Perry's (1970) conjectured epistemological development of college students as his theoretical frame, Ryan (1984) finds a relationship between students' belief that knowledge is "an array of interpreted and integrated propositions"--as opposed to a view of knowledge as "an unorganized set of discrete and absolute truths"--and their ability to produce coherent text. In these studies, the researchers have examined college students' conceptions as a basis for thinking about instruction. Research of this type parallels the work of Britton, Burgess, Martin, McLeod, and Rosen (1975) with precollege learners. Britton and his colleagues found that students write for their teachers with the purpose of reporting what they know.

Our review of the literature on history failed to turn up research on college students' understanding of history. Wilson (1988) has described the historical understanding of novice, developing, and expert teachers and, in so doing, has delineated the differences in the kind and amount of knowledge that teachers in each of these categories exhibit. Missing from the literature are investigations of the evolution of learners' understandings of critical historical concepts such as causation, sequence, and development and their notions of what doing history means.

As we have argued above, students' encounters with the disciplines in liberal arts courses likely shape their notions of the *nature* of the subject matter, as well as their disposition to think about and find out more about ideas in a given field. Imagine the difference between prospective teachers who experience history as an argument about what happened in the past and why and those who encounter history as what is represented in a textbook. And yet, with the exception of the types of studies described above, researchers tend to ignore the intellectual constructions in which college students are involved and focus instead on instructional issues, such as the relative advantages of lecture or discussion approaches to teaching (see Dunkin and Barnes, 1986). As a result, we understand far too little about what prospective teachers learn from their college study of specific subject areas.

Learning Subject Matter From Teaching It

As we have seen, most prospective teachers have few, if any, opportunities in school, college, or the wider culture to come to understand the substance and nature of their subject matter or to develop dispositions that would enable them to teach in ways that their students, in turn, can understand in meaningful, connected ways. Another potential source of subject matter knowledge is the experience of teaching in the classroom. The experience of coming to understand, for example, the division of fractions, or the causes of the American Civil War, or the meaning of "In a Station at the Metro" while actually teaching is probably fairly common. Yet, neither teachers themselves nor those who study teaching appear to have written enough about such subject matter epiphanies to help us understand the conditions that produce them.

Recently, however, the Knowledge Growth in Teaching Program at Stanford University has set as its goals exploring and better understanding beginning teachers' subject matter knowledge (Wilson, Shulman, and Richert, 1987). Based on intensive data collection on 12 beginning secondary teachers whom they began to follow in their teacher preparation programs, Wilson and her colleagues (1987) propose a model of pedagogical reasoning that is posited on teachers' comprehension of their subject matter:

> Teachers must critically understand a set of ideas, a piece of content, in terms of both its substantive and syntactic structure. History teachers should understand the causes of the American Civil War. English teachers should be able to do analyses of the themes and characters in *To Kill a Mockingbird.* Teachers should also understand the relationships between that piece of content and other ideas within the same content as well as ideas in related domains. Math teachers should understand the relationships between fractions and decimals. English teachers need to have some knowledge of the Bible in order to understand the symbolism in *Moby Dick.* (p. 119)

Such understanding of the subject matter, these researchers argue, is a precondition for students to come to understand their subject matter in a new way for teaching. As they struggle to teach their subject in ways that make it meaningful to the students, the beginning teachers in the Stanford study draw on their growing knowledge of students, of the context, of the curriculum, and of pedagogy. In short, they evolve a new understanding of the content, informed by their new knowledge, that Shulman (1986) has termed pedagogical content knowledge.

The case studies that have come out of the project provide evidence of the transformation of teachers' extant subject matter understanding in teaching; however, evidence that teachers' personal knowledge of the substance and structure of the subject matter has grown is lacking (Grossman, 1987a, 1987b; Reynolds, 1987; Reynolds, Haymore, Ringstaff, and Grossman, 1986;

Wilson, Shulman, and Richert, 1987; Wineburg and Wilson, 1988). Whether the absence of data on growth in the teachers' subject matter knowledge is because such growth did not seem to occur or because the researchers focused on pedagogical content knowledge is not clear. One exception to the generalization that novice teachers' substantive knowledge and knowledge about the subject matter do not appear to change is the case of a first-year teacher described by Wineburg (1987) who began teaching social studies from the perspective of her undergraduate major--physical anthropology--and moved toward a broader view under the influence of the social studies textbook. One could argue, in this case, that this teacher's understanding of the nature of the subject matter as well as her substantive knowledge were increased by her practice.

