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ABSTRACT

Studies have addressed the substantive knowledge of teachers and the content that is actually taught in classrooms. Some research has indicated that teachers have difficulty teaching certain areas because they themselves lack sufficient understanding about those areas. In considering the kind or amount of subject matter knowledge teachers need, discussion centers around the content of the subject itself, the organization and structure of that content, and methods of inquiry used within the subject. These three aspects are construed as the core aspects of subject matter knowledge. Consideration of subject-specific pedagogy provides the example of a science teacher who wants students to understand the scientific method. Three different pedagogies are described, each teaching something different about the scientific method. An analysis of the kind of policies that address subject matter knowledge focuses on: research pertaining to the generally accepted concept of teachers and their functions, current methods of evaluating teachers' subject matter knowledge, and the difficulty of attaining the high standards considered desirable. A 48-item bibliography is included. (JD)

TRENDS AND ISSUES IN: TEACHERS' SUBJECT MATTER KNOWLEDGE

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TRENDS AND ISSUES IN:
TEACHER'S SUBJECT MATTER KNOWLEDGE

Since the beginning of schools, there have been doubts about the adequacy of teachers' subject matter knowledge. However, until recently, it has been assumed that if teachers held a bachelor's degree, they would know enough about the subjects they would teach. Certainly they would know more than their students knew. But the fraction of teachers who do not hold a bachelor's degree has diminished to almost none in the past several decades, and questions about the adequacy of teachers' subject matter knowledge have become salient once again. This unusual development has raised questions about the nature of the degree one needs for teaching. Some argue that teachers need more college credits in academic subjects and fewer in teacher education; others argue that increasing the number of credits in a subject will not assure that teachers will be able to teach that subject. This paper reviews recent trends and arguments with respect to four issues:

1. *Why is subject matter knowledge questioned?*
2. *What subject matter knowledge do teachers need?*
3. *Does subject-specific pedagogy exist, and if so, what is it?*
4. *What policies address teachers' subject matter knowledge?*

Why is subject matter knowledge questioned?

Several recent sets of research findings have generated questions about the amount and quality of our students' subject matter knowledge. In 1986, the Congressional Budget Office (CBO) documented declines in student achievement that stretched through the 1960s and 1970s, spanned most grade levels and nearly all content areas. Declines were greater in upper

grades than in lower grades, and in higher-order skills such as reasoning and problem solving than in basic skills. These declines ceased near 1980; that is, with students who were born in the early- to mid-1960s. Although test trends have remained relatively constant since that time, they have not indicated any upward movement that might compensate for the long-term downward movement (Congressional Budget Office 1986).

Completing the picture further are subject-matter-specific studies of the knowledge and ability of contemporary American students. In mathematics, for instance, international comparisons indicate that American eighth graders can compute better than students in some other countries, but that they do worse than most in problem solving (McKnight et al. 1987). In writing, American students know basic grammar and punctuation but most cannot write an analytic or an expressive paper (Applebee, Langer, and Mullis 1986). International comparisons of science performance indicate that American students are less able than their peers in other countries to engage in scientific reasoning (International Association for the Evaluation of Educational Achievement 1988). And finally, a recent assessment of high school students' knowledge of history and literature indicated that they lacked knowledge about a number of central concepts in both fields (Ravitch and Finn 1987).

Other studies have addressed the substantive knowledge of teachers themselves. Evidence suggests that high school students who plan to teach score lower on achievement tests than do students who don't plan to teach, and that their SAT scores have declined more over time than have those of high school students in general (Weaver 1978). In its analysis of trends in achievement test data, the CBO said that, while there was an apparent decline in teachers' achievement scores, this decline began too late to account for the declines observed in children's tested achievement. CBO estimates that the first cohort of teachers to enter teaching with lower test

scores would have entered teaching in 1978, when the decline in student test scores was nearly over (CBO 1987).

The decline in test scores of would-be teachers, then, could be a result of, rather than a cause of, the declines in student achievement. But the disparities between the scores of high school graduates who plan to teach and those who don't still warrant concern. Moreover, higher-scoring college graduates who plan to teach are the least likely to actually take teaching positions and, among those who do become teachers, those with higher achievement test scores are most likely to leave the teaching profession (Kerr 1983; Vance and Schlechty 1982). Robertson, K[illegible]ch, and Page (1983) found a negative relationship between tested ability and high school students' interest in becoming teachers. Thus, even if much of the decline in entering teachers' tested ability reflects a general decline in the tested ability of our youth, there is some evidence that the profession is selectively attracting relatively less able young people.

A second set of research findings has to do with the content that is actually taught in classrooms. Recent descriptions of classroom activities have found them tedious, boring, repetitive, and intellectually empty lessons in virtually all subjects and all grade levels (Goodlad 1983; Powell, Cohen, and Farrar 1985). For example, Porter (1989) summarizes research at Michigan State indicating that fifth-grade teachers tend to orient their mathematics time to the four basic computation skills rather than toward higher-order mathematical thinking; that the time spent on "applications" was limited to applications of these skills, not to more complex problem solving; and that the majority of other topics were taught only superficially, receiving no more than thirty minutes of time throughout the entire school year. That is, for most topics, the teachers' goal was only to expose students to the topic, not to assure that they understood it.

Several explanations have been offered to account for these findings. Walter Doyle's (1986b) Texas study of how teachers manage academic tasks indicates that classrooms are more easily managed when students engage in routine tasks--those associated with learning simpler skills--whereas novel tasks, the kind usually needed for higher-order thinking and conceptual development, are more difficult to manage and their outcomes are more unpredictable. In teaching writing, for instance, routine and simple assignments are easy to do, whereas complex assignments take longer to explain and engender more questions and confusion. These problems motivate teachers to simplify the tasks assigned (Carter and Doyle 1987). Doyle interprets these studies, and others like them (Doyle 1983, 1986a) as suggesting that to maintain orderly and predictable classroom environments teachers either trivialize the content entailed in higher-order tasks, thus rendering them more routine, or remove them altogether from their classroom curricula.

But Stodolsky (1988) found that the intellectual tasks given to students varied by subject. That is, a single teacher may concentrate on simpler, more routine tasks when teaching one subject, but introduce more complex problems when teaching another subject. She found that, in general, mathematics tasks tended to be low-level tasks such as receiving and recalling information or learning concepts and skills, yet in social studies, students often engaged in activities that required thought and discussion. Stodolsky suggests that this difference between subjects might result from the fact that mathematics is considered a basic skill and consequently teachers may feel more accountable for assuring that students have mastered it, whereas social studies does not suffer from this constraint.

Yet a third hypothesis is that these pedagogical preferences for lower-level or higher-level learning reflect teachers' understandings of the nature of the subject. That is, a single teacher may perceive mathematics as cut-and-dried, filled with fixed facts for students to digest, but perceive social

studies as amorphous, filled with conjecture and ambiguity, and changing and evolving over time. McDiarmid, Ball, and Anderson (1989) and Ball (in press) argue that teachers' curricular decisions are closely related to their perception of the subject matter they are teaching. For some, subject matter means a particular set of skills; for others it means a set of ideas or concepts; for still others it may mean a way of reasoning about certain kinds of problems.

Such varying perceptions could motivate teachers to teach different subjects differently. Evidence is accumulating to suggest that teachers' beliefs can have a substantial impact on their practices (Clark and Yinger 1987; Clark and Peterson 1986; Thompson 1984) and Peterson, Fennema, Carpenter, and Loef (1989) found that teachers' beliefs about teaching and learning mathematics were associated not only with how they taught, but also with what their students learned.

A fourth hypothesis, related to the third, is that teachers have difficulty teaching certain areas because they themselves lack sufficient understanding about them. Researchers at the University of Pittsburgh (e.g., Leinhart and Greeno 1986; Leinhart and Smith 1985) for instance, have found that knowledge of the subject is very important to teaching. Lampert (1988) uses lack of subject matter knowledge to interpret findings from a study by Good, Grouws, and Ebmeier (1983) in which the researchers tried to train teachers to implement a variety of practices associated with gains in student achievement. Teachers were able to learn all of the behaviors but one: explaining and demonstrating concepts for students. Lampert suggests that training teachers in the pedagogical behavior of "explaining" cannot succeed if teachers do not adequately understand the content they are supposed to explain. Similar conclusions follow from studies by Steinberg, Haymore, and Marks (1985) and Carlsen (1987) who found that quality of teaching varied with the quality of the teacher's

understanding of the content being taught. Individual teachers often changed their pedagogy when they moved from one subject to another with which they were more or less familiar.