Ball and Feiman-Nemser (1988), writing about prospective elementary teachers, also offer examples of learning from textbooks. For instance, one of the student teachers they studied, Sarah, unsuccessful in developing her own unit to teach fifth graders about numeration and place value, discovered the conceptual essence of the topic by working through the textbook. At the beginning of the unit, she dismissed the approach taken by the textbook. She could see no reason why the text asked students to expand numerals--e.g., 74 as "seven tens and four ones." Sarah spent over three weeks working on place value with her class and, during this time, gradually came to see position and value as critical conceptual features of numeration. She observed,

> I had to really think about what place value *is*. Last week, if you'd asked me what place value was, I don't *know*. . . . [But] like today, I thought of that example of 1263 and 2136 on the spot to get them to see about *places*. . . . (p. 419)

That teachers may learn about the substance and nature of their subject matter from textbooks may, however, be viewed as problematic, given the ways in which disciplinary knowledge is misrepresented in many school textbooks (for example, see Bettelheim and Zelan, 1982; Fitzgerald, 1979; Gagnon, 1988; Hashweh, 1987; Jenkinson, 1979; Kantor, Anderson, and Armbruster, 1983; Romberg, 1983; Schmidt, Caul, Byers, and Buchmann, 1984; Smith and Anderson, 1984; Sykes, 1985). History texts, for example, tend to portray accounts of the past as factual and finding out about the past as a process of looking up information. History texts are also notably silent on the histories of minority peoples and have been criticized for the particular accounts they choose to include (Fitzgerald, 1979). In mathematics, textbooks often foster an algorithmic approach to the subject--e.g., "To divide by a fraction, just multiply by the reciprocal" (*Mathematics Around Us*, 1975, p. 147).

Stodolsky's (1988) analysis of elementary math textbooks suggests that concepts and procedures are often inadequately developed, with just one or two examples given, and an emphasis on "hints and reminders" to students about what to do. Mathematical thinking, when it is addressed at all, is often portrayed as a linear step-by-step process. With an emphasis on the substance of mathematics, the texts also tend to emphasize calculational skill and to give short shrift to other central aspects of mathematics. Similar criticisms of the ways in which texts misrepresent both the substance and the nature of science and writing (or composition). In short, learning from textbooks, while it may (as in the case of Sarah above) help to illuminate subject matter concepts for teachers, may also contribute to the perpetuation of thin or inaccurate representations of subject matter.

Teachers' subject matter knowledge may also be affected by the attitudes and expectations that their students bring to the classroom. As was discussed above, if teachers face learners who rebel against uncertain or complex intellectual tasks, they may feel pulled to simplify content, to emphasize algorithms and facts over concepts and alternatives (Cohen, in press; Cusick, 1983; Powell, Farrar, and Cohen, 1985). Not surprisingly, teachers' capacity to increase, deepen, or change their understanding of their subject matter for teaching depends on the personal understandings of the subject matter they bring with them to the classroom (e.g., Wilson and Wineburg, 1988). While teachers' knowledge about learners, the curriculum, pedagogy, and the context seems to increase from their practice, that they will learn enough about their subject matter from their teaching to shore up inadequate knowledge and understanding is unclear. Although there is some research that has contributed to our understanding of what teachers can learn about their subject matter from practice, this has not been a focus of most research on the development of experienced teachers' knowledge. We need to understand more about the conditions that contribute to teachers learning subject matter from teaching it.