Research from the National Center for Research on Teacher Education also has indicated that teachers often do not understand their subjects in a way that enables them to explain important concepts to students, even when the concepts being taught come from the elementary school, rather than the secondary school, curriculum. For instance, when asked to illustrate the mathematical sentence, 1 3/4 divided by 1/2 with a story problem, many prospective teachers and even many mathematics majors provide a story that required division by two, rather than by 1/2 (Ball 1990). Similarly, when given a problem that requires selecting a singular or plural verb, many prospective teachers, as well as many English majors, were unable to explain the concept of subject/verb agreement and how it applied to the sentence (Kennedy 1989). These findings indicate that possession of a baccalaureate degree, and even a major in a particular subject, do not assure that a person can explain concepts.

There are, then, several reasons for being concerned about the place of subject matter knowledge in education, and in teacher education. Student achievement is not as high as it should be, particularly in higher-order thinking; teachers' test scores are also not very high; teachers tend to concentrate on trivial content and on routine tasks; and teachers are often not able to explain important substantive concepts to students. And there are several explanations for the lack of substance in most school learning: teachers are unable to manage classrooms when the academic tasks are more unpredictable, as conceptual and problem-solving tasks are; teachers don't perceive some or all subjects as conceptual subjects; or teachers don't understand conceptual aspects of the subjects themselves, and therefore are able to teach only the more trivial aspects of these subjects. The first

hypothesis, that teachers are unable to manage classrooms for certain kinds of tasks, could be construed as either a generic or a subject-specific problem. That is, one might interpret this problem as a general classroom management task, or one might argue that teachers need to learn specific pedagogies for teaching the complex aspects of each subject separately.

This paper attends to those hypotheses that address teachers' subject matter knowledge. It reviews evidence and arguments for more or better knowledge about and understanding of school subjects, and evidence and arguments for more subject-specific pedagogical knowledge.

What subject matter knowledge do teachers need?

Findings, such as those described above have led, among other things, to calls for more and better subject matter knowledge for teachers (e.g., Grossman, Wilson, and Shulman 1989; Quimby and Barnes 1986; Shulman 1986a, 1986b). But what exactly do teachers need to know about the subjects they teach and how does their knowledge need to differ from the kind of knowledge others have of these subjects? Mathematics, for instance, is used by engineers, household planners, mathematicians, and carpenters, as well as by mathematics teachers. Knowledge of literature and writing is used by poets, college students writing term papers, novelists, and journalists, as well as by writing teachers. Still, even though many groups use subject matter in their daily tasks, we generally consider some groups more expert than others in each of these subjects. People who are fluent in a subject are distinguished from others in at least three respects: (1) they know a great deal of specific content, that is, facts and ideas; (2) they have formed a variety of complex relationships among these pieces of content; and (3) they understand how to approach new problems or dilemmas and how to produce new ideas within the subject. They have acquired mores, habits, perspectives, and a host of other

intellectual and personal dispositions that could be construed as part of their subject matter knowledge.

The content of the subject includes the facts, concepts, principles, or laws that have been gathered through decades or centuries of inquiry into the subject. Content is usually presumed both to increase in volume and to change in character over time. In history, it evolves with the discovery of new details about events and with the development of new interpretations of events; in science it grows and changes with new research findings as well as new theoretical developments; and in literature it expands with new pieces of literature and it changes with new interpretations of existing pieces.

The organization and structure of the content refers to the network of relationships among facts and ideas which students of the discipline have developed. Though a subject may contain numerous particular facts or ideas, these are not important in their discrete, isolated forms. Instead they are rendered important through the patterns of relationships that are constructed among them. It is the patterns, the networks, the interstices among these facts and ideas that form a body of knowledge, such that the significance of any one idea or fact is ascertained by its apparent relation to other ideas and facts.

The methods of inquiry include a set of assumptions, rules of evidence, or forms of argument that are or can be employed by those who contribute to the development of the discipline. Some of these rules of practice are tacit--a novelist may "use" rules of sentence structure or story structure routinely, but not be able to describe these rules to someone else. Others are explicit--the historian who challenges another's findings must be able to articulate the rules of evidence used in the challenge. Whether tacit or explicit though, these methods of inquiry provide practitioners in the field with a

way to evaluate new ideas, challenge or defend them, interact with one another and with the content--in general, to function within their field.

These three aspects of subjects--the content of the subject, the organization of the content, and the methods of inquiry used within the subject--could be construed as the core aspects of subject matter knowledge. Whether one actually attains all three aspects of subject matter knowledge by majoring in it in college, however, is another matter. But since many secondary teachers take the same sequence of subject matter courses that any other subject matter majors take, we should expect them to hold the same knowledge of subject matter as any other subject matter major.

But some teachers use the subjects they study differently than others do. Teachers are not historians, but rather teachers of history; not scientists, but rather teachers of science. Yet lab technicians, engineers, or journalists are not scientists either, as many of their college classmates may be. To distinguish the particular kind or form of knowledge teachers need, we need to determine how teaching differs from these other applications of a subject. We need to determine whether teachers need to know the same aspects of subject matter that these other practitioners know, or whether they need to know more or less. And we need to determine how, if at all, a teacher's knowledge of a subject should differ from that of others who use the subject in their work. That is, if someone has majored in a subject, and knows these three aspects of the subject well, is that person therefore also qualified to teach it?

Answers to these question fall into three categories. First, it has been proposed that teachers need to know *less* about their subjects than do others who major in the subjects, for they need to know merely what the curriculum or textbook provides to students. As long as teachers are a bit ahead of their students, they will be OK. Second, it has been proposed that teachers need to know *more* than do others who major in the same subject, for in addition to

the aspects of subject matter knowledge described above, teachers also need to know three other aspects of subject matter: its social norms, the relationship between the subject and various social issues, and the utility and relevance of the subject to everyday life. Third, it has been proposed that teachers' knowledge of their subjects must be *different* than that of their counterparts, for, whereas others may be able to draw on a largely tacit understanding of their subject, and may be able to take many of its premises for granted, teachers' knowledge must be explicit and self-conscious if they are to explain it to naive students.

The first proposal suggests that the role of the teacher lies mainly in conveying to students the particular curriculum content assigned to the grade level or courses they will teach. If this is true, then relevant subject matter knowledge for teachers can be identified by examining the content of elementary and secondary school textbooks (Allen 1988). This view suggests that, for instance, a fourth-grade arithmetic teacher need not understand fundamental mathematical concepts if they are not explicitly dealt with in the fourth-grade arithmetic textbook. It assumes that teachers teach precisely the content that is in the textbook and that students accept virtually all the facts, skills, or ideas presented without question. Yet, ironically, it is often the most naive students who ask the most perplexing and fundamental questions about a subject. It is not college students but elementary school students who ask such fundamental things as, what does "zero" mean? What makes a sentence "complete"? What is a "civil" war? That children may pose such questions suggests that the specific curriculum content may not be a useful guide for defining teacher knowledge. Teachers of virtually all grade levels and subjects may need to understand fundamental concepts and values within the subjects they teach (McDiarmid, Ball, and Anderson 1989). Moreover, teachers rarely teach precisely what is in their texts (Porter 1989; Schwille et al. 1983), but instead make numerous decisions of their own about what to teach, in what

sequence to teach it, and how much time to devote to it. Kerr (1981) argues that, to make such decisions, teachers need an analytic understanding of the subject for it cannot be presented as a whole.

The second proposal suggests that teachers may need to know about more aspects of their subjects than others with baccalaureate degrees in those subjects. In addition to the content, the organization of content, and the methods of inquiry within a subject, teachers must be prepared to address such aspects of subjects as their social norms, their relation to social issues, and their value in everyday life. Let us review the arguments for each of these in turn.

The social norms of a subject dictate the kind of scholarship that is valued or shunned, the kinds of findings that are considered important as opposed to routine, the kinds of issues that are considered worth pursuing, and how members of the discipline are expected to interact professionally. The culture of a subject is closely related to its method of inquiry, but extends into norms of interpersonal relations. Even if practitioners within a discipline can function without awareness that their field has a separate culture, students may shun certain fields because they feel alienated from them. When James Watson (1968) tells the story of discovering DNA, he describes, among other things, the competitiveness that he and his colleague, Crick, felt toward other biologists and describes some of his views about women colleagues. Without realizing it, he gives us an insider's view of a highly competitive, male dominated culture of science. Teachers who are aware of these cultural anomalies within each discipline may be able to find ways to prevent student alienation.