Conclusions

Until a few years ago, the subject matter knowledge of teachers was largely taken for granted in teacher education as well as in research on teaching. Recent research, focused on the ways in which teachers and teacher candidates understand the subjects they teach, reveals that they often have misconceptions or gaps in knowledge similar to those of their pupils (e.g., Mansfield, 1985; McCloskey, 1983). This paper argues that as teachers are themselves products of elementary and secondary schools in which, research has shown, pupils rarely develop deep understanding of the subject matter they encounter, we should not be surprised by teachers' inadequate subject matter preparation.

While the perspective taken in this paper is an expansion of the traditional one that assumes that subject matter preparation is what occurs as part of prospective teachers' general college education, it is still a relatively narrow view. Understandings of subject matter are acquired in significant ways outside of schools; to assume that teachers' subject matter preparation is confined to experiences of formal schooling would be to ignore a major source of teachers' learning and ideas. People construct understandings of phenomena from their everyday experiences--from their activities in their environment, from what they see adults around them doing, from messages they receive from others in the community (Cohen, in press). In addition to understandings of particular concepts, people also develop notions about knowledge itself. Ideas about the knowledge as objective fact, as authoritative truth, have roots deep in Western intellectual traditions (Cohen, in press).

It is not just as a consequence of schooling that most people view mathematics as a set of arbitrary rules, indisputable and fixed, or think history books tell the truth about what really happened. In short, everyday experience and cultural traditions are a significant and often overlooked source of people's subject matter knowledge. In fact, Cohen (in press) argues that "family and community influences on children's learning are more powerful than the schools' influences." Future research on teachers' subject matter preparation should consider the relative impact of nonformal sources.

A second issue worthy of consideration has to do with what teachers learn from subject matter study. Subject matter classes usually aim to help students acquire substantive knowledge--specific information, ideas, and topics--of the subject. Yet there is a hidden curriculum in subject matter classes, a curriculum especially important for the education of teachers. Students, spending thousands of hours in subject matter classrooms, also develop ideas about teaching and learning particular subjects (Lortie, 1975). Watching their teachers, they acquire specific scripts for teaching particular topics (Putnam, 1987) and develop views about the what teachers should and should not do, beliefs about what contributes to academic success, and notions about what makes a good class (Feiman-Nemser, McDiarmid, Melnick, and Parker, in press). They also form ideas about testing and evaluation as well as about how to interest students in the subject. These conceptions of subject matter study appear when young children play "school"; they also constitute the standards against which older students' judge their teachers and courses. To regard physics or English classes exclusively as sites for learning about force or Mark Twain is to underestimate their potential impact.

The central question for research on teachers' subject matter preparation is: How can teachers and prospective teachers increase their knowledge of the subjects they teach? What kinds of experiences seem to make a difference in teacher candidates' knowledge of mathematics, science, or writing? Researchers need to search out and investigate the various efforts to provide more effective subject matter preparation--courses, workshops, and thematic programs. Such research should track the changes in teachers' and prospective teachers' understandings over time as they participate in such experiences. The experiences themselves also need to be documented to provide knowledge about approaches that may be effective in improving the understandings with which many students, on their way to becoming elementary and secondary teachers, leave high school and college.

A related question is whether and what teachers learn about subject matter *from* their own practice. According to common belief, graduating teacher candidates may lack adequate subject matter preparation, but they will develop deeper knowledge as a result of having to explain it to others. In fact, we have little evidence to support this assumption. *Does* this happen? If so, how and under what circumstances? How do teachers' understandings of their subjects change as they teach? Are some aspects of subject matter knowledge (e.g., knowledge of facts or procedures) more likely to change than others (e.g., understandings about the nature of knowledge in the discipline)? Do certain approaches to or conditions of teaching foster teachers' subject matter learning more than others?

New research in this area should attend to how to change and deepen teachers' subject matter knowledge. Continued documentation of the inadequacy of subject matter preparation will not help to improve the problems we face in teacher education and teaching, for the contributing views of knowledge, teaching, and learning are deeply rooted in educational institutions and in the wider culture. Altering these patterns will not be easy. We should turn our future efforts and attention to the difficult task of improving teachers' subject matter preparation.

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