The relationship (as opposed to mere relevance) of a subject to social issues includes such things as how white historians have examined and portrayed the interactions between white settlers in America and Native

Americans, or how history tends to deal with white European culture while anthropology tends to deal with Third World and minority cultures (Banks 1989). Increases in our knowledge of biology not only have led to improved medical care but have also introduced a host of new ethical issues in medicine. Understanding how a subject both creates new social issues and helps resolve social issues can assist teachers to present the subject in meaningful ways to students.

The value of the subject to everyday life includes not only the specifically utilitarian applications of say, computational skills, but also the ways in which mathematical reasoning influences our thinking and how knowledge of scientific principles can influence our actions. The teacher who can apply the dilemma Brutus faced in *Julius Caesar* to dilemmas that students face (Wilson, Shulman, and Richert 1987), who can draw on knowledge of electricity to discuss the relative risk of carrying a battery operated radio versus an outlet powered radio into the shower, or who can use mathematical probabilities to interpret a weather forecast, is more likely to increase students' interest in and retention of their subjects.

The third argument suggested that teachers' knowledge must differ in its character, rather than its content, from the knowledge of other baccalaureates. This argument distinguishes teachers' subject matter knowledge by suggesting that it must be explicit and self-conscious, rather than tacit. That is, although an author can write with tacit knowledge of sentence structure and story structure, teachers cannot teach writing without explicit knowledge of sentence structure and story structure. Many members of a discipline can work within their paradigm and draw on the central tenets of their subject without being able to say aloud what these tenets are or why they matter. In fact, Dreyfus and Dreyfus (1988) have argued that expertise arises when one has so completely internalized the principles of one's discipline that one's actions seem to be based on intuition

rather than on formal reasoning. A mathematician may take the complexities of "zero" so much for granted that she or he would be hard put to lay them out for a fifth grader. But teachers must be able to articulate these issues if they are to help students understand them. Even if their teaching method is to develop classroom activities and assignments that will enable students to grasp these ideas and values on their own, rather than to explain directly the ideas, teachers must be explicitly conscious of what these ideas and values are.

Does subject-specific pedagogy exist, and if so, what is it?

Though the notion of subject-specific pedagogy has existed for some time, Lee Shulman (1986b, 1987) and his colleagues at Stanford have done the most to give the concept contemporary value and have made great strides in defining pedagogical subject matter knowledge (Grossman, Wilson, and Shulman 1989; Wilson and Wineburg 1988; Wineburg and Wilson, in press). These authors argue that the main task of teachers is to find ways to represent the subject to students in ways they can understand. For the Stanford group, pedagogical subject matter knowledge includes virtually all of the aspects of subject matter knowledge described earlier, for these aspects of subject matter knowledge enable teachers to generate appropriate analogies, metaphors, or examples that render the content understandable to students; to choose class projects that would expose students to particular concepts or methods; and to choose questions that would challenge students in fruitful, rather than disheartening ways.

Others (e.g., Anderson 1980; Lampert 1986, 1988; McDiarmid, Ball, and Anderson 1989) suggest that pedagogical subject matter knowledge also requires teachers to understand the unique difficulties that each subject presents to students, and to know how students, in general, tend to learn these subjects. A substantial body of evidence now exists indicating that

students do not learn by passively receiving information given by the teacher, but instead actively construct mental images of the material. In so doing, they are prone to unique kinds of difficulties with each subject. In science, for instance, students are likely to construct erroneous models of physical phenomena. They may assume light rays enable them to see by illuminating objects, not by reflecting off objects and into their eyes. Once this image is adopted, they may misconstrue virtually everything they see and hear about light rays in their science class, for they are interpreting this new information with an erroneous image (Anderson and Smith 1986). In mathematics, on the other hand, students are more likely to become confused about computational procedures because they do not understand the concepts, such as place value, that validate these procedures (Lampert 1988). Finally, in writing, students are unlikely to see any purpose to grammar if they have not had any reason for writing anything of their own.

Whether such knowledge differs from the multifaceted knowledge of the subject matter that we described above, however, is not clear. Presumably, teachers use their understanding of the organization of the content to determine the sequence with which ideas will be introduced and to decide which student questions are fruitful to pursue and which lead to blind alleys; they use their understanding of the methods of inquiry to choose assignments and projects that are appropriate to the subject and to pose meaningful questions to students; they use their understanding of the relationship of the subject to social issues and their understanding of the value of the subject to select illustrations and to select hypothetical problems for students to work on.

Having pedagogical subject matter knowledge implies still another special form of knowledge--not only knowing the subject matter in all the ways described above, but knowing something about students as well--knowing, for instance, how students are likely to interpret what they see and

hear in class, what kinds of misunderstandings students are likely to hold or to acquire through different forms of analogies, and what fifth-grade children are likely to be interested in. Wilson, Shulman, and Richert (1987) quote a secondary teacher who says he needs 150 different ways of knowing his subject, a unique way of representing it for each student. Pedagogical subject matter knowledge requires a blending of knowledge of the subject with knowledge of the students.

The key to pedagogical subject matter knowledge is the word "blend." A blend of knowledge is different from a sum of two kinds of knowledge--on one side, subject matter and on the other side, students. That is, it is possible to learn one's subject matter by majoring in it, and to learn about students and how they learn in other courses, and yet still lack pedagogical subject matter knowledge. When writing, theorists write about a pedagogy for teaching writing. They mean a pedagogy that follows from research about the nature of writing itself, not from research on teaching in general.

Of all the core disciplines--those taught from elementary classrooms to college classrooms, writing is the only one that has explicitly recognized a unique pedagogy associated with teaching it. This may be because writing is the only subject whose label is a verb rather than a noun. Thus, teaching writing is a matter of teaching someone to *do* something, whereas teaching other subjects could be construed as a matter of teaching someone a body of content.

Moreover, knowledge of the pedagogy of writing is considered important not only for elementary and secondary teachers, but also many colleges and universities now require graduate students who will teach writing courses to take a university sponsored class in writing pedagogy. They do not require these same graduate students to take an analogous course to teach literature, and no other discipline requires such courses for graduate students. The

implicit assumption is, no unique pedagogy is required to teach other subjects.

Research on writing suggests that writing is purposeful and that it entails an iterative problem-solving process that involves generating ideas, drafting, receiving feedback, and revising. This has led writing educators to suggest that writing teachers should encourage students to select their own topics, rather than write to assigned topics; create classroom environments that encourage students to talk with one another about their work; and respond to the ideas students are trying to develop, rather than to the propriety of their punctuation or grammar.

Even though writing is the only discipline with such a unified theory of its own pedagogy, each subject includes a method of inquiry as well as an accumulation of facts and ideas. Teaching these methods necessarily requires a teacher to consider subject-specific pedagogy. If a science teacher wants students to understand the scientific method, any of several pedagogies could be used, but each pedagogy teaches students something different about the nature of the scientific method.

One method for teaching the scientific method is to transform it into a list of facts and ideas--to tell students what the scientific method is and how it is done and to provide some illustrations, perhaps describing famous critical experiments. That is, students are taught how scientists have conducted their work in the past, and the body of facts and ideas they have generated through their efforts. This pedagogy does not allow students to experience the method themselves; they learn to define the scientific method but not to reason like a scientist, to develop clear arguments, or to design critical experiments to test competing ideas.

Another approach to teaching the scientific method is to have students re-enact particular critical events, perhaps the same experiments they learned about in the class above, so that students can relive the experience that the original scientists experienced. This method is common in science education, where lab classes often accompany lecture classes, so that students can try experiments for themselves. Through this pedagogy, students learn how to conduct experiments and they see the connection between particular experiments and particular content. But these experiments are emulations of experiments already done, whose outcomes are already known, so that students are still not learning to reason as scientists do, but instead are learning the procedures of particular known experiments.

A third way to teach the scientific method is to define the components of the scientific method--things like observation, measurement, hypotheses generation, and so forth, and give students practice in these components (Lawson 1989). Unlike the first pedagogy, which emphasizes the relationship between scientific reasoning and the accumulation of new content, and unlike the second, which emphasizes particular procedures associated with particular experiments, this pedagogy emphasizes generic reasoning strategies. It could, in principle at least, teach method without imparting any content at all. Students learn a particular way of reasoning, and perhaps some rules of evidence, but do not learn the way in which arguments are justified or challenged, nor the content that was derived from using these procedures in the past.

Finally, one could teach the scientific method by transforming the classroom into a miniature scientific community in which students argue about particular phenomena and then conduct experiments to ascertain which of their hypotheses makes most sense. Through this pedagogy, students develop their own body of scientific content, not only by applying the techniques of the scientific method, but by engaging in the reasoning and

debate that are part of the scientific community. Although students learn more about the culture and norms of science, they may learn less about the particular content that scientists have learned through their application of the scientific method.

These four pedagogies each presumably teach the scientific method. Yet they differ from one another and so do their outcomes. To choose among these pedagogies science teachers must be prepared to choose among these learning outcomes--to decide which of these things is most important for students to learn and why. And science teachers must understand the relationship between pedagogy and content--between how they teach and what students learn and don't learn. The former may derive from a multifaceted knowledge of the subject, but the latter does not.

What kind of policies address subject matter knowledge?

Teacher education has, almost since its inception, rested on an assumption that subject matter and pedagogy are separate bodies of knowledge: they can be thought about, taught, and learned separately. Subject matter knowledge is usually taken for granted in teacher education courses, as both faculty and students assume that the students already know their subjects, or that they will get it from their liberal arts courses. Buchmann (1982) pointed out several years ago that both teacher educators and their students, themselves prospective teachers, often overlook content as an important issue in their thinking about teaching. And indeed, on the other side of campus, teacher education candidates study the subjects they will teach through courses offered by the various subject matter departments--Departments of Mathematics, Biology, English, History, and so on. The closest connections teachers will encounter between these two bodies of knowledge come in methods classes, where teachers may learn methods for teaching mathematics, methods for teaching language arts,

methods for teaching music, and so forth. Yet, Floden, McDiarmid, and Weimers (in press) have shown that methods instructors, like other teacher educators, usually take their students' knowledge of the subject matter for granted and spend their time providing specific techniques for handling specific topics, rather than on helping their candidates' better understand how children learn this content, what is conceptually difficult about it, or what is conceptually important about it.

Rather than altering this bifurcation, state policies have tended to reinforce it. Like teacher educators, public policy makers tend to think of subject matter and pedagogy as separate entities and to assume that majoring in a subject will assure satisfactory understanding of that subject. Darling-Hammond and Berry (1988) found that over 1,000 pieces of legislation addressing teachers had been passed during the 1980s, indicating a substantial departure from previous state involvement in this area. Yet their descriptions of these policies suggest that few, if any, address the problem of bifurcation.

Some states, such as Texas, Virginia, and New Jersey, restrict the number of courses prospective teachers take in teacher education, thereby allowing more space in their college curricula for courses in other subjects. The apparent assumption of such policies is that pedagogy and subject matter are not only separate, but that they are fixed in a zero-sum relationship, such that increases in one area necessarily result in decreases in the other.

Other states have developed alternative routes into teaching that will permit people who have majored in a subject, and who therefore presumably know their subjects well, to teach (Gray and Lynn 1988). Though alternative route programs differ substantially from one another, most seek candidates who presumably already know their subjects and are bright

enough that they can learn a lot on the job (Darling-Hammond, Hudson, and Kirby 1989). With such candidates, the reasoning goes, the program need only provide a relatively small portion of the teachers' knowledge--a few things that would not have been obtained in college and cannot be obtained on the job. Two common topics, for instance, are child development and classroom management strategies. The tendency in these programs, then, is to assume that teaching knowledge consists of two relatively separate parts: subject matter knowledge on one side and generic pedagogical knowledge on the other.

While these policies aim to assure adequate subject matter knowledge by requiring new teachers to hold bachelors' degrees in the subjects they will teach, others aim to improve pedagogy through teacher assessments. These assessments, however, generally assess only a list of specific behaviors that researchers claim make a difference (Rudner 1987), ignoring such matters as the intellectual value of the content being taught, how accurately the content is represented, and whether students engage in higher-order thinking about the content. These assessments stand in sharp contrast to the assessments of a century ago, which concentrated almost entirely on subject matter knowledge (Shulman 1986b), and assume instead that the knowledge teachers need resides in a collection of discrete behaviors (Shulman 1987).

The analyses and evidence presented earlier suggest, however, that policies based on a bifurcated view of teacher knowledge may not significantly improve the substantive knowledge of teachers, nor necessarily increase their ability to teach higher-order thinking within the various subjects. For, as Philip Jackson (1986) has argued, no content carries with it a pedagogical imperative; that is, we can't assume that "knowing" a particular piece of content automatically entails knowing how to teach it. Secondary teachers have always taken plenty of courses in the subjects they teach, yet have not

necessarily acquired, through these courses, the kind of substantive understanding or pedagogical subject matter knowledge needed for teaching. Indeed, the findings from research such as that of Ball (1990) and Kennedy (1989), described above, refer to mathematics and English majors, respectively, as much as they do to elementary teaching candidates. Other research (e.g., Begle and Geeslin 1972) has also shown that the number of course credits in a subject is not always related to teaching quality.

But the problem extends beyond bifurcation. Educational researchers also tend to focus on pedagogy while leaving issues of content to their disciplinary colleagues. Since educational researchers addressed the way teaching is currently done, most of their findings about pedagogical practices are valid only for the teaching of routine skills, not for teaching higher-level thinking, nor for adequately representing subject matter to diverse learners. Perhaps the most remarkable evidence of this avoidance of subject matter appears in a response by Barak Rosenshine (1986) to a high school history lecture given by then-Secretary of Education William Bennett. Rosenshine said he could not judge the merits of this lesson because research on teaching had not studied the teaching of content, only the teaching of skills.

Moreover, evidence is mounting to the effect that college level subject matter courses are not providing students with opportunities to gain a deep understanding of their subject matter. McDiarmid (1989) has summarized a variety of studies showing that college level teaching, like elementary and secondary teaching, attends more to discrete facts than to big ideas, to the significance and interrelations among those ideas, to their relevance to everyday life, or to the way in which ideas within the discipline are developed and argued about within the discipline. By way of illustration, Roth (1989) contrasts the understanding of science she acquired as a college student with that which she needed for teaching. When she graduated from college, she perceived science as technical, esoteric, and unrelated to everyday life, something that only scientists could do. Most of her laboratory classes

focused on doing the experiment right, so that she would get the right outcome. None of this enabled her to present science to youngsters or to answer the kinds of questions they were likely to ask.

White (1987) proposes that we change our conception of teachers: instead of thinking of them as effective managers, who need only learn generic skills, or as bright, well-educated people who know their subjects well and will be able to pick up teaching skills on the job, we should conceive of teachers as brokers of scholarly knowledge, who transform disciplinary knowledge into pedagogically sound lessons. Thinking of the job this way helps us remember that the task requires a blend of multifaceted subject matter understanding and knowledge of students and how they learn. To produce such teachers would require a new method for preparing teachers, one that provides them not with more content but rather with the kind of multifaceted understanding that contributes to teaching. Improvements in teacher education are necessary to help students learn the relationship between pedagogy and different kinds of knowledge (McDiarmid, Ball, and Anderson 1989), and may require candidates or experienced teachers to relearn their subject matter in a way that enables them to organize it meaningfully, to learn its methods of inquiry, and to see its significance to everyday life.

Better methods for assessing teachers are also needed. Most observational assessments concentrate on discrete pedagogical moves, rather than the intellectual content of lessons. Tests of subject matter knowledge tend still to be paper-and-pencil tests that require teachers to recognize or recall right answers, but not to judge the merits of arguments or to generate or explain concepts. Such assessments may maintain the status quo, encouraging more low-level skills teaching, rather than teaching of higher-order thinking (Melnick 1988). The National Professional Teaching Standards Board hopes to develop an assessment that recognizes the full

range of demands teachers face in teaching academic subjects (National Board of Professional Teaching Standards 1989). This is one promising effort toward improved teacher assessment.

Finally, policymakers need to take into account the enormity of the teaching population, and the likelihood that this nation can ever attain the intellectual standards it desires on so large a scale. Lanier (1986) points out that 10 percent of our college educated women and 4 percent of college educated men are teachers, and that no other profession absorbs such large fractions of educated adults. The size of the population alone mitigates against holding too high a standard, but is even more problematic when the attractiveness of the teaching profession is lower than that of other occupations available to college educated youth. When this is coupled with the tendencies of schools to place teachers in positions for which they are not qualified, the problem of selecting and assigning individuals to teaching positions is even more complicated. Policies that restrict out-of-field teaching surely raise the substantive qualifications of teachers. But in addition to these measures, policymakers and school districts may need to develop alternative ways of organizing schools, so that they rely on fewer well-educated people and more assistants or paraprofessionals.

